SPONS' ENCYCLOPÆDIA

OF THE

INDUSTRIAL ARTS, MANUFACTURES,

AND

COMMERCIAL PRODUCTS.

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DIVISION II.

CONTAINING
BEVERAGES (*continued*), BLACKING, BLACKS, BLEACHING POWDER, BLEACHING, BOGWOOD, BONES, BORAX, BROMINE, BROOM-CORN, BRUSHES, BUTTONS, CAMPHOR, CANDLES, CANE, CARAMEL, CARBON, CARBON BISULPHIDE, CATGUT, CELLULOID, CEMENTS, CHICORY, CHLORAL, CHLORINE, CHLOROMETRY, CLAYS, COAL-TAR PRODUCTS, COCOA, COFFEE, CORK, COTTON MANUFACTURES, &c.

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Some brewers admit the water into the mashing tun at a higher temperature than is necessary for the mash, allowing it to cool before the malt is put in. In other breweries, the malt and water are introduced together into a machined mash tun, the initial heat of the mash being much higher than that required for the operation, so as to compensate for the loss of heat communicated to the mash tun. But it is preferable first to heat the mash tun with water, and then to introduce the malt, because the loss of heat in this instance only accrues from the malt admixed, and the operation can be conducted with greater certainty. Another plan extensively adopted is, to moisten the malt to be mashed with water at a low temperature, in sufficient quantity to cause the malt to swell, and then to add the remainder of the water at an increased temperature, necessary to impart the proper temperature for the mashing. The water added is generally at the temperature of 88° to 90° (190° to 194° F.). This plan is stated to have two advantages: it lessens the tendency to set, and is very exhaustive of the extractive matter of the goods. It enables the diastase to act more freely upon the starch, because the larger part of the sugar is dissolved out during the first wetting, leaving the remaining constituents in a better condition for attack by the solution. With regard to this system, other authorities affirm that, because the diastase is very soluble, it is removed with the sugar and from direct action on the starch. Upon this consideration, as well as from others, the general defects of mashing as usually employed, in any system, have been summed up as follows:—Inefficient extraction, portions of the gluten and starch of the grain becoming a gelatinous mass, which prevents, by forming an impermeable coating, the remaining constituents from being attacked. The starch remains unconverted into glucose in consequence of too low a temperature being employed in the operation.

Donovan gives the following temperatures for mashing: For well-dried pale malt, the first mash water should not exceed 77° (170° F.); the second, 82° (180° F.); and the third, 85° (185° F.); assuming the temperature of the atmosphere not to exceed 10° (50° F.). Sullivan states that under his experiments 100 parts of starch were transformed into 100 parts of sugar, but that this sugar was intermediate in molecular structure between grape sugar and starch, and he termed it maltase, as previously referred to. This sugar is white, soluble in water, but less soluble in alcohol than glucose.

English mashing, which is an infusion process, differs from the Continental, and distinctly from the Bavarian process, since the latter is a method of decoction. With the English process, the malt is first opened or cracked, and sometimes comes from the rollers not perfectly crushed; on the Continent, the malt is more finely crushed. Formerly, the malt was allowed to fall into water that had been first placed in the mash tun, but in present practice the malt is brought into contact with hot water, at a temperature determined by the circumstances of the particular situation and arrangement of the brewery. The English process depends chiefly in the use of water at a tolerably high temperature, and its characteristic is a high initial temperature.

The English brewer seeks to avoid having too much albuminous matter in solution; whilst the German brewer endeavours to render the albumen as soluble as possible, because he has to make a beer intended to be kept only for a short time. In parts of Germany and Belgium, the English system of employing a high initial temperature is adopted, but with some modifications. The mash first of all is given a temperature of 38° to 49° (100° to 120° F.), and sometimes as high as 60° (140° F.). It is allowed to stand for a short time, and hot water is added to bring up the temperature to about 65° to 71° (150° to 160° F.), the wort being run off after sufficient infusion. A higher temperature is sometimes employed, even boiling liquor being added in order to raise the mash to 77° (170° F.), when it is left to digest, until iodine water or an alcoholic solution gives no blue reaction. The infusion process, general on the Continent, differs therefore in starting with a lower temperature, and in attaining a higher temperature by successive additions of hot water.

As an example of the process of decoction, the old Bavarian method may be cited; and this consists in boiling the wort along with the grains. The malt after it is properly ground is thrown into cold water, and is allowed to remain therein for from one to three hours; after this, hot water is added to raise the temperature of the mash to 35° to 38° (95° to 100° F.). After standing a short time, the tap is opened, and grains, meal, in fact the whole of the contents of the tun, run off into the boiler. This thick mash, termed "dickmaisch," is boiled vigorously for half an hour, and is then run back again into the mash tun, where it has a temperature of 49° to 52° (120° to 125° F.), and the infusion process is allowed to go on. A second thick mash is pumped up into the boiler, and boiled for half an hour; it is then run into the mash tun, the temperature being raised in this manner to 63° (145° F.). After a little mashing, the contents of the tun are allowed to remain. The third mash, or "lautermaisch," is then run off, and is a tolerably clear mash unmixed with grains. This is boiled in a copper for about half an hour, when it is run into the mash tun, to raise the temperature to 75° (165° F.). The contents of the tun are then tapped and sparged with cold water.

In Belgium, where malt and raw wheat are used together, the process is first conducted according to the English infusion method, a portion of the thick mash being pumped into the boiler and boiled. Although this boiling destroys the diastase, it thoroughly breaks up the integuments of the malt, and in this way the starch is converted into a kind of starch paste; when returned to the tun, this paste meets with the diastase remaining unconverted, and then very rapidly undergoes change into dextrine and sugar. From the nature of the German process, the wort is rich in dextrine and poor in sugar; consequently when fermented it yields less alcohol.

Graham has experimented, for the purpose of answering the question, in what way can the practical brewer alter the ratio of dextrine to glucose; to ascertain if it can be altered to any extent, and whether there is a limit to the action of the diastase on the starch. The experiments were confined to one malt, analysis of which gave—

Water	7·51	Albuminous bodies (insoluble)	10·71
Glucose	5·48	Ash	2·50
Dextrine	8·82	Woody fibre, empyreumatic products, and the like	14·37
Starch	48·77		
Albuminous bodies, soluble	1·48		

Cold Aqueous Extract.

	15 minutes.	30 minutes.
Glucose	5·48	7·14
Dextrine	8·82	9·65

Alcoholic Extract.

	80 per cent.	50 per cent.
Glucose	1·00	5·68

When this malt was treated with water there was obtained, after a period of fifteen minutes, 5·48 per cent. of sugar, and 8·82 per cent. of dextrine, or in an additional fifteen minutes, 17·14 of sugar and 9·65 of dextrine. An almost identical solution was obtained with 50 per cent. of alcohol, and from this fact it was concluded that the particular sample of malt contained an amount of sugar equal to 5½ per cent. The next point ascertained was the amount of action taking place at different temperatures in a given time; and starting with cold water at 15° to 21° (60 to 70° F.) the liquor was raised to the temperature indicated in the following table, and continued for two hours:—

	38° (100° F.)	43° (110° F.)	49° (120° F.)	54° (130° F.)	60° (140° F.)
Glucose, per cent	24·19	30·00	32·17	35·71	37·50
Dextrine and starch	34·00	29·25	27·33	24·11	26·70

These results show that there is a gradual increase in the amount of sugar formed, and that at 60° (140° F.) the process instead of being gradual, suddenly increases in intensity, yielding a much greater amount of extract.

Graham also has tested the validity of the assertion as to the German process, varying in the range of temperature of 74° to 75° (165° to 167° F.), being the most favourable for the conversion of starch and dextrine into sugar. The mashing heat was started on the principle of a low initial temperature, raised up in the first hour to 38° (100° F.). It was then kept for two hours at a temperature of 60° to 63° (140° to 145° F.), and was finally raised to 74° or 75° (165° or 167° F.). The following table shows the results:—

	Two hours at 74° to 75° (165° to 167° F.)		Six hours at 74° to 75° (165° to 167° F.)	
Weight of extract per cent.	70·25		70·55	
Draff "	21·58		20·71	
Glucose "	39·06	= Starch 62·52	41·67	Starch 62·51
Dextrine "	27·36		25·00	

These results show a considerably larger amount of extract than with cold water, very much higher even than in the English infusion process. By prolonging the period for the temperatures at a higher stage, the German brewer is correct in his idea of getting a larger amount of sugar, and it remained to be seen, as an interesting experiment, what an extreme temperature of 79° (175° F.) would affect. A sample of malt was taken, and heated gradually, during sixty minutes, from the cold up to 77° (170° F.). It was then kept at that exceedingly high temperature for two hours, and the amount of sugar formed and extract obtained, are as in the following table:—

	(1)	(2)
Weight of extract, per cent.	69·70	69·10
Draff "	23·51	23·35
Glucose "	32·10	32·05
Dextrine "	30·29	30·60

Graham considers that these experiments are conclusive as to the advantage of low initial temperature, and a high final temperature, and therefore experimented as to the best way to arrange the mashing temperatures. Malt was heated from the cold up to 29° (85° F.) for one hour, then from 29° to 60° (140° F.) for one hour, when it was kept for three hours at 60°, and then boiled. In the second series of experiments the malt was raised during the first hour from the cold to 60°, when it was allowed to remain for two hours, and then raised very rapidly to 79°, when it was boiled. In the third experiment it was raised in the first hour to 60°, maintained during the second at that temperature, and in the third hour raised to 79°.

	(1)		(2)		(3)	
Weight of extract, per cent. ..	71·50		71·06		69·00	
Draff „ ..	21·70		22·35		22·61	
Glucose „ ..	41·66	= Starch 62·59	40·07	= Starch 62·51	35·72	= Starch 60·67
Dextrine „ ..	25·09		36·45		28·65	

The first two series give practically the same results, but with rapid increase of temperature there was great reduction in the amount of extract, as well as in the ratio of the sugar to the dextrine. Graham considers these experiments to show that the more gradually the temperature is raised, the more complete is the extract, and the higher the sugar-forming ratio.

In Graham's experiments, the starch was broken up, not according to Musculus' theory, but in the reverse ratio. There was a larger amount of sugar and a smaller increase of dextrine. Referring to the experiments on the English infusion process at 60°, 33·5 per cent. of glucose is formed. As the temperature increases so the amount of sugar decreases, until at 77° the decrease is very great. These experiments prove that the higher the initial temperature, the less active the diastase; and the less extract in a given time, the less sugar is formed. By starting with a low initial temperature, and raising it in the course of an hour to the temperature indicated, maintaining that temperature for two hours, there is a gradual increment of sugar with a gradual increment of total extract.

Malt Infusion, Low Initial Temperature.

	38° (100° F.)	43° (110° F.)	49° (120° F.)	64° (130° F.)	60° (140° F.)
Sugar	24·79	30·0	32·2	35·7	37·5
Dextrine	34·00	29·2	27·3	24·1	26·5

From this table, it will be seen that at 60° the percentage of glucose has risen to 37·5 per cent., indicating that a low initial temperature is best for the solution of the diastase. But for a given time, the diastase, when dissolved, attacks the starch most vigorously at a temperature of about 60° to 63°; and whilst this temperature is advantageous for the rapid conversion of starch into sugar and dextrine, experiments have shown that the temperature of 74° to 75° was best for rapid conversion of dextrine into sugar. Graham makes the following deductions as to the practical bearings of these facts.

Barley malt when well prepared contains an amount of albuminous substances, or diastase, produced in the germination process, greater than is needed for the conversion of starch found in the malt. Time is an important element in the changes produced, and the longer the time at a low temperature, the more diastase is dissolved, and therefore in subsequent stages, the more starch converted and sugar formed. The action of the diastase initially, when the mass of the diastase is small compared with that of the starch, is to form dextrine into sugar in the ratio of 2 to 1. In malt, however, there is so large an amount of diastase, that even in a short digestion an amount of sugar is obtained greater than in this ratio. In the English infusion process with its initial temperature varying between 60° and 68° (155° F.), but generally no higher than 66° (150° F.), there is an equal ratio of glucose and dextrine; and this has been determined from worts obtained from four large breweries in different parts of England. As the initial temperature was raised above 66°, the total extract decreased, as well as the ratio of sugar to dextrine; and when the initial temperature was decreased below 66°, within certain limits, the total extract increased, as well as the ratio of sugar produced. The limits of these varying ratios cannot exceed two of dextrine to one of sugar, or two of sugar to one of dextrine, and the ratios produced in any given time, in any particular mashing trial, depend on the varying conditions of the experiments; upon the relative masses of starch and diastase; upon the temperature; and on the quantity of water. It has been well authenticated that from 100 parts of starch not more than two-thirds can be obtained as sugar by the action of diastase; and this deficit is accounted for by Sullivan, who has proved the formation of maltase, as previously referred to. Maltase has a peculiar action on Fehling's copper solution, by which this test solution represents only an amount of reduction equal to two-thirds of that which would occur if 100 parts of glucose were taken. Maltase formed in the mashing process, breaks up under the action of the potash and the copper solution into two parts of glucose and one of dextrine. In the ordinary mashing process, there occur, it would appear from this consideration, two parts of dextrine and one of sugar; and as the process continues, the ratio becomes more nearly equal, and is reversed by the application of more heat and long-continued action, practically illustrating the fact that the brewer may within certain limits vary the ratio of dextrine to sugar at will.

In order to increase the ratio of the sugar, the brewer may start with a low initial temperature, and secure the solution of a large amount of the active principle of diastase. This solution obtained, the temperature of the mash may be raised to 60° to 65° (140° to 150° F.), either by adding hot piece liquor, or by steam driven under the false bottom of the mash tun, or by means of a heated coil, or by causing the wort to circulate through coils of pipes, delivering it finally to the top of the goods. After digestion for a certain period at this temperature, the mash should be raised to 74° (165° F.), because at that temperature more sugar can be produced than at 63° (145° F.), and because the higher temperature gives the additional advantage of a high tap heat. Upon the present plan of high initial temperatures, the brewer can increase the ratio of sugar by simply adding it. Cane sugar may be employed, and this can be converted into glucose by the action of the diastase, if added in the mash tun, or it can be converted partly into diastase by the action of the acids of the wort, by making the addition when the wort is boiled. If the cane sugar were to be added, without previous conversion, to the fermenting tun, it would require more yeast than glucose, because the yeast would have to do a greater amount of work, to break down the complex structure of the cane sugar to the more simple one of glucose. Cane sugars are dangerous, however, because they contain large amounts of albuminous substances likely to putrify, and it is preferable to convert the cane sugar into invert sugar. Invert sugar is the sugar produced by the action of acids on cane sugar, dextro-glucose, and lævo-glucose. As glucose sugar can be made, not only from cane sugar, but from starch, there is nothing to prevent the brewer preparing his own grape sugar from starch, by treating this with dilute sulphuric acid and afterwards destroying the acid by means of chalk. Although the process may leave about one-half per cent. of gypsum in the sugar, this is an advantage in the fermenting tun, rather than a disadvantage.

A variety of plans may be employed for increasing the quantity of dextrine. Dextrine when in large quantities, after the worts are fermented, gives what is termed roundness of flavour to the beer, and is therefore preferable for porter, stout, and the heavier class of ales. The dextrine of the wort may be increased by modifying the Bavarian method. Or the diastase may be rendered inert by infusing at 38° to 49° (100° to 120° F.), raising the temperature to 60° (140° F.), with tolerable rapidity, and when the infusion is complete at that temperature, again increasing to 79° (175° F.), allowing digestion to go on at that temperature. Another plan is to add unmalted grain, barley, or maize, but in this case the unmalted grain should be kiln-dried at a temperature of 100° to 110° (212° to 230° F.), in order to render the albuminous matters less soluble, to decompose them in the presence of the moisture of the grain, to produce empyreumatic matters, and to obtain colouring products. Practically this treatment yields a malt not containing diastase.

Having considered the theoretical principles of mashing, as well as having described the most approved processes, it may be advantageous to deal shortly with the latter, from a more practical point of view. The practical brewer should regard mashing as a triple, rather than a single process; and should feel assured there is nothing to prevent the obtaining of good beer, when proper heats are taken. Like the extraction of the juices of meat in the making of soups, the extraction of the albumen from the malt depends upon the non-coagulation of the albumen at the commencement of the mashing. In the most approved practice, it is generally agreed that the heat of a pale beer mash, when all the malt and water are put in and finally mixed, ought to be 71° (160° F.). It is at this heat of the first mash that the best flavoured extract is produced, and the entirely chemical action of saccharification occurs. But this temperature must be gradually approached, because its sudden application would coagulate the albumen of the malt. The triple nature of the mashing process may be practically regarded as consisting in saturating, saccharifying, and extracting, to prevent setting or coagulation.

The malt should be wetted at a heat that would give in the mash tun 64° to 66° (148° to 152° F.), or several degrees below the best saccharifying point. When goods are thoroughly wet, water is applied at a higher suitable heat, with the internal rakes of the mash tun revolving, until the goods are at the temperature of saccharification; after four or five hours' continuance of the saccharifying heat, the temperature should be reduced to that at which the brew began. Mashing, as performed in Steel's or other saturator, may commence at 64° for light, and 66° for heavy beers; this means mixing about 1½ barrel of water to the quarter of malt, and finishing with a firkin to a kilderkin, to a quarter, more of water at 87° to 90° (190° to 195° F.). The copper heats for the water employed will average about 77° (170° F.).

A plentiful supply of cold water should adjoin the hot-water pipe, to secure regulating power.

When the mixture is in the mash tun in a saturated condition, the copper water, at 87° to 90° (190° to 195° F.), should be let in without delay, and the rakes kept going, until the goods are uniformly heated to 68° (156° F.). These heats are for perfect malt. For imperfect malt, or half barley, lower saturating heats may be used advantageously, but imperfect malts should never be used for fine beers, as neither a sufficient nor economical extract, nor good flavour can be obtained in the mash tun. The preceding observations refer to the first mash.

The draining and extracting of the goods ought to proceed within two hours from the completion of the mashing operation. The mash should not be tapped through one cock, but should be drained through three or more, placed in the bottom of the mash tun. Draining should at first proceed slowly, until sufficient grains have settled around the cocks to act as a filter, which occurs in about twenty minutes. If the extract is to be completed by repeated mashings, the cocks, after the first mash is run off, should be closed, and the mash tun recharged with hot water, in such quantity as to make up the second mash of the brew, at a goods' heat of about the same as the first mash. The first mash ought to lie about an hour, and when run off, the third mash, if required, should be made up for a temperature with the goods of 66° (150° F.), and this mash should lie for half or three-quarters of an hour only. The copper-water heats, and quantities of water required for these two after mashes are only to be obtained from actual experience with the particular plant. The second mash water will require to be about 79° (175° F.), and the third about 74° (165° F.), for mashes of ordinary quantities. This process gives roughly a three-mash brew. As it is difficult for the brewer to calculate these quantities accurately, it is preferable to keep the mash waters short of the quantities required, and to sparge at the end, with tepid water, to make up the copper charge. Another plan approved of by many brewers, is to make two mashes of reasonable thickness, and sparge up the remainder of the charge. In this case the sparge water ought to be of such a temperature as would allow the heat of the goods to fall to 66° (150° F.).

In that known as the Edinburgh mode of mashing, all the water required is sparged on after the first mash. By this method, as soon as the taps have become fine, sparging is commenced, and tapping and sparging go on simultaneously until the extraction is complete. In working this system, the error is commonly made of putting on the sparging water too hot, even at a temperature of 82° to 88° (180° to 190° F.). The first sparge heat should not exceed 77° (170° F.), and if the temperature of the mash exceeds 68° (156° F.), the sparge water may be at only 71° (160° F.). The tun covers should be removed whilst sparging is proceeding; and water should not lie on the top of the goods whilst sparging, which always occurs if the mash has been too hot, or the sparge water added at too high a temperature. The water remains on the surface of the goods in consequence of coagulation having commenced, and the temperature of the sparge water should be at once lowered, and the taps closed for a short time. When the temperatures have been properly adjusted, the goods freely rise from the bottom of the mash tun and float, and allow the extracting liquor to readily percolate. This is an important point, and the goods should be kept up at least 6 inches from the bottom of the tun until the end of the sparging. As small brews must have the same time to extract as large brews, the runnings must of course be smaller in quantity; and for this reason the sparge water must be hotter than with large brewings, where the running off is performed so much more quickly. The small quantity of water falling from the sparger will cool more quickly than the larger quantity falling through the same space.

After a mash has been maintained with the sparger at the temperature of 68° (156° F.) for about two and a half hours, the heat of the water should be suddenly lowered 12° or 15°, so as to reduce the action of heat upon the goods to 66° (150° F.) towards the end of the sparging and running. In making strong beer, the necessity for strength will have required the running to have been stopped within two and a half hours, before the reduction of temperature, so that the effect of this reduction will be felt on the afterwort only, which may be table beer. If it is required to pump the tail ends of one mash over for the sparge liquor of another, all that is necessary to ensure success is that the tail goods come off one mash at 63° to 66° (145° to 150° F.), and are reheated by a steam coil, attached to the pump, to the necessary sparge heat of 77° (170° F.), or that producing 68° (156° F.) in the mash.

Tap heats afford no safe guide to the brewer, for the almost obvious reason that these do not truly represent the temperature of the mash.

In the best practice in porter brewing, the temperatures of the mash do not differ much from those given for ale. Saturation should take place at about 1° lower, the temperature for the mash being ultimately the same as for beer, or 68°. The peculiarly dry, sub-acid flavour, common to Irish porters, is the result of too great range of mash heats, by beginning at too low and finishing at too high a temperature, thus twice submitting the mash to the chances of acidity. Porter is best made from malt two-thirds of which is well-dried pale, and the remainder high amber and black. Roasted malt should be used to the extent of 1 bushel to every 5 or 6 barrels of finished beer. Brown or blown malts are a mere waste of grain, will not keep, and yield little extract. The roasted malt is generally put into the mash tun amongst the other malts, but sometimes it is put into the wort copper and boiled with the hop. An alternative method of great profit to the brewer on the large scale, is to mash the roasted malt by itself in a small tun fitted with a rake and false bottom, and an inner perforated concentric diaphragm through which to drain off the black extract. The washing out is performed with the extract from the large mash tun.

Before proceeding to the description of the apparatus used in mashing, it will be convenient to describe the operation of sparging, as the mechanism employed in both cases can then be classed, as they are used, together. Sparging is the process of extracting the remaining wort, which adheres to the insoluble draff or grains. The sparging is carried out by means of hot water, and if the wort has been run off at a temperature of about 63° to 66° (145° to 150° F.), the sparging liquid, as has been stated, should not be used above 77° (170° F.). This process goes on in different breweries to different extents, sometimes it is carried to such an extent that the wort obtained is excessively weak, containing only some 4 to 6 lb. a barrel. This is not usedt a once for the production of beer, as a rule; it is not mixed with the previous wort, but is pumped up into the copper and there used for the subsequent wort. This return wort, as it is called, is exceedingly liable to undergo decomposition, by which acidity, mainly due to lactic acid, but probably to other acids as well, is produced. In order to prevent the return wort from becoming acid, it is found convenient to keep it at a temperature of at least 88° (190° F.), and from time to time to add a little bisulphite of lime. Throughout the whole of the period, whether during the night or during the day, until the next time of use, the return wort must be kept at least as high as 88°, for if allowed to fall to 66°, acidification is very liable to set in. The wort resulting contains not only sugar and dextrine, but also an amount of albuminous matter; this amount depends upon two or three conditions, and chiefly upon the nature of the barley originally employed. For instance, if the barley came from the North of England or Scotland, or if it had been growing on heavy land, it would contain much more albuminous matter, than barley grown on a light warm soil. And brewers occasionally make an error in judging of the strength of the wort, by merely depending on the use of the saccharometer, because the soluble albuminous matter sustains flotation of the instrument as well as sugar and dextrine. The amount of albuminous matter in the wort also depends on the previous malting process; lastly, it depends on the nature of the water employed.

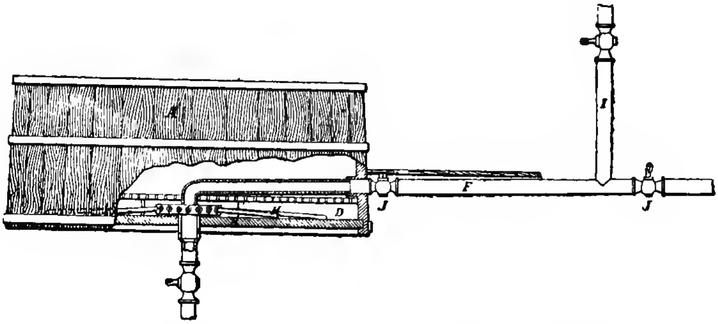
The process of mashing having been described, the apparatus employed must be considered. A mash tun in its simplest form is a vessel of convenient size and shape, in which the malt and water can be mixed together, and from which the wort can be drained off. Mash tuns are usually made of wood, but cast-iron tuns are rapidly extending in use. A mash tun should have a capacity of from three to four barrels of malt, at least. Cast-iron mash tuns are constructed in segments bolted together, the connecting flanges being planed and truly fitted, or rust-joints being used. The bottoms of such tuns are usually formed of segments around a central casting, having as many sides as there are segments. It is necessary to case these metallic tuns in order to prevent too rapid radiation of heat; and the smaller the mash tun, the greater is the necessity for this protection, because the area of exposed surface is in greater proportion to the contents than with tuns of more considerable capacity. To enable the worts to be drained from the goods, mash tuns are made with perforated false bottoms, placed at a short space above the bottoms of the tuns. These false bottoms are made of wood, of cast iron, galvanized sheet iron, or of copper. When wooden false bottoms are used, the holes in them should be burnt, not bored, so that they may not be liable to close up by the swelling of the wood when damp, and they should be well countersunk on the under side. The cast-iron false bottoms are also countersunk on the under side, the countersinks being cast in the plate, whilst the holes are drilled or punched.

The removal of the worts is effected at four or more points independently, so that in the event of the wort drawn from one portion of the tun not being clear, the tap communicating with it can be shut off. Another plan for attaining this end, is by an arrangement of mash-tun bottom, of which Fig. 302 is a section. The peculiarity in this form of mash-tun bottom is that the wort is drawn off from a number of points, at one and the same time, through a series of radiating tubes, H, of various lengths. The pipes H communicate with a central chamber, fitted with a removable top. The space below the false bottom with which the pipes H communicate is divided into compartments by the strips D, on which the false bottom rests, and the whole apparatus is constructed so that it can be readily removed from the mash tun for cleansing purposes. The pipes F and I serve for the removal of the wort, regulated by the cocks J.

Mash-tun covers vary greatly in construction and efficiency, and in some instances, as in the case of the mash tuns used for porter brewing at the City of London Brewery, they are dispensed with; this, however, is an objectionable practice, particularly in the case of large mash tuns. The simplest form of cover is a plain wooden disc, fixed a short distance above the mash tun; the space between the disc and the tun itself being closed by sacking whilst the mash is being made. Mash-tun covers of this kind are used at Reid's and other breweries. At Mann, Crossman, and Paulin's brewery flat wooden covers are used, but are suspended so that they can be lowered to the mash tuns.

Another form of wooden mash tun cover is adopted in Allsopp's brewery. In this instance the mash tuns are covered by a permanent wooden roof, carried by a framework extending above the sides of the mash tun, and this frame is fitted with sliding shutters. Another plan is to form the cover of wooden segments of convenient size, applicable to mash tuns of moderate dimensions. At Hoare's brewery there is a very large cast-iron mash tun, capable of mashing 190 qrs., fitted with a dome-shaped cast-iron cover; the central portion is fixed whilst the curved rim is formed of a number of flaps hinged to the centre. At Truman's brewery, the covers are formed of sheet copper, stiffened by brass ribs of T section. Each cover is in two parts, the central part carried by suspension rods at a fixed height above the tun, and the outer part, hung from chains which pass over pulleys, and provided with balance weights, so that this part of the cover can be raised and lowered. The junction between the two parts of each cover is formed with a projecting flange, which bears upon a ring of indiarubber carried by a corresponding flange on the central part of the cover.

302.



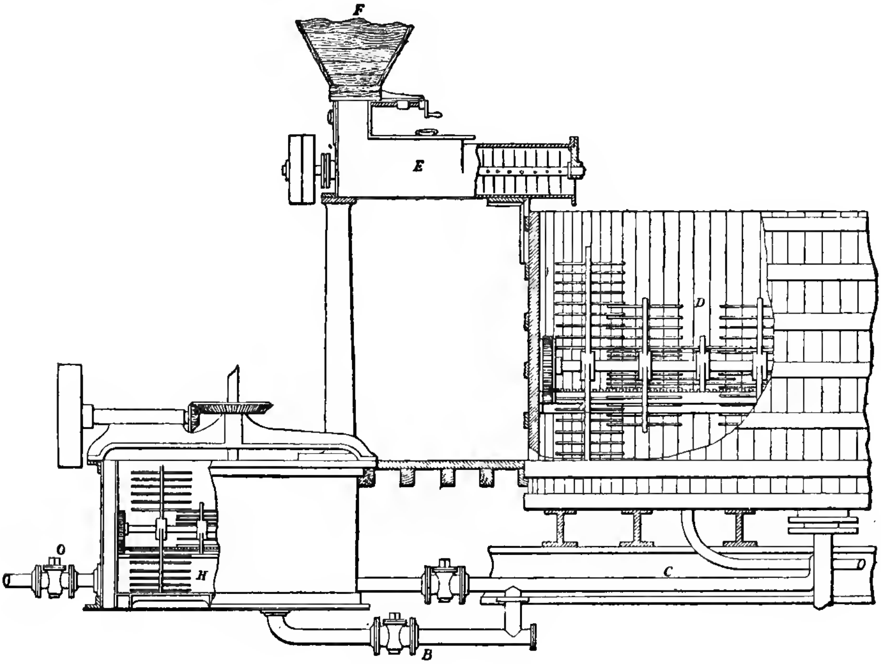
Before the introduction of machinery, the malt and liquor were mixed in the mash tun with oars, or wooden stirring-rods, and this method is still adopted in very small breweries. Where larger mash tuns are employed, such a method of mashing would not only be too laborious, but would produce most unsatisfactory results. The appliances most desirable for mashing are those best effecting the thorough mixing of the hull and flour of the crushed malt with the liquor, and leaving the goods in a porous condition, so as to be readily penetrated by any further amount of liquor. One of the earliest mashing machines, still in use in many old breweries, consists of a radial frame, which travels round in the mash tun. This frame has two horizontal shafts, one above and slightly in advance of the other. Each shaft carries a number of chain wheels, and over these work chains fitted with transverse teeth or rakes. As the shafts revolve, the teeth on the chains are drawn up through the goods, all parts of the latter being successively acted on as the frame carrying the shafts travels round the tun. At Barclay's, all the mash tuns but one are fitted with chain rakes of this kind, and they are also in use at Reid's and other London breweries. At Barclay's, the chains are now made of malleable cast iron. At Reid's, where there are four mash tuns, each capable of mashing 160 qrs., the mashing machine in each tun is double, or instead of the frame carrying the chain wheel shafts being merely a radius of the tun, it extends across the whole diameter. By this arrangement the goods are turned over twice during each revolution made by the frame, and the mixing is thus effected more quickly. In slow gear, the frame makes a complete revolution in fifteen minutes, whilst in quick gear it completes the circuit in ten minutes, the speed being equivalent to one revolution in five minutes with a single machine. In Reid's machines, the rake chains are of wrought iron throughout.

An improvement on the chain rakes is the so-called porcupine machinery, which has perhaps been more extensively adopted than any other form of mashing apparatus. This mashing apparatus consists of a series of rakes carried by curved arms fixed to a pair of horizontal shafts, placed one above the other; the rakes being arranged so that as the shafts revolve they pass each other, and thoroughly turn over the goods in the mash tun. The inner ends of the horizontal shafts are carried by plummer blocks attached to brackets, which encircle the central vertical or driving shaft, the lower end of which rests upon a suitable bearing at the bottom of the mash tun. The outer ends of the rake shafts rest in bearings carried by a kind of frame, which is connected by tie bars with the brackets encircling the central shaft, and supported by a pair of rollers bearing on the rim of the mash tun. Each shaft carries a sliding clutch for connecting it to its pinion, and these clutches are both worked by one lever, so that they cannot be engaged simultaneously. One of the pinion shafts extends inwards towards the centre of the mash tun, and at its inner end carries a bevel wheel, which gears into a bevel pinion on the central shaft, this pinion being about one-third the size of the wheel. The rake shafts also carry bevel wheels, which gear into equal sized-wheels on the vertical shaft, the pairs of wheels being arranged so that the two rake shafts are both caused to revolve in the same direction. From the vertical shaft, motion is communicated to the rake shafts, and a slower motion to one of the shafts carrying a pinion gearing into the circular rack. From this shaft a still lower motion is communicated to the other shaft. When one of the rack pinions is thrown into gear with its shaft by means of its clutch, the whole apparatus will be made to travel slowly round the mash tun, and the rakes will be brought to bear upon the whole of the goods. The direction of motion of the apparatus, and the speed at which it is caused to travel, will depend upon which pinion is thrown into gear. This arrangement of travelling gear is similar to that adopted with chain rakes. The mashing apparatus here described has been very largely adopted; it is in some breweries used alone, and in others with a separate mashing machine, such as Steel's. In most cases the arms and teeth are of wrought iron, but the teeth are sometimes of wood, and occasionally both the teeth and arms are wood. At the City of London Brewery, where mashing machines of this kind are in use, the central shafts are fitted with teeth, which act upon the central portion of the goods not touched by the revolving rakes; and at Charrington's brewery, where there are three mash tuns 18 ft. in diameter, and capable of mashing 100 qrs. each, these porcupine machines are also used, the rake shaft being made to extend across the diameter of the tuns. Another arrangement for stirring the goods within the tun, consists of a central shaft carrying two curved arms, which work close to the false bottom of the mash tun, and act upon the lower portion of the goods only. The mixing of the malt and water is effected by a Steel's masher before the goods enter the tun.

Brewers are now of opinion that it is better to effect the mixture of the malt and liquor in detail as these enter the mash tun, than to deal with the goods in a mass. Separate mashing machines have consequently been adopted. The masher designed by Steel, of Glasgow, has probably been more extensively used than any other. This masher is of exceedingly simple construction. It consists merely of a cylindrical casing, within which revolves a shaft provided with a number of radial arms. The casing is open at one end and closed at the other, the shaft passing through a stuffing-box at this closed end, and provided outside with fast and loose belt pulleys. The grist and liquor are admitted to the casing by branches at the closed end, and as they pass through to be delivered into the mash tun from the open end of the casing, they are thoroughly mixed together by the action of the arms on the revolving shaft. The branch through which the malt enters is fitted with a regulating slide, and both the main casing and branch are fitted with hand holes which give access for cleaning. The water branch communicates with the side of the casing, and is fitted with a cock. In some mashers, there is no slide for regulating the supply of the malt, the latter being received direct from a small hopper placed below the malt mill. The casing of the masher, instead of being cylindrical, tapers slightly in its diameter, being reduced towards the end from which goods are delivered into the mash tun; and to further delay the progress of the mash through the machine, the central shaft is fitted at intervals with flat arms, or oars, in addition to the usual circular arms. The liquor is delivered into the casing from the branch through two openings opposite each other, these openings communicating with a passage cast around the branch. Arrangements are made for admitting either hot or cold water through the openings. The central shaft of the masher is driven by bevel gearing.

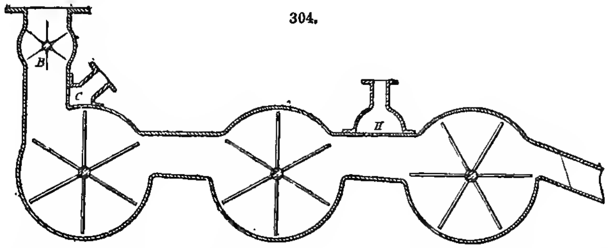
In numerous breweries, Steel's mashers are used alone, and the whole of the mashing is effected by them; in other cases they are used in combination with larger mashing apparatus placed in the mash tun. Where separate mashers are alone employed, it is the practice to make but one mash, and to sparge the remainder of the length of liquor; where mashing appliances are provided within the tun, a series of mashes may be made, the goods being turned over during each mash. To ensure a steady supply of malt to the mashing machine, and to prevent balling, a malt feeder has been designed. This feeder is placed between the grist shoot and the mashing machine. It consists of a casing containing a drum, which has an oscillating motion imparted to it by an eccentric fixed on the central shaft of the mashing machine. On each side of the oscillating drum are flaps, the position of which regulates the quantity of malt passing through; the drum, as it oscillates, leaving an opening between it and each flap alternately. Fig. 303 illustrates Steel's masher as arranged for pale and black malt mashing combined. F is the ground-malt hopper; E, the outer masher or saturatòr; D, the mash tun, with its revolving rakes arranged as previously described; B, the pipe conveying the wort from the mash tun through the infuser; H, the black malt infuser and rakes; o the pipe from the infuser to the copper, where porter is being made. When the large mash tun D is charged with pale and brown malts, the proportion of black malt required for the brew is mixed with water in the small mash tun H, termed the infuser, at a temperature equal to that of the goods in D. The infusion of the black malt depends on the time of infusion of the other malts; when these are infused sufficiently, and ready to be run off, the tap in the pipe C is opened as well as that in the pipe communicating between D and H. The half-pale extract from the large tun D is used to dissolve, absorb, and carry off the colouring matter from the black malt in H. This plan has been found economical and certain, as it gives all the colour that can be obtained by mixing the pale, brown, and black malts together, in addition to the quantity lost in dyeing the grains. The pale and brown grains becoming whiter by this mashing, are worth more in the market. The only uncertainty that can arise is from the wort losing heat, and this can be prevented by steam jacketing the pale and brown wort pipes.

303.



Another masher (Fig. 304) designed by Sorrell, and extensively used, consists of a casting forming three cylindrical chambers connected by intermediate passages, about 8 in. in length. Each chamber is fitted with a shaft, carrying a number of pins. These pins extend across the chamber, and are arranged so that all parts of the chamber are subject to their action. The three shafts each carry a bevel wheel at one end, gearing into three level wheels on a longitudinal shaft, carried by brackets on one side of the machine. The bevel wheels are arranged so that the shaft in the central chamber is driven in the opposite direction to that of the other two. The shafts are driven at a speed of about 200 revolutions a minute. The first chamber, to the left in the figure, is constructed with a vertical neck, which is attached to the ground-malt hopper or grist case; and in the neck there is a feed-roll, B, which regulates the supply of malt to the masher. The feed-roll is driven by a belt from a pulley on the stirring-shaft passing through the first chamber. Below the feed-roll there is fixed to the outside of the neck the water-box C; this box is supplied with liquor from the copper, and communicates with the interior of the machine through holes in the casting. Another water-box, H, is also fixed on the neck between the second and third chambers to receive water of a higher temperature.

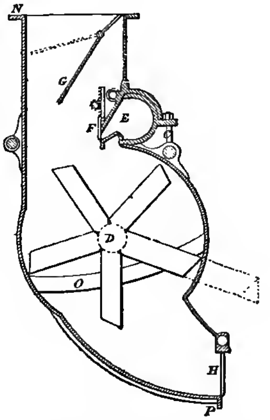
304.



The operation of working this masher is as follows:—The cock communicating with the water-box C having been opened, and a supply of liquor at the temperature of 76° (168° F.), admitted, the motion is communicated to the shafts, when the malt, as it falls from the feed-roll, is met by liquor entering through the holes in the casting. Any liquor not absorbed by the falling malt is received in the first chamber, where it is thoroughly mixed with the partially wetted malt by the action of the pins on the agitating shaft. From the first, the partially formed mash is passed on to the second chamber, traversing on its way the intermediate neck. These intermediate necks are an important feature in the machine, as the malt during its passage has time to absorb the liquor. In the second chamber, the mashing process is repeated, and the mash is then passed on through the neck between the central and third chambers, where it is met by a second quantity of liquor admitted through a number of holes communicating with the water-box H. This second supply of liquor is at a higher temperature than the first, the malt having been prepared, by the stiff mashing it has already undergone, to receive a higher heat. The mixture of the second supply of liquor with the malt is completed in the third chamber, and from this the mash is delivered into the mash tun, where it remains from one and a half to two hours. Sparging can then be commenced, and continued until the required length has been run over.

Another mashing machine, designed by R. Wilson, of Alloa, differs from those described in being self-acting. It is driven not by power externally applied, but by the action of the malt and water. This masher, Fig. 305, is attached by the flange N to the spout leading from the grist-case, and the admission of the ground malt is regulated by the valve G, the spindle of which carries a lever handle fitted to a catch. The malt, as it falls, has to pass through a thin sheet of hot liquor which issues from the pipe E, the opening of this pipe being fitted with a sluice F, by which the quantity of liquor admitted can be regulated. Passing on, the malt and liquor fall into the buckets of the breaker wheel D, and cause the latter to revolve at a high speed. The buckets of the breaker wheel are of V form, and by their action and that of knives between which they work, the mash is mixed as it passes to the lower part of the machine. The spindle of the breaker wheel passes through the sides of the machine, and carries at one end the fly-wheel, which tends to equalize the motion, and also serves as a hand-wheel when necessary. The mash is delivered into the mash tun through the nozzle P, this nozzle being fitted with a serrated balance plate H, hinged at its upper side, and working over the discharging mash, levelling it, and preventing it from splashing into the mash tun.

305.

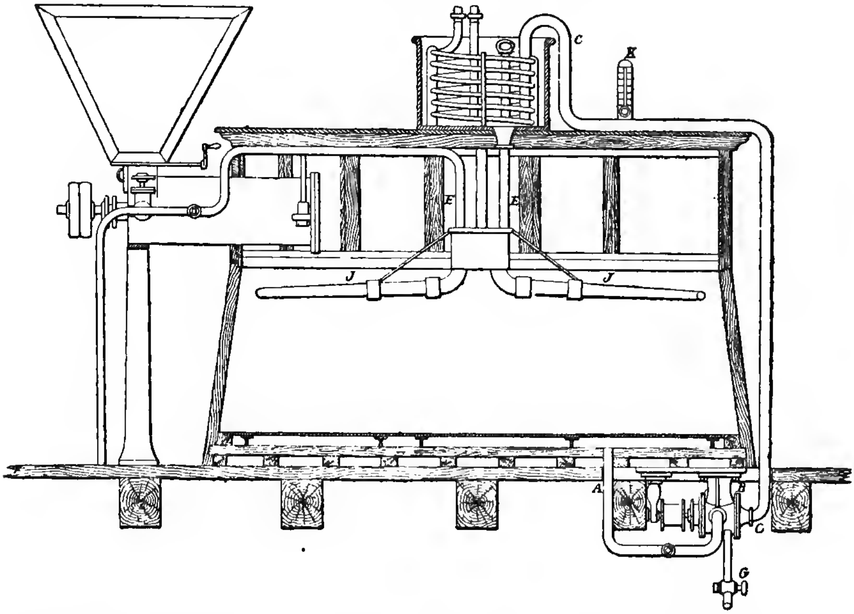


It is desirable to have the contents of a mash tun at all times completely under control, and several arrangements are employed for this purpose. Beneath the false bottom of the mash tun there is sometimes placed a pipe, coiled spirally. Into this pipe, steam can be admitted and the temperature of the mash increased, the action of an arm working above the false bottom tending to some extent to equalize the temperature in the different parts of the tun. This arrangement is simple, but it is scarcely applicable for ordinary use, as the increase of temperature is not sufficiently uniform in all parts of the mash.

A more suitable apparatus for controlling the heat of the mash is the mash tun attemperator, designed by J. Crockford. The attemperator, Fig. 306, is shown as fixed to a wooden mash-tun with sliding doors and fixed roof, as used in the Burton breweries. It consists of a circular cistern, fixed on the top of the mash tun, and containing a coiled steam pipe. When it is desired to raise the temperature of the mash, the wort is drawn from the tun by the pipe A, and the centrifugal pump B is set in action, the wort being raised into the attemperator through the pipe C. There it is heated by the action of the steam in the coiled pipes, and is then led down through the pipe E to the central vessel of the sparger J, which distributes it over the goods. The pipe C conducts the wort to the bottom of the attemperator, whilst the pipe E draws off the wort from near the surface, where it has greatest heat. The central pipe in the attemperator is for admitting the ordinary supply of hot liquor to the sparger. So long as the pump B is in action, a constant current is maintained through the goods, the wort being drawn off at the bottom, heated, and again sparged on the top continuously. By the use of the attemperator, the temperature of the mash can be maintained for any period; and in the case of small brewings, where the loss of heat from radiation is proportionately very great, the apparatus is particularly valuable.

It is the custom to complete the length, or total quantity, of a brewing by distributing over the goods the required amount of liquor by the aid of a sparger. A sparger in its usual form consists of two or more tubular radial arms, perforated on one side, and leading from a central cistern. These arms are mounted to revolve freely over the goods in the mash tun. In some cases, the cistern rests upon a point, and in others it is carried by friction wheels. When the mash tun contains mashing apparatus driven from the central shaft, the cistern of the sparger is made annular to surround the shaft. The shaft carries a disc, on which run the friction wheels of the sparger; in many instances the bevel wheel on the shaft serves as brace for the friction wheel. The cistern is in most cases open at the top, the liquor being delivered into it by a pipe conveniently placed; but in some instances the vessel is connected to the supply pipe by a joint, so that the water may be delivered under pressure, the joint being formed so as not to interfere with the reaction of the sparger. Spargers are chiefly driven by reaction, the water issuing from the perforations of the arms, imparting motion to them on the principle of Barker's mill. But spargers are sometimes driven from the shafting by a light belt or cord, with the object of ensuring regularity of motion, and consequently equal distribution of the liquor over all parts of the goods; but if a self-acting sparger is well constructed, the irregularity of its motion must be extremely small.

306.



A point of far more importance than any slight irregularity of motion is the proper distribution of the holes in the arms of a sparger. In order that the liquor may be equally distributed over all parts of the goods, it is necessary that the quantities of water delivered from different points in the arms should be in exact proportion to the areas swept over by those points. If the first hole in the arm of a sparger is 6 in. from the centre, and the last hole distant 6 ft. from the same point, the latter hole will, as the sparger revolves, cover a circle twelve times as great as the former, and in order that the goods passed over by the two holes should be equally wetted, the delivery of water from the outer hole should be twelve times that from the inner. The required increase in the delivery from the outer ends of the arms may be obtained either by increasing the size of the holes, or by placing them nearer together as they are farther from the centre, or by combining these two methods. The sparger arms are sometimes straight and sometimes curved, the object of the curving being to cause the water to tend outwards in radial lines. The curvature to be given depends upon the speed at which the sparger revolves and the rate of flow. If the arms be formed of tubes of the same diameter throughout, the flow will be most rapid near the centre, the rate of flow at any point being approximately proportionate to the area of the discharging holes beyond that point. The best practice is to taper the arms gradually outwards, observing that the sectional area at any given point is at least equal to the combined area of the discharging holes beyond that point. If the taper of the arms be properly proportioned, the rate of flow will be constant at all points. Whether the arms are curved or straight will then make but little practical difference, so long as the sparger revolves at the usual moderate speed.

The next apparatus in the order of use is the underback, which receives the wort from the mash tun. In some breweries, the wort is run direct into the coppers. The underback is a necessity where the coppers are situate at a higher level than the mash tuns. Underbacks are of various shapes and materials, chiefly wood, and rectangular. A circular form is better, as it is more easily kept clean.

When cast iron is used it should be lagged with felt and wood, unless the wort can be very rapidly raised into the coppers, or unless the underback is fitted with steam pipes, so that the temperature of the wort may be maintained.

The underback should be situate so that the taps through which the wort is discharged are in full view. In drawing off the wort, the taps are at first partially opened, being more fully opened when the wort runs off clear. The wort is generally drawn from four or more points in each mash tun, and in the event of any tap not delivering clear wort, it is shut off for a time. The appearance of the wort will vary according to the kind of malt used. The wort drawn from the first mash should closely resemble in colour the mixture of malt used, and it should have a close and tough, silvery white head, changing to a delicate cream colour. The temperature or tap-heat at which the wort is drawn varies according to the nature of the malt used; but it is about 62° to 63° (144° to 146° F.). If the heat of the mash be too high, the head on the wort will have a brown tinge; and if too low, the head will be deficient in closeness and firmness, and the wort will not be bright or well flavoured. Wort of this kind is particularly liable to acetification, and it should be exposed to the air as little as possible. Wort of any kind is not benefited by exposure at this stage, and should never be allowed to remain in the underback longer than is necessary.

When the wort has been drained into the underback, the mash tun is cleared of the waste malt or grains. This is ordinarily done by men with wooden shovels, but involves waste of labour in large and deep tuns. A better method is to provide the tuns with openings in the side near the bottom, communicating with shoots. The wort when drawn from the mash tun is composed of water, glucose or saccharum, and gum or mucilage, together with small proportions of starch, gluten, and albumen. During the early part of the process of boiling, diastase effects the conversion of the starch into sugar, dextrine, and gum; and as the boiling goes on, the wort is concentrated, and a certain proportion of the albuminous matter present is deposited in a flocculent form. The hops are added to the worts at this stage.

Boiling.—The time during which the boiling must be continued will depend upon several circumstances, such as the evaporative power of the copper and the amount to which the wort has to be concentrated. Generally the proportion evaporated during the boiling is about one-seventh; and there is a further loss by evaporation as the wort cools down from the boiling point. In determining the duration of the boiling, the time required to obtain the necessary extract from the hops has to be considered. The stronger the hops, the longer boiling they require to obtain the full extract.

The quantity of hops added to the wort depends upon the quality of the beer being brewed and the time it is intended to be kept. The measured quantity of hops is sometimes merely thrown into the copper, and stirred into the wort; sometimes the hops are picked out and strewn on the surface, where they are allowed to remain for some time before being stirred in. The object of surface treatment is to allow the hops to be permeated by the rising steam, thus opening the pores before immersion in the wort. When boiling takes place in an open copper, the layer of hops on the surface of the worts prevents contact with the atmosphere. In many breweries, where two or three mashes are made, the hops, after boiling with the wort from the first mash, are discharged with it to the hop-back, and are returned into the copper to be boiled with the second wort, and so on. This is the general practice at the London breweries, and in some the hop-backs are fitted with elevators, by which the hops can be transferred to the coppers. At Charrington's, a long Archimedean screw, similar to those used for transporting malt or grist, placed at an angle of about 30°, is used for raising the hops from one of the hop-backs to the copper. When hops are treated in this way, the moisture finally retained in them, which, unless the hops are allowed ample time for drainage, will amount to one barrel for every 60 lb. of hops, is only of the strength of the wort with which they were last heated, and is of comparatively little value. Another plan is to discharge the hops from the copper with the first wort, and allow them to remain in the hop-back, the succeeding worts being merely poured over. This plan effects a gradual weakening of the liquor retained by the hops. Another method of preventing loss by the retention of wort, is to subject the wort to pressure. At Salt's brewery at Burton the practice is, with the best pale ales, to boil the hops with only the first wort. After discharge from the copper with the wort, they are removed from the hop-back and pressed, and are then available for another brewing. The hops are sometimes boiled with the first and second worts, and are then pressed, so as to thoroughly remove any wort held by them. At Allsopp's, Bass's, Salt's, and other large breweries, hop presses, worked by hydraulic power, are used, whilst in smaller establishments screw presses are employed. At Younger's brewery at Edinburgh, the wort is expelled from the hops in centrifugal drying machines.

Extended series of experiments on heating by tubes containing steam have been made, and very various results have been obtained by the several authorities. It will be sufficient for general purposes to be enabled to calculate the amount of surface necessary to boil or to evaporate one barrel of water in one hour by means of steam pipes, and as well to furnish similar data for steam-heated boilers with double bottoms. The steam may be assumed as at 30 lb. pressure a square inch above atmospheric pressure.

A barrel of water weighs 360 lb., and to increase its temperature from 52° to 212° F., or 160°, it is necessary to impart 360 × 160 = 57,600 thermal units. As the latent heat of steam at atmospheric pressure is 966°·6, additional heat amounting to 360 × 966°·6 = 347·976 thermal units is necessary to convert a barrel of water into steam; or a total of 405,576 thermal units is required to evaporate one barrel of water from an initial temperature of 52° F.

Proceeding in this way, it has been calculated that the areas of steam-heated surface required to raise one barrel of water an hour from an initial temperature of 52° F. to the boiling point, is for

	Sq. ft.		Sq. ft.
Copper steam-pipes	1½	Copper with double bottom	2
Iron	3	Cast-iron boiler with double bottom ..	4½

The areas of steam-heated surface required to evaporate one barrel of water an hour from an initial temperature of 100° (212° F.) are:—

	Sq. ft.		Sq. ft.
Copper steam-pipes	24½	Copper with double bottom	30
Iron	40	Cast-iron boiler with double bottom ..	73½

The same data for 100 gallons are:—

	To boil.	To evaporate.
Copper steam-pipes	4¼ sq. ft.	.. 67½ sq. ft.
Iron	8 „	.. 111 „
Copper with double bottom	5 „	.. 82 „
Cast-iron boiler with double bottom	12½ „	.. 203 „

Graham is of opinion that unboiled wort, after fermentation, no matter how vigorous the yeast may have grown, never produces sound ales. Worts therefore must be boiled, and the action prolonged, so that the albuminous substances may be broken down in complexity, their activity destroyed, and at the same time colouring matters produced as in malting. In the boiling process, if there should have been, by chance, any insoluble starch carried over with the wort, it will be converted into soluble starch, but not into dextrine, for soluble starch is not converted into dextrine by the action of boiling. If any insoluble starch is run into the copper, that starch will be found throughout the subsequent stages. Dextrine in the boiling process is not converted into sugar, although some brewers hold that opinion.

According to the present theory of brewing, boiling may be considered a necessity. Some theorists assert that it is not required, but no practical progress has been made in evidence of good results arising from omission of this part of the brewing process. By boiling, two results accrue, the elimination of a large quantity of albumen from the beer, which is completed after about twenty minutes from the commencement of boiling, and the absorption by the beer of the bitter principle of the hop. But for neither of these results is ebullition necessary, as both may be attained by exposure of the wort to certain high temperatures. With low-dried malts, heat below the boiling point of water will precipitate the albumen of the malt, and a temperature either higher or lower will abstract the better principle of the hop, with, however, slight differences of flavour, resulting from different temperatures. Boiling is practically necessary as a means of evaporation. A copper can easily be made to evaporate 15 per cent. of the water from the beer while the albumen and hop are under treatment, allowing of an equivalent of water being used in the mash tun to extract the malt. Coagulation of the albumen by boiling may be seen, when a sample of the wort is taken in a glass; where the malt is low-dried and unsafe, the flakes are large, but when the malt is new and has been well dried the flakes are small. The precipitation is less from the second and third boilings of the mash tun, than from the first; but notwithstanding this fact, it is the practice to boil the lighter mashes longer, for what purpose there does not appear sufficient reason to show, except that the first portion of the mash cannot be boiled long unless it is a very light brew, while the after portion may be boiled for evaporation as long as the brewer may desire. Boiling is continued for about two hours for the general class of beer. For export beer, where a great quantity of hop has to be boiled down in a single copper, three hours are sometimes allowed. Heavy beer will require only one to one and a half hour, as the greater density of the wort is the cause of considerable increase of temperature in the copper. If heavy beers are boiled too long, the pale wort becomes brown, and a flavour similar to that of porter is given to the beer. Coagulation, and the discolouring of strong worts, occur in comparatively shallow depths, say about 4 ft. in some coppers, so that coppers should be made wider for strong beers than for light beers. The boiling of heavy beers should always be followed by the boiling of light beer, in order to work out the mash-tun products, and utilize the half-extracted bitter of the hop, as well as to recover the strong wort absorbed by the hop in the boiling of the heavy beers. The method of working with repeated boilings and returning the contents of the copper is highly economical, and is generally pursued in the porter trade, where three boilings and returns of hop are common. Double boilings of hop are, however, supposed to be the safe limit in beer brewing, and many large brewers will not exceed one boiling with the hop, but disperse the quantity boiled over the malt, amongst the boilings of the mash extracts from which the worts have been taken. In this case, the hop is sent to be pressed to obtain the final amount of extract. It is the opinion of some brewers, who have had large practice, that reboiling of the hop affords great economy in brewing, and is perfectly safe when exposure to air is prevented. Most of those who have failed in trials of reboiling have worked with high final temperatures, technically termed high tail heats, which have given unsound products in the mash tun, and these, acting on the hop in the copper, extract from it an astringent principle imparting a bad flavour to the beer.

For the production of a fine beer, more depends upon boiling than brewers generally admit. There is more that should be considered than mere ebullition or mere attainment of 100°; the influence of barometric pressure, shape of the copper, whether it is closed or open, are of great importance, but have not received that attention which experiment has shown them to merit. The peculiar flavour of London porter is undoubtedly due to the particular method of boiling, and to the use of large boiling coppers. A column of water 2 ft. 3 in. high, gives a pressure of 1 lb. a square inch, and a temperature difference at the two extremities of about 1°, when heated as beers usually are, so that a boiler of 12 ft. in depth may have a difference of about 5° (8° F.) from the temperature of an ordinary beer copper. A wide copper, that allows freedom to the currents of ebullition, keeps its wort cooler than a narrow copper, in which the upper and downward currents come into contact. For this reason a wide bulging copper, with an ascending current in the centre and descending currents at the side, is best fitted for pale beer; and a deep copper with almost perpendicular sides, by constricting the space for circulation and causing the descending currents to return upon the ascending currents, in other words, the cold currents upon the hot, is best for porter. In boiling, any hindrance to circulation causes increase of temperature. The wort at the bottom of the copper, loses solidity, becomes frothy and thus loses its conducting power, so that the copper bottom attains a temperature which renders the copper bad for ale, but better for converting extract of black malt into porter. Boilers with steam tubes at the bottom, and a false bottom at some distance above the tubes, intended to keep the hop from contact with the source of heat, are unsuccessful, because there is no circulation, and the wort beneath the false bottom is superheated, whilst that above remains cold. In Scotch breweries, the coppers are much wider than they are deep, whilst in the West and North of England they are deeper than wide; on this account Lancashire beer takes its peculiar flavour. The high temperature employed in boiling Lancashire beers is beneficial only so long as the malt is properly cured, and so dried as to approach an amber colour, but, without this preparation of the malt, it is useless to attempt rectification in the copper. It is agreed in the best practice that extra heat in the copper will not give additional keeping quality to either black or pale beers, unless the malt has been cured and heated to correspond with the temperatures of the coppers. Narrow coppers are wasteful and troublesome, because the contents are liable to be forced over the lips from the want of space for the currents of ebullition. Scotland and Lancashire may be regarded as presenting examples of the extreme limits of form for coppers. In London breweries, domed coppers are employed, and this may in some measure account for the superior flavour of London porter. Porter must be boiled at a temperature of 107° to 110° (225° to 230° F.), and this temperature can be attained in a straight-sided boiler, well fired, by boiling at a charge depth of 12 ft., or with a pressure in a small domed-boiler of 4 or 5 lb. a square inch. Domed coppers, besides the safety valve, have a vacuum valve to prevent collapse; steam boiling is attended with some difficulty unless carried out in double-bottom coppers, which require the use of tubes to give 50 per cent. of steam surface over that of fire surface.

Graham is of opinion that long boiling is necessary, and that a portion of the quantity of hops should be added after the first half-hour's boiling, the scum removed, hops again added, and boiling continued for an hour or an hour and a half, as may be required.

All beers when kept for a few months, age and lose the distinctive flavour of the hop. In the hopping of beers, the range of quantity between 4 to 24 lb. a quarter occurs in practice. Scotch mild ale is made with 4 to 6 lb. to the quarter, and Scotch pale ale with 10 lb. of hop; Burton mild ale, 12 lb.; Scotch export ale, 16 to 20 lb.; Burton home pale ale, 20 to 24 lb. Porter, for early sale, is made with 8 to 10 lb. of hop, and for export, with 12 to 14 lb. good quality. Stout for home use is hopped with 12 to 14 lb.; and export stout 16 to 18 lb. a quarter. The hop for porter and stout is always reboiled.

In raw hopping the beer in cask, 1 lb. to the barrel is usually allowed for home sales, and 2 lb. to the hogshead for export beers. The finest new hop is selected for this purpose; delicate for home, and strong for extract beer. Vatted ales are always raw hopped. Stouts are sometimes thus treated, according to the practice of the brewer. In the best practice, it is generally admitted to be a mistake to hop the beer both in copper and cask, especially for the purpose of correcting stale malt; a better plan is to re-dry the malt.

Cooling.—Before the introduction of refrigerating apparatus, beer wort was cooled on cooling floors, flats of buildings floored and flanged round to a depth of about 6 in. These floors were of oak, teak, cast iron, or copper, but the loss of beer from the old wooden coolers through absorption by the wood was sometimes equal to 5 per cent. of the net results of the brewing. Considerable difference of opinion occurs as to the advantages of refrigerators over coolers, but beyond the advantage of evaporation, in helping to remove the mash water, there is no benefit from the use of a cooler. The most economical and safest brewing is that conducted with refrigerators, so that the wort may be run direct from the hop-back through the refrigerator to the permeating tun. If the refrigeration is effected with cold water, the supply necessary is equal to double that needed to cool with the cooler, if the wort is at a temperature when it begins to run, of about 55° (130° F.).

After boiling, the worts are, as a rule, discharged from the copper or boiling back, as the case may be, into the hop-back, a large tank or vessel fitted with strainers for separating the hop from the wort. In those breweries in which the wort has to be pumped from the hop-back into the coolers, the former, in addition to acting as a strainer, serves as a reservoir from which the pumps can draw. Sometimes the hops are placed in the boiling back, enclosed in a perforated sheet-iron vessel, and as in this case they cannot mix with the wort, the latter does not require to be strained after boiling, and it is therefore run direct from the boiling back to the coolers, no hop-back being used.

A hop-back should always be capable of containing the full contents of the copper in connection with which it is worked, and if it is of any great size, it should be fitted with elevating machinery, for returning the hops to the copper. To enable hop-backs to act as strainers, they are fitted with perforated false bottoms, constructed generally of cast-iron plates, arranged to be readily removed for cleaning purposes. The space below the false bottom communicates either with the suction pipe of the pumps, or with a pipe leading direct to the coolers. The perforations in the false bottoms are sometimes narrow slits about $\frac{3}{32}$ in. in width, and 2 in. or 3 in. long, and sometimes small holes about $\frac{1}{8}$ in. or $\frac{3}{16}$ in. in diameter. In either case, the perforations are well countersunk on the inner side of the plates, so that the thickness, through which the narrow openings extend, is not great. The draining power of any hop-back varies directly as the area of the openings in the false bottom, and, as these openings must not be limited in size, they should be placed as closely together as possible. As the flow of the wort through the perforations is accelerated by increasing the depth of wort, there has been an erroneous tendency to make hop-backs deeper than needful, to obtain increased head. With a given quantity of wort, an increased depth can only be obtained by a reduction of the horizontal, and consequently of the drainage, area, hop-backs, as a rule, being furnished with perforations only at the bottom. The reduction of drainage area consequent upon the increase in depth varies directly as that increase, whilst the velocity of flow through the perforations in the false bottom is augmented only as the square root of the increase in depth. For example, a hop-back has a drainage area of 40 sq. ft., and the wort stands at a depth of 4 ft. above the false bottom. The theoretical velocity of flow through the perforations should be about 16 ft. a second. If the hop-back be supposed to be contracted until the horizontal area is reduced to 10 sq. ft., the depth of the wort will be increased to 16 ft., and the flow due to this head will be 32 ft. a second. The velocity of flow will only have been doubled, whilst the drainage area has been reduced to one-fourth ; and the quantity of wort drained from the back in a given time will only be half that in the former case. The greater the depth, the greater also will be the quantity of hops deposited on each unit of area of the bottom, and the more resistance offered to the passage of the wort. When the depth of the wort above the false bottom is 5 ft. 9 in., there will be about one barrel above each square foot of bottom area, and the quantity of hops deposited a square foot will nearly correspond to that quantity a barrel, whilst, if the depth is but 2 ft. 10½ in., there will be but half this quantity deposited a square foot, and so on. A certain portion of the drainage area can be kept clear by raking away the hops; but the area covered by the hops will always depend upon the depth of wort originally contained in the back. Hop-backs should, therefore, not be more than 2 ft. 6 in. or 3 ft. deep above the false bottom. Where the wort is pumped from below the false bottom of a hop-back, an artificial head is caused by the exhaustion, if the pumps are sufficiently powerful. In a hop-back at Charrington's brewery another plan has been adopted, to avoid loss of drainage area by the deposit of hops. This hop-back is provided with vertical grilles, in addition to the ordinary perforated bottom. The back, 48 ft. long by 12 ft. wide and 5 ft. 3 in. deep, is provided, at a distance of 6 ft. from each end, with a diaphragm or partition. The partitions are each formed of a series of angle irons placed vertically side by side, with spaces $\frac{1}{8}$ in. wide between. These vertical angle irons, forming the grids, are riveted at the top to an angle iron. Between the diaphragms or screens, the hop-back is provided with a false bottom, placed 3 in. above the real bottom, and constructed of cast-iron plates. The cast-iron plates are each 3 ft. long by 1 ft. wide by $\frac{9}{16}$ in. thick round the edges, and $\frac{3}{8}$ in. thick at the perforated portion. The holes are $\frac{3}{16}$ in. in diameter, and are deeply countersunk on the under side, and are placed at 1 in. pitch. The space between the false bottom communicates at each end with those portions of the hop-back beyond the vertical grilles, the end openings being each protected by a curved grill, formed of angle irons similar to those used in the vertical screens, but placed closer together. The bottom of the back is laid with a fall of $\frac{1}{8}$ in. a foot from each end towards the centre, where a gutter, 3 ft. wide by 5½ in. deep, is formed, with which the suction pipe of the pumps communicates.

The action of this arrangement is as follows: When the worts are poured in, drainage takes place through the false bottom between the diaphragms in the usual manner; and in addition to this the wort also passes through the vertical grilles or diaphragms into the end divisions of the back. From these latter it passes through the curved grilles, which serve to separate any hops that may have passed through the vertical diaphragms, and so into the space below the false bottom, and thence to the pumps.

When drawn from the hop-back, the wort has to be cooled to the temperature at which it is placed in the fermenting tun. This temperature varies from 12° to 18° (54° to 64° F.), and allowing for some loss of heat in the hop-back and communicating pipes, the temperature of the wort has to be reduced about 83° (150° F). This reduction is sometimes effected by exposing the wort to the air in shallow vessels, or coolers; sometimes by passing it through a refrigerator, and very generally by a combination of the two methods.

Wooden coolers are those most frequently met with, probably on account of cheapness, but they are open to many objections. They are usually made of Dantzic deals about 1¼ in. thick, the boards being pegged to the joint pieces with wooden pins. The coolers should be laid with a slight inclination towards the point at which the wort is drawn off, and the boards should be planed as smooth as possible, so that they may be more readily kept clean. Too much care cannot be paid to the cleanliness of the coolers, and they should be frequently well washed with lime water. If the coolers are not in almost continual use, it is advisable to keep them covered with water when not required for the wort, as the pores of the wood, which have been opened by the action of the hot wort, are prevented from absorbing air which would come into contact with the next wort, and cause incipient fermentation, generally termed foxing.

Metal coolers are generally placed so that their under sides are exposed to the air as well as the upper surface, and the cooling effect is thus increased. This arrangement should be adopted in all metal coolers. At Truman's, the coolers are of copper, and are two in number, each 110 ft. long by 25 ft. wide. They are made of thin copper, the weight a square foot being about 3½ lb., and are supported merely on joists, the under sides being freely exposed to the air. The wort is not allowed to remain in these coolers, but is run over them in a thin stream to a refrigerator, which completes the cooling process. These coolers are capable, under ordinary circumstances, of cooling about fifty barrels of wort an hour from the boiling point to a temperature of 43° (110° F.); the combined surface of the coolers being 5500 sq. ft. This is a very high result, and is partly due to the wort being kept in circulation over the coolers, and to the coolers being made of thin copper.

Special rules for the dimensions of coolers are inadmissible. Besides the variations in temperature and state of the atmosphere, which exercise a most important influence on the efficiency of cooling surface, the position in which the coolers are placed, and the degree in which they are protected from free currents of air by surrounding buildings, modify considerably their refrigerating power. Coolers should always be placed so that the air has free access, and to this end it is usual to make the walls of the rooms containing them of louvres, which can be opened as may be required. If the wort is to stand on the coolers, these should be of such size that the depth of the wort may not exceed 2 in. or 2½ in., or, in other words, have an area of about 36 sq. ft. a barrel, each square foot thus carrying a gallon of wort. When covered with wort to this depth, a well-situated cooler will, under ordinary circumstances, effect the required reduction of temperature in six to eight hours.

The cooling power of a certain area of cooler surface may be increased by causing the wort to flow over the coolers instead of remaining quiescent, or by causing the surface to be swept by an artificial current of air.

If coolers are worked in connection with a refrigerator, so that there may be a regular flow of wort, they should be of considerable length in proportion to the width, or if of nearly square shape, divided by partitions placed so as to leave passages past the alternate ends, so that the wort may have to travel through a series of long and comparatively narrow channels. The wort should be drawn off from different points in the width of the stream, either through a number of openings communicating with a single pipe, or by letting the wort fall over a kind of weir extending across the stream. By these means, greater uniformity of current will be ensured.

Of the extent to which the cooling power of a given area of wort surface is increased by the passage over it of a current of air, some idea may be gained from Dalton's experiments on evaporation at natural temperatures. With water at 100°, and an atmospheric temperature of 15°, it was found that a surface of about 27 sq. in., which would evaporate 2·1 grains a minute in still dry air, would evaporate 3·3 grains a minute when there was a brisk current of air passing. When coolers are placed at an elevated part of the brewery, as is very usually the case, they are generally subjected to natural currents of air of greater or less force; but in addition to this it is the practice in many breweries to assist the cooling by the use of fans. Fans, having each three or four vanes, are caused to rotate horizontally immediately above the surface of the wort, the blades or vanes being placed with their surfaces inclined to the plane of rotation so that the current of air is deflected downwards as well as caused to spread radially. Fans arranged in this way not only cause a constant change of the air in contact with the wort, but give rise to currents in the wort itself, and thus tend to equalize its temperature throughout.

Another arrangement for obtaining an artificial current of air over the wort has been adopted. A cooler is attached to each pair of mash tuns, and is of sheet iron, supported on open joists, so that the under sides are freely exposed to the air. At one corner of the cooler is a fan, communicating with a wooden trunk, led along one side of the cooler, having openings through which the air can enter. The moist air, drawn off by the fan from the surface of the wort, is expelled through a pipe, which rises through the roof of the building.

The best brewing practice is now tending to the employment of refrigerators alone for cooling the wort, and for this there are many reasons. A lengthened exposure to the atmosphere, to which the wort is subjected on the coolers, is far from beneficial, and in comparatively warm weather apt to induce acidity. There is also a loss by absorption on the coolers, and a loss by evaporation. As this latter loss is merely of water, it may, at first sight, appear to be of but small consequence; in reality this is not the case. Under ordinary circumstances, the loss by evaporation alone is about 8 per cent., and this involves the use of 8 per cent. more liquor in washing than would otherwise be necessary to produce a wort of a given final strength. The quantity of wort to be boiled is also increased 8 per cent., and since the quantity of fuel used is, in large brewings, proportional to the quantity of wort and liquor heated, an additional consumption of 8 per cent. of fuel is the result. When the wort is cooled entirely by passing it through a refrigerator, the loss by evaporation is of course *nil*, and since a less quantity of liquor will have to be used in mashing, there will be a less quantity to heat as liquor, and to boil afterwards as wort. In many cases, the hot water obtained from the refrigerators may be fed into the liquor boilers. Again, where fans are used, the expense of the engine power required to drive them has also to be considered.

Against the disadvantages of the coolers are to be set the expense of the refrigerator and the cost of supplying it with water, either by pumping or otherwise; in all but very exceptional cases, the balance will be in favour of the use of the refrigerator. In many instances, the water heated by passing through the refrigerator can be used for brewing purposes, and even when the water used for refrigeration is not available for brewing, the supply of hot liquor can generally be turned to some account. Coolers are best employed only for effecting the reduction of the temperature of the wort from boiling point to 43° (110° F.) or 50° (120° F.), the cooling being completed by a refrigerator.

In the cooling process, a precipitate is formed due to two causes, the simple action of cold being one. Part of the albuminous matter, that which combines with tannic acid to form tannate of albumen, is precipitated, the precipitate being also due to oxidation. During a long cooling from a high temperature, as when the worts are cooled upon open coolers, oxidation is set up by the air, the most dangerous temperatures being from 39° to 50° (100° to 120° F.). If starch is present in soluble condition it is likely to set up decay, which Graham states is not due to the action of vital organisms, but to the division of the grape sugar or glucose into two equal molecules, each containing $C_3H_6O_3$, or lactic acid; the molecule of glucose simply breaks up into two molecules of lactic acid, no gas being given off nor precipitate formed, but the acid is produced by simple alteration of the molecular arrangement. This action is likely to occur in a prolonged exposure to temperatures between 16° and 38° (60° and 100° F.). Rapid cooling therefore is essential.

Wort cooled on cooling floors is stated to be sound and good if it presents a black appearance on the surface, a reddish hue being indicative of putrefaction. When this red colour occurs, the coolers must be thoroughly cleansed with chloride of lime and quick lime, not with bisulphite of lime. Graham considers that cooling should be continued to about 18° (64° F.) or 19° (66° F.). In Burton, it is carried to 14° (57° F.), and in Bavaria, where the bottom fermentation process is employed, to 6° (42° F.).

Fermentation.—When cooled, the wort is led to the vessels or tuns in which it is to undergo fermentation. The nature of the chemical changes known as fermentation, and the conditions under which they take place, have been described and indicated in a former article (see Alcohol, p. 194).

The sugar in the wort on its transformation into glucose takes up two equivalents of water; therefore the combined weights of the carbonic acid and the alcohol resulting from the fermentation is greater than that of the sugar originally contained in the wort. It follows that there should be an increase in the specific gravity of the solution or wort during the time that the conversion of the cane sugar into grape sugar is taking place. This is actually the case, and it is a fact of which the brewer takes advantage. As the evolution of carbonic acid gas progresses, the specific gravity of the liquid is observed to decrease; and this gradual reduction of specific gravity is by brewers termed the "attenuation." The attenuation of the wort is accompanied by a rise in temperature, and it is by this increase of temperature, combined with the reduction of the specific gravity, as observed by the saccharometer, as, well as by the appearance of the head formed, that the brewer is enabled to judge how the process of fermentation is proceeding.

In the fermentation of a malt wort, the conversion of the saccharine constituents into alcohol and carbonic acid does not occur alone. The albumen and gluten become insoluble in the alcohol formed by the process of fermentation. Under the circumstances of the English method of procedure, one portion of these insoluble substances is buoyed up by the ascending globules of carbonic acid forming the frothy head which collects on the surface. The remaining portion of the insoluble matters is deposited as bottom barm, which consists of gluten mixed with the denser impurities of the wort, and is a cruder material than the yeast floating on the surface. The proportion that the floating yeast will bear to the bottom barm will vary with the nature of the malt, the heat of the mashing process, and with the temperature at which the fermentation is carried on. In the case of the Bavarian brewing process, in which the fermentation is allowed to proceed very slowly, a mere film is formed on the surface of the wort, the insoluble matters being almost entirely deposited as a viscid sediment, termed the "unterhefe."

The initial temperature at which the wort is pitched or mixed with the yeast in the fermenting tuns exercises an important influence upon the energy of the fermentation, and it has to be regulated according to the atmospheric temperature of the tun room and the strength of the wort. According to the English practice, the pitching temperature ranges from 11° (51° F.) to as high as 18° (64° F.), but in the Bavarian system it is kept as low as 7° to 10° (45° to 50° F.) In winter, the air, being at a low temperature, tends to check the energy of the fermentation; whilst, in summer, as the air is frequently at a higher temperature than that at which the wort is pitched, the fermentation is more difficult to control. For these reasons, it is necessary that the pitching temperature should be lower in summer than in winter, unless means are provided for keeping the tun room cool. The smaller the vessels in which the fermentation is carried on, the greater will be the surface exposed by them in proportion to their contents, and the greater therefore will be the influence exerted by the atmospheric temperature. So long as the temperature of the air in the tun room is below that of the wort, the energy of the fermentation may be checked by dividing out the wort into a number of small vessels; but if the atmospheric temperature in the tun room is higher than that of the wort, the reverse effect would, of course, be produced by such a system of division. Care is generally taken to so construct and place the tun room that it may be kept at a moderate temperature even during the hottest weather, whilst in some instances special arrangements for cooling the air are adopted. Another point to be considered with respect to the initial temperature is the character of the beer to be produced; a light beer, intended for immediate consumption, may be pitched at a comparatively high temperature, but in the case of a strong stock ale the initial temperature should not be higher than 12° or 13° (54° or 56° F.), and it should not be allowed to rise more than 10° (16° F.) during the process of fermentation. Pale ales, also, which usually receive a liberal allowance of yeast, should be pitched at a low temperature. The quantity of yeast to be added, like the pitching temperature, depends upon so many circumstances that it is impossible to give any general rule.

The best yeast is considered to be that obtained from pale gyles towards the completion of alcoholic fermentation, this yeast being denser than that thrown off during the earlier stages, and free from admixture with old yeast that has been added to the wort to induce fermentation. Yeast, if collected from the stillions and placed in reservoirs or tubs, is apt to work and lose strength; it is better to let it remain in the stillions with a portion of the drawings, until required, when the drawings should be strained off. If the yeast has to be stored, it is best covered with water, and kept in the coolest place available. The water should be quite cool, and should be occasionally renewed.

The heavier, or in other words the stronger, the wort, the greater will be the proportion of yeast necessary, and this proportion will also be affected by the degree of attenuation to be produced. The quantity of yeast required depends also upon the temperature at which the gyle is pitched; the higher this temperature, the less the quantity of yeast necessary. Black states that if the worts are got together in the gyle tun at a temperature under 15° (60° F.), about 1 lb. of yeast a barrel for every 10 lb. of gravity, as indicated by Long's instrument, will be found to produce a loss of 1 lb. in attenuation for every degree of heat gained, and he considers this to be a good working rule. It should be remembered in all cases that a deficiency of yeast is better than an excess, since it is possible, if the fermentation is sluggish. to add more yeast; whereas, if the latter be in excess, a too violent fermentation may be set up, which it may be impossible to control. Yeast added after the fermentation should be first mixed with a portion of the wort, and then well stirred in; but this practice is not to be recommended, since it is likely to impart a rank flavour of yeast to the beer. In all cases where the weight of the yeast per gallon is not accurately known, the yeast should be apportioned out by weight, and not by measurement. Before the yeast is placed in the tun, it is mixed with a small quantity of wort, and left in a warm place until fermentation commences, when the mixture, termed "lobb," may be added to the gyle in the tun. Some brewers add the full quantity of yeast at once, whilst others reserve a certain proportion to be added subsequently to stimulate the fermentation. So long, however, as the quantity of yeast required is accurately known, the former system appears to be preferable.

In a thoroughly healthy fermentation, the rise of temperature which ensues as the process goes on should be steadily accompanied by a decrease in the gravity of the wort, or, for every degree of heat gained, a pound of saccharine matter per barrel should be transformed into carbonic acid and alcohol, an effect which will be shown by the saccharometer. Of course, this correspondence between the increase of heat and the attenuation attained is to some extent liable to modification by extremes of heat or cold. The stages of a healthy fermentation are as follows:—Some six or eight hours after the yeast has been added, minute bubbles of carbonic acid gas begin to rise, and a thin creamy froth is formed, first round the edges of the tun, but gradually extending over the whole surface of the liquid. As the temperature rises, and the decomposition of the saccharine matter becomes rapid, the evolution of the carbonic acid gas takes place more freely, and, as a consequence, the froth rises, forming what is termed the "cauliflower head." At this stage, the aroma becomes very perceptible. The cauliflower head should rise two or three feet above the surface of the gyle, and it should be of a brownish-white colour; a bluish-white colour at some parts indicates unsoundness. The next change consists in the breaking up of the cauliflower head into what is termed the "rocky head." The rocky head is produced by the bursting of the globules of froth, the yeast at first thrown off not being sufficiently viscid to retain the accumulation of carbonic acid. At this stage, the head should fall some three or four inches, and the aroma should be very pungent and vinous. In the next and last stage, the head again rises, forming what is known as the "close yeasty head," this having the appearance of yeast all over the surface. If the fermentation be a healthy one, the head will at this stage be covered with small bubbles at the top, these constantly bursting, discharging their gas, and being replaced by new ones. This goes on until the beer is considered to be ready for cleansing or skimming, a process which consists in removing the yeast from the surface. Different methods of conducting the cleansing will be described later. The object of the operation is to prevent the imparting of a bitterness or yeast-bitter flavour to the beer, which might be the case if the beer were allowed to remain in contact, at a temperature approaching 21° (70° F.), with yeast that had to some extent entered into putrefactive fermentation.

During the progress of fermentation, the temperature of the liquid rises, the maximum heat being attained when the fermentation is at its highest point. In some instances, the rise of temperature is upwards of 14° (30° F.), but generally lower, and in the case of stock, and Scotch ales, it is as low as 10° (16° F.). If the heat is allowed to rise too high, the glutinous constituents of the beer are not perfectly removed in the yeast, and as the gyle does not cleanse perfectly, an after fermentation ensues, technically termed the "fret." On the other hand, too low a temperature causes sluggish fermentation, and, as a consequence, the beer is apt to gain a yeast-bitter flavour from being retained too long in contact with the yeast. To avoid these results, various contrivances are employed to keep the temperature at all times under control.

In connection with the subject of fermentation, it is advisable to discuss briefly the determination of what are called "original gravities," or the gravities of the worts from which any given samples of beer may have been made. According to Act of Parliament, 10th Victoria, cap. 5, a drawback of 5*s.* a barrel is granted on all beer exported, on condition that the worts before fermentation were not of less specific gravity than 1·081. A brewer knows the strength of the wort from which the beer has been made; but it is necessary that the revenue officer also should have the means of obtaining independently from a sample of the beer the same information, and this necessity has led to the close investigation of changes which take place during fermentation. For each sample of beer there have to be determined the original gravity of the wort from which it was produced, the specific gravity of the beer itself, or, as it is sometimes called, the beer gravity; the spirit indication; and the proportions of unfermented solid matter, or extractive matter, held in solution by the beer. The specific gravity of the beer can be determined by the hydrometer, while the extract gravity, or the specific gravity, of the beer without its spirit, may be obtained by partially evaporating a given quantity of beer, to expel the alcohol, and making up the original bulk by the addition of water. By comparison of the specific gravity of the beer with the extract gravity, an indication may be obtained of the quantity of alcohol in the beer. This quantity may also be ascertained by distillation, by the refracting power of the beer on rays of light, or by observation of its boiling point, which lowers with increase of alcohol. It is possible, if the amount of alcohol in the beer is known, to roughly determine the original gravity of the wort by increasing the extract gravity by the amount due to the quantity of starch sugar which would have to be decomposed during fermentation to produce the known quantity of alcohol. Original gravities thus determined, however, are useless for practical purposes, because the final or beer gravity is the result, not merely of the attenuation produced by the decomposition of the saccharine matter, but also of the changes effected in other constituents of the wort during the process of fermentation.

In comparing the specific gravities of various solutions of sugar, malt, and other ingredients, Graham, Hofmann, and Redwood take as their standard of comparison the proportion of carbon that a given solution contains, and they have proved that the specific gravity of a solution, containing a given proportion of carbon will vary to some extent according to whether that carbon is present in the form of sugar, dextrine, or extractive matter. The annexed table shows the specific gravities of various solutions compared in this way:—

Specific Gravities of various Solutions containing equal Quantities of Carbon.

Carbon in 1000 parts by Weight of Solution.	Equivalent parts of Cane Sugar in 1000 parts by Weight of Solution.	Solution of Cane Sugar.	Solution of Starch Sugar.	Solution of Pale Malt.	Solution of Brown Malt.	Solution of Caramel.	Solution of Dextrine.	Solution of Extractive Substance.
10·53	25	1010·1	1010·4	1010·0	1010·0	1008·7	1009·7	1008·9
21·05	70	1020·2	1020·8	1020·3	1020·2	1017·3	1019·3	1017·8
31·58	75	1030·2	1031·3	1030·6	1030·6	1026·2	1028·8	1026·5
41·10	100	1040·6	1042·6	1041·2	1041·2	1034·9	1038·3	1035·5
52·63	125	1051·0	1053·5	1052·1	1052·0	1043·8	1047·9	1044·7
63·16	150	1061·8	1064·9	1063·0	1062·9	1052·8	1057·3	1053·9
73·68	175	1072·7	1076·0	1074·2	1074·0	1062·3	1066·9	1063·0
84·21	200	1083·8	1087·8	1085·5	1085·5	1071·8	1076·6	1072·7
94·73	225	1095·2	1099·4	1097·2	1097·2	1081·3	1086·3	1082·3
105·26	250	1106·1	1111·4	1109·0	1109·0	1091·0	1095·8	..

It has been stated that, when fermentation occurs in a solution of cane sugar, there is at first a slight increase of density, due to the transformation of the cane sugar into starch sugar, followed by attenuation, due to the formation of alcohol and the evolution of carbonic acid. In a wort containing cane sugar, a transformation of this into grape or starch sugar precedes the vinous fermentation, and this change occasions an increase of gravity of nearly 3°, in a solution of which the original gravity is 1055. The rate at which the rise in gravity occurs varies according to the amount of yeast added to produce fermentation. A similar effect results when the transformation of the cane into starch sugar is effected by the addition of acids instead of yeast. The comparative densities of solutions of cane and starch sugar are given in the preceding table, and the fact that they differ is important, for the original gravity of a fermented liquor or beer must be different, according as it was derived from a wort of cane sugar or of starch sugar. Since, in a small wort, the saccharine matter is present in the form of starch sugar, there is no increase of density previous to fermentation.

With regard to the densities of solutions of pale and brown malt, it is interesting to observe that the gravities of the solutions of the two malts agree very closely, and that they occupy a position intermediate between that of the two sugars. That the malt wort is of less density than a solution of starch sugar, containing the same proportion of carbon, indicates that a portion of the carbon in the wort exists in some other form than that of starch sugar; for if the whole carbon of the malt wort were present in the form of starch sugar, the gravity of the wort should somewhat exceed that of the pure starch sugar solution, since a small proportion of alkaline and earthy salts exists in the malt infusion, and must add to its gravity. The carbon present in the small quantity of albumen of the malt could not affect the result materially. The lesser density of malt wort as compared with a solution of starch sugar containing an equal proportion of carbon is no doubt in part due to the presence in the former of certain proportions of dextrine and caramel, substances which both produce solutions considerably lighter than those of starch sugar containing similar amounts of carbon. Both dextrine and caramel are forms of the sugar principle, and the presence of the former in a wort is due to the incomplete saccharization of the starch of the malt during the mashing process. The presence of caramel, or burnt sugar, is no doubt due to the changing of the starch sugar by heat during the process of kiln-drying the malt. It exists in larger quantities in highly dried malt than in the paler kinds, whilst in the case of the black malt used in porter and stout brewing, almost the whole of the soluble portion appears to be caramel.

Graham, Hofmann, and Redwood also point out that a substance greatly resembling caramel is produced during fermentation, owing to the saccharine matter of the wort never being wholly converted into carbonic acid and alcohol, even under the most favourable circumstances. A portion of solid matter always remains which is unfermentable, even if the alcohol is distilled off and fresh yeast used. This residuary has been termed gummy substance, but when obtained by the fermentation of pure sugar it partakes more of the character of caramel, or of glucic acid, particularly in the low gravity of its solution in water. Of pure sugar fermented, 4·4, 3·72, and 3·70 per cent. was converted into this substance in three fermentations, in which one and a half, three, and six measures of yeast were employed to one hundred measures of solution, containing one-seventh of its weight of sugar. This extractive substance may be obtained in the form of a dark-brown syrup by evaporating the liquid after the completion of the fermentation. This syrup reddens litmus paper; gives, like caramel, a transparent blue solution, with sulphate of copper and caustic potash in excess; is not fermentable by yeast even after being boiled with sulphuric acid, whilst it is precipitated by baryta water, and when treated with subacetate of lead gives a brown precipitate more voluminous and of a lighter colour than the precipitate produced by the same means from a solution of pure caramel. That it is a compound of two or more substances is proved by the fact that a portion of it is precipitated by the addition of a solution of neutral acetate of lead. Solutions of this extractive substance have densities very closely agreeing with those of caramel containing similar quantities of carbon. The presence of this extractive substance, which is produced during the fermentation of malt worts, as well as sugar worts, appears to exercise a greater influence than dextrine in giving to fermented worts an apparent attenuation without a corresponding production of alcohol, and the more nearly the worts are exhausted by fermentation, the greater is its effect. The indication by gravity of the extractive substance is so much lower than that of starch sugar, that the former substance only indicates about five-sixths of the saccharine principle that has given rise to it. Hence it is that original gravities cannot be calculated on the assumption that the solid matter in beer is sugar, or a substance having the same gravity as sugar. In the maturing of beer by time, an increase of attenuation is observed, which is no doubt due to the slow continuation of the vinous fermentation, with the disappearance of sugar and formation of alcohol; but there is some reason to believe that the attenuation is not entirely due to that cause. Part of the loss of gravity appears to be occasioned by the change in condition of the saccharine principle, from that of starch sugar to that of the extractive substance, a change which involves a loss of specific gravity without a corresponding production of alcohol.

During the process of fermentation of a malt wort, a change is produced in the proportion of albuminous matter; this proportion is diminished in consequence of the formation of yeast, which causes a proportion of the albumen to assume an insoluble form. In a wort made from pale malt with hops, of the gravity of 1088, and containing 21 per cent. of solid matter, it was found that the nitrogen amounted to 0·217 per cent., and might be considered as representing 3·43 per cent. of albumen; whilst after this wort had been fully fermented the proportion of nitrogen was reduced to 0·134 per cent., corresponding to 2·11 per cent. of albumen. Solutions containing 2·11 and 3·43 per cent. respectively of egg-albumen, have been ascertained to have the sp. gr. 1003·1 and 1004·2, therefore the loss of albumen which took place during the fermentation of the wort corresponded to a reduction of gravity from that cause alone of 1°·1. In the same wort, the mineral constituents, consisting of soluble salts of the earths and alkalies, amounted to 0·443 per cent. before and 0·463 per cent. after fermentation, a variation of no practical importance.

The determination of what is termed the "spirit indication" does not present great difficulty Graham, Hofmann, and Redwood have ascertained that a knowledge of the extract gravity and spirit indication of beer is sufficient to enable the original gravity to be determined with certainty.

The following tables were compiled to enable the original gravity of a beer to be determined from an observation of its spirit indication. These tables show the number of degrees of gravity lost by an ordinary malt wort corresponding to the different degrees of spirit indication, the first table being intended for use when this indication is obtained by the distillation process, and the second when it is obtained by the more practical process of evaporation. When the distillation process is used, a convenient quantity of beer is carefully measured in a glass flask, and then placed in a retort fitted with a tubular condenser.

ORIGINAL GRAVITIES BY THE DISTILLATION PROCESS..

Degrees of Spirit Indication.	·0	·1	·2	·3	·4	·5	·6	·7	·8	·9
0	..	·3	·6	·9	1·2	1·5	1·8	2·1	2·4	2·7
1	3·0	3·3	3·7	4·1	4·4	4·8	5·1	5·5	5·9	6·2
2	6·6	7·0	7·4	7·8	8·6	8·5	9·0	9·4	9·8	10·2
3	10·7	11·1	11·5	12·0	12·4	12·9	13·3	13·8	14·2	14·7
4	15·1	15·5	16·0	16·4	16·8	17·3	17·7	18·2	18·6	19·1
5	19·5	19·9	20·4	20·9	21·3	21·8	22·2	22·7	23·1	23·6
6	24·1	24·6	25·0	25·5	26·0	26·4	26·9	27·4	27·8	28·3
7	28·8	29·2	29·7	30·2	30·4	31·2	31·7	32·2	32·7	33·2
8	33·7	34·3	34·8	35·4	35·9	36·5	37·0	37·5	38·0	38·6
9	39·1	39·7	40·2	40·7	41·2	41·7	42·2	42·7	43·2	43·7
10	44·2	44·7	45·1	45·6	46·0	46·5	47·0	47·5	48·0	48·5
11	49·0	49·6	50·1	50·6	51·2	51·7	52·2	52·7	53·3	53·8
12	54·3	54·1	55·4	55·9	56·4	56·9	57·4	57·9	58·4	58·9
13	59·4	60·0	60·5	61·1	61·6	62·2	62·7	63·3	63·8	64·3
14	64·8	65·4	65·9	66·5	67·1	67·6	68·2	68·7	69·3	69·9
15	70·5									

Distillation is carried on until the whole of the alcohol is brought over, the alcohol being received in the flask in which the beer was originally measured. The alcohol collected is next made up to the original bulk of the beer by the addition of water, and the sp. gr. of the liquid is then carefully observed at a temperature of 60° by the aid of the weighing bottle or a delicate hydrometer.

Original Gravities by the Evaporation Process.

Degrees of Spirit Indication.	·0	·1	·2	·3	·4	·5	·6	·7	·8	·9
0	..	·3	·7	1·0	1·4	1·7	2·1	2·4	2·8	3·1
1	3·5	3·8	4·2	4·6	5·0	5·4	5·8	6·2	6·6	7·0
2	7·4	7·8	8·2	8·7	9·1	9·5	9·9	10·3	10·7	11·1
3	11·5	11·9	12·4	12·8	13·2	13·6	14·0	14·4	14·8	15·3
4	15·8	16·2	16·6	17·0	17·4	17·9	18·4	18·8	19·5	19·8
5	20·3	20·7	21·2	21·6	22·1	22·5	23·0	23·4	23·9	24·3
6	24·8	25·2	25·6	26·1	26·6	27·0	27·5	28·0	28·5	29·0
7	29·5	30·0	30·4	30·9	31·3	31·8	32·3	32·8	33·3	33·8
8	34·3	34·9	35·5	36·0	36·6	37·1	37·7	38·3	38·8	39·4
9	40·0	40·5	41·0	41·5	42·0	42·5	43·0	43·5	44·0	44·4
10	44·9	45·4	46·0	46·5	47·1	47·6	48·2	48·7	49·3	49·8
11	50·3	50·9	51·4	51·9	52·5	53·0	53·5	54·0	54·5	55·0
12	55·6	56·2	56·7	57·3	57·8	58·3	58·9	59·4	59·9	60·5
13	61·0	61·6	61·2	62·7	63·2	63·8	64·3	64·9	65·4	66·1
14	66·5	67·0	67·6	68·1	68·7	69·2	69·8	70·4	70·9	71·4
15	72·0									

The number of degrees by which this specific gravity is less than that of water is the spirit indication.

The spirit indication may be more readily obtained by simply subtracting the beer gravity from the extract gravity, a method used by the German brewers. This is a more convenient method than the former, since, to obtain the extract gravity, the beer has merely to be evaporated in an open flask, without collecting the spirit. In cases where the spirit indication has been determined by the latter method, the second of the foregoing tables has to be used to ascertain the original gravity. Thus, if the spirit indication is 9°·6, and the extract gravity 1044·7, the original gravity will have been 1044·7 + 43 = 1087°·7, for 43° is according to this table the loss of gravity corresponding to a spirit indication of 9°·6. It will be noticed that the tables do not exactly agree, for the spirit indication obtained from any given beer by the distillation process is always somewhat greater than that obtained by the other process. The reason of this is that when alcohol is added to pure water, the density of the mixture is lower than that of the water. An addition of 8 per cent., by weight, of alcohol, gives a mixture having a density of 986·7, which is a loss of gravity of 13°·3; but 8 per cent. of alcohol in the same volume of water containing 10 per cent. of cane sugar, occasions a loss of gravity of only 12°·92, or a reduction from 1036°·47 to 1023°·55. The degrees of spirit indication obtained are therefore less from the same absolute quantity of spirit in the sugar solution than in pure water. The sugar solution containing alcohol represents the beer, and gives the loss of gravity which the beer sustains by evaporation. On the other hand, the first mixture of pure water and alcohol represents the dilute spirits obtained from the same beer by distillation. The results are:—

Degrees of spirit indication .. .. 13·30 by distillation.
" " " .. .. 12·92 by evaporation.
Difference .. .. 0·38

Thus the addition of a certain proportion of alcohol leaves the specific gravity of the mixture a little higher when the water contains sugar in solution.

Fermentation demands the greatest care of any stage in the brewing process. Errors in malting or even in mashing, may be rectified; but a slight error in the fermentation process is attended with very serious results.

It was at one time the practice amongst the Scotch brewers to employ fermenting rounds only, and to cleanse from these directly into the casks. The fermentation was completed in the rounds. Under this system the process of fermentation required from one to three weeks. The wort was usually pitched at a low temperature, 10° or 11° (51° or 52° F.), and no more yeast was used than strictly necessary; if the quantity first introduced failed to produce sufficiently active fermentation, the contents of the rounds were agitated twice daily, or a further quantity of yeast was added and well stirred in whilst the fermentation was going on. The yeast formed was not skimmed off, and the fermentation was allowed to proceed until the ale was reduced to about one-fourth of the original gravity. The attenuation proceeded so slowly at the completion of fermentation as not to exceed half a pound a day. For some days previous to the drawing off, the head of yeast was not disturbed, and it floated on the surface as the ale was drawn off from below.

This process is now modified by the adoption of "cleansing squares," into which the ale is discharged from the fermenting rounds, when within two or three degrees of the required attenuation. In the cleansing squares, the ale deposits its yeast, and becomes cool and is fined. From the squares it is drawn off into casks. Both the fermenting rounds and the cleansing squares are, in the best arranged breweries, fitted with attemperators, for reducing the temperature of the ale. The amount of refrigerating power required in these attemperators is small, for the fermenting rounds are almost always of very moderate capacity, seldom exceeding 40 barrels, and if larger, they are still shallow, and have large exposed surface; consequently a considerable loss of heat by radiation occurs. The depth of the ale in the tuns is seldom more than 4 feet; the wort is usually pitched at a temperature of from 11° to 14° (52° to 57° F.). The fermentation in the rounds generally occupies from four to six days, during which time the temperature increases to 21° or 22° (70° or 72° F.). The cleansing in the squares occupies from 24 to 36 hours.

In Yorkshire, and the northern and southern counties of England, a system known as the stone or double-square system is very largely used. Fermentation is carried on in a somewhat deep square, divided at the middle of its depth by a horizontal partition in which is an opening. The worts are contained in the lower portion of the square, and the upper division is used as a chamber, into which the yeast rises through the opening. The beer is occasionally pumped from the lower chamber of the square into the upper one, where it becomes mixed with the yeast and again flows down into the lower compartment. The squares are commonly of stone, and the double square in which the fermentation proceeds is enclosed in another larger square, a space being left between the two into which water can be admitted for regulating the temperature. In the double square system, the beer is kept during fermentation at a temperature of about 13° or 14° (56° or 57° F.), and this temperature, when the desired attenuation has been reached, is reduced to about 56° by causing water to circulate through the exterior chamber and through attemperating pipes immersed in the liquid. This temperature is maintained during cleansing.

In the large porter breweries, the fermenting tuns are of very great capacity, in some instances 1500 barrels. The usual capacity is between 200 and 700 barrels. These tuns are almost always of wood. Timber employed in the construction of tuns should be well seasoned, or the sap will mix with the wort and injure it. The round tuns are made of staves held together by hoops like those of a cask, the bottoms being supported by the beams on which the tuns rest. In the case of the square tuns, the planks are fastened together by bolts, and the sides are connected by cross stays stiffened by external beams. Square tuns have the advantage that they can be stowed with less waste of room than round tuns; but the round form is the best for wooden tuns, and should always be adopted where space permits. Fermenting tuns are generally fitted with attemperators. A common plan is to carry these pipes round the tun at a short distance from the sides, and to support them by brackets. Attemperators are sometimes fitted across the tun, and when thus fitted are very efficient, as the cooled wort descends and gives the warmer currents free access to the pipes. Before the plan of fitting the tuns with attemperating pipes came into use, the somewhat clumsy expedient of immersing in the wort casks filled with hot or cold water was employed for the purpose of accelerating or retarding the fermentation. The casks so used were termed "nurses," and are still used in some breweries.

At Reid's brewery, the tuns, instead of being open at the top, are completely closed, with the exception of a small opening left for sampling; the carbonic acid gas evolved during fermentation is led off by descending pipes into a reservoir, where it is stored. From this reservoir it is drawn off at intervals into indiarubber bags, whence it is supplied to the Aerated Bread Company for the manufacture of bread on Dr. Dauglish's system.

At some of the London breweries, large quantities of ice are used in summer time to lower the temperature during fermentation, as well as for preserving the yeast. In the case of the fermenting wort, the ice is used both to cool the air of the tun room and also the wort itself; in the latter case being commonly immersed in the wort, which is made of greater strength in order to allow for the reduction of gravity caused by the admixture of the melted ice.

Where large quantities of wort are collected in the fermenting tun it would be more or less difficult to complete the fermentation satisfactorily in these vessels; and it is therefore the practice, amongst London brewers, after the fermentation has proceeded to a certain extent, to divide out the beer from the large tuns into a number of pontoons or cleansing rounds, having a capacity of about five to twelve barrels each. Stout, for instance, having an original gravity of, say, 32 lb. a barrel, is usually pitched at a temperature of 13° or 14° (56° or 57° F.), the quantity of yeast added being about 1½ lb. a barrel. The attenuation is allowed to go on in the fermenting tuns until the gravity is reduced one-half. The beer is then divided out into the cleansing rounds, where the fermentation is completed, the final gravity being for ordinary London trade 9 lb. or 10 lb. a barrel. With porter, the original gravity is usually from 20 lb. to 22 lb. a barrel, and the fermentation is continued until the gravity is reduced to about one-third; the quantity of yeast added is only about 1 lb. a barrel.

Cleansing rounds, squares, or pontoons, are covered vessels, each furnished at its upper side with an opening through which the yeast formed by the fermentation of the contained beer can escape. The rounds are completely filled with beer, and as there is a certain loss of liquid during the progress of the cleansing, they have from time to time to be filled up, in order that the proper level may be maintained. The refilling is termed topping up, and it is performed sometimes by an arrangement of ball-cock or similar self-acting valve, and sometimes by hand. The supply of beer necessary for maintaining the level in the pontoons is drawn from rounds placed at a higher level, and termed topping-up rounds, and filled with a well-fermented beer. The division of the beer amongst a number of small vessels greatly checks fermentation, and unless care is taken to push it sufficiently far in the fermenting tun, there is probability of the process being incomplete, and of the beer consequently remaining too sweet. The rounds being completely filled with beer, the yeast formed rises through the openings in the heads, and is conducted by spouts to troughs or backs in which it is collected. By this process the beer is gradually freed from the particles of yeast and glutinous matter held in suspension, which if not removed would keep the beer turbid. It seems probable that the composition of the water used in brewing affects to some extent the process of cleansing, for when the water contains a considerable proportion of compounds of lime, a double decomposition is set up with the salts present in the malt, and consequently in the wort, with the result of the formation of a lime salt, which is precipitated, and carries down impurities with it.

Cleansing rounds were formerly made of wood, a common arrangement being that of casks placed on end in groups of four, with spouts leading from openings in the upper heads of the casks to a vertical spout carried down through the space in the centre of the group. From these rounds the beer is pumped through an attemperator or refrigerator to a settling tank, and thence into the vats. Cleansing squares constructed of slate are now largely used at the principal breweries. Slate appears to be the best material for the construction of cleansing squares, or for tanks for holding cold beer. The slates forming the divisions between the squares are best so connected that no metal is exposed inside. The squares should be arranged in groups, and the slabs forming the divisions between the squares jointed to that forming the front of the group. The bolts securing the front slab may be screwed into nuts sunk in the division slabs, the hole containing the nut being filled in with putty. In some cases the slabs of slate squares are connected by angle-pieces, the heads and nuts of the bolts being tinned. The squares may be arranged in a series of double rows, having spaces between, into which the yeast is discharged. The lips, or short spouts by which the yeast issuing from the openings in the tops of the cleansing squares is discharged into the yeast troughs, may be of copper tinned, of tinned wrought iron, of wrought iron enamelled, or of cast iron painted and varnished. An objection has been raised to the employment of slate for cleansing squares, that it is a too good conductor of heat, and that the beer is subject to considerable atmospheric variations of temperature; but this objection has no practical value.

The fermentation of porter and stout at the London breweries is generally completed in cleansing rounds, but in some cases it is commenced and finished in squares holding from 170 to 320 barrels; these squares are usually fitted with attemperators and with parachutes into which the yeast is skimmed. At the City of London Brewery, the fermentation of porter is commenced in tuns holding 600 barrels, and completed in cleansing rounds having a capacity of 5½ barrels each, or in hogsheads arranged in a similar manner to the Burton unions.

For ale, it is usual to employ much smaller fermenting tuns than for porter, and frequently the fermentation is completed in these tuns. The tuns are sometimes fitted with small parachutes, by which the yeast can be removed and the fermentation checked. At Charrington's, the ale, after casking, is allowed to cleanse further, the casks being arranged on stillions or gutters, by which the yeast is received. The casks are filled up by hand. At Hoare's, the fermentation of the pale ales is completed in union casks, on the Burton system. At the City of London Brewery, the fermentation of ales is, in some instances, commenced in tuns of 140 barrels, and is completed in cleansing casks. At this brewery are copper fermenting tuns capable of holding 40 barrels each; these tuns consisting of a copper vessel enclosed in an outer casing containing water. In these tuns the fermentation is commenced and completed, the temperature being regulated by water circulating between the tuns and their casing.

The parachute consists of a kind of a copper funnel, having a stem which extends through the bottom of the tun. This stem is provided with a telescopic joint. By a lifting arrangement, the height of the parachute can be adjusted, so that its lip is slightly above the level of the beer in the tun; as the yeast formed flows over into the parachute and down through the tubular stems, the cleansing proceeds in the same manner as in the cleansing rounds. As the cleansing proceeds, there is a certain loss of liquid from the tun, and the parachute has to be lowered from time to time to maintain its level. Parachutes are sometimes balanced to float on the surface of the beer, and descend automatically. Usually, the top of the parachute has only a small area in proportion to the surface exposed by the beer, and the yeast is then skimmed into it. When fitted to fermenting squares, parachutes are sometimes made rectangular, and placed so that they extend across the squares. By the aid of parachutes the yeast can be removed from the tuns in a much more cleanly and convenient manner than by skimming.

Another method of conducting fermentation is that known as the "Burton union system." In 1838, P. Walker, of Warrington, invented the method of cleansing beers, this method having for its object the superseding of the necessity which then existed for supplying by power or hand labour the place of the liquor discharged during fermentation, to keep the casks full; and to prevent the yeasty head from being broken in upon the wort. According to his plan, independent passages were afforded for the flowing off of the yeast, and for the downward current of liquor, by which the cask or vessel was filled up. Another advantage was that the liquor for filling up could be introduced at the lower part of the cask, the yeasty head being left unbroken, and the attenuation allowed to go on in a regular and uniform manner.

307.

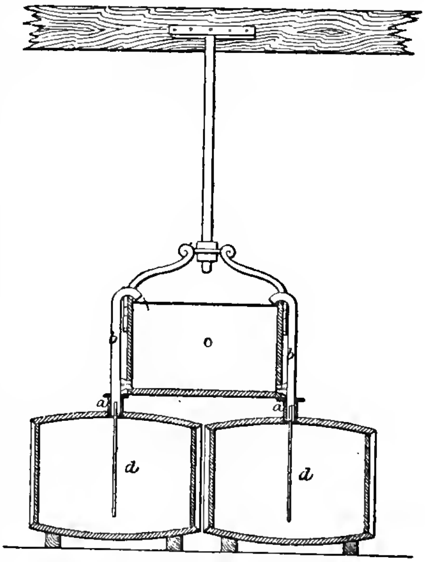


Fig. 307 is a transverse section of such an apparatus applied to casks; *a* is a conical tube inserted in the bunghole of a cask; from the upper part of this tube there rises the tube *b*, termed the yeast tube, so that the yeast as it rises may be delivered into the trough *c*. A tube *d* descends through the conical piece *a*, nearly to the bottom of the cask, and this tube is at its upper end connected with a branch pipe which communicates with the trough at the bottom. These tubes are the filling tubes, and by them the casks are filled and are kept supplied with liquor from the trough *c*, to compensate the loss of that thrown off during fermentation. The joint-piece by which the branch pipe is connected to the trough, is constructed with a plug like an ordinary cock, so that when the branch pipe is disconnected it can be turned downwards, and the flow of liquor shut off.

The trough, which may be of any length required, is here shown suspended, whilst the casks are arranged on each side on sunk stillions. The malt liquor, in a sufficiently advanced state of fermentation, is run into the trough, from which it flows into the casks through the filling pipes, enough liquor being supplied to fill the casks, and to leave a certain quantity at the bottom of the trough. The liquor thus left, together with that which is carried off with the yeast and which subsides in the trough, serves to make up the loss during cleansing. The yeast, as already stated, rises up through the tubes *b*, and flows into the trough *c*, and the fermentation and cleansing thus go on without attention until the completion of the operation, which is indicated by the yeast no longer flowing from the tubes.

The system of fermentation followed at Burton somewhat resembles both the Scotch and the London systems, but differs from both. In the Burton system, as in the Scotch, the fermenting tuns are of moderate size, from 20 to 100 barrels; instead of the fermentation being essentially a slow one, the wort is stimulated with large quantities of yeast, and the same result brought about as is caused by the great bulk of beer fermented in a single tun at the London breweries. The Burton, like the London brewer, after the fermentation has proceeded for a certain time, finds it desirable to divide out the beer, the usual course being to distribute it amongst the requisite number of union casks, in which the cleansing takes place. On the Burton system, the wort is pitched at a low temperature, say about 13° or 14° (55° to 57° F.), and receives a liberal allowance of yeast, of 4 lb. to 5 lb. or even more a barrel. For the best ales the original gravity of the wort is about 22 lb. or 23 lb. a barrel, and the attenuation is allowed to proceed until the gravity is reduced to 4 lb. or 5 lb. No yeast is removed from the ale whilst in the fermenting tuns, the cleansing being performed entirely in the union casks; in these the ale remains about a week before being discharged into the settling tanks. The fermenting tuns at the Burton breweries are in all cases of wood, and are fitted with attemperators. The tuns as a rule contain a greater depth of wort than those used in the Scotch breweries. At a number of the establishments at Burton, open wooden troughs are employed instead of pipes to distribute the wort to the fermenting tuns. At Bass's, the fermenting squares are disposed in double rows, down each of which a pipe is led; and from these pipes the squares are filled by the aid of open wooden troughs. At the Burton brewery, the fermenting rounds of a working capacity of 40 barrels are placed in groups of eight, and are filled from movable wooden troughs, which receive the wort from a main trough situated round the walls of the tun room. Each movable trough extends across four tuns, and these are filled simultaneously through holes in the bottom of the trough; the holes are fitted with plugs so that the wort can be shut off from any tun. Similar open troughs slung from the ceiling are also used at many of the Burton breweries to distribute the fermented wort from the tuns to the troughs of the union casks. The advantages of open wooden troughs as a means of distributing the wort, are, that they are less in first cost than pipes, and may be kept thoroughly clean. They are, however, cumbrous, and are only applicable when the wort is supplied from higher level than the tuns. Union casks have generally a capacity of four barrels, and instead of being placed on the ground, as previously described, are slung on axles resting in bearings carried by a strong wooden frame. Usually the casks are disposed in double rows, each frame supporting from twelve to twenty casks. Above the casks is placed the yeast trough. When the casks are thus mounted, the method of employment is as follows:—The ale to be cleansed is pumped, or run, into the yeast trough above the casks, and the plugs which close the pipes leading from the bottom of this trough being removed, the liquor runs down into the casks. When these are filled, the plugs are inserted, and the swan necks are thus left as the sole vents through which the yeast can escape.

The yeast troughs belonging to the union casks are in almost all instances fitted with attemperating pipes. The attemperating pipes of yeast troughs are sometimes so fitted, that by means of cords passing over pulleys fixed to the ceiling, they can be lifted up clear of the troughs, when the latter have to be cleaned. The union casks also are fitted with attemperators. A good arrangement consists of a hollow brass plug screwed into a suitable mounting on the top of the cask, this plug having two nozzles, which respectively communicate each with one of the tinned copper pipes extending from the plug into the cask. These pipes are connected at their inner ends, and a current of water can be made to enter at one nozzle, flow through the corresponding pipe, and return by the other pipe to be discharged by the second nozzle. The nozzles are respectively connected by flexible tubing to cold water and return pipes led along the sides of the yeast trough. These attemperators can be readily removed, and the holes through which they were inserted being closed by plugs, the cask can be rotated for cleansing in the usual way.

To reduce the labour incidental to the disconnection of the casks for cleaning, the plan of filling and feeding each cask through one of its axles has been introduced. At one end of each cask, the axle or trunnions, cast in one piece with the cast-iron cross fixed to the head, is hollow, and is fitted with a brass bush secured by a nut. At the inner end, the brush or tube is made conical, so that it fits tightly into the hole in the head of the cask, whilst, at the other end, it has a spherical bearing formed on it, which fits into a corresponding seat at the end of the branch pipe from which the cask is filled. The spherical bearing and its seat are held in close contact by bolts, the nuts of which exert their pressure through spiral springs. By this means a joint is obtained, that, although perfectly tight, does not interfere with the rotation of the cask. The main pipe running along each range of union casks, communicating both with the feed reservoir and with the fermenting tuns, is furnished with cocks, by which the supply from either source can be regulated. Each branch pipe is also furnished with a cock for regulating the supply to the particular cask to which it belongs, and each branch is also formed for a portion of its length of flexible tubing to enable the lower end to be readily disconnected. For turning the casks, spur wheels and crank handles are provided.

The "Untergährung," or system of bottom fermentation followed by the Bavarian brewers, differs materially from any adopted in this country. The object of the Bavarian process is to completely clear the wort of gluten, and, by removing the oxidizable matters, render the beer incapable of being soured by even a prolonged exposure to the atmosphere. To effect the separation of the gluten, the Bavarian brewers, instead of adding ordinary yeast to the wort, mix it with the peculiar kind of deposited yeast termed "unterhefe." The fermentation is effected in comparatively shallow backs or squares, placed in cool cellars, where the atmospheric temperature is not allowed to exceed 8° to 10° (46° to 50° F.). The process requires three or four weeks, the carbonic acid gas being disengaged in very minute bubbles, that carry up a mere film of froth. The insoluble gluten or yeast is deposited at the bottom of the fermenting vessels as a viscid sediment, the unterhefe. This deposited yeast is gluten oxidized in a state of *eremacausis*, or slow combustion, whilst the ordinary surface yeast is gluten oxidized in a state of putrefaction, and the former, when added to wort at a low temperature, is incapable of causing the direct oxidation of the gluten dissolved in the wort, although it possesses the power of causing the transformation of the saccharine matter into alcohol and carbonic acid. In the Bavarian process, the oxidation of the gluten has to be effected by the action of the atmosphere, and the large area exposed by the fermenting vessels, together with the freedom of the surface of the beer from any protecting layer of yeast, gives every facility for this atmospheric action. It might be supposed that the atmospheric action which causes the Bavarian beer to deposit its gluten would also induce an acetic fermentation in the wort. Such an occurrence is prevented by the low temperature maintained in the fermenting rooms, a temperature below that at which acetic fermentation of alcohol will take place.

The unterhefe employed by the Bavarian brewers may, by some expenditure of time and trouble, be prepared from ordinary yeast. If some of the latter be added to wort at the low temperature of 8° to 10°, and a slow fermentation allowed to take place, the yeast will be partly deposited and partly carried up to the surface. If this deposited yeast be collected to produce another fermentation, this will result in the deposition of a bottom yeast still more resembling unterhefe; and by repeating these operations, unterhefe is at length obtained.

It is in very many instances desirable that a similar arrangement should be provided, in other countries than Bavaria; for during the summer months the high atmospheric temperature prevents, to a great extent, successful brewing of the best kinds of malt liquor, and loss of time is occasioned to the brewer. With a view of affording a more perfect control over the process of fermentation, Barclay Walker, of Warrington, designed an atmospheric tun-room attemperator. It consists of a fan, by the aid of which a supply of air is forced to traverse a number of flattened tubes immersed in cold water, or surrounded by ice or a freezing mixture; the air, after being thus cooled, is led off by pipes extending over the range of tuns in the tun room. From the pipes, branches are led down into the tuns, these branches being furnished at their lower ends with perforated roses, which distribute the cold air a short distance above the surface of the wort. Each branch is furnished with a slide, so that the supply of air to each tun can be regulated. By this arrangement, the temperature of the air above the surface of the fermenting wort can be kept at that point which produces the best results, and a command over the process is given which cannot be obtained under ordinary circumstances.

Where yeast cannot be got by exchange, it may be originated from a mixture consisting of 14 lb. of grated potatoes, a similar quantity of molasses, coarse sugar, or honey, mixed with 3 gallons of water at a temperature of 21° to 24° (70° to 75° F.). This mixture should be set in a warm place until it ferments, and then mixed into three times its quantity of fresh first wort from the mash tun. This yeast is often made by distillers, and is known under the term of "bub." When the brewer is compelled to use bub, he ought to employ it on a small brew, to raise barm for future brews. The quantity proposed will ferment 40 or 50 barrels.

It may be here recapitulated that in the best practice good brewing depends upon careful malting, so as to have the malt always in the same condition of freely yielding the extract required from it. Careful curing of the malt on the kiln at the time of drying, and storing it in suitable backs, so as to retain the properties acquired in the kiln. To keep these backs of a size that when opened will allow of their contents being used, before the malt loses its curing, or suffers the slightest decomposition; the only alternative being to re-cure the malt so that it may be sound when it comes to the mash tun. In mashing, to wet the malt first into a thick mash within the point of the ultimate temperature, so far as to allow the variations in the heat of the malt under use to expend itself within the given ultimate temperature, and thus prevent the setting of the mashes, and the passing to the fermenting tun of pasty, unconverted materials that may afterwards decompose in the beer. This wetting process should produce a homogeneous temperature of 65° (150° F.), and immediately after this wetting hotter water should be turned on, and the mashing rakes started to bring the temperature to 69° (156° F.).

The mash, after standing one hour and three-quarters, should have the sparge temperature regulated, to keep the goods at 69° for two and a half to three hours from the time of setting the tap; and if the goods are not extracted by this time, the water must be lowered in temperature 10° or 14° (20° or 30° F.) or more, if necessary, to bring the goods in the tun to 65° by the time the extraction is complete. In mashing, time and temperature may be considered nearly synonymous terms; preponderance of heat should be compensated by reduction of the time during which the goods are exposed. In sparging, if the goods heat rises to 70° (158° F.), or even 71°, the sparge-water temperature should be lowered for the first half hour, or for a whole hour, sooner than the three hours given as a standard period of high heat exposure, so that the goods will have been brought to 65° at the end of the process. If second mash and a sparge be the method followed, the second mash heat may be 69°, like the first, but the sparging to follow ought to lower the mash apparatus gradually to 65° at the end of the mash; and if a third or fourth mashing must be taken, neither ought to make the goods over 65°.

Vatting and Fining.—It was formerly the practice of the London brewers to keep immense stocks of their porter in store for eighteen months or two years. The store vats, some of which were of enormous size, were made of well-seasoned oak strongly hooped, and their heads were covered with sand, so as to exclude the air as much as possible. At the present time, the practice of vatting beer for long periods is not followed.

At numerous breweries, it is the practice to pump or run the beer from the cleansing rounds to settling tanks or racking squares, and after allowing it to deposit any floating matters, to draw it off direct into casks. In casking pale ale, from ½ lb. to 1½ lb. of fresh choice hops a barrel is added; these hops materially assist in keeping the ale, and also impart to it a fine aroma. Stock ales also receive about 1 lb. of hops a barrel when casked. The pale ale should be kept in cask at least six months before being consumed, and if well brewed it may be kept from twice to three times that period with advantage. London porter now seldom remains in a vat more than a month, and as a rule it is stored only for a day or two. The change effected in beer by storing it in close vessels appears to be due to an insensible fermentation, which goes on for a considerable time, resulting in the impregnation of the liquor with carbonic acid gas. Ure considers that the quality of the beer never remains stationary when in the store vats, and that from the moment it ceases to improve it begins to deteriorate by acetic fermentation.

To clarify beer, finings, made usually from isinglass, are frequently employed. Finings are prepared by placing the isinglass, or other materials, such as sole skins or sounds of cod-fish, in a vessel, and covering it to a depth of 5 or 6 inches with vinegar, or sour old beer. When the isinglass has softened and swollen up, so as to absorb this liquor, a further supply of sour beer is added, and the mixture well stirred up, the process being repeated until the whole becomes of a uniform consistency. In some breweries this pulpy liquid is mixed with weak bright beer, and strained through a hair sieve; whilst in other cases it is thinned with the bright beer, and then allowed to become clear by depositing the insoluble matters in settling tanks. The final gravity of the finings should be about 1·025.

In using finings, they should be first mixed with a large bulk of the beer to be clarified, and after agitation the mixture should be poured into the main body, and well stirred in. After this the beer should be allowed to stand about twenty-four hours, when the impurities will be deposited. Ure considers that the clarifying action of isinglass is due to the tannin of the hops combining with the fluid gelatine, and forming a flocculent mass which envelops the muddy particles of the beer and carries them to the bottom as it falls.

Isinglass varies considerably in value, and it is important that brewers should have a ready means of judging of its quality. The best isinglass consists almost entirely of gelatine, and does not contain more than 2 per cent. of substances insoluble in water. One method of testing isinglass consists in placing a known quantity of it in water, boiling and weighing the insoluble matters that may be separated by straining the solution. Another test consists in steeping the isinglass in spirits of wine, in which gelatine is insoluble, and then adding a few drops of tincture of galls. If a deposit is formed, it shows the existence of impurities; whilst if the liquid remains clear, there is a strong presumption that the isinglass is of good quality. A practical and simple method of testing the value of isinglass or of other materials used in the manufacture of finings consists in dissolving a given weight of the isinglass to be tested in a fixed quantity of sour beer, and then pouring the solution into a funnel, the neck or spout of which is carefully bored out to a known diameter of about $\frac{3}{32}$ inch. The solution is allowed to flow from the funnel into a graduated glass measure for a period of time measured by a sandglass, and the quantity of solution which has run through in this time indicates the quality of the isinglass. The higher the quality, the thicker will be the solution, and the more slowly it will flow from the funnel.

Graham remarks on the general process of brewing, that the simplest arrangement is to carry out the fermentation through its first stages in the fermentation square or round, and afterwards to complete the secondary fermentation in settling squares. This method is less wasteful and is very efficient. But in carrying out such a process exceeding care must be taken that in the settling square the beer should be covered with a layer of carbonic acid, or in other words the gyle must be run off into the settling square before it is become dead. Graham further remarks that a rapid process is not always attended with equally excellent results, and those specially engaged in preparing store ales must bear in mind that it is quite impossible for them by any rapid driving process to produce an ale of the highest excellence in a short space of time. With proper treatment of store ales, it occasionally happens that they become sour, and in such cases it is necessary to employ materials that contain quick lime or other acid-neutralizing agent.

In bottling ales, it may be necessary for the bottler to carry on the German system of slow feeding, and as it is illegal to employ sugar for the purpose, the brewer should be called upon to supply a few barrels of wort excessively rich in sugar, and containing but little of the malt extract. This wort ought to be very highly charged with bisulphite of lime. When the store cask is fed with a little of this wort, a small quantity of bisulphite introduced into each barrel will do good rather than harm, and there is thus the advantage of slowly feeding the store cask and not in any way running counter to the excise laws.

If beer containing yeast cells is heated to a temperature of 50° to 60° (120° to 140° F.), the yeast cells are killed. Graham proposes a process based upon this discovery of Pasteur's. The beer should be run from the store cask and corked with a paraffined cork, that is with a cork saturated with paraffin wax, by which the loss that occurs from the cork giving insufficient protection against pressure is avoided. The next process is to destroy the ferment in the ale itself, because however bright the ale may be, there are always floating on it minute yeast cells. If the ale were placed in a bottle and heated to a sufficient temperature to destroy these yeast cells, ale that did not contain sufficient carbonic acid would be unpleasant to drink because it would not effervesce. It is necessary therefore for the bottler to charge each bottle with carbonic acid; and this may be done by merely allowing the bottles to remain until there is produced in the ale enough carbonic acid by subsequent fermentation—a process occupying two or three weeks. When the ale has thus obtained sufficient carbonic acid, it must be heated to about 60°. But if the bottler be pressed for time, and the ale is very flat and is required for immediate export, carbonic acid may be forced into the ale by an ordinary carbonic acid apparatus, and the bottles afterwards heated. In heating Burton ale up to 60°, there is a lessening of the amount of haziness due to albuminous matter, and with Edinburgh ale there is a very distinct improvement in the brilliancy. In the public-house and restaurant, beer is sometimes fed with molasses or is rendered sparkling by the use of carbonic acid apparatus.

The racking of beer is an operation nearly obsolete in England and Scotland, and, when followed, is employed only from the necessity of supplying small purchasers. As a rule, racked beer becomes stale and unpalatable before the barrels are emptied. But any attempt to deal with porter without racking would prove a failure, as its lees are very bitter and nauseous. The turning over of these lees when the casks are moved to be sent out is certain to impair the flavour. To produce the head, which is an essential feature of draught porter, as without it the beer is unpalatable, the porter is mixed, previously to being sent to the consumer, with new unfermented wort, and the mixing is most conveniently effected on the racking system. The mixing material has technically the name of fillings, and is wort taken from the cooler at the same time that the fermenting vat is filled. This wort is put into open-ended puncheons, and lightly barmed with a quart of yeast a puncheon, to prevent spontaneous fermentation until required for use. The puncheon first required for use is given extra barm in the quantity of about half a gallon, and all the puncheons, in their successive order of use, are given as much additional yeast on the night before they are required as will make them ready for the next day's use. If the fillings vessels are in underground cellars, their temperature will not need raising artificially, but in winter, if exposed, the temperature of small quantities will become too low to form a head without pan-heating to 18° or 19° (64° or 66° F.). In Ireland, where a brisk porter is in demand, small service vats are filled in the night with proper proportions of new and old porters, ready for the next day's demands. A similar procedure is followed by the London retailers. Fillings are used principally for draught porter, and the allowance ranges from 10 to 20 per cent., as the stock is new or old. The best draught porter is obtained from matured, well-attenuated old porter, mixed with 15 to 20 per cent. of rich unfermented raw wort or fillings.

Cellaring in England, as compared with Continental storing, has a disadvantage in the want of ice; and the ice machine, the substitute for ice, ought to be in every brewery, so as to afford the brewer the means of readily lowering the temperature to a point of comparative safety. Ice itself is not a necessity; water at 4° (40° F.) is fully effective, and not very costly to produce. It would be advantageous to employ some special means of cooling transit casks before they are sent out in the hot weather, as their contents, however good before leaving the brewery, often refuse to fine, and even if they do fine, become tart.

Beers for use at the end of the season should be deposited in the cellars of the publican in the spring, before the frost has left the atmosphere. Such beer ought to be set apart, and the beers required up to the commencement of August taken in the meantime from the brewery. Beer deposited in a cool state in a cool cellar with the publican, and not disturbed, has the advantage over that coming direct from the brewer's cellar, that it is not remixed with its yeast deposits, and then heated by the summer's sun. All beers ought to go out to the consumer when cleansed, and be used in the first fining down, for once fined in the brewery, and turned over in summer, and heated in transit, it is improbable that beer will fine again before acetification sets in. Brewers on this account should not set up store in spring or summer, after the hot weather has commenced, but the brewing should stop on the first appearance of heat. It is very bad policy to brew in May or June the stock of beer to go out in August or September, with risk of souring, when beers can be brewed as well at the end of summer as at the beginning, if the malt is in order. A good brewer will clear out his stock in July or August. It is advisable in cellaring to send out the best beers first, as in waiting to get rid of inferior beers both may be lost.

Export beers are made of gravities from 0·40 upwards, rising in stages of 0·5 to 0·115. Exports so low as of 0·40 are very rare, and the principal article of so low a gravity is a light porter for storing in the West Indies and in Nova Scotia. Its specific gravity is generally 0·47, and it is made of a well-dried malt, one half pale the other half amber and black, and hopped with 12 lb. of good Bavarian or American, double boiled. It is sent out in hogsheads from London, Edinburgh, and Glasgow. The usual export beers commence at 0·50, and generally average 0·55, 0·60, and 0·66.

Bottled beer generally has a gravity of 0·70. Beer for bottling should be kept nine to twelve months at least, and should be brewed from October to May; it is laid down as an imperative rule that such beer should undergo a summer's heat and autumn's fermentation in cask in England before bottling to be sent abroad. The most economical method of bottling is to run the store hogsheads and butts off, dry to the hop, into vats containing about two days' supply, and there fine it down a week before it is wanted. These vats ought always to be well sulphured before filling. Casks for export are always now steam seasoned, being set on end with the steam jet in the tap-hole; the bung-hole is filled up with an old shive having an open spile-hole in it by which to learn the pressure of the steam. This method is preferable to that of steaming casks on their sides through the bung-hole, a system that is the cause of breaking large quantities of bung staves. Old casks should not be steamed, but should be filled with water to which a handful of quick lime is added. E. S.

Cider. (Fr., *Cidre;* Ger., *Apfelwein.*)—Cider is an alcoholic beverage made by fermenting the juice of the apple. It is largely prepared in different parts of England, France, and the United States, where the fruit is chiefly cultivated.

Cider, like wine, is the product of the juice of a sweet fruit; it contains alcohol, extractive matters, acids, and salts, and it possesses a flavour and aroma which are agreeable to nearly every taste. Cider, as usually made, contains a much smaller proportion of alcohol than most wines, and a much larger proportion of gummy and nitrogenous substances; the acids, while they impart to it refreshing properties, are more enfeebling to the system than tartaric acid; its taste is not so pleasant to the palate as that of wine, and its effects are not nearly so powerful. The nitrogenous substances, although making the drink more nutritive, render it liable to decompose and be spoiled.

In spite of the many different opinions on this subject, cider, if carefully prepared, is a very excellent beverage, and second only to good wine; it possesses many qualities which render it in many respects greatly superior to beer. Unfortunately, however, both in England and abroad, so little care is bestowed upon the preparation of this drink, and such antiquated and faulty methods are employed, that the ordinary cider of commerce is a far inferior article to what might be made by processes based upon scientific principles and conducted with more care and discrimination. The inferior quality, made from unripe fruit and not carefully fermented, is decidedly unwholesome, and its consumption liable to cause colic.

The best cider contains from 8 to 10 per cent. of alcohol; and the ordinary varieties, from 4 to 6 per cent. The former kind is made at the present day in Normandy, New Jersey (U.S.), and Herefordshire, the remainder being chiefly made in Devonshire and Somerset.

The following table represents an average analysis of the apples and pears used in cider-making:—

	Apples.			Pears.		
	Unripe.	Ripe.	Mellowed.	Unripe.	Ripe.	Mellowed.
Water	85·50	83·20	63·55	86·28	83·28	67·73
Sugar	4·90	11·00	7·95	6·45	11·52	8·77
Vegetable matter	5·00	3·00	2·06	3·80	2·19	1·85
Gum	4·01	2·11	2·00	3·17	2·07	2·62
Albumen	0·10	0·50	0·06	0·08	0·21	0·23
Acids (malic, pectic, tannic, &c.)	0·49	0·50	0·60	0·22	0·13	0·65
	100·00	100·00	76·10	100·00	100·00	76·85

The loss of 23·9 per cent. in mellowed apples, and of 23·15 per cent. in mellowed pears, is due to the evaporation of the water and the decomposition of a portion of the organic matter, especially of the sugar, which is converted into alcohol and carbonic acid. The sugar which is contained in the ripe fruit is sufficient to furnish from 3·12 to 7·34 per cent. of alcohol by volume.

The keeping qualities of the fermented juice of apples and pears depend upon the presence of a sufficient quantity of alcohol and sugar, and upon the absence of all nitrogenous, fermentable matter, especially of aromatic principles, which are abundant in the unfermented juice. Unless alcohol be present in the fermented juice in the proportion of 18 or 20 per cent. by volume, the latter is certain sooner or later to undergo acetous fermentation. Now, ciders made from the juice of the apple alone, without any addition of water, cannot possibly attain a higher richness than from 3 to 7 per cent. of alcohol, which gives an average of 5 per cent. for common ciders, or only one-fourth of the proportion required to ensure its keeping. From this it is clear that the alcohol alone will not prevent the drink from undergoing acetous fermentation, but that the absence of any fermentable principle must also be ensured. In order to render the fermented cider preservable, the apple juice should, at the time of fermentation, always stand at 8° or 10° B. But since this proportion of sugar will not produce a sufficient quantity of alcohol to prevent an acetous fermentation from taking place, it should be considered only as an auxiliary to certain other precautions, to be treated of later.

It may be assumed, from what has been already said, that 5 per cent. of alcohol is a sufficient quantity, provided that the causes of after-fermentation have been carefully removed, but that a larger quantity, if it can be obtained, is much to be preferred.

Besides increasing the density of the juices, and thus augmenting the proportion of sugar contained in them, there is another method by which the saccharine richness of the "must" may be considerably raised, and this method is by far the best, notwithstanding the time which it occupies. It consists in gradually replacing the ordinary and less sweet varieties of apple by those which are much richer in sugar, and this is by no means impossible, or even difficult. It is true that there exists still a deep, but utterly unfounded prejudice against sweet apples among cider-makers; this prejudice, however, may be easily combated, since it is opposed to the first principles of fermentation and of œnological science. Unless the fruit employed for cider-making contain a proper quantity of astringent substances, it is true that the product obtained from it is subject, though only after an incomplete or careless fermentation, to the annoying accident termed "viscous fermentation." It is owing to this that cider, made by the usual faulty process, from *sweet* apples, is more liable to alteration than that made from apples containing less sugar. But this objection loses all its force when the process has been carried on upon sounder and more correct principles, and hence it is that cider-makers have, in their ignorance, been compelled to make use of fruit containing but little sugar, and thus to produce cider insufficiently rich in alcohol to be either agreeable to the taste or capable of resisting acetification and other vexatious alterations. It should be remembered, that the more sugar any fruit contains, the more alcohol it will yield, and the smaller, consequently, will be the chances of any subsequent alteration of the product, provided that certain substances favourable to alteration have been carefully eliminated.

Although it has been stated that it is advisable to employ only the sweetest apples obtainable, the cider-maker must be cautioned against excluding those varieties which are rich in tannin, or the astringent principle. He should always have in view the cultivation of a fruit containing the maximum of both sugar and tannin. Apples and pears, which are at the same time very sweet and very bitter, furnish the elements of a beverage which will be rich in alcohol, and which can be kept for a very long period without degenerating. Sugar yields alcohol in proportion to its own abundance, and the tannin, by partially or entirely removing the albuminous matters, effectually protects the fermented drink from being spoiled by after-fermentation.

Referring to the analysis given above, the average composition of the fruit in all three stages will be found to be represented by the following figures:—

Water	77·40	Albumen	0·22
Saccharine matter	7·95	Malic, pectic, tannic acids, &c.	3·83
Gum and mucilage	2·70		92·10

By removing the water, and leaving the fruit perfectly dry, the following figures are obtained:—

Grape sugar	64·26	Albumen	2·92
Vegetable tissue	17·53	Malic acid, &c.	2·92
Gum	12·33		99·96

From these figures, it will be seen that by subjecting the fruit to a process of desiccation it is possible to give to the product any alcoholic strength desired, and the necessity of improving the must by the addition of sugar or glucose is thereby entirely avoided. If it be admitted, for example, that ripe apples contain 11 per cent. of sugar, this corresponds to 8 per cent. of pure alcohol by volume, and it will be easily possible, by the addition of dried fruit, to increase the strength to 10 per cent., which is about that of the common French wines. It requires 16 per cent. by weight of sugar to give, theoretically, 8 per cent. by weight, or 10 per cent. by volume, of alcohol, and such a quantity of dried fruit as will bring the product up to, at least, this strength should be added to the must. This would mean, on an average, 5 per cent. of sugar to be added, which would correspond to about 7 lb. of dried apples. Since the desiccation is never by any means complete, as assumed above, this quantity should be doubled, in order to afford to this must an alcoholic richness of 9 to 10 per cent., which strength would greatly improve and ensure the preservation of the finished product.

In order to bring into practice the plan just described, it is necessary only to keep a large stock of dried fruit of the best varieties, and to add this in proper quantities to the unfermented juice; by this means, cider of the very best description, and capable of being kept for a great number of years, may be easily prepared. The same result might doubtless be obtained by concentrating a quantity of the must to the consistency of a syrup and adding it to the ordinary must; this method would probably be more easily practicable and more economical than the one just described.

When the juice of the apple has been extracted by the best method possible, and its active fermentation has been conducted for a sufficient length of time and at a proper temperature, it only remains to remove all foreign matter, whether suspended or settled down; to clear the cider thoroughly from all soluble albuminous matter, whether coagulable or non-coagulable; in short, to submit it to a complete defecation, in order to allow of its being kept without fear of spoiling. This should be effected by drawing it off carefully after the suspended matters have settled down; clarifying it carefully by the ordinary methodical processes of refining; guarding it against the adverse influences of air and warmth; and by exercising as much care over these processes and over the product itself as is customarily bestowed upon wines from the grape.

Careful attention to all the points here enumerated is all that is required to produce a really good beverage, and one that will not be inferior to many wines, instead of the crude, harsh-flavoured drink that is commonly sold under the name of cider.

Before pointing out the method of putting into practice the improvements suggested in the foregoing paragraphs, it is desirable to describe the old-fashioned processes, which are still generally followed.

Common Method of Cider-making.—The apples used in cider-making are just, or nearly, ripe when gathered, a state that may be recognized by their appearance and odour, or by the blackness of their seeds. Those which fall, or are gathered before maturity, are laid aside for a week or ten days, in order that they may become mellow; any which may have become rotten during this time are carefully picked out and rejected. In some places, it is the custom to preserve all the fruit, whether ripe or unripe, for a certain length of time, varying from a week to six weeks, care being taken not to let the apples lie until they become pulpy, as in this condition they are wholly unfit for cider-making. They are next ground in a mill, in order to break up the cellules and set free the saccharine juice. When much fruit is being dealt with, the old-fashioned horse-mill is still in vogue. It consists of a circular stone trough, in which a large stone wheel is made to revolve on its edge; the apples are poured into this trough and crushed by the wheel, which is turned by a horse. or by two horses, much in the same way as the tanners grind their bark. When about half ground, a little fresh water is added to the mash. In such a mill, three or four hogsheads of apples may be ground in the day; but the cider has usually an unpleasant taste, acquired from the rinds, stems, and seeds of the fruit, which in these mills are much bruised. Another and better mill consists of two cast-iron, fluted cylinders, one of which is turned by a handle and communicates its motion to the other. These are fixed in a wooden case, and the apples are fed in through a hopper placed directly above. The crushed fruit should be passed twice through the mill in order to extract the whole of the juice. This mill will crush fruit enough in one day to make nearly twenty hogsheads of cider.

The next operation is to press the crushed fruit, which is performed after it has stood for about twelve hours, at the most, in a wooden tub or cistern. Here, fermentation commences, and the breaking up of the cells takes place, by which the subsequent separation of the juice is much facilitated. The crushed pulp is then placed in hair-cloth or coarse canvas bags, and allowed to drain into suitable receivers, after which it is subjected to a powerful pressure in the cider-press, a large screw-press. The juice which runs away is at first foul and muddy, but is afterwards as clean and pure as if filtered through paper. It is common to throw away the remaining thin, dry cakes of pressed pulp, as useless, or to feed pigs with them; or sometimes it is ground a second time with water and pressed for an inferior kind of cider, which is very weak, and must be drunk at once, as it will not keep. The first runnings may be strained through a sieve; the whole is then placed in large casks, filled to the brim, where it soon begins to exhibit tumultuous fermentation; the froth or yeast which collects upon the surface of the fermenting liquor is always removed. A bung-hole affords a sufficient exit for the carbonic acid gas disengaged. The fermentation is usually conducted in airy sheds, where the warmth is scarcely greater than that of the open atmosphere. If the liquor be much agitated, the process may last only one day; but when allowed to remain at rest, the fermentation commonly goes on two or three days, and even five or six. No ferment is used. The liquor is then racked or drawn off from the lees, and put into fresh casks. A fresh fermentation usually commences after racking, and if it becomes violent another racking is often performed in order to check it, in consequence of which the same liquor may require to be racked afresh five or six times. It is customary to fumigate the cask before running in the liquor by burning inside it a strip of linen coated with sulphur; this is kindled at one end and lowered into the casks through the bung-hole, the bung being immediately replaced. The object of this operation, called "stumming," is to prevent the liquor from "fretting," or undergoing the after-fermentation already mentioned. The casks containing the cider are then stored in a cellar, barn, or other cool place, where a low and regular temperature can be maintained, and left to mature or ripen. By the following spring, the cider is considered fit for consumption and bottled or re-racked for sale.

Cider is made of three different qualities: rough, sweet, and bitter. In the manufacture of the first or lowest quality, very little trouble or care is taken. The rougher the drink, the farther it will go, and the more acceptable it is to the working man. A palate accustomed to a sweet cider would judge the rough cider of farmhouses to be a mixture of vinegar and water, with a little dissolved alum to give it roughness. The method of producing this austere liquor is to grind the fruit in a crude, unripe state, and subject the juice to a full fermentation. For sweet cider, the sweeter fruits are chosen and ground in a perfectly ripe state, the fermentation of the juice being, also, checked before completion. To produce the bitter cider, particular varieties of fruit must be used, and the season in which it is matured must be taken into consideration.

The temperature at which the fermentation is conducted is a matter of much importance, though it very rarely receives from cider-makers the attention it requires. The juice, when expressed from the fruit, is left in a cool place, at a temperature of about 10° or 12°. When, as is frequently the case, the juice is permitted to stand in the full heat of the autumn sun, much of the alcohol undergoes acetous fermentation, being thus converted into vinegar, to which the unpleasantly rough and acid taste of common cider is entirely due. These properties are especially characteristic of the cider of Devonshire, in which county but little attention is paid to this part of the process; the result is that the cider will keep, at the most, only four or five years, whereas, that made in Herefordshire and Worcestershire, where the fermentation is more carefully conducted, can be kept for a much longer period.

Before bottling, it is customary to improve the flavour or strength of weak cider, and for this purpose there are many plans in use. The want of strength is supplied by brandy or any other spirit, in sufficient quantity to prevent acetous fermentation. To supply flavour, an infusion of hops is sometimes added, which is said to communicate an agreeable bitterness, and at the same time a fragrant odour. The want of colour is sometimes supplied by elderberries, but more generally by burnt sugar. Isinglass, eggs, or the blood of oxen are often made use of to refine and brighten the liquor. The proper time to bottle cider depends greatly upon the quality of the liquor itself; it can seldom be bottled with propriety until a year old, sometimes not until it is two years old. It should have just acquired its utmost degree of richness and flavour in the cask; and this it will preserve for many years in bottles. The liquor called "ciderkin" is made of the marc or gross matter remaining after the cider is pressed out. To make this liquor, the marc is put into a large vat, with a proper quantity of boiled water which has just become cold; the whole is left to infuse for forty-eight hours, and then well pressed. The liquor which runs out from the press is immediately tunned up and stopped; it is fit to drink in a few days, and serves in families instead of small beer.

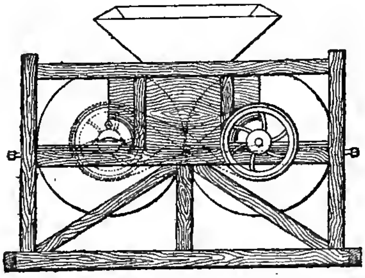
Improved Method of Cider-making.—When the juice of any fruit is required for use, it is a matter of much importance that as complete an extraction be made as possible, since the economy of the entire process depends primarily upon this. It is not effected easily, even by maceration, unless the vegetable tissue has previously been thoroughly disintegrated, in order to break open the minute cellules of which it is composed, and thus to set free the saccharine juices held in them. The more carefully this disintegration is conducted, the more easy is it, by mechanical means, to effect a thorough extraction; and an incomplete disintegration not only leads to very poor results, but also renders it necessary to employ a process of maceration in order to obtain all the sugar, instead of submitting the pulp to the action of a press, which is a far quicker and more economical method. To obtain, therefore, the maximum yield of juice from his fruit, the cider-maker should consider it an indispensable condition that the apples be thoroughly crushed or ground before subjecting them to pressure.

Many different forms of apparatus are employed in crushing the fruit. The ordinary horse-mill, in which it is ground to a pulp by means of a circular stone wheel, described above, presents many disadvantages, to all of which the manufacturer still persists in shutting his eyes. It requires an enormous amount of labour, and it consumes far more time than is necessary. Besides this, in such a mill, the pippins or seeds of the fruit are crushed as well as the pulp, a contingency which ought to be carefully guarded against. The seeds of apples contain 25 per cent. of a colourless fixed oil, which is not absolutely injurious; but they contain also a minute quantity of a volatile essence, closely resembling, if not identical with, the oil of bitter almonds. This oil, if present in cider in any quantity, effectually covers the flavour of the drink, and exerts a most powerful action upon the nervous system, and particularly upon the brain. To its presence are probably due the prolonged intoxicating effects and the serious disorders which follow excessive indulgence in this drink. The breaking up of the seeds does not render the cider more alcoholic, but it adds greatly to its intoxicating effects, and should therefore be avoided in every possible way.

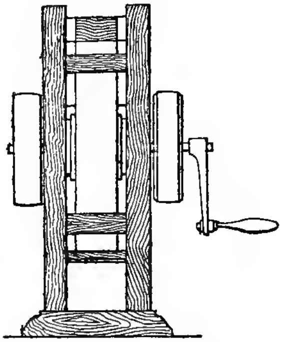
Another mill, used only in England, and much to be preferred to the one just mentioned, consists of two cylinders, having a number of knife-blades attached to them; these move in opposite directions, and reduce the fruit, which is fed in from above, to small slices. The apples, thus divided, fall between two other cylinders, made usually of granite, which crush them to a pulp of more or less fineness, according to the distance apart at which the cylinders are placed. By this means, the fruit is prepared for the press without any danger of bruising the seeds and stems.

A machine, preferable to either of the above for crushing apples, was devised by Berjot, and is now used in France; it is shown in Figs. 308 and 309, from which a good idea of the method of working will be gained. The two vertical wheels are of granite; they work in opposite directions, and may be regulated to stand at any required distance from each other. The apparatus is worked by horse-power, and can be made to crush 5 bushels of apples a minute. One of its chief merits is that there is no iron used in its construction; contact with this metal is very injurious to the quality of the juice. It may be used for a variety of other purposes besides crushing fruit; it occupies but little space, and, by reason of its extreme simplicity, it is very readily repaired. Manual labour may be employed to work it if desired. This mill is decidedly the best at present in use, and we recommend it, above all others, to the cider-makers of this country.

308.



309.



The fruit having, by the above method, been reduced to a kind of pulp, and a large quantity of its juices expressed, the next operation is to extract, if possible, the whole of the remainder. If this extraction were completely effected, 100 lb. of apples would yield nearly 98 lb. of must for fermentation. Nothing like this quantity is, however, obtained at present, the deficiency being made up by the addition of water. It is true that no apparatus has ever been devised by which it is possible to extract the whole of the saccharine juices; but it is easily possible, with improved machinery, to get a yield of at least 70 or even 75 per cent. Moreover, by the application of the principles of maceration to the residues, or marcs, this yield might be increased to about 90 per cent., and a residue left equal to no more than one-tenth of the original weight of the mass. Whereas, with all the large and clumsy apparatus at present used, and all the labour expended, a yield of more than 45 per cent. is rarely obtained.

Many presses have been devised to take the place of the huge, old-fashioned cider-press. This unwieldy piece of mechanism often covers an area of 50 square yards, and requires the united strength of fifteen men to work it; and yet, though many ingenious and labour-saving substitutes have been invented, this cumbrous monstrosity is still retained in many of the cider-producing districts of England and France.

Of the improvements referred to, the best and most convenient is the hydraulic press; unfortunately its price prevents its economical use by makers who produce only small quantities, but where the make is considerable it is to be preferred to any other. In small farms, an ordinary small screw press may be used with advantage. It is shown in Fig. 310. It will be seen that the principal screw turns two others, which are placed one on each side of the former; by this means, the upper plate is subjected to a more uniform pressure, and better results are obtained than with a single screw. It furnishes a yield of 65 to 70 per cent. at the first pressing.

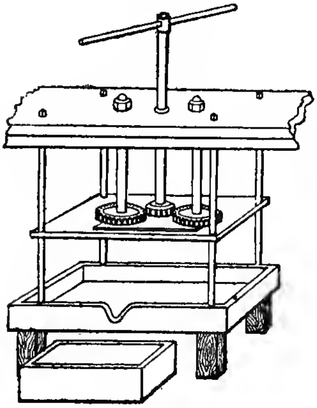
The practice of submitting the crushed pulp to maceration, in order to extract the remainder of the juice, may be recommended without any hesitation. Two principal methods may be employed, according as it is desired to use the process simply as an auxiliary to the work of the screw press, or as a means for the extraction of the whole of the juice.

In the first case, as much as possible of the juice is obtained by means of the press, the pulp being enclosed in bags ranged in rows, separated from each other by hurdles of wicker-work. The bags, when taken from the press, are placed in a tub, and subjected to the action of a sufficient quantity of tepid water for an hour. After this first maceration, they should be removed and placed in another tub with more water, while other bags are being put into the first tub. This is continued until the pulp has been subjected four successive times to the action of water of decreasing density, when the contents of the first tub will have acquired the density of the natural juice. The macerated pulp is afterwards pressed, the resulting liquid being used instead of pure water for the maceration of new supplies.

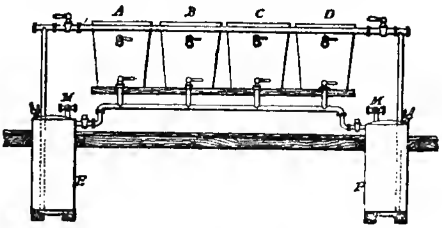
In the second case, when the maceration is required to extract the whole of the juice, the apparatus is not quite so simple. It is shown in Fig. 311. The four vessels, A, B, C, and D, may be made of wood; there may, with advantage, be six instead of four, in order to ensure the perfect maceration of the fruit. The cylinders E and F should be so constructed as to serve, should occasion require it, as receptacles, or as heating apparatus. When steam cannot be had, a coiled tube may be placed in each of these, through which may be passed the products of combustion from an ordinary stove.

If the cylinder E contains liquid which it is required to raise into A, the register or regulator, which admits the heated gases into E, is opened; the liquid thereby becomes heated, and the steam produced drives it up the tube into A. If, on the other hand, it be desired not to heat the contents to the boiling point, a small air-pump may be connected to M, by means of which the liquid can be driven up into A whenever the requisite temperature is reached. This latter method is preferable, since it is not advisable to heat the juice to a higher temperature than 70° (158° F.), in order to avoid the coagulation of albumen in the must.

310.



311.



The fruit is, of course, prepared for the process by slicing with ordinary root-cutters. The liquid, when equal in density to the pure juice, is run directly into the fermenting vats; the exhausted slices may either be pressed, or used at once as food for cattle.

All the technical and mechanical questions concerning the advisability of macerating the fruit have been answered already by the success of the process in the extraction of sugar from the beet. There is now no reason why it should not be employed with equal success in the preparation of cider.

Assuming that the juices of the apple have been extracted by either of these methods, and that all the precautions urged above have been carefully taken, the cider-maker has in his hands a must containing more or less saccharine matter, which requires only the process of fermentation to convert it into good cider. The same rules which regulate this operation in the case of wine, or any other alcoholic beverage, are applicable to this drink also; and all those conditions which have been previously pointed out in the article on Alcohol as indispensable to its proper conduct must be scrupulously observed by the cider-maker desirous of success. And there are other conditions which he must not neglect in order to produce an article of good quality, containing a sufficient proportion of alcohol. One of these is to avoid too slow a fermentation, which invariably tends to produce lactic acid in place of alcohol, and in a very large proportion when the must contains much gum, dextrine, or viscous substances. If nitrogenous matter be present together with these, they will be decomposed, giving rise to myriads of fermentable germs, which cause the alteration and ultimate ruin of the product. A hurried fermentation is no less injurious: it produces the formation of acetic acid at the expense of alcohol, thus affording the harsh, disagreeable flavour which characterizes nearly the whole of the cider made at the present time. Above everything, care should be taken to see that the must contains water and sugar in correct proportions before submitting it to fermentation. The cider-maker, for the sake of increasing his yield, too frequently commits the serious blunder of diminishing an already inadequate proportion of sugar by additions of water to his must, thereby rendering it impossible to produce a drink of sufficient alcoholic strength. A must containing too little sugar infallibly gives rise to a bad fermentation. Acetic, lactic, and viscous fermentations ensue, in inverse proportion to the saccharine richness of the unfermented liquor. To avoid this, the maker must take every precaution to ensure a sufficient quantity of sugar therein, and he must not on any account whatever diminish it by the addition of water. By observing a simple rule, he may produce a cider equal in every respect to many wines, and capable of being preserved for any length of time. This rule is as follows:—To see that the *saccharine* density of the must is as high as 10°·5 Baumé; or, since other soluble matters are present besides sugar, which raise it as much as 1°·5 or 2°, the *total* density of the must should stand at from 12° to 13°·5 Baumé.

Besides having the proper relative proportions of water and sugar, the must should contain a sufficient quantity of *astringent* substances, and these, if not present, must be furnished to it. This is necessary to the success of the subsequent operation of clarifying the fermented liquor, which cannot be performed by artificial means without the assistance of these foreign matters. Catechu is the most convenient, on account of its comparative cheapness, and also because it imparts no taste to the drink. The quantity to be added varies, of course, with the natural astringence of the juices, but, as a general rule, a solution of 30 grm. per hectol. (about 20 grains per gallon) is sufficient.

The process of active fermentation should be conducted at a temperature of not less than 15° (60° F.), and not higher than 25° (77° F.), in order to avoid either retarding or hastening the reaction. The process may be carried on in the open air, in vats of sufficient capacity, say 600 to 800 gallons. When the vat is filled to about five-sixths of its capacity, the sugar should be added, if this is necessary, either in the form of good fresh molasses, or of concentrated juice at a density of 28° to 30° Baumé. The solution of catechu is next added, if the must is found to be wanting in astringence; a good test is to add a little of a weak solution of gelatine, which, in that case, produces no precipitate, or a very faint one. The temperature of the must, and of the surrounding atmosphere, should then be carefully noted; the latter should stand at 15° (60° F.) throughout the operation; that of the must ought to be raised to 18° or 20° (64° or 68° F.), either by the addition of heated must or by steam. Great attention must be paid to these points of temperature.

Although the juices contain minute quantities of a fermenting principle, it is always advisable, though by no means customary, to add a little good brewer's yeast; 15 to 20 grains per gallon is quite sufficient. It should be mixed first with a little of the must, and then added to the contents of the vat with vigorous agitation. The vat may then be tightly closed, and the process suffered to proceed. In an hour, the contents of the vat are in a state of brisk fermentation, and carbonic acid gas is disengaged in considerable quantities. It is never necessary either to remove the scum or to agitate the liquor in any way. The process is complete when the disengagement of gas ceases, and the liquor has fallen in density to 1° or 1°·5, showing that all the sugar has undergone conversion into alcohol. It is then drawn off into tuns or barrels, where it undergoes another fermenting process. The usual length of the first or active fermentation is about sixty hours.

The tuns into which the fermented liquor is drawn off hold usually 130 to 150 gallons; they are completely filled, and the bung-hole at the top is simply covered with a piece of linen stretched across it. As soon as the fermentation recommences, the particles of suspended matter are carried to the surface and driven out at the bung-hole; by this means the liquor becomes considerably purified. When this process is complete, which may not be for two or three months, the liquor is ready for clarification, which means the entire removal of all the causes of after-fermentation. The cider is first racked off into clean casks, which have been well sulphured, as already described. Here the process of clarification is performed. If the addition of catechu to the unfermented liquor have been made, the soluble albuminoid substances will be removed, by its means, on the further addition of a little gelatine or albumen; more than enough to precipitate the catechu should not on any account be added. It is well to subject the cider to another clarification in a few weeks' time, especially if it is destined for sale. After this treatment, cider will keep as well as wine, and if sufficiently rich in alcohol, it will be much improved by bottling.

The conditions of preservation are identical in the case of cider with those of the preservation of wine. When made from ripe fruit containing much sugar, and when there has been enough astringent matter in the must, and the two processes of fermentation have been properly conducted, and those of clarifying and racking have received due attention and care, there is no reason why cider should not be kept for an indefinite number of years, always provided that it be kept in a cool cellar, in good casks or bottles, and well out of contact with the atmosphere.

In concluding this article it will be well to recapitulate briefly the most important points in the manufacture, and those to which the cider-maker should give his careful attention.

1. Many varieties of the fruit should be cultivated, in order that there may be a certain supply in all seasons; those are especially to be desired which, when just ripe, contain the maximum quantities of sugar and tannin.

2. The apples must not be gathered before they have attained full maturity; they should fall to the ground when the tree is lightly shaken.

3. The gathered apples should be at once protected from rain or frost. If perfectly ripe, there is no necessity to lay them aside before using.

4. The division of the fruit is best performed by means of root-cutters if maceration alone is to be employed to extract the juice; or by Berjot's mill if the press is to be used.

5. The extraction of the juice may be performed either by maceration or by pressure.

6. When maceration alone is used, the must should be brought to the density of the natural juices; in the case of pressure, maceration may be used to exhaust the squeezed pulp, but in such a way as not to increase the proportion of water, or to diminish the density of the must to less than that of the natural juices.

7. The extraction of the juice by pressure should be performed in a screw press, or hydraulic press if in great quantity, of simple construction, requiring but little power, and capable of producing at least 65 to 70 per cent. of juice.

8. The saccharine density of the must should be as high as 8° Baumé for ordinary cider, and 12° to 13°·5 for cider destined for exportation.

9. A convenient quantity of catechu (20 grains per gallon) should be added to the must if the latter do not show a distinct precipitate when treated with a solution of gelatine.

10. These additions of sugar and catechu should be made to the must in the fermenting vat; the latter should be rather deeper than wide in order to lessen the surface exposed to the air.

11. The temperature of the air in the fermenting room should be regulated at 14° or 15°; that of the must should stand throughout the process at from 18° to 20°; the process should be started by means of brewer's yeast (15 to 20 grains per gallon). The vats should be filled to about five-sixths of their capacity, and should be covered up as soon as the process commences.

12. The liquor should be drawn off as soon as the process is complete—after about sixty hours. The head or scum should be removed from the surface before drawing off.

13. The secondary fermentation should be conducted in clean tuns, of 130 to 150 gallons capacity, and quite full.

14. When the secondary fermentation is over, the liquor is racked off, during which process it is kept as much as possible from contact with the air, into casks properly sulphured and cleansed.

15. Clarification must be performed immediately after the first racking off. A test of the liquor with gelatine should be made before adding more catechu.

16. Another racking should follow immediately after the clarification. A second clarification and racking off should be performed upon cider for exportation. When made, the cider should be placed in casks of 50 to 60 gallons capacity, similar to those used for wine. These should be stored in cool cellars.

17. When sweet cider is desired, the first process of fermentation may be checked as soon as the cider has attained the proper degree of sweetness. Secondary fermentation should be hindered by frequent repetitions of the clarifying and racking-off processes, and by well sulphuring the casks.

Careful attention to all these points cannot fail to result in the production of an exceedingly agreeable and perfectly wholesome beverage, which is certainly more than can be said of the cider of to-day. The process which has been described is in actual operation in Normandy, and it yields results which are little short of perfection. There is nothing to prevent similar results from being attained in this country, and the preparation of really good cider would be a source of much benefit to the community at large, since it might to a large extent take the place of beer, a beverage which is extensively adulterated, and hence often very injurious to its habitual consumers. Cider is, or might be, also much more cheaply produced than beer. The cultivation of apples upon land highly favourable to their growth, but now lying utterly waste, such as railway cuttings and embankments, would in a few years greatly increase the production of fruit, and tend to lower the cost of the manufactured beverage. Vast numbers of acres of such land, upon which thousands of tons of apples might be grown, with profit to the cultivators and benefit to the community, now, for want of a little enterprise on the part of the railway companies, produce nothing but rank herbage of little use as fodder, and consequently of no commercial value. The cost of covering this land with apple and pear trees would be very small; and, apart from the value of the fruit itself, the presence of the trees would probably be of great service as a means of preventing the soil from slipping. This mode of utilizing the slopes of railways has already been partially adopted in some countries of the Continent.

Perry. (Fr., *Poiré;* Ger., *Birnwein.*)—Perry is another wholesome beverage, resembling cider, and made from pears in the same manner that cider is made from apples. The harsher sorts, or those that are too tart for eating purposes, make the best perry.

The manufacture of this drink is exactly similar to that of cider; and the remarks made concerning the latter apply, in every particular, to perry. As shown in the table on p. 414, pears contain a little more sugar than apples, and consequently yield a slightly larger proportion of alcohol.

Cocoa. (Fr., *Cacao ;* Ger., *Cacao.*)

Cocoa, a preparation of the roasted seeds of the *Theobroma Cacao,* is very widely consumed in various forms. It is wholesome, pleasant flavoured, and highly nutritious; and the quantities in which it is prepared and sold for use as a beverage proclaim it to be an article of commerce second in importance only to tea and coffee.

As common beverages, these three have a strong claim to consideration, not only on account of their universal consumption in this country, but also ecause, familiar as people are with them, few really know how to prepare them in the most wholesome and agreeable form, and much of their flavour and tonic properties is frequently wasted by an incorrect mode of preparation.

The active principle in cocoa is *theobromine*, an alkaloid closely resembling those contained in tea and coffee, but of less powerful effects. It also contains 50 per cent. of a peculiar fatty or oily substance, called *butter of cacao;* and 20 per cent. of albumen, from which it obtains its nutritive properties. The cocoa of the shops is always mixed with a small proportion of arrowroot, or some other starch, in order to render it soluble, or rather emulsive. Being very nourishing and at the same time very easily digestible, cocoa, when well prepared, strengthens the digestive organs and quickly raises the tone of an exhausted or enfeebled system. Hence it is the favourite beverage of invalids and dyspeptic persons. Its exhilarating effects are nearly equal to those of tea and coffee. Upon some persons, however, it acts, for reasons which are not well known, as a mild emetic.

Cocoa appears in the market in three forms, besides that of chocolat: cocoa nibs, flake cocoa, and soluble cocoa. Cocoa nibs are the roasted seeds from which the skins and husks have been removed in a "kibbling-mill." They should be of a dull, greyish-red colour; but they are often coloured with Venetian red. Flake cocoa is the purest of the other two varieties, since it contains no sugar and only a small quantity of starch; it is prepared simply by grinding the roasted "nibs" in a mill constructed of two metallic cones working one inside the other. Soluble cocoa is the form in which the substance is generally used; it consists of the roasted nibs ground up with varying proportions of starch and sugar, for the purpose of rendering the cocoa readily diffusible in water. Sago and arrowroot are the most wholesome ingredients, but much adulterated and highly coloured starch of an inferior description is employed by second-rate makers.

Chocolat is cocoa made into a paste with sugar and certain flavouring ingredients, usually vanilla. It is pleasant and nutritive, but sometimes disagrees with weak stomachs. Good, unadulterated chocolat may be known by the following characteristics:—It is compact, brittle, and of a reddish-brown colour. It should break only with a moderate effort, and the fracture should be clean, and the grain fine. When worked into a paste, it should be perfectly homogeneous. It should melt easily in the mouth and possess a pleasant, fresh flavour. It should dissolve readily in milk or water, leaving no residue. Chocolat is made by crushing cocoa nibs in a mill, the rollers of which are made either of stone or metal, and heated by steam in the interior. By this means, the fat or butter is melted, and the cocoa is softened into a thick, smooth paste. To this paste is then added the required amount of sugar and vanilla or other flavouring matter, and the whole is well mixed together in a mixing mill until the mass becomes perfectly homogeneous, when it is moulded into various shapes.

Chocolat is made as a beverage by reducing the necessary quantity to a fine powder and placing it in a jug, or other receptacle, with a little boiling water. The whole is then well mixed and stirred up with a spoon into a thin paste, and the jug is filled up with boiling milk and water. Sugar may either be mixed in with the paste or added afterwards in proper quantity. The drink ought never to be prepared before it is required for the table, since, on reheating, it not only loses flavour, but the oil or butter separates and collects on the surface, which is generally the cause of the ill effects produced by chocolat on weak stomachs.

Cocoa is usually prepared for the table by simply pouring boiling water upon the soluble powder. If the flaked variety or nibs be used, they must be placed in boiling water and simmered gently for from four to six hours. Great care must be taken to see that the liquid does not boil, in order that the albumen may not be coagulated, and the cocoa thus prevented from thoroughly mixing with the water.

Cocoa beverage is an *emulsion;* that is to say, it is a liquid which contains solid matter in suspension, and hence may be considered as food and drink combined. While the liquid portion of the beverage has almost as exhilarating an effect upon the system as tea and coffee, the solid portion, consisting of carbonaceous and nitrogenous matter, is highly nutritive.

Coffee. (FR., *Café;* GER., *Kaffee.*)

Coffee is a decoction or infusion prepared from the roasted berries of the *Coffea Arabica*, a plant largely cultivated in Arabia Felix and in various other parts of the globe. Some notion of the importance of coffee as a beverage may be gained from the fact that forty millions of pounds are consumed annually in the United Kingdom, and it is said that the annual consumption of the entire world amounts to the enormous quantity of six hundred million pounds.

The chief constituent of coffee, to which it owes its peculiar effects, is *caffeine*, a powerful alkaloid identical with theine and closely resembling theobromine. It also contains tannic acid and small quantities of a bitter aromatic oil. The action of these constituents is stimulating, tonic, and exhilarating, without producing any unpleasant after-effects. They promote digestion, raise the spirits, and are strongly anti-soporific. Coffee berries undergo important changes during the process of roasting. It is carried on until they have changed to a chestnut-brown colour and lost 18 per cent. in weight, but it should not be stopped before, or carried farther than, this point.

The object of the process is to develop the aroma of the coffee and to render the berries less tough, in order that they may be easily ground in a mill. Too much heat removes the peculiar principles which it is desired to retain, converting them into others of disagreeable flavour and odour; too little heat, on the other hand, produces raw, green, and flavourless berries, the infusions of which are unpalatable and liable to cause vomiting.

Coffee is rarely made in a proper way in England. The chief characteristics of English-made coffee are weakness and lack of flavour, owing to the fact that it is invariably made as a decoction instead of an infusion; that is to say, instead of allowing the powder to *digest*, simply, in hot water, it is almost always *boiled*, often for a considerable length of time. It must not be supposed, however, that the boiling is in itself objectionable; that this is not the case is sufficiently proved by the fact that the very best coffee is made by making a decoction of one half of the powder, and an infusion of the other half, and then mixing the two liquids; but if the whole of the coffee is boiled in the pot, it loses its delicate flavour, becoming rank, and quite unpalatable.

The French proceed far more intelligently in their methods of making this infusion, and the superiority of the French coffee over that made in England is everywhere acknowledged. The object is, by treating the powdered coffee with boiling water, to extract the whole of the soluble constituents of the berry, or those in which its peculiar flavour or aroma are contained. In the first place, the French take much larger quantities of the coffee than is customary in England; the proportions used being about one ounce of the powder to each breakfast-cupful of water; if the coffee be required very strong, this proportion may be doubled; the addition of a teaspoonful of freshly ground and roasted chicory is thought by some to improve the flavour of the beverage. The coffee is generally both freshly roasted and ground. When the berries have been well roasted, the product, after treatment with boiling water for a few minutes, should contain the whole of the flavouring, and a few other soluble constituents. It is the custom in France to improve the quality of the drink by pouring a little boiling water upon the exhausted "grounds," allowing it to macerate until cold, then boiling the separate liquid and using it for making infusions of fresh coffee. In cafés, the grounds made during the day are afterwards mixed together in a pot, and boiled with water; the decoction thus made is added in small quantities to the infusions of fresh coffee and it much improves their quality.

In order to remove the suspended grains and to render the coffee perfectly clear, a little isinglass or white of egg may be added to it; these, however, diminish the astringency and vivacity of the coffee. In France, it is customary to effect this by pouring a little cold water upon the surface of the hot coffee in the pot; the cold water being heavier than the hot liquid underneath it, sinks at once, carrying with it all the suspended matter. In Arabia, a cold, wet cloth is often wrapped round the pot for the same purpose.

The best and most convenient form of coffee-pot is called a "percolator," and is the invention of a Frenchman named De Belloy. It consists of two metal vessels, placed one above the other, the upper one being made to fit into the lower one. The bottom of the upper vessel is perforated with numerous very small holes. The powdered coffee is placed in this, and boiling water poured over it, the lower vessel receiving the beverage ready-made. After removing the upper vessel, a little of the decoction made, as already described, is added, and the coffee is clarified as above, when it is ready for the table.

The addition of milk to coffee is said to destroy much of its tonic properties.

Ginger-beer. (Fr., *Bière de gingembre;* Ger., *Ingwerbier.*)

Ginger-beer is a cooling and refreshing beverage containing an infusion of ginger, and is strongly effervescent. Being very wholesome and cheap, it has become a favourite summer drink among the lower classes of society. It is often recommended as a restorative after fatigue. Below are given several good recipes for its preparation on a large or a small scale.

1. Best lump-sugar, 1 lb.; Jamaica ginger, unbleached and well bruised, 1 oz.; two or three sliced lemons; cream of tartar, ¾ oz.; boiling water, 1 gallon. Macerate until nearly cold in a covered tub or clean vessel, with constant stirring; add 1½ or 2 oz. of yeast, and place the vessel in a warm place to ferment. Allow to stand until the next day; then decant the clear liquor and strain it through a piece of flannel; allow to ferment again for a day or two, according to the weather. It may then be skimmed, strained, bottled, and securely wired down.

2. White sugar, 18 to 24 lb.; Jamaica ginger, 1½ lb.; Narbonne honey, 1 or 2 lb.; lemon or lime juice, 1 quart; pure soft water (which has been boiled and allowed to settle), 18 gallons. Boil the ginger in 3 gallons of the water for half an hour; add the sugar, lemon juice, honey, and the remainder of the water, and strain the mixture as above. When nearly cold, add the white of one egg and ½ oz. of essence of lemon; stir well for half an hour. Allow to stand from three to six days, according to the weather, and bottle it, placing the bottles on their sides in a cool cellar. The ginger-beer is ready for use in about three weeks, and will keep several months.

3. Best white sugar, 8 lb.; Barbadoes ginger root, 12 oz.; gum-arabic, 8 oz.; tartaric acid or cream of tartar, 3 oz.; essence of lemons, 2 drachms; water, 9 gallons. Boil the ginger root for

half an hour; strain the liquor; add the tartaric acid and sugar; boil well, removing the scum; add the gum-arabic, dissolved in a separate portion of the water, and the essence of lemons: allow to cool to about 38° (100° F.); add a little fresh yeast, and carefully ferment as above. The liquor may then be bottled for use.

Lemonade. (Fr., *Limonade;* Ger., *Limonade.*)

The manufacture of effervescing lemonade on a large scale has been fully treated of under Aerated Waters. But it is often required to produce this beverage on a small scale, for domestic use. Its agreeable flavour and very refreshing effects render it a favourite drink in hot weather, especially for children. And, in cases of fever, it is of great use as a refrigerant and antiseptic. The following recipes for its preparation are therefore given:—

1. Sliced lemons, two in number; sugar, $2\frac{1}{2}$ oz.; boiling water, $1\frac{1}{2}$ pint. Mix well; cover the vessel and allow it to stand until cold, stirring it occasionally. Pour off the clear liquid, and strain through a muslin or hair sieve.

2. Juice of three lemons; peel of one lemon; sugar, $1\frac{1}{4}$ lb.; cold water, 1 quart. Digest for five or six hours, or all night; then strain as above.

3. Citric acid, 1 to $1\frac{1}{2}$ drachm; essence of lemon, 10 drops; sugar, 2 oz.; cold water, 1 pint. Mix well together and stir until dissolved.

Made as above, lemonade is a very refreshing and wholesome beverage. Instead of the citric acid in the last recipe, tartaric acid is sometimes used. Lemonade for icing should contain a larger proportion of sugar than is indicated in the above recipes.

The refreshing effects of lemonade are greatly increased by aeration. Aerated lemonade may be made, in small quantities, without the aid of machinery, in the following ways:—

1. Place in the bottles 1 to $1\frac{1}{2}$ oz. of lemon syrup; essence of lemon, 3 drops; bicarbonate of soda, $\frac{1}{2}$ drachm. Then nearly fill the bottles with water, having the corks ready prepared, and add to each bottle 1 drachm of crystallized tartaric acid, instantly corking and wiring it. The bottles should be kept inverted in a cool place, or preferably in a vessel of ice-cold water. In this recipe, instead of lemon syrup, $\frac{3}{4}$ oz. of lump-sugar may be used.

2. Lump-sugar, 1 oz.; essence of lemon, 3 drops; bicarbonate of potash, 25 grains. Fill the bottles with water and proceed as before, adding of crystallized citric acid, 45 grains. This recipe gives a more wholesome beverage, especially for the scorbutic, dyspeptic, rheumatic, and gouty.

The following are recipes for lemonade powders:—

1. *For one glass.*—Powdered citric or tartaric acid, 12 grains; powdered white sugar, $\frac{1}{2}$ oz. essence of lemon, 1 drop, or a little of the peel rubbed off on to a lump of sugar. Mix the whole well together.

2. White sugar, 4 lb.; tartaric or citric acid, $1\frac{1}{2}$ oz.; essence of lemon, $\frac{1}{4}$ oz. Mix well and keep in a bottle for use when required. One to two dessert-spoonfuls make one glass of lemonade.

3. *Effervescing.*—For the blue papers, powdered white sugar, 1 lb.; bicarbonate of soda, $\frac{1}{4}$ lb.; essence of lemon, $1\frac{1}{2}$ drachm. Mix well and put up in six dozen papers. Then put up 5 oz. of citric or tartaric acid in six dozen white papers. Or the two powders may be kept in separate bottles.

On the Continent, mineral lemonade is the name given to various beverages, consisting of water to which a little mineral acid has been added, and sweetened with sugar. Thus they have *limonade sulphurique, chlorhydrique, nitrique, phosphorique,* &c.; these are used as cooling drinks in cases of fever, inflammation, skin diseases, &c.

Spruce-beer. (Fr., *Sapinette;* Ger., *Sprossenbier.*)

Spruce-beer is a cooling and refreshing beverage, made from essence of spruce and molasses or sugar. There are two kinds made, the brown and the white, the latter being generally used and preferable to the other. It may be prepared by dissolving 7 lb. of loaf sugar in $4\frac{1}{2}$ gallons of hot water. When the heat has fallen to about 32° (90° F.), 4 oz. of essence of spruce is mixed in and dissolved perfectly by agitation. Half a pint of good brewer's yeast is then added and mixed thoroughly. In summer, fermentation speedily sets in; but in winter, it should be excited by keeping the cask in a warm place. When the fermentation slackens, the liquor is drawn off, the cask well washed, and the liquor returned to it. A new fermentation soon commences, and, when complete, the liquor may be bottled. The bottles should be wired; and in order that the liquor may mature quickly, it is advisable to place them on their sides until it has become brisk; then they should be set on end to prevent them from bursting.

Brown spruce is made in the same way, brown sugar or molasses being substituted for loaf sugar.

Another good recipe for spruce-beer is the following:—Essence of spruce, $\frac{1}{2}$ pint; pimento and ginger (bruised), of each, 5 oz.; hops, $\frac{1}{2}$ lb.; water, 3 gallons; boil the whole for ten minutes, then add of moist sugar, 12 lb.; warm water, 11 gallons; mix well, and when lukewarm, add of yeast, 1 pint. After the liquor has fermented for about twenty-four hours, it may be bottled.

Spruce-beer is diuretic and anti-scorbutic; it is an agreeable drink in summer, and is considered particularly useful during long sea-voyages.

Tea. (Fr., *Thé*; Ger., *Thee.*)

Tea is an infusion of the dried leaves of the Chinese tea-plants *Thea Bohea*, *Thea viridis*, and others.

Of all the beverages of this class, tea is by far the most extensively drunk in this country; upwards of 140 millions of pounds are annually consumed in the United Kingdom; the total import of tea in 1876 nearly reached the enormous quantity of 186 millions of pounds. On the Continent, however, the consumption is very small as compared with that of coffee.

The principal constituent in tea is *tannin.* Besides this, it is found to contain a volatile oil, to which its aroma is due, resin, gum, extractive matters, nitrogenous substances analogous to albumen, various salts, and an alkaloid called *theine*, which is identical with the *caffeine* of coffee; the proportion of nitrogen in the dried leaves is from 5 to 6 per cent. Of the total constituents, the amount soluble in boiling water varies from 38 to 47 per cent., and depends chiefly upon the age of the leaf.

The action of tea upon the system is stimulating and invigorating. It is an agreeable antacid, and is exceedingly refreshing if drunk when fatigued or after exercise. The proper time to drink tea, and when its effects are most beneficial, is about three hours after dinner. At this time, the digestion of the meal is just complete, and there remains in the stomach an excess of gastric juice which creates an uneasy sensation unless it is neutralized by a mild antacid such as tea or coffee. For this purpose, the simple infusion, containing no milk or cream, or very little, and no sugar, is best adapted.

The presence of the alkaloid *theine* in tea has the remarkable effect of sensibly retarding the waste of the animal body, and thus of diminishing the necessity for food to repair it in an equal proportion. In other words, by the consumption of a certain quantity of tea, the health and strength of the body will be maintained in an equal degree upon a smaller supply of ordinary food. Tea therefore stands to a certain extent in the place of food, while at the same time it refreshes the body and stimulates the mind. Tannin probably aids also in the exhilarating effects produced by tea; it imparts to the infusion an astringent taste and a somewhat constipating effect upon the bowels.

The practice of "facing" tea, as it is termed, cannot be too strongly condemned. Formerly, large quantities of Prussian blue were used in China to impart a fictitious colour to green teas; about 1 oz. being used to 14 lb. of tea. More recently it is said that indigo has been substituted, in consequence probably of the injurious effects which European writers have described the Prussian blue as possibly producing on the constitution of green-tea drinkers. Less doubt exists as to the pernicious qualities of an adulterated tea largely manufactured by the Chinese, under the name of Lie tea. This consists of the sweepings and dust of the tea-warehouses, cemented together with rice-water and rolled into grains. These adulterated teas have been imported into this country to the extent of half a million pounds weight in a single year. In this, as in other similar cases, the poorest classes, who can least afford it, are the greatest sufferers from the fraudulent introduction of the spurious mixture into the teas they buy. Black teas are sometimes faced with finely powdered plumbago or blacklead.

The common way of making the infusion is well known to everyone. The tea is placed in a teapot, is previously heated with hot water, and covered with boiling water. This is allowed to infuse for some minutes, and the teapot is then filled up with boiling water as required. If the water be boiling when poured upon the tea, as it always should be, about ten or fifteen minutes suffice to extract the whole, or nearly the whole, of the soluble constituents.

Toddy. (Fr., *Toddi*; Ger., *Toddy.*)

Toddy is the sweet juice obtained from various trees of the palm species. When the trees are required to yield toddy in place of fruit, the flower-stalks are, when just efflorescent, cut off, and a deep incision is made in the stump, from which, after repeated beatings, the toddy flows into vessels hung beneath to receive it. One tree, when full-grown, will sometimes yield as much as six pints of toddy per diem.

Toddy, when quite fresh, is a cool, delicious, and wholesome beverage; after standing a few hours, it ferments and becomes highly intoxicating. It serves extensively as yeast, and throughout Ceylon, no other is employed by the bakers. A kind of vinegar is also prepared from it which is used for pickling gherkins, limes, the undeveloped leaves of the cocoa-nut and the palmyra trees, and various other vegetable substances. By far the larger quantity of toddy made is used in the manufacture of "*jaggery*," a species of sugar, resembling maple sugar, of which it is said that upwards of 1000 tons are annually made in Ceylon. According to Forbes, three quarts of toddy will produce 1 lb. of jaggery. In Jaffna, the unfermented juice is boiled to the consistence of a thick syrup; this is poured into baskets made of plaited palm-leaves, when, on cooling, it crystallizes into jaggery. In these baskets, the jaggery is kept for home consumption, or exported to other lands to be refined. Jaggery forms an article of commerce from the upper to the lower provinces of Burmah, and is also of importance in some of the islands of the Indian Archipelago. Besides being exported in large quantities from Ceylon, it forms a considerable portion of the food of the Tamil population of Jaffna. Amongst a variety of purposes to which it is put is that of being mixed with the white of eggs, and with lime from burnt coral, or shells. The result is a tenacious cement, capable of receiving so beautiful a polish that it can only with difficulty be distinguished from the finest white marble.

Water. (Fr., *Eau;* Ger., *Wasser.*)

In an article on Beverages, water claims to occupy a prominent position, both on account of its own importance as a common drink, and by reason of its forming the basis of numerous others. Besides, though water for drinking purposes is not manufactured or prepared, it is nevertheless an article of commerce, since it must be purchased by its consumers from the water companies which collect and supply it, and paid for in much the same way as any other article of food or of daily consumption. For this reason, also, it could not properly be omitted from the list of commercial beverages.

The primary source of water is the sea; but all fresh water reaches us through the medium of the clouds, which are water in a state of vapour suspended in the atmosphere. A gigantic process of distillation is continually going on, owing to the evaporation of the water of seas, rivers, lakes, &c., by the heat of the sun. The vapour of water thus formed is recondensed by contact with a colder atmosphere above, and falls back to the earth in the form of rain, snow, and hail. In this way, the earth is furnished with a constant supply of water distilled from the ocean by the agency of the sun and the natural heat of the earth. As it falls through the atmosphere, rain absorbs a considerable quantity of the free gases existing in it, and hence becomes aerated with oxygen, nitrogen, and carbonic acid in varying proportions. Rain water is a powerful solvent, and therefore always contains more or less matter in solution, together with small quantities of dust which float about in dry air and are washed down by the first portions of the rain. Besides the free gases of which the atmosphere is composed, there are many gaseous impurities present, of which traces are invariably found in rain water; these, however, are generally in such minute quantities that, if free from suspended matter, rain water may be practically considered as pure. If it is caught in basins or tanks, and stored for any length of time, especially with exposure to the air, it soon becomes foul and impure by the introduction of foreign matter containing seeds or germs, too minute to be visible, but capable, under the influence of light and heat, of loading the water with myriads of living organisms, which die and become putrid. In this state, water is wholly unfit for drinking purposes, and it must be carefully filtered before using. Rain water, owing to the absence of saline matters, is more favourable to the production and development of these organisms than water obtained from rivers, brooks, and springs, and should therefore never be used after long exposure to the air. Soft water, containing carbonic acid gas, exerts a solvent action upon lead; hence tanks and pipes of these metals should never be employed. The insipid character of rain water and its liability to develop organic life render it unsuitable for general use as a beverage.

The water in lakes and ponds which are not supplied by running streams is rain water caught and retained in natural depressions of the earth, or in valleys closed at the lower end by some obstacle. Here it comes into contact with the soil and with vegetable matter, and becomes charged with organic impurities; these, however, are not injurious to health unless they are permitted to become putrid. The vegetable life so abundant in most lakes and ponds of large size gives off much carbonic acid gas, which is retained in solution in the water, and this gas renders it much brisker and fresher to the taste than ordinary rain water. That the water of ponds is better fitted than any other for drinking purposes is clearly shown by the fact that the instinct of cattle leads them to prefer it to running water, or to rain water caught in tubs, and that they are more healthy when they have access to the former kind.

Rain water which falls in hilly districts and on the sides of mountains collects in streams and brooks, of greater or less size; these gradually unite, forming rivers. In such waters, the impurities are often visible to the eye. It is frequently of a red colour as it flows through rocks of red marl, which contain much oxide of iron in their composition; it becomes milky in colour as it descends from the glaciers of Iceland or the slopes of the Andes, owing to the fine white sand which it takes up in its course. Many of our English rivers are grey or brown in colour; they are brown when running through a peaty or boggy country; and when the quantity of suspended vegetable matter is excessive, they are sometimes quite black to the eye. Only when perfectly clear, is the blue colour natural to large masses of water distinctly perceptible. But among the rocky and other materials with which water comes in contact in and upon the earth, there are many which it can dissolve, and the presence of which cannot be detected by the sense of sight. Hence, the clearest and brightest of waters—those of springs and transparent rivers—are never chemically pure, even when filtered; they all contain in solution a greater or less quantity of saline matter, sometimes so much as to give them a decided taste, and to form what are called mineral waters. The following table shows the amount in grains per gallon of solid mineral matter contained in the waters of some important lakes and rivers:—

Boston (U.S.) water-works ..	1·22 grains.	Detroit River, Michigan ..	5·72 grains.
Charles River, Massachusetts	1·67 „	Ohio, at Cincinnati	6·74 „
Bala Lake	1·95 „	Spree, at Berlin	7·98 „
Loch Katrine..	1·96 „	Loire, at Orleans	9·38 „
Thirlmere	3·60 „	Danube, near Vienna	9·87 „
Schuylkill River, Philadelphia	4·26 „	Lake of Geneva	10·64 „

Lime in combination with carbonic and sulphuric acid is the most common impurity in stream and river water; and it is to this substance and to magnesia that such water owes the property termed "hardness," or that of curdling with soap. Pure waters are always soft; and from this quality the absence may be inferred of any large proportion of lime and magnesia salts.

Waters containing much lime are often bright and sparkling to the eye and agreeably sweet to the taste. They become somewhat milky when boiled, and leave a sediment which encrusts the inside of kettles or boilers. When strongly impregnated with lime, they will even deposit a calcareous coating along their channels as they flow in the open air, or will petrify, as it is termed, any substances immersed in them. These circumstances are due to the fact that the lime is held in solution in the water by the help of free, dissolved carbonic acid gas, and when this gas is permitted to escape, or driven off by boiling, the lime can no longer be retained in solution, and it is accordingly deposited. Hard waters, therefore, are generally made much softer and purer by boiling. If, however, much lime be present in the state of sulphate, mere boiling will not soften it, but if a little soda be added during the boiling, the sulphate will be decomposed and readily separated. A good and cheap method of softening hard waters is now being carried out by several of the largest English water companies. It is known as "Clark's process," and consists in adding lime water to the water already containing lime. The lime added combines with the excess of carbonic acid gas, which holds in solution the lime present in the water, and the latter portion, and also the newly formed carbonate, are precipitated to the bottom of the tank or reservoir.

It will thus be seen that the water which collects in hilly districts and flows in streams and rivers through all kinds of country and over many different rocks and soils may, and generally does, contain organic and saline matters both in solution and in suspension. It is not, therefore, to be recommended for drinking purposes until it has been softened and filtered.

Spring and well water is that which falls upon and filters through porous rocks. Owing to the carbonic acid which it contains, it dissolves a large quantity of saline matter as it filters through the different strata. In its downward course, this water sooner or later reaches a stratum which it cannot permeate, and is hence brought to a stand. If, however, the stratum happen to lie on an inclined plane, the water runs along it, and eventually issues from the earth where the rock crops out. It is in this manner that all springs and wells are formed, the latter being constructed by digging through several strata until one is reached upon which water is standing, or over which water is flowing.

As we have already seen, the solvent properties of water enable it to take up many substances from the rocks and soils through which it passes, and it often happens that in the neighbourhood of dwellings and farmyards, and especially in towns, the water of shallow wells becomes very impure, and consequently unwholesome to drink. The rains that fall upon the filth accumulated in towns wash out the soluble substances it contains, carry them into the soil, and through this, by degrees, to the wells by which the wants of the inhabitants are supplied. This has often been productive of serious and fatal disease. Hence arises the necessity of preventing, as far as possible, the accumulation of refuse, and, when such accumulation is unavoidable, of placing it at the greatest possible distance from wells which yield water for daily use. And hence, also, the advisability of bringing water from a distance for the supply of large towns.

The proximity of graveyards to wells and springs from which drinking water is obtained is still more liable to render the water unwholesome by charging it with all kinds of objectionable matter. Water from a well standing close to an old churchyard in the neighbourhood of London, and analyzed by Noad, was found to contain the enormous quantity of 100 grains of solid matter per gallon, more than half of this consisting of nitrates of lime and magnesia. The presence of these salts in such quantity could only be traced to the proximity of the graveyard, as they are invariably produced by the decay of animal matters in porous soils. Well water frequently contains vegetable matter also, and of a kind which renders it wholly unfit for drinking purposes. In sandy districts, the decaying vegetable matters of the surface-soil are observed to sink down and form a thin yellow layer in the subsoil, which is impervious to water. Being arrested by this layer, the rain water, while resting upon it, takes up a certain quantity of the vegetable matter; and when collected in wells, it is often dark-coloured, marshy in taste and smell, and very unwholesome. Purification of such water may be effected by filtering it through charcoal, or by putting chips of oak wood into it. Or it may be boiled, thus causing the organic matter to coagulate, as it were, and to collect in flocks, when the water cools, leaving it wholesome and nearly free from taste and smell. This property of being coagulated by boiling, and by the tannin contained in oak wood, show that the organic matter in water is of an albuminous character, or resembles white of egg. By coagulating, the organic substances not only fall themselves, but carry down other matter, thus completely clarifying or purifying the water.

The sources from which country villages are supplied with drinking water are almost always shallow wells, each house or cottage having its own. As a rule, no care is taken to prevent the water in these wells from being contaminated with foul organic refuse, and hence it is rarely fit for drinking purposes. In some cases, manure heaps, pigstyes, and even cesspools, are permitted to remain in close proximity to the well which supplies whole families with water for drinking, cooking, and other purposes. Water from such wells is not only unfitted for consumption, but, from a sanitary point of view, absolutely dangerous. If it be impossible to avoid the contamination of the water in these wells, the best and safest plan to adopt in villages would be to establish one large deep well for the supply of the whole, placed in such a position as to be readily accessible and yet far removed from all chance of pollution with sewage and other injurious foreign matter. In the larger villages and towns, the supply is obtained either from such deep wells or from a neighbouring stream or lake, the water being purified sometimes by filtration through a bed of sand or gravel, and then conducted by means of underground pipes to the different streets and houses. Water thus supplied is, of course, much more wholesome than that obtained from shallow wells, but it is well never to use it for drinking purposes without careful filtration through a carbon filter, in order that any accidental impurity taken up in the underground pipes may be removed.

Many means have been adopted of removing impurities from natural water, in order to render it potable. Muddy water is easily rendered clear and bright by processes of filtration on a large scale. In places where the only available water is muddy, the purification is effected in what are termed "filtering tanks." These consist of large, water-tight basins, on the bottom of which is placed a layer of small stones; above these is placed a second layer of coarse sand or gravel; over this again a layer of fine sand, and at the top a layer of river sand. The muddy water is introduced from above and filters through the several layers, collecting in the bottom one. From thence it passes into reservoirs, or shafts built vertically in the basin, and having their walls so perforated at the lower extremity that nothing but filtered water can pass through them; this water is pumped up from the shafts when required. Iron tubes perforated below are sometimes used instead of the brickwork reservoirs. The greater portion of the suspended impurities contained in the water is retained in the uppermost layer of sand, which has, consequently, to be renewed from time to time.

In order to remove decaying organic matters or impure gases held in solution, powdered charcoal is frequently used as the filtering medium. In this way, not only are all suspended matters eliminated, but water which is coloured brown and possesses an offensive taste and smell, from the presence of the above matters, may be rendered clear, tasteless, and inodorous. The cost of the charcoal, however, which soon becomes impure and useless, prevents its application to this purpose on a large scale. And it is possible that charcoal which has become saturated with organic impurities at a low temperature may give up a portion of the absorbed substance when the water to be filtered has a higher temperature. Carbon filters are frequently used on a small scale with great advantage for the filtration of impure waters. (See Filtration.)

Drinking water should be clear and colourless, that is, absolutely free from suspended impurities, such as clay, organic matter, &c. It should contain small quantities of dissolved carbonate of lime, chloride of sodium, oxygen, and carbonic acid gases. It should *not* contain any salts of lime and magnesia, except the carbonates, nor the smallest trace of any nitrates from which the presence of ammonia or nitrogenous organic matter may be inferred. When drinking water is boiled to dryness, it should leave a residue of from 10 to 30 grains of solid matter for every 100,000 grains of water, and of this quantity about one-half should be carbonate of lime. Water containing less than 10 parts of solid constituents in every 100,000 is soft and insipid, and less fitted for drinking purposes than that which contains a higher proportion. Of the free gases held in solution by the water, it should always contain 0·8 per cent. by volume of oxygen, 0·7 per cent. of nitrogen, and a considerable quantity of free carbonic acid. Suspended and organic impurities should invariably be removed, if present, by passing the water through a carbon filter. Indeed, no water should ever be used for drinking purposes, especially in large towns, which has not been subjected to careful filtration.

Water that is to be used for brewing ales and porter should contain a considerable quantity of saline constituents, and principally of carbonate and sulphate of lime; that used in brewing the best Burton ales contains from 10 to 20 grains per gallon of each. Common salt is also a valuable constituent. There should be no organic matter. Analyses of some of the best waters for brewing will be found in the article on Beer. For wine-making, the water employed should contain a smaller proportion of mineral constituents than that required for beer. The very best would be rain water, to which the necessary proportion of the various salts has been added. This, however, would be impossible in practice, and it is found most convenient to use river or stream water, the composition of which is known and may be constantly relied on. The water of springs, or of stagnant ponds and marshes, which might contain putrid organic matter, either in suspension or solution, must not on any account be employed. The same conditions apply to water which is to be used in preparing whisky, or other spirit; it should contain a small proportion of mineral salts; it should be free from organic matters; and it should always be clear and bright. For making infusions of tea and coffee, the most suitable is a *soft* water, or one containing no salts of lime, or very little. Rain water, carefully filtered, is the best for this purpose.

Below are given some typical analyses of waters obtained from the differcut sources described, namely, lakes, rivers, and deep wells:—

Thirlmere Lake (in 100,000 parts).

Total solid impurity	2·66	Nitrogen (as nitrates and nitrites)	0·002
Organic carbon	0·194	Total combined nitrogen	0·008
Organic nitrogen	0·004	Chlorine	0·52
Ammonia	0·003	Total hardness	0·70

The Thames, at Twickenham.

Total solid contents	32·01	Sulphate of potash	0·95
Carbonate of lime	18·23	Chloride of lime	2·50
„ magnesia	1·47	Silica	0·39
Sulphate of lime	0·64	Organic matters	4·97
„ soda	2·86		

The Seine, above Paris.

Total solid contents	17·90	Sulphates of soda and magnesia	1·00
Carbonate of lime	9·20	Chloride of lime	1·00
„ magnesia	3·90	Silica, alumina, and iron	0·80
Sulphate of lime	2·00		

The Rhine, at Strassburg.

Total solid contents	23·18	Chloride of soda	0·20
Carbonate of lime	13·56	Nitrate of potash	0·38
„ magnesia	0·51	Silica	4·88
Sulphate of lime	1·47	Alumina	0·25
„ soda	1·35	Iron	0·58

The Rhone, at Geneva.

Total solid contents	18·20	Sulphate of soda	0·74
Carbonate of lime	7·89	Chloride of soda	0·17
„ magnesia	0·49	Nitrate of soda	0·85
Sulphate of lime	4·66	Silica	2·38
„ magnesia	0·63	Alumina	0·39

The Danube, at Vienna.

Total solid contents	12·62	Sulphate of magnesia	1·57
Carbonate of lime	8·37	Sulphates of soda and potash	0·20
„ magnesia	1·50	Silica	0·49
Sulphate of lime	0·29	Iron	0·20

The Spree, at Berlin.

Total solid contents	11·40	Sulphate of potash	0·60
Carbonate of lime	6·50	Chloride of soda	1·20
„ magnesia	0·90	Nitrate of soda	0·30
Sulphate of soda	0·60	Alumina and iron	1·30

The three following analyses, made by Professor Wanklyn, are of samples taken from the deep wells at Croydon, in Surrey. No. 1 is from the well in Waterworks Yard; No. 2 from that in Mint Walk; and No. 3 from the Old Well; they are expressed in grains per gallon:—

(1)

Total solid contents	29·3	Carbonate of magnesia	1·4
Silica	1·2	Chloride of soda	2·0
Carbonate of lime	17·8	Sulphate of soda	0·9

(2)

Total solid contents	21·6	Carbonate of magnesia	0·7
Silica	1·0	Chloride of soda	2·0
Carbonate of lime	17·0	Sulphate of soda	0·9

(3)

Total solid contents	21·6	Sulphate of magnesia	1·4
Silica	trace	Chloride of soda	1·8
Carbonate of lime	14·1	Nitrate of soda	1·4
Sulphate of lime	1·8	„ potash	1·1

An analysis of a well in the Red Sandstone at Liverpool gives the following figures:—

(Parts per 100,000.)

Total solid contents	26·400	Total combined nitrogen	0·436
Organic carbon	0·020	Chlorine	2·680
„ nitrogen	0·020	Hardness { Temporary	4·000
Nitrogen as nitrates and nitrites	0·416	Hardness { Permanent	9·600

The three following analyses, made by Professor Wanklyn, show the composition of the water supplied to London by the West Middlesex, New River, and Kent companies respectively. The first is obtained from the Thames at Hampton, the second from the Lea and other rivers, and the third entirely from wells in the chalk; the analyses are expressed in grains per gallon:—

West Middlesex Company.

Silica	0·3	Sulphate of magnesia	0·6
Carbonate of lime	12·9	Nitrate of magnesia	1·1
Sulphate of lime	2·4	Chloride of sodium	2·0

New River Company.

Silica	0·26	Nitrate of lime	1·00
Alumina, &c.	0·14	„ magnesia	1·28
Carbonate of lime	12·70	Chloride of sodium	2·02
Sulphate of lime	1·60		

Kent Company.

Silica	0·75	= 18·3 insoluble solids.
Alumina, &c.	0·22	
Carbonate of lime	16·30	
Water	1·03	
Silica, alumina, &c.	0·28	= 12·0 soluble solids.
Sulphate of lime	5·37	
„ magnesia	0·93	
Nitrate of magnesia	1·20	
„ soda	1·21	
Chloride of soda	2·64	
Water	0·37	

The growing importance of deep wells as sources of drinking water renders it necessary that the geological character of the strata in which they are situate should be subjected to careful investigation, and a good deal of trustworthy and interesting information has been gathered together on this head during the last few years. The influence exerted upon the water by the different strata through which it passes is very great, and hence the subject is one of considerable importance. In its descent through the different beds, the water passes downwards with greater or less rapidity, according to the porosity of the strata, until at length it reaches one which is impermeable: this stratum forms a kind of floor upon which the water is stored, the quantity depending upon the thickness and extent of the strata above, and their degrees of porosity. These impermeable, or dry, strata have no influence upon the water which lies upon them further than assisting to store it. When such an impermeable bed lies upon the surface, the rain falling upon it, not being able to penetrate, runs away and collects in brooks and streams; hence, in districts where the upper beds are of this nature, there is an abundance of stream water. In its downward course, the water is completely filtered from all suspended organic and other matters, being thus rendered beautifully clear and bright; it also dissolves a portion of the soluble salts, generally of lime, with which it comes in contact in the various strata, and becomes, in consequence, more or less "hard." The seven most important permeable or water-bearing strata in this country are: (1) Chalk and upper Greensand; (2) Lower Greensand; (3) Purbeck and Portland beds; (4) Coral Rag and Grit; (5) Oolites and upper Lias sands; (6) Middle Lias; and (7) New Red Sandstone.

The following table sets forth the principal characteristics of these water-bearing strata:—

Formations.	Thickness in Feet.	Quality of Water.
Chalk	645 to 1000	Hard.
Upper Greensand	100 „ 400	Rather hard.
Lower Greensand	20 „ 500	Soft and good.
Purbeck and Portland beds	0 „ 60	Rather hard.
Coral Rag and Grit	40	„ „
Great and inferior Oolites	200 „ 450	Hard.
Upper Lias sands	20 „ 200	Soft.
Marlstone or middle Lias	30 „ 250	Rather hard.
New Red Sandstone	0 „ 2150	Soft or variable.
Lower Permian beds (alternating characters)	Variable.	Soft.

In endeavouring to ascertain the qualities of the underground waters derived from different formations, it may be generally assumed that those drawn from limestone formations are "hard," and those from sandstone "soft." Owing, however, to variations in the nature of some of the strata in different localities, and to the greater or less proportion of carbonate of lime, carbonate of magnesia, salts of iron, &c., which they contain, the quality of the water from the same formation is liable to variation according to locality. Although this subject has been fully dealt with by various authors, it may be well to give here a brief summary of the results, as far as they have been ascertained, in different localities.

(*a*) Water from the Chalk.—The percolation of the rain through this formation, amounting in proportion to about one-third of the actual rainfall, is so exceedingly slow, that the water has abundant time to take up a large proportion of carbonate of lime from the rock itself, hence chalk water is naturally hard. It seems, from observations made on the chalk hills, that it takes from four to six months for the rain to reach a depth of 200 to 300 ft., so that the water which is drawn from this depth in summer belongs to the rainfall of the preceding winter. The total quantity of solid matter in chalk water varies from 31 to 32·5 in 100,000 parts, of which 16·4 to 21 parts are carbonate of lime. In the case of large works, this mineral ingredient can be dealt with by Clark's softening process; but for country villages there seems to be no plan of easy application for lessening the amount of calcareous matter, except that of boiling, by which the hardness is reduced from 24·7 to 3·7 in extreme cases. Chalk water, though hard, is very suitable for many purposes, especially for the important one of brewing.

(*b*) Upper Greensand.—The water from the upper Greensand, which immediately underlies the Chalk, is probably a little less hard than that from the Chalk itself.

(*c*) Lower Greensand.—The water from this formation, which is separated from the upper Greensand and the Chalk by an impermeable stratum known as the Gault, is remarkably pure, and decidedly "soft." Samples taken from five localities gave a mean result of 7·9 of solid matter in 100,000 parts of water. Water obtained from this source is therefore very suitable for drinking purposes. As the sands are generally loose and incoherent, they absorb nearly all the rain which falls on their surface, except that given off by evaporation or imbibed by vegetation.

(*d*) Oolite Limestones.—The water from these formations, which are much interstratified with sand-beds, is more or less hard, yet less so than that from the Chalk. Of the proportion of solid matter in the waters of the Oolites, that found in the fine springs of South Cerney, near Cirencester, which rise along the line of a large fault, may be taken as a sample. The total amount of solid matter was found to be 18 grains per gallon, of which 1·25 grain was of organic origin. The water from the Severn springs near Cheltenham, from the inferior Oolite, gave 6 grains per gallon, of which 2 grains consisted of organic matters. The well at Thames Head, sunk in the Great Oolite near Cirencester, yielded water containing 16 grains per gallon. And the waters of the Chelt, near Cheltenham, which rise from springs at the base of the inferior Oolite, gave 20 grains per gallon, of which 4 grains consisted of organic matter.

(*e*) New Red Sandstone.—Next to the Chalk, the New Red Sandstone, including the Bunter and

Lower Keuper divisions, is the most important water-bearing formation, and the water which it yields possesses an advantage over that of the Chalk in being softer, and generally capable of being used for all domestic and manufacturing purposes. From the numerous analyses that have been made of these waters in different localities in the central and north-western counties, we have the means of arriving at general conclusions on this subject.

The beds of the Bunter Sandstone are wonderfully adapted to act both as natural filters and as reservoirs for that portion of the rain which sinks below the surface. This may be assumed as one-third, on an average, of the actual rainfall; while in some districts—where the formation consists of soft sandstone, or unconsolidated conglomerate, devoid of a thick covering of drift clay—the amount of absorption must reach well-nigh one-half the amount of the rainfall. Owing also to its uniformity of composition, and the absence of beds of clay or marl of any importance, the whole mass of rock below a certain level, and throughout a depth of several hundred feet in some districts, becomes water-logged; and wells sunk therein do not, as in the case of the Chalk, generally depend for their supply on the presence of fissures, water being nearly always found after the "water-level" of the immediate district has been reached.

The amount of solid matter per gallon in the water of the New Red Sandstone varies from 6 to 15 grains, when it has been taken from wells not too shallow, or from those which are free from contamination by sewage pollution or other causes. It is to such a cause that the large proportion of saline and other ingredients in some of the Liverpool and Manchester wells, amounting in some instances to 24 and 36 grains per gallon respectively, is attributable. In general, the proportion of these ingredients occupies a central position between those of the Chalk and other limestone formations, on the one hand, and the surface waters of mountain districts, composed of Millstone Grit or of Silurian rocks, on the other.

Wine. (Fr., *Vin;* Ger., *Wein.*)

Wine is a generic title applied to a very large number of beverages produced by the fermentation of the juice of the grape. The art of making these has been known and practised since the remotest ages of which we have any record.

The wine of grapes is, and always has been, the principal fermented drink of the southern European nations. In the United Kingdom, its consumption has been steadily increasing for many years; without the aid of figures it would be impossible to give a just notion of the immense importance of wine as a beverage in this country. In 1857, the total consumption was more than 7,000,000 gallons; while twenty years later, in 1877, we find that it has increased to the enormous amount of nearly 17,000,000 gallons. Owing to the costliness of wine, its consumption is almost exclusively confined to the upper and middle classes, beer and spirits being the poor man's substitute. In France, Spain, and Italy, where beer is not largely drunk, and where wine is much less expensive, it constitutes, as already stated, the national alcoholic beverage, being consumed alike by rich and poor.

The composition and properties of different wines are influenced by a vast number of conditions and circumstances. The climate of the country, the nature of the season, the soil in which the vines are grown, the variety of grape, the mode of culture, the time of gathering, the treatment of the gathered fruit, the mode of fermenting the must, the temperature and length of time of preservation,—all these, and numerous other considerations of minor importance, have a direct influence upon the composition and quality of wine. All wines, however, contain alcohol, but in widely varying proportions, sugar, and certain flavouring ethers to which the peculiar bouquet or aroma of each is due. Besides these, among the regular constituents of wine may be mentioned glycerine, extractive and mucilaginous matters, mineral and colouring matters, and eight distinct organic acids. Of these latter, four are formed in the juice and skins of the grape, viz. tartaric, malic, tannic, and gallic acids; while the remaining four, carbonic, acetic, formic, and succinic acids are formed during the process of fermentation. Water is, of course, the largest constituent of wine, as of all other fermented beverages.

The amount of alcohol in wine depends upon the quantity of sugar held in the must before fermentation, and hence varies considerably. The proportion by weight of absolute alcohol in some of the best-known wines is shown in the following table:—

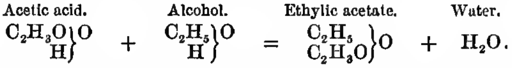
Port	15 to 20 per cent.	Rhenish	8 to 12 per cent.
Sherry	17 ,, 19 ,,	Moselle	8 ,, 9 ,,
Madeira	17 ,, 18 ,,	Malmsey	16 ,,
Marsala	15 ,, 17 ,,	Tokay	9 ,,
Claret	8 ,, 10 ,,	Champagne	7 ,, 12 ,,
Burgundy	8 ,, 12 ,,	Carlowitz	11 ,,

A good proportion of alcohol is necessary to the proper preservation of wine. Such wines as port, sherry, and Madeira, which contain nearly 20 per cent. of alcohol, cannot possibly undergo after-fermentation, and may be kept for any length of time. French wines average from 8 to 10 per cent. by volume of alcohol, and require much care for their preservation. Wines containing less than this quantity do not bear transport well, and on exposure to the air turn sour from the formation of acetic acid. In Spain, Portugal, and France, it is customary to add alcohol to wine after fermentation, and in these cases the whole of the alcohol in the wines does not originate from the sugar of the must. Unless the deficiency be made up in this way, precaution must be taken, by means of repeated clarifications, to remove every trace of fermentable matter from the wines, and thus to prevent the possibility of its being ruined by acetification and other degenerating influences.

The sugar which is invariably found in wine is that of the grape, which has escaped the decomposing action of the fermentation. To this unaltered sugar is due the sweetness or "*fruitiness*" of some wines, and notably of port. They are called "*dry*" when the proportion of sugar is very small. Sugar is generally added to the must of the champagne grape before fermentation, in order to give it body, and also to keep it sparkling and prevent acetification. Only the very purest cane-sugar is ever used for this purpose, since the senses of taste and smell can easily detect the presence of impurities in the wines derived from the sugar, which cannot by any of the senses be detected in the sugar itself. Burgundy, claret, Rhenish, Moselle, and Carlowitz contain no sugar, or only a trace. The amount usually found in the most important sweet wines is shown in the following table:—

Lachrymæ Christi	27 per cent.	Port	4 per cent.
Patras	15 „	Madeira	2·5 „
Champagne	7 „	Sherry	2 „

The agreeable, vinous odour of grape-wines is imparted by a minute proportion of an ethereal substance termed œnanthic ether. This substance, when separated from the wine, is a mobile, volatile liquid, possessing an exceedingly sharp, unpleasant taste, and so powerful an odour as to be almost intoxicating. It does not exist naturally in the grape, but is formed during fermentation, and it appears to increase in quantity as the wine grows older. The faintest trace is sufficient to impart bouquet, since few wines contain more than $\frac{1}{40000}$ part of it by volume. This ether is present in all wines; there are other ethers, however, which possess less fragrance, and which are different in different varieties of wines, giving to each the peculiar bouquet by which it is characterized; these are present in even smaller quantities than the œnanthic ether. The formation of these is due to the action of the acids in the wine upon the alcohol, as shown in the following equation, in which ethylic acetate is formed by the union of acetic acid and alcohol:—



$$\overset{\text{Acetic acid.}}{\left.\begin{matrix}C_2H_3O\\H\end{matrix}\right\}O} + \overset{\text{Alcohol.}}{\left.\begin{matrix}C_2H_5\\H\end{matrix}\right\}O} = \overset{\text{Ethylic acetate.}}{\left.\begin{matrix}C_2H_5\\C_2H_3O\end{matrix}\right\}O} + \overset{\text{Water.}}{H_2O}.$$

Some wines acquire their aroma partly during fermentation and partly after storage.

The following table gives the average proportional quantities of some of the chief constituents of wine per litre. The figures are obtained from analyses of French, Swiss, and German wines:—

	grm.		grm.		grm.
Alcohol (by weight) from	50·0	to	200·0	—generally	80
Glucose	1·5	„	10·0	„	2
Glycerine	1·0	„	4·0	„	2
Bitartrate of potash	1·0	„	8·0	„	4
Residue (dried at 100°)	18·0	„	30·0	„	22
Ash	1·5	„	3·0	„	2

An analysis of the substances which compose the ash is as follows:—

	grm.		grm.		grm.
Sulphuric acid, from	0·17	to	0·27	—generally	5·20
Phosphoric „ {white wines} ..	Average		0·155		
Phosphoric „ {red wines} ..	Average		0·335		
Hydrochloric acid, from	0·04	„	0·06		
Peroxide of iron „	0·01	„	3·02		
Phosphate of alumina „	0·03	„	0·06	„	0·04
Lime „	0·05	„	0·09		
Magnesia „	0·11	„	0·15		
Potash „	1·00	„	2·00	„	1·00

Red wines are richer in phosphates than white wines because the former remain for a longer time in contact with the seeds and skins of the grape, which are extremely rich in phosphates.

Tartaric acid exists in the natural juice of the grape as bitartrate of potash or cream of tartar.

After fermentation, and when the wine is left at rest, this salt separates out, and is deposited in a thick crust upon the sides of the casks or bottles. The presence of this acid in wine tends to diminish the exciting or intoxicating effects of alcohol; hence, as the wine gets older, it gradually becomes less acid, and stronger in proportion. Every year, therefore, added to the age of a good wine increases its strength and value.

The principal effect of the presence of tannic acid or tannin is to aid in preserving wine, and to moderate the action of the alcohol. Wines containing much tannin produce intoxication much more slowly than those which contain but little. The wines of Bordeaux contain a large proportion of the astringent principle, and to this is probably due the fact that they are much less intoxicating than other varieties which are not more alcoholic.

New wine contains more than its own volume of dissolved carbonic acid gas, formed during fermentation. This quantity, however, diminishes during storing, by diffusion through the pores of the casks, its place being taken by atmospheric air, which assists in maturing the wine. When bottled, it does not usually contain more than one-fourth of this quantity. When not in excess, its presence is believed to moderate the intoxicating influence of the wine, acting more or less as a corrective. It produces a gentle, stimulating effect upon the stomach, and greatly assists digestion. Wines, however, like champagne and sparkling hock, which contain much carbonic acid, are doubtless rendered more "heady" by its presence.

The remaining acids, acetic, malic, pectic, &c., are seldom abundant in good wines, and have but little influence upon them beyond neutralizing, to some extent, the action of the alcohol.

The general physiological effects of wine are well known. The first effect, when taken into the stomach, is to stimulate the action of that organ, producing in it, at the same time, a gentle and agreeable warmth. After a short time, the spirit penetrates into the blood, the movements of the heart and lungs are rapidly accelerated, the heat of the entire system is increased, and the circulation of the blood powerfully excited. If the quantity imbibed is too great, the pressure of blood in the brain becomes intense, and intoxication rapidly ensues.

Vines cannot be grown in any climate. The proper development of perfume and of sufficient sugar in the grape requires a warm and constant sun, such as is to be had only in the warmer climates. The cultivation of the vine is most successfully carried on in the countries lying between the 35th and the 50th degree of latitude, and it is in these that the most celebrated vine-growing districts are situate. Colder climates produce wines poor in alcohol, though sometimes of very agreeable perfume; they are difficult to keep, and turn sour with remarkable rapidity, since they do not contain enough alcohol to preserve them.

The nature of the soil in which vines are grown exerts considerable influence upon the quality of the grape. Vines will grow everywhere, and in a fertile soil will flourish exceedingly; but experience has shown that the value of the wine is rarely proportional to the luxuriance and strength of the vine from which the grapes were obtained. Hard, clayey soils are not favourable to the growth of grapes; neither are *damp* soils, of any nature whatever. They yield vigorous and beautiful vegetation, but wine obtained from them is invariably watery and wanting in bouquet. A calcareous soil is, as a rule, highly favourable; the culture of the grape in light, dry soils is more simple than in any other, and they yield a wine which is spirituous and of a fine bouquet and flavour. The best possible soil is that which is at the same time light and flinty. Volcanic earths yield very delicious wines, as proved by those of Tokay and the finest Italian wines. To sum up, the vine may be cultivated advantageously in a great variety of soils, provided they be light, dry, finely divided, and such as will readily receive and filter water. Heavy, moist, or clayey earths must be avoided in laying out a vineyard, and the first consideration should always be lightness and porosity.

The amount of exposure to weather to which the vine is subjected has a marked influence upon it. Grapes gathered from the summit, the sides, or the bottom of a hill, may vary widely in quality; and they vary also according as the land inclines towards the north, south, east, or west. Grapes grown on the top of a hill where they have been subject to many changes of temperature and weather are less abundant, never reach perfect maturity, and produce an inferior wine to those grown on the hill-side, where they have been sheltered from these atmospheric variations. The bottoms of hills and valleys are also unfavourable to vine-growing: in such places, the air is charged with moisture, and the soil is constantly damp, the result being that the grapes are coarse, and the leaves and wood of the vine are forced at the expense of the fruit. The best possible situation for a vineyard is on a hill-side, looking south-east or south.

That different seasons produce widely different wines is a well-known fact. In a rainy season, the fruit develops neither sugar nor aroma, the wine is weak and insipid, and can be preserved only with difficulty. A cold season yields a rough and ill-tasted wine; and high winds and fogs are highly detrimental to the fruit. The most favourable year for vine-growing is that in which the vine flowers in warm, dry, tranquil weather, followed by gentle rains as the fruit begins to form; and when the development and maturation of the grape are assisted by constant heat, with occasional showers and no fogs. For the harvesting of the fruit the weather should be very hot and perfectly dry.

The finest vine-growing climate and soil is afforded by France, and this country has always produced the largest quantity of wine; the wines of Champagne, Burgundy and Bordeaux are, perhaps, more extensively consumed than any others. The following brief description of the preparation of wines generally is the one commonly followed in that country.

Vintage.—The harvesting of the grapes is known as the "vintage." It is hardly necessary to insist on the necessity for waiting until the grapes have attained maturity, the indications of which state are sufficiently well-known. The vintage should be commenced only in fine weather and under a hot sun, and when the earth and the grapes are thoroughly dry; therefore not before eight o'clock in the morning. A sufficient quantity of grapes to fill a vat must always be gathered at a time, and at an even temperature; failing the latter condition, they must be exposed in a warm place till the heat of the mass is uniform. Rotten grapes are cut off close and thrown away; green bunches are left. To produce good wine, the crop must be gathered in three or four successive pickings. To give the wine more sweetness and body, the grapes are, in some districts, allowed to dry on the bunches by leaving them exposed to the heat of the sun until they become covered with a down resembling mouldiness. The bunches arrived at a state of maturity are gathered first, and produce very sweet, full-bodied wines. This picking being finished, the second is commenced, of those bunches which have matured in the meantime, and which yield finer and more alcoholic wine than the first. A short interval is now generally allowed to elapse, that the combined influences of the hot days and dewy nights of the end of October may complete the ripening of the remainder, which are picked over three or four times yet, the last picking including everything that remains on the vine. The harvest will scarcely be concluded in less than a month. In hot countries, the vintage will bear delay, especially when sweet wines are desired; but where the grapes do not ripen readily, the vintage must precede the maturity of the crop, to avoid the injurious effect of the autumn rains. In this case, the deficiency of sugar must be made up by sweetening the must as hereafter explained. The bunches of grapes are gathered, principally by women and children, into wicker baskets, care being taken to reject those which are sour, rotten, or scorched. The contents of the baskets are emptied into small tubs placed in waggons, for transport to the place where they are to undergo the various processes of conversion into wine.

Preparation of the Must.—When the crop is gathered, the must is prepared by squeezing or pressing the grapes. This may be done in a variety of ways. The most crude method—that of treading out the juice with the naked feet—is now probably obsolete, but in many places it is done by workmen wearing large sabots. In some other places, they are crushed in small quantities at a time in shallow tubs, a tedious operation. The use of a "martyr" for the purpose is, perhaps, most general; this is a wooden box, having a bottom formed of laths so closely set that the grapes cannot pass between them. Into this box, which is placed upon bulks above the vat, the grapes are thrown as they arrive, and are crushed by a workman in sabots. The juice runs through into the vat, while the solid matters remain behind, to be subsequently withdrawn at the side, and either added to the must in the vat or not, as occasion may require. This is repeated till the vat is filled conveniently high. The pressing of the grapes is an absolute necessity, because the saccharine juices will not ferment until liberated from the cells in which they are enclosed; but there is no reason why the barbarous methods still existing should not be supplanted by machinery such as is used for crushing sugar-cane.

A vat should be filled in at most twenty-four hours, for too long a period will entail a succession of imperfect fermentations, the process being completed in one portion of the mass before it has begun in another.

The best authorities agree that the grapes should be picked off the bunches before pressing, as the large stems contain but little matter useful to the fermentation of the must or the preservation of the fermented liquor. This operation is usually performed by a three-pronged fork. On the other hand, the pippins and skins of the grapes should always be added to the must, the former containing the preserving element, the tannin, and the latter the colouring principle. But in making white wines from black grapes some modification will be necessary. In the first place, taking advantage of the fact that the colouring matter in the skins is dissolved only after prolonged maceration, the pressing must be done as rapidly as possible and the skins removed. In order, however, to correct the great defect of all white wines—the difficulty with which they are preserved—the pippins should be introduced into the must either in their natural state, or the tannin may be extracted from them by boiling and the decoction added to the must.

Fermentation.—In the fermentation of grape-must, the process is arrested before its completion by withdrawing the liquor from the vat, in order that it may be subsequently continued in a less degree in the casks.

The juice which runs from the grapes during their transport to the works commences to ferment long before it reaches the vat, in spite of all the care taken to prevent it. In the case of highly-esteemed brands of wine, this juice is fermented separately to produce the choicest varieties, but as a rule it is added to the juice obtained by pressing, and all is fermented together. The fermentation is conducted in vats of masonry or wood, the former being preferable, as they require less repair, maintain a more constant temperature, and are less exposed to accidents. The latter, however, when free from iron inside, are useful for small quantities. The vat must be scrupulously cleaned before admitting the must. Stone vats are washed with warm water, and coated with milk of lime; wooden ones are washed with warm water, and then scrubbed with brandy. These precautions are needed to ensure the destruction of fungoid life and acid or fatty products that would injure the must.

The established conditions of fermentation are a certain degree of heat, contact with the air, and the existence of a vegeto-animal principle, and of a saccharine principle in the must. The most suitable temperature is about 19° (66° F.); it is too slow below this point, and too rapid above it, ceasing altogether under the influence of great heat or great cold. If the temperature of the surrounding air does not equal at least 15° (59° F.), it must be raised to this point by artificial means, and the must heated by mixing some boiling must with it, or better, by introducing, as in Burgundy, a bath cylinder. This precaution concerning the temperature is absolutely necessary, and certain results cannot be counted upon without it. The fermentation also is slower in proportion as the temperature at the time of the vintage was lower. This inconvenience also is obviated by heating the must and raising the surrounding temperature to 15° to 19° (59° to 66° F.). Experience proves that grapes gathered in the morning are slower to ferment than those plucked after noon under a hot sun and in fair, clear weather. Dews, showers, and slight frosts also hinder fermentation; hence the necessity for observing the conditions of weather before alluded to.

Air is favourable to fermentation, and is necessary to its initiation, though it may be dispensed with subsequently. It is necessary, on the other hand, that the carbonic acid liberated shall have free egress; but this disengagement entails great loss of alcohol and of bouquet, so that it is well to cover the vat with planks, on which cloths are spread in such a manner that the contents are preserved from contact with the cold outward air, still leaving a small outlet for the generated gases. The fermentation is thus regulated; the temperature is maintained at a higher point; the loss of alcohol and acidification of the "head" are prevented; the aroma and bouquet are preserved; and the fermentation is maintained under varying atmospheric conditions. The fermentation is also more rapid and complete according as the mass is larger; but against these advantages, and the additional one that the wine keeps better, must be counted the facts that the larger vats require longer to fill, and that the increased heat may cause the volatilization of a portion of the bouquet.

Very sweet grapes yield sweet and full-bodied wine, because the ferment is not in sufficient quantity to decompose all the sugar; less sweet grapes may require sugar to be added to the must to nourish the action of the ferment and to employ the whole of it in producing alcohol. Very thin must is as difficult to ferment as very thick must. The mean consistence should be 10°·5 to 11°·5 B. (about 1·080 sp. gr.). When the must is very watery, the resulting wine is weak and very liable to change. Cold countries, wet lands, and rainy seasons produce grapes containing more water and ferment than is necessary to decompose the sugar formed in the fruit, and the wine is liable to turn sour in consequence of the superabundance of ferment remaining after the spirituous fermentation. Mention has already been made of a means adopted for correcting this evil. In sugaring the must, it is necessary to remember that cane-sugar does not undergo alcoholic fermentation till it has arrived at a more hydrated condition than the sugars of fruit, or glucose. To avoid the delay thus occasioned in the fermentation, it is well to transform the crystallizable sugar before introducing it. Tartaric acid is preferably employed for this purpose, and the sugar solution should be boiled in the must for two hours in presence of 2 per cent. of this acid. If the grapes were insipid and flat, only a partial neutralization by the aid of chalk is needed, while with very acidulated musts the tartaric acid should be completely neutralized. By this plan is obviated the fault ascribed to the sweetening of some musts that it leaves a sickly taste in the mouth, due to the fact that the sugar used has not been entirely decomposed, because then all the added sugar is transformed into alcohol as rapidly as the grape sugar itself. Neither need there be any fear that the addition of the sugar will postpone the commencement of the fermentation; therefore it may be added as early as desired, instead of waiting till towards the end of the operation. Obviously the sugar may also be converted by means of sulphuric acid or phosphoric acid on condition that the subsequent neutralization be complete; but tartaric acid is specially named, as it is normally found in the fruit of the vine, and a solution of it may be economically prepared by treating dry lees, which abound in vine countries.

The fermentation first manifests itself by little bubbles which appear on the surface of the must: little by little it raises the centre of the mass, agitates the whole, and produces more or less effervescence, due to the liberation of carbonic acid. The suspended matters are distributed, raised, and precipitated until one portion settles on the bottom and another portion collects on the surface to form the "head." The fermentation commences as soon as the vat is filled, and lasts ordinarily from twenty-four to thirty hours, with a temperature of 30° to 32° (86° to 89°·3 F.) in the centre. The volume of the mass increases considerably. The "head" raises itself, cracks open, and disengages abundance of froth; heat develops in the liquor in proportion to the mass, and the colour is intensified. Then the symptoms diminish, the head sinks, the liquor clarifies itself, and the work is nearly terminated. The heat, being greatest in the centre, must be equalized by pressing down and agitating the mass. The effervescence, agitation, and heat observable in the must are more intense when the skins, pippins, and stems are present. If the movement relaxes, the vat is mashed and the head precipitated several times. This is done by means of a stirrer, but it must be dispensed with when the skins exhibit any change. Acidity in the head is prevented by protecting it from the action of the air; and by precipitating the froth in the bath, the ferment it contains becomes mixed with the liquid and nourishes the fermentation. The more completely the grapes have been crushed and the more carefully the saccharine fluid has been extracted from the cells, the more regularly the alcoholic fermentation develops itself.

Sometimes instead of mingling the skins with the must in the vat, a lid pierced with holes is fitted to it in such a way that the skins are thus kept immersed in the must. This arrangement has some advantages and some drawbacks. Clearly it avoids the necessity for agitating the mass, since the solid particles are plunged into the liquid and the wine reaches the surface. A second cover surmounts the vat, but if it does not close hermetically and the air obtains free access to the wine, there is danger of its causing acidity. The fermentation may be left to complete itself without any manipulation, provided the second cover be perfectly closed, preserving only an exit for the generated gas by means of a bunghole of sufficient size. This plan, however, is not in favour with the best authorities, who declare that considerable advantage is derived from mashing the mass while in the vat, since the wines gain in quality by the agitation.

The carbonic acid which disengages itself from the mass, and the deleterious effects of which are well known, displaces the atmospheric air resting on the vat, and then falls to the bottom of the room by reason of its density. Ventilation must be provided with the utmost care in order to avoid the risk of suffocation to the workmen. Milk of lime and alkaline solutions absorb it.

The proportion of alcohol produced is in accordance with the sugar which the fruit contains, and is, in consequence, very variable, since the musts may have any density from about 8° to 18° B. (about 1·060 to 1·143 sp. gr.). The proper moment for drawing off the wine and placing it in casks is when the fermentation has rendered the presence of the sugar insensible and replaced it by alcohol, though *all* the sugar has not absolutely disappeared, but sufficient still remains to excite the complementary fermentation in the casks. Concerning the colour of the wine, it may be remarked that it is more intense according as the fruit has been more pressed and longer fermented, as the grapes are riper, and as the wine is more alcoholic. As a general principle, lively and prolonged fermentation is destructive of bouquet and aroma, which constitute the merit of some wines; on the contrary, a very complete fermentation should be allowed to wines whose principal quality is alcoholic strength. Finally, energetic mashing, often repeated, prevents change in the "head," provided that the must has entered freely into fermentation under the influence of a sufficient temperature and with a suitable proportion of sugar. The disengagement of carbonic acid will be such as to obviate any reason to fear the access of atmospheric air, if the mass does not remain in the vat too long after the liberation of the gas is finished.

The operation of racking the wine will presently be considered, but a few words must first be devoted to the "fortification" of wines, and the results to be expected from it.

Fortification.—This consists in introducing a certain proportion of alcohol into the wine for the purpose of strengthening and preserving it, the alcohol opposing secondary fermentation by paralyzing the action of the ferment and precipitating the albuminoid matters; it also improves the condition of weak and acid wines. The operation may be performed either in the vat or in the casks, preferably the former. The must is fortified by adding a proportion of sugar corresponding to the alcoholic strength desired, or by adding alcohol itself when the fermentation is approaching its end, or about twelve to fifteen hours before racking. Wine in the cask is fortified by an addition of alcohol or by a mixture with very alcoholic wines. The wine may also be submitted to congelation, which removes a portion of its water in the form of ice. Fortification sweetens too acid wines, in that the alcohol precipitates the excess of cream of tartar, and combines in time with the free acids present to form ethers. It also affects the colour of red wines, alcohol being a solvent of the violet principle of the grapes. The colour of the wine is due to a mixture of this normal violet with a red colour due to the effect of the air and acids. It therefore follows that better results on this head are obtained by fortifying in the vat, for by direct fortification in the cask the red tint is diminished and precipitated in the lees.

It is evident then, that independently of its direct action, alcohol de-acidizes too acid wines, favours the formation of ethers, increases the colour, and gives a body to the wine. These are sufficient reasons in its favour; but the *direct* addition of alcohol must almost always be condemned. Not only are the most detestable compounds brought into the market after treatment with alcohol, but the plan has also this great disadvantage, that wines so treated cannot possess that degree of *homogeneity* which arises from fermentation, and which is one of the principal merits of natural wine. Ill-advised, however, as the direct addition of alcohol is, it is, nevertheless, only too often resorted to, because the cost of the alcohol produced by fermenting additional sugar in the must is a trifle higher than the commercial price of manufactured alcohol. It does occasionally happen, however, that good may result from the addition of alcohol to the must towards the end of the fermentation in the vat.

Racking.—From the preceding observations it is evident that the moment for racking wine cannot be submitted to fixed and invariable rules, but that it will differ with the climate, the season, the quality of the grapes, the nature of the wine to be produced, and other considerations which must not be lost sight of. The sinking of the head is not a sufficient sign, as some wines should be drawn off before this happens, while others improve by remaining for some time afterwards. The cessation of sparkling and froth, indications drawn from the odour, taste, colour, cooling, and density, do not always form a safe guide, though the last mentioned does, in the majority of cases, mark the precise moment. Wines for distillation must be thoroughly fermented; while weak, perfumed wines need less, notably some white wines whose speciality is to be sparkling. Racking must invariably be performed when the sweet taste has become insensible, and is replaced by a vinous flavour. The lowering of the density to 0° or 1° B., cannot always be considered a proof of the end of the fermentation, since the proportion of alcohol and other matters renders it inconstant. Chaptal gives the following rules:—

1, The must should ferment for a length of time proportionate to the sugar it contains; 2, It should ferment less for sparkling wines, and be introduced into the casks immediately after pressing; 3, It should ferment less as the colour is weaker; 4, It should ferment less as the temperature is higher and the mass greater; 5, It should ferment less as the wine is to be more perfumed; 6, It should ferment longer if it is to be distilled; 7, It should ferment longer as the temperature was lower at the time of vintage; 8, It should ferment longer as the wine is to be more coloured; 9, And it should ferment longer in small vats than in large. Consequently the vatting may vary from 24 hours to 12 or 15 days. Nothing is more arbitrary in practice than the moment for racking, but there is no doubt it may take place the instant the active fermentation ceases, and the vatting need never be prolonged beyond 72 hours for very rich wines, and 30 to 36 hours for delicate wines; while the latter period much more than suffices for very light wines or those for immediate consumption.

The racking is done in a very simple way, either by a siphon or by a tap placed in the bottom of the vat, at the interior orifice of which a grating or birch broom has been placed to retain the pippins and impurities. The wine is caught in large tubs, and then filled into casks which have previously been scrupulously cleaned.

When the vat has been emptied of wine, a residue is found in it composed of stems, skins, and pippins, as well as a variety of vegetable débris, froth, and albuminoid matters combined with tannin. The wine contained in it is removed by pressure. The mass is placed in the press, and the wine which runs from it is added to that already obtained without pressure. After the first pressing, the mass is turned over and pressed again till the fourth time. The product of the first pressing is the strongest, that of the last is the hardest, the most sharp, and the most deeply coloured. Often the products of these several pressings are mixed in separate casks to produce a deeply coloured wine that will keep very long; at other times it is mixed with the unpressed wine to give it strength and a slight astringency, and to obtain one uniform product from the whole vintage.

The solid mass of skins, &c., assumes almost the hardness of stone when well pressed, and is applied to several purposes. In some countries, it is used for brandy making; in others it is treated with water to form a thin vinous drink for the labourers. Elsewhere, it is employed in the manufacture of verdigris; and again, of vinegar. It is widely applied to cattle feeding, and may be burnt to produce alkali. The pippins form excellent poultry food, and yield oil.

When the must has undergone its due period of active fermentation and has been placed in casks, it has by no means reached its last degree of elaboration. There is still a modified amount of fermentation to be undergone, after which the inert alcohol deposits itself at the bottom of the vessel with the greater part of the insoluble suspended matters, thus constituting the "lees." In order that the wine may acquire its due degree of spirit, it is essential that all the convertible sugar be transformed into alcohol by the slow fermentation which follows the active process in the vat; besides which, it must be made to keep by separating the deposits, the foreign suspended matters, and the soluble substances, which might cause an alteration in it. The work thus entailed constitutes the duty of the cellarman, but before alluding to the several points involved, it will be necessary to say a few words about the cellars where the wine is worked and stored as well as about the preparation of the tubs and casks for its reception.

Maturation and Storage. Vaults and above-ground Cellars.—The following rules should be observed with regard to a wine vault:—

1. The vault should face the north, the temperature being then much less variable; 2, It should be deep enough to ensure the temperature being constant; 3, Its humidity must be constant without being too great, for excess of moisture mildews the papers, taps, &c., while dryness may cause the casks to open and let out the wine; 4, The light must be very subdued; 5, *It must be absolutely secure from disturbance*, for the shaking caused by the passage of waggons along a road, or by a thunderstorm, stirs up the lees, mixes it with the wine and provokes acidification; 6, All green wood, vinegar, or other substances likely to ferment must be kept away from the vault. Accordingly the vault must be excavated several fathoms beneath the surface of the earth; the outlets must face the north; it must be distant from all roads, factories, streams, &c., and must be vaulted over. The best vaults are generally those cut in solid rock. Above-ground cellars are built where the soil is sandy. They should unite as far as possible the same conditions as the underground vaults. The Bordeaux cellar is made in the following way:—It is built as near to the fermenting vats as possible, of varying length, and about 20 to 25 yards broad. The floor may be on the same level as the earth outside, but the air is fresher when the floor is lowered a few inches, in the case of dry soil; but where the soil is wet it should rather be raised a little. It should be shaded on the south by tall trees or by a building; the windows, of very small dimensions, are pierced in the north wall. It is ceiled with plaster or planking. Four rows of casks are placed in it, two down the middle and one along each side, supported on long beams a few inches above the floor.

Receptacles for Wine.—In principle, the most capacious and most tightly closing vessels are the best. Use is chiefly made of casks, of various sizes, constructed of oak, whose principal inconveniences are that they sometimes present soluble substances to the wine, and are more or less porous. When made, the wine is stored in casks or glass bottles. In any case, the receptacles must be thoroughly cleaned in good time before they are required. Those having an unpleasant smell after cleaning should not be used. The best mode of cleaning is as follows. The cask is first soaked in cold water, and then in hot water to swell the wood and close all interstices. It is afterwards thoroughly washed with a mixture of sulphuric acid with fifteen times its weight of water, and finally subjected to two washings, the first in boiling, the second in cold water, to remove all trace of the acid.

During the "insensible fermentation" in the casks, a more or less abundant froth forms on the surface of the liquid, and must be carefully removed. At this time, therefore, care is taken to keep the casks constantly full, in order that the scum may escape at the bung-hole which is only imperfectly closed by a leaf or by lodging the bung loosely on it. In some countries, the level is adjusted every day during the first month, every four days during the second, and then once a week till the wine is drawn off. The intervals are modified elsewhere, the object being to let out the scum and prevent the action of the air on the wine while the disengagement of carbonic acid is relaxed or spent.

The causes which diminish the contents of the cask are evaporation and absorption by the wood of the cask. The casks should be hermetically closed as soon as the generation of carbonic acid is not sufficient to oppose the free access of the air, but a vent-peg should be inserted for the purpose of letting out the gas now and again. The working of wine consists in a gradual and complete purification, performed after the fermentation, and intended to eliminate all convertible foreign matters, but especially the soluble and insoluble nitrogenous matters.

For all wines of good quality the filling up should be done with the *same* wine, some being reserved specially for the purpose, but with common wines it may be done with the press liquor. In any case, the vessel containing the complementary wine should not be left open.

It is unnecessary to state that the casks ought to be raised on stands in the cellar, at such a height as to render the drawing off as easy as possible. They should also be placed perfectly horizontal, for if tilted up at the back, the lees collect at the front, rendering it necessary to place the tap inconveniently high in order to prevent it from running out with the wine; and, if raised at the front, it is impossible to draw off the whole of the clear liquid; whereas, when lying perfectly horizontally, the lees collect in the centre of the lower cavity, without being disturbed when the wine is racked. The casks, thus disposed, must be inspected frequently, in order that any accidents may be discovered and remedied at once. This is especially necessary during the month which precedes and follows the equinoxes; at these times, the wine is particularly subject to undergo fermentation, especially new and white wines. If allowed to ferment, the wine exercises considerable pressure in the casks, the staves frequently giving way unless an exit be made for the carbonic acid gas, or, rather, unless several litres of the wine be immediately removed from the cask. During the equinoxes also, the casks are liable to be rotted by vapours exhaled from the ground; this is especially the case in deep cellars. Great care must be taken, too, to see that none of the casks become leaky or worm-eaten; large quantities of wine may be lost from these causes.

Drawing off.—There are so many influences which cause the lees to remingle with the wine after having deposited itself at the bottom of the vessel, that the first care necessary after the conclusion of the complementary fermentation, is to separate the wine from the deposit by drawing it off.

This is performed at various times according to fancy, but the most reliable rule is that weak wines should be drawn off in winter, medium wines towards the end of that season, and strong, full-bodied wines in summer. The operation is repeated as many times as may be necessary for the purification of the wine. It is best performed by means of a siphon, or a simple air-pump.

As long as a wine preserves its colour, flavour, and aroma, there is no necessity for re-racking it; but as soon as it begins to lose its transparence, becoming turbid and flavourless, it must at once be drawn off into another cask, which has been well sulphured the moment before. The effects of sulphuring are pointed out in the ensuing paragraph.

Sulphuring.—This operation consists in burning sulphur in the casks. Its first effect is to make the wine thick and its colour disagreeable, but the latter returns in a short time, and the wine clarifies itself. Its object is to prevent acidification and all ulterior fermentation. It also displaces the air.

Wines are sometimes sulphured without being withdrawn from the cask. A small quantity is drawn off, and the sulphured wick inserted at the bung-hole and burned just above the surface of the wine. While the empty portion of the cask is filled with the sulphurous gas, the bung is replaced, and the cask agitated violently, in order that the gas may be entirely dissolved. The cask is then refilled with wine. Another method of sulphuring wine consists in introducing a small quantity of a solution of the sulphurous gas in water.

Clarification.—The processes of racking-off and sulphuring remove a large portion of the impurities of a wine, but there still remain particles of suspended matter, which must be precipitated by a process of artificial clarification. This process not only removes suspended matters but aids in precipitating dissolved impurities, even after a considerable lapse of time. Hence it constitutes a powerful means of improving and preserving wines, and cannot possibly be dispensed with. The substances most commonly employed to effect this clarification are fish gelatine, the whites of eggs, blood, and various other substances artificially prepared. When fish gelatine is employed, it should be chopped into small pieces and stirred up with a little wine and an equal weight of tartaric acid; it swells, softens, and forms a glutinous mass. This is thrown into the wine in small quantities and with much stirring, after which the wine is left to stand. During this time, the gelatine combines with the tannin of the wine and falls to the bottom, carrying with it all particles of suspended matter, and leaving the wine clear and bright. Five grammes of fish gelatine is sufficient to clarify 150 litres of wine. To prepare it for use, 5 grm. may be dissolved in 7½ decilitres of white wine and made up to the litre with brandy; this preparation will keep indefinitely if kept tightly corked. In warm climates, egg-albumen may be used with advantage in winter; the whites of five or six eggs are sufficient to clarify 150 litres of wine. They are beaten up with a pinch of salt, and then thrown into the cask. Eggs which are not absolutely fresh must not on any account be employed. Blood-albumen may be substituted either for fish gelatine or white of eggs; one portion is coagulated by the alcohol, and the rest combines with the tannin and colouring matters of the wine. Its use tends greatly to improve the colour of the wine, especially if its colour has become altered by age. In order to preserve blood, it may either be mixed with an equal portion of alcohol at 58°, or it may be dried. Many different powders, consisting of albumen in various forms and bearing particular names, are prepared and vended in France as clarifying powders.

Classification of Wines.—Wines may be divided into several different classes, according to the point of view from which the classification is regarded. The most obvious division is that of colour: they may be either white or red. White wines are prepared from both white and black grapes, but the juice after expression is not allowed to remain in contact with the skins and seeds of the black variety, or it will extract the colouring matter. Red wines are made from the black grapes only, and the must is allowed to lie upon the seeds and skins until it has become of the desired colour. Or wines may be classed again as "sparkling" or "still" wines. The qualities of sparkling wines are afforded to them by placing in the bottles a little cane-sugar, and so causing them to undergo a second fermentation; still wines are those which have not received this addition of sugar. A very common classification of wines is as "dry" or "fruity"; the former being those, like Rhenish wines, which contain little or no free sugar, and the latter those, like port and sherry, which contain much sugar and have a sweet or "fruity" flavour. Wines may be further spoken of as simple or compounded, or mixed, the latter being, of course, mixtures of two or more simple wines made for the purpose of blending their distinctive qualities of taste, bouquet, and colour. Such mixtures are much drunk in this country.

The wines of the South of France are strongly alcoholic, stimulating, and of a warm flavour. Some of them are highly aromatic and saccharine and all possess a fine, delicate aroma. Those of Champagne and Burgundy are moderately alcoholic, full-bodied and delicately perfumed; they are both red and white. The Spanish wines, port, sherry, and Madeira, are the most alcoholic wines made; the former is dark in colour and the two latter are white or golden; all of them have an exquisite bouquet. The wines from the Rhine are dry and acid, of a light flavour, and poor in alcohol, and of a fine golden colour. Bordeaux wines are tonic and astringent, nutritive, stomachic, and of a delicate flavour and perfume. Those of Tokay, Alicante, Malaga, Malvoisie, and Cyprus are very saccharine, tonic, and stimulating.

Preservation of Wines.—The preservation of wine presents no serious difficulties provided that certain rules be carefully attended to. The principal conditions of success are the following:—

1. The more alcohol a wine contains, up to 18 or 20 per cent. by volume, the better it will keep.
2. It should also contain a good proportion of free sugar.
3. A wine, though rich in alcohol and poor in sugar, is more liable to spoil in proportion as it contains germs of nitrogenous organic matter, whether soluble or insoluble, coagulable or non-coagulable by heat.

From these conditions, it will be seen that when wine contains an average proportion of alcohol, or of alcohol and sugar, but when by repeated rackings all suspended matters have been removed, and if it contain sufficient tannin to effect the removal of soluble albuminous substances, and the processes of clarification have been scrupulously followed out, there is nothing to prevent its being preserved for an indefinite length of time, provided it be kept from the oxidizing action of the air.

The principal alterations and maladies to which ill-made or carelessly stored wine is liable are acetous and viscous fermentation, excess of astringent or of colouring matters, ropiness, and bitterness. These may all be avoided by careful attention to the rules which have been given for the proper conduct of the various processes.

Testing Wine.—The good or bad qualities of a wine may be recognized by the application of three senses—sight, smell, and taste. An eye accustomed to the examination of wines can readily discover whether the colour is homogeneous or not, and whether it is natural or artificial. By the sense of smell, the aroma of different wines is distinguished one from another; this method of examination becomes an almost infallible indicator when the organs of smell are extremely sensitive. The sense of taste, when carefully exercised, is the most to be relied on. When a wine is pure and unadulterated, the different component principles are blended together, forming a perfectly homogeneous whole, which leaves one flavour only upon the tongue and the roof of the mouth; but when the wine is the result of a mixture, the constituents are not intimately combined, but merely loosely mixed. By keeping such wine in the mouth for a short time, the warmth volatilizes the lighter and more volatile constituents, rendering them at once sensible to the roof of the mouth, while the extractive and heavier matters are made evident to the tongue and lower part of the mouth; if the wine has been diluted with water, it is detected at once by a practised taster, by a sensation of flatness and insipidity. Physical and chemical instruments, such as thermometers and œnometers, are frequently employed in testing the qualities of wines, in order to ascertain their vinous or saccharine richness.

Mixing Wines.—The mixing of wines is performed in order to rectify certain defects by bringing together two opposite qualities. Thus red wines are mixed with wines of too light a colour; light wines, containing little alcohol, with stronger wines, in order to ensure their preservation, and so on. These mixtures, when judiciously made and in proper proportions, always produce wines superior in quality to either of the two originally mixed; they are generally more wholesome and more agreeable. The art of making such mixtures is a difficult one, since not only have the appearance, the taste, and the smell of the wine to be consulted, but also the taste of the consumer; hence it is not possible to base it upon any definite rules.

The wines of Southern France are dark and heavy, but when mixed with white wines, obtained from a light, chalky soil, they yield splendid wines of a beautiful, brilliant colour. If a fresh, sweet white wine is mixed with an acid wine, the product is also one of very good quality. A small quantity of a new wine, or two or three years old, added to an aged wine which has lost its freshness, or has begun to turn bitter, completely restores it, and often quite removes the bitter flavour. Highly coloured red wines, when mixed with white ones which have become yellow, are much improved in flavour and quality.

The practice of mixing wines not only improves and assists in preserving them, but also renders them capable of being transported for great distances without fear of injury, which could not possibly have been the case with the unmixed wines.

The well-known harshness of some Bordeaux wines is frequently corrected by adding Hermitage, and colouring with those of Cahors, Gard, and Hérault; these mixtures can only be made when the wine is new, in order that, after mixing, they may undergo an insensible fermentation, by which the added wines are closely united with the Bordeaux; the result is a fine wine commonly sold as Medoc.

It will thus be seen that the wines to be used for mixing, and their proportions, vary extremely, and must be adapted to the different tastes of different consumers. The taste of the majority of Englishmen is quite different from that of the Russians, and that of the Russians is different again from that of the Germans; and therefore the wine-dealer is obliged, in order to satisfy all demands, to make a profound study of this question of mixtures. He has also, by various means, to increase the strength of his wines, especially if they are destined for the English market; this he frequently effects by adding alcohol, in proportions of 2 to 5 litres to each cask of wine, or by provoking a second fermentation in it by adding unfermented must, in close vats.

In the South of France, the wines chiefly used for mixing are those of Alicante, Bernicarlos, Hermitage, Rousillon, Gaillac, and others. In Burgundy, when the vintage has been a small one, the deficit is made up by adding equal portions of the wines of Tavel, Cher, Rousillon, or Narbonne, and then a sufficient quantity of water to bring the mixture to the regular alcoholic strength. These wines, when brought together, speedily undergo a continuation of the fermenting process, which renders them absolutely homogeneous, and produces a wine which cannot be distinguished from the finest Bordeaux. For a wine of the first quality, the proportions of the mixture are:—

Wine of Cher	1 pipe.
„ Marseilles	1 „
„ Bordeaux (white)	1 „
„ Rousillon	10 gals.

For a wine of the second quality:—

Wine of Touraine	1 pipe.
„ Rousillon	10 gals.

And for an ordinary wine:—

Wine of Rousillon	1 pipe.
„ Burgundy	30 gals.
River or rain water	1 pipe.
Alcohol	5 quarts.
Good vinegar	1 quart.
Tartaric acid	500 grm.
Tannin	59 „

When the wine is of too deep a colour, a dry, white wine may be substituted for the Burgundy. It is advisable to allow the mixture to stand for a month or more.

It is often the practice to send mixed wines into the market as soon as they are made; but this is a great mistake, since the elements of the mixture have not had time to become properly mixed and to form a homogeneous whole. A month is generally sufficient to effect this, but in the case of some wines a much longer time is requisite; others, indeed, never mix at all, the particular taste of each single wine is distinguishable after a considerable lapse of time.

When a wine possesses certain characteristics which render it of superb quality, it ought never to be mixed with other and inferior wines, as is too frequently the case. An old wine, unless it is deteriorating and lacks freshness, ought not to be mixed with wine of less than two years of age, at the risk of losing both bouquet and colour. No wine which has undergone alteration or deterioration of any kind should ever be used for mixing, or the disease will inevitably spread until the whole mixture is ruined. The improvement of a wine is commonly effected in one of two ways: either by natural means, such as mixing it with one or more different wines; or by an artificial method, such as imparting to the wine itself, or to the mixture, those particular principles which are lacking. Examples of the first method are afforded by mixtures of the wines of Touraine and Cher, made for the purpose of improving the former; by mixtures of different brands of Burgundy; by mixtures of strong and weak wines, or of a wine which is becoming enfeebled by age with another of the same brand but some years younger, &c., &c. By the second method, wines lacking sweetness are improved by the addition of syrup; wines which are too sweet, by the addition of a little solution of tartaric acid; those wanting in bouquet, by affording to them the particular bouquet by which they are characterized; and those which have none at all, by the addition of any which may be desired. By these and various other methods, and with the exercise of a good deal of judgment and experience, the wine merchant is able to remove or cover any defect to which a wine is liable.

In these processes of mixing consists the great art of cellar management, and to such an extent is it carried on, both abroad and in England, that it may be confidently asserted that few wines ever reach the consumer in an unmixed or natural state.

Strengthening Wines.—Wines are often strengthened by the addition of alcohol, for the purpose of rendering them preservative and preventing alteration. The fortification is generally performed with Montpelier spirit, of 86°; it is preferable, however, to use spirit of about 58°, obtained by distillation. This method of fortifying wines is very defective, since it imparts to them a crude, rough flavour and odour, which will not permit them to be used for a very long period. To avoid this, the following mixtures may be employed with advantage, instead of the raw spirit:—

Water	70 litres.
White sugar	6 kilos.
Carbonate of soda	30 grm.
Pure tannin	15 „
Alcohol (86°)	25 litres.

Or better still:—

Water	57 litres.
White sugar	6 kilos.
Carbonate of soda	30 grm.
Pure tannin	15 „
Brandy (58°)	38 litres.

In making the first of these preparations, the sugar and carbonate of soda are dissolved in the water, and the spirit is then added. For the second, the sugar, previously dissolved on the fire in a little water, is added to the brandy, then the carbonate of soda, also dissolved in a little water, and finally the rest of the water is added. These preparations improve much on being kept. Their use will preserve wines from many maladies, and will even restore those which have been suffered to spoil.

Imitation of Wines.—The practice of adding various substances to inferior wines, in order to pass them off as wines of great age and value, has become extremely wide. All sorts of tinctures and infusions are employed in making these imitations; and it will be well to give here the recipes from which they are chiefly prepared, and then to point out briefly the methods used to imitate certain wines of well-known brands. The following are a few recipes for these tinctures:—

Tincture of Iris.

Alcohol (50° to 58°)	1 litre.
Water	½ „
Florentian iris (powdered)	125 grm.

Allow to stand for twenty-four hours; then distil to obtain 1 litre.

Tincture of Strawberry roots.

Alcohol (85° to 90°)	5 litres.
Dry strawberry roots (powdered)	500 grm.

Tincture of Iron.

Oxide of iron	500 grm.
Crystallized tartaric acid	500 „
Water	2 litres.

Dissolve these by heat.

Tincture of the dried husks of nuts.

Alcohol (85° to 90°)	5 litres.
Dried husks	500 grm.

Infusion of Raspberries.

Alcohol	10 litres.
Raspberries (ripe and picked)	10 kilos.

Tincture of Almonds.

Alcohol (85° to 90°)	5 litres.
Essence of bitter almonds	5 grm.

These preparations, after about a month or so, may be utilized in imitating various different wines. If it be required to make Burgundy, Mâcon, or Bordeaux, those wines are chosen which most resemble the one required in age, colour, strength, &c. For Burgundy, a small quantity of the infusion of raspberries is added to each cask, either alone or with a little of the tincture of almonds. For Mâcon, the infusion of the husks of nuts and the tincture of strawberry roots are employed, a litre of each being added. For Bordeaux, the tincture of iron is used to produce the characteristic roughness; 1 to 2 litres of the infusion of raspberries to every cask of 280 litres; and a minute quantity of the tincture of iris to give the bouquet. The exact quantity of these tinctures required to give the right flavour or bouquet must be left to the dealer, as they depend entirely upon the nature of the wines dealt with.

Various shades of colour are imparted to wine, when necessary, by adding small quantities of tinctures made from different foreign woods. Some wines, owing to age, begin to lose their characteristic qualities; this is frequently prevented by adding to it wine of the same brand, but perfectly new, by which means the old wine regains its freshness, colour, or bouquet. As a rule, however, the older the wine the finer does it become and the more agreeable is it to the palate. For this reason, many plans have been resorted to in order to make a new wine pass for an old one. These methods rarely succeed in deceiving a practised taster, and since they almost always injure the wine to some extent, they are not by any means to be recommended.

It is seldom absolutely necessary to impart fictitious colours to wines, but it is the custom to do so in order to gratify the eye of the consumer; this is especially the case in seasons when the grape has not arrived at full maturity, and the wine is, consequently, of a poor colour. Many colouring preparations are made for this purpose from different Indian and Brazilian woods, and from the seeds and berries of the elder-tree, privet, danewort, whortleberry and other plants. By the use of such preparations any desired shade of colour may be easily obtained. A much better means of imparting colour will, however, be found in the employment of red hollyhock flowers, dried and picked, and steeped in either red or white wine. This preparation, made when required or a few days previously, will serve to give a white wine any desired shade of red; and if kept for some time, it becomes capable of imparting a very fine brownish-red tinge. Its special advantage is that it cannot be detected in wine by any process whatever. By fermenting mulberries, a preparation may be made, having not only a magnificent colour, but a very fine perfume also; by mixing it with brandy, a colouring medium is obtained which is quite equal to the preceding, and of a far superior aroma. These substances, and some others, have been employed in France for colouring wines with the most complete success.

The method of making the first-mentioned colouring preparation, viz. that from the hollyhock, is as follows:—To operate on a large scale, a cask is raised slightly from the ground on a wooden stand; this cask has a trap-door in its bottom, for the introduction and withdrawal of the flowers, and also a perforated false bottom, placed about 4 in. from the real bottom, and a stop-cock midway between the two. It is then filled to nine-tenths of its capacity with dried and carefully picked leaves of the red hollyhock flowers, and wine poured upon them until the cask is quite full, when it is covered over. After a period of eight days or more, the wine is drawn off into another cask and the flowers allowed to drain before being covered with wine afresh; the second infusion is added to the first. A little tartaric acid is added to the tincture in order to brighten the colour, and also a quantity of alcohol, after which the whole is allowed to age. The flowers may be infused once or twice more, and should finally be well pressed to extract the remaining drops of wine.

Three hundred grammes of the leaves are sufficient to impart to 100 litres of white wine, a fictitious colour resembling that of the wines of Narbonne. In order to know what quantity of the flowers is necessary to heighten the colour of a light wine to the required degree, a litre of the wine is taken and such a quantity of the tincture is added to it as is necessary to produce that colour, the quantity being carefully noted. The correct proportion required to colour 100 litres, or any other quantity, can then be readily deduced.

The method generally employed to extract the colouring matter from the berries of the elder-tree, privet, danewort, whortleberry, or mulberries, consists in bruising the fruit and subjecting it to fermentation, with the addition of a little water if necessary. Or the fruit may be infused simply in alcohol, at from 65° to 85°; such infusions have a finer aroma than the products of fermentation, and they are more readily preserved. A little solution of tartaric acid may be added to them with advantage about once every month.

Fruity or *liqueur* wines contain less water and more sugar and alcohol than the dry wines, and have also a stronger aroma. They are generally of a somewhat syrupy consistence. Owing to their large proportions of alcohol and sugar, they have the property of keeping for many years without undergoing sensible change. The best known and most esteemed of these wines are those of Alicante, Grenache, Cyprus, Lacrymæ Christi, Madeira, Malaga, Port, Sherry, and Tokay. The liqueur wines of commerce are, however, almost always imitations, made at Cette or Montpelier. They are made by mixing different wines with alcohol and sugar, and some aromatic infusion, in such proportions as agree with the character of the wine imitated. These aromatic substances are very numerous; those most frequently employed are infusions of raspberries, green walnuts, cloves, iris, and bitter almonds; recipes for these are given below:—

Infusion of raspberries.—Alcohol (85°). An equal quantity of ripe and carefully picked raspberries.

Infusion of green walnuts.—	Alcohol (85°)	100 kilos.
	Green walnuts	100 „
Infusion of cloves.—	Alcohol (58°)	4 litres.
	Bruised cloves	500 grm.
Infusion of iris.—	Alcohol (85°)	4 litres.
	Grated iris (Provence)	500 grm.
Infusion of bitter almonds.—	Shells of bitter almonds	20 kilos.
	Alcohol (58°)	40 litres.

The shells should be roasted like coffee berries, and placed in the spirit while hot.

These infusions ought to be made a month or two before they are required for use. The recipes of some favourite liqueur wines are as follows:—

Alicante.—	Wine of Bagnols	80 litres.
	Alcohol (85°)	9 „
	Syrup of raisins	10 „
	Water	5 „

Mix well together, and add a little of the infusion of iris.

Cyprus.—Muscatel (very old)	25 litres.
White wine (dry and alcoholic)	64 „
Alcohol (85°)	5 „
Infusion of walnuts	1 „
White sugar	2 kilos.
Water	1 litre.

Mix the different wines together; add the alcohol and the infusion of walnuts; dissolve the sugar in the water, and boil till the solution becomes of a golden colour; add it to the mixture, with a little of the infusion of cloves.

Grenache.—Collioure (dry)	80 litres.
Syrup of raisins	12 „
Infusion of walnuts	1 „
Infusion of bitter almonds	1 „
Alcohol (85°)	5 „
Burnt sugar (yellow)	500 grm.

Proceed as for Cyprus.

Lacrymæ Christi.—Bagnols (old)	85 litres.
Gum kino	50 grm.
Infusion of walnuts	1 litre.
Syrup of raisins	6 „
Alcohol (85°)	8 „

Dissolve the gum kino in the alcohol; mix the whole together, and allow to stand.

Madeira.—Picardan (dry)	60 litres.
Tavel (old and strong)	25 „
Infusion of walnuts	2 „
Infusion of bitter almonds	2 „
Sugar candy	1·5 kilos.
Brandy (58°)	10 litres.

Melt the sugar candy in a portion of the wine and mix the whole together.

Malaga.—Bagnols (old)	80 litres.
Syrup of raisins	10 „
Infusion of walnuts	2 „
Alcohol (85°)	8 „

Proceed as for Madeira.

Port.—Rousillon (old)	70 litres.
Old Ratafia	25 „
Alcohol (85°)	5 „

Mix thoroughly, and set aside for two months.

Sherry.—Add to the substances indicated for Madeira, from 1 to 2 litres of an infusion of white raspberries.

Tokay.—Bagnols (very old)	80 litres.
Syrup of raisins	10 „
Dried elder flowers	300 grm.
Infusion of white raspberries	2 kilos.
Infusion of walnuts	1 „
Alcohol (85°)	6 litres.

Dissolve the syrup in a little warm water; infuse the elder flowers in it until cold; pour the wine upon it, and agitate the whole briskly.

The two most important fruity wines, viz. port and sherry, are adulterated to an enormous extent. In Portugal the juice of elderberries is largely added to port in order to heighten its colour, and extract of rhatany for the purpose of improving the colour and imparting an astringence to the wine. In England, beetroot, Brazil wood, the juices of elderberries and whortleberries, the pressed core of elder-wine, extract of logwood, &c., are commonly added to port to give it a fictitious colour; and oak sawdust, alum, and extract of rhatany to give it an astringent taste. A mixture of elder-juice, grape-juice, brown sugar, and crude brandy, called "*jerupiga*," is the commonest adulterant of port, both in this country and in Portugal; its addition to the wine in bond is permitted by the Custom-house authorities.

A mixture commonly sold for sherry consists of Cape wine, to which a nutty flavour is imparted by means of bitter almonds, and a fulness by the addition of honey, and rendered more alcoholic by a little plain spirit or pale brandy; this mixture is subjected to an insensible fermentation, and is then sold as good sherry. Sherry is coloured by means of concentrated must, burnt sugar, or spirit colouring.

All the wines which have been considered above are the pure, genuine wines of the grape. Large quantities of imitation wine are manufactured, however, both in this country and in France, and it is now bought and sold to such an extent among the poorer classes that it is desirable to describe here the methods by which this inferior wine is made. Different recipes in common use for its preparation are therefore given in full.

1. To make 150 litres, take 50 litres of wine of Rousillon, Narbonne, or St. Gilles, of three years of age, and 100 litres of the following mixture:—

Cold river water	85 litres.	Tartaric acid	300 grm.
Common brandy	20 ,,	Powdered iris	15 to 20 ,,
Good vinegar	1 ,,	Powdered wood charcoal	500 ,,

Place in a barrel the water, vinegar, and brandy; dissolve the tartaric acid in a little of the mixture, and stir up the charcoal in it, returning the whole to the barrel and mixing well together; beat up the whites of two eggs in a little water and add them to the mixture with constant stirring. In twelve hours' time the liquid will be clear, when it is drawn off and mixed with the wine; in a month or two the liquor is fit for consumption, and possesses the flavour, strength, and colour of a good red wine.

2. Add to 100 kilos of unpicked grapes 100 litres of the following mixture:—

River or rain water	100 litres.	Boracic acid	60 grm.
White sugar	18 kilos.	Gall nuts (well bruised)	30 ,,
Cream of tartar (powdered)	300 grm.	Common salt	100 ,,

Infuse the gall nuts for twenty-four hours in an earthenware vessel with 1 or 2 litres of boiling water. Then crush the grapes in a barrel, slightly raised from the ground and having a stop-cock. Take 25 or 30 litres of the water and heat just to boiling; dissolve in it, first the boracic acid, then the cream of tartar, and afterwards the sugar and salt, adding the solution to the remainder of the water. Pour in the infusion of gall nuts and add the whole to the crushed fruit in the barrel; mix thoroughly by agitation.

The mixture thus made begins spontaneously and almost immediately to ferment, which continues for a week or more, In order to impart a good colour to the wine, the stems and skins of the fruit are allowed to remain in the fermenting liquor, and kept at the bottom by means of laths. The barrel is carefully covered during the process. If a deeper colour be required, it may be imparted by adding 200 or 250 grm. of dried hollyhocks before fermentation. This process complete, the wine should stand for a day or two, and may then be drawn off into a cask, when it enters at once into the secondary or insensible fermentation.

3. Another common wine is often made from the *marc* resulting from the process just described, which is usually rich in fermentable matter. One hundred litres of water containing the same ingredients as are mentioned in the last recipe, and also 200 grm. of dry, picked hollyhocks, are added to this marc. In less than two hours, fermentation commences, and proceeds for some days, after which the liquor attains considerable strength and a good colour. It is usually added to the wine made by the preceding recipe.

Instead of the 18 kilos of sugar employed in the first recipe, 30 kilos of syrup may be used, the other ingredients remaining the same. To obtain wine of good quality and capable of long preservation, the must should indicate at least 10° by the saccharometer before fermentation. It is needless to state that the more sugar the must contains, the stronger and better will be the wine produced.

4. A very cheap wine may be made by placing in a bucket 40 or 50 litres of river water, and adding 35 to 40 kilos of raisins. Dissolve also 200 grm. of cream of tartar, and 40 grm. of boracic acid in 1 or 2 litres of boiling water, and pour the solution upon the raisins. When the fruit has swollen until the skins are almost bursting, the liquor is poured off it, and it is placed in a barrel with 100 litres of the mixture described under the second recipe; the barrel is then covered over, a small outlet being left for the escape of the gas. Fermentation commences only after a day or two, and should be provoked by incessant stirring for a few hours. The wine made in this way should be clarified in a month's time with the whites of six eggs to each cask. In the bottles it is very bright and sparkling. If suffered to age in the cask it becomes dry, heady, and pleasant to the taste.

5. For another wine, either white or red, the ingredients are:—

White sugar	5 kilos.	Common brandy	12 litres.
Raisins	5 ,,	River water	95 ,,
Common salt	125 grm.	Gall nuts (bruised)	20 grm.
Tartaric acid	200 ,,	Brewer's yeast (in paste)	200

Soak the raisins in a little of the water until they swell; dissolve the tartaric acid in 2 litres of hot water; infuse the gall nuts for twenty-four hours in 2 litres of boiling water; then dissolve the sugar and salt in the remainder of the water, place the whole in a cask; add first the brandy, and then the yeast beaten up in two tumblerfuls of water, and stir up briskly with a stick inserted through the bung-hole. In twelve hours' time, if fermentation has not commenced, it is provoked by renewed stirring, and then left to proceed of itself.

To make this wine of a red colour, it is necessary only to add to the above ingredients 250 to 300 grm. of dry, picked hollyhocks, taking care to keep them at the bottom of the cask.

Deterioration of Wines.—Nearly all wines are subject to alterations of different kinds, many of them being easily prevented or cured; some occur naturally, whilst others are accidental. Those are considered to be natural disorders which are not brought about by outside causes, such as ropiness, sourness, bitterness, and loss of colour. Accidental disorders are principally the results of frost, contact with the atmosphere, or taints derived from the cask, mouldiness, and bad eggs. The means employed to correct these disorders have to be modified according to the age of the wine, and to the nature and development of the alteration.

When a wine becomes ropy, it loses its fluidity and becomes oily. White wines are most subject to this disorder, and especially those which have not been allowed to complete their fermentation. It occurs chiefly after a rainy season, when the wine contains but little tartar and tannin. It rarely needs special treatment, as the wine usually recovers in the course of time; if it does not, a good cure is to add 30 grm. of pure tannin dissolved in half a litre of alcohol at 85°, and to whip the mixture well. Sourness is the most common disorder of all wines; it occurs chiefly in wines fermented in the presence of air. To avoid it, the casks destined to receive wine should always be sulphured, as has been stated already; great care must also be taken to allow as little contact with air as possible, both during fermentation of the must and the several racking operations. It is almost impossible to permanently restore a wine which has advanced far in this malady, since it almost invariably reappears after a length of time, however much care be taken to avoid it. The best way out of the difficulty is either to mix it with a sweet wine for immediate consumption or to dispose of it to the vinegar manufacturers.

Bitterness is a common disorder of aged wines and especially of Burgundy; it is always preceded by an alteration of colour. It may be remedied by adding to each cask affected, 135 grm. of tartaric acid, or more, according to the degree of bitterness, and from 10 to 15 grm. of tannin. This treatment generally arrests the progress of the malady, and if after eight or ten days it be drawn off into a sulphured cask, clarified, and treated with 200 grm. of well-washed vegetable black, it will probably be restored to its original condition.

One of the principal accidental alterations of wine is the effect of heat. Too high a temperature in the cellar is likely to excite active fermentation in the casks, which frequently results in the bursting of the latter and the entire loss of the wine. To avoid this, a quantity must be drawn from each cask, and air freely admitted, in order to check the process. Sometimes ice is introduced into the casks, or a quantity of fresh cold water for the same purpose. The most effectual remedy, however, is to submit the wine to two consecutive rackings and clarifications in a well sulphured cask, with the addition, before each racking, of from 400 to 500 grm. of powdered wood charcoal. When, in very cold weather, a portion of the wine has become frozen, it is best to draw off the liquid portion, since that which is solidified is nothing but water and may be removed without injury, the wine being rather strengthened and improved thereby. If the wine be allowed to melt again, the colour will be seriously impaired. The casks into which it is drawn must be well sulphured, and a little tartaric acid may be introduced with advantage, in order to assist in restoring the natural colour.

Taints arising from mouldiness are due to the condition of the casks when filled. Wines tainted from this cause, or from the use of unsound eggs in the clarification, must never be mixed with other wines, or they will infallibly impart their disagreeable taste to the whole mixture. When so tainted, the wine should be racked off, and pieces of well-burnt wood charcoal introduced into the casks to purify it. It may then be racked again on the following day, with the addition of 500 grm. of good oil, well whipped in. It will not be fit to mix away with other wines until it has stood in the cask at least a week or ten days.

Wines which have been affected with any of the disorders mentioned above, and successfully treated, should be at once disposed of for immediate consumption, since the affection is liable to return, after a lapse of time, with renewed energy. Ropiness is the only disorder which it is possible to effectually and permanently cure.

Bottling.—The secret of bottling wine with success consists in the exercise of much care and cleanliness. The bottles should be sound, clean, and dry, and free from the least trace of mustiness. Experience proves that wines bottled in fine, dry weather preserve their clearness and liquidity much better than those bottled in damp weather, or in a southerly wind. The wine should be clear and brilliant, or it must be carefully fined and clarified before being finally bottled.

Indeed, it is well to submit it invariably to this process previously. Care must be taken to avoid shaking the cask, and so distributing the sediment during the operation. The remaining portion, which cannot be drawn off clear, should be strained through the "wine-bag" and then bottled as inferior wine. The corks should be of the best quality, and immediately before being placed in the bottles should be compressed by means of a cork-squeezer. They should also be coated with a wax, when inserted, in order to preserve the mouth of the bottle from moisture, insects, &c. A good recipe for such wax is to mix and melt together the following substances:—

Resinous pitch	1 kilo.	Tallow	100 grm.
Burgundy "	500 grm.	Prussian red	125 "

The quantity so made is sufficient to wax 300 bottles. In performing the operation, in order to avoid bursting the bottles, the mixture must be kept melted at a heat below its boiling point, and the necks of the bottles must be perfectly dry.

When the process is finished, the bottles should be stored in a cool cellar, and on no account placed in an upright position, or in damp straw, but on their sides, in sweet, dry sand or sawdust.

To give a wine sparkling properties, a few grains of white lump-sugar or of sugar candy may be introduced in the bottles before finally stoppering. Champagne is invariably treated in this way in France. The sugar undergoes gradual fermentation during the sojourn of the wine in the bottle, and a quantity of carbonic acid gas is thus formed and held in solution until the bottle is opened, thus affording to it the agreeable briskness and creaminess, which are so much prized in sparkling wines.

Wine-production.—Among the wine-producing countries of the whole world, France occupies the first place both for quantity and quality. In the year 1788, the total amount of space covered by the vine in that country was about 3,365,000 acres; in 1829, it was estimated at 3,975,000 acres; in 1849, at 5,482,000 acres; in 1859, at 5,875,000 acres; and in 1869, at 5,975,000 acres. At the present time, notwithstanding the loss of Alsace and Lorraine, the area covered by vineyards in France may be considered, in round numbers, 6,500,000 acres. These figures serve to show to what an enormous extent the cultivation of the grape has increased during the last century.

The departments in the south-east of France are admirably situate, as regards climate and soil, for the production of good wine; the produce of this region might be made equal in every respect, if not superior, to the wines of Beaujolais, Medoc, Hermitage, and Tokay. Unfortunately, however, by much the larger portion of it is rendered inferior by adulteration and mixing. The principal wines of some of these departments are the following:—*Hérault*—(red wines), Chuselan, Tavel, Saint-Geniès, Lirac, Ledelon, Saint-Laurent-des-Arbres, Cante-Perdrix; (white wines), Frontignan, Lunel, Marseillan, Pommerols, Maraussan. *Pyrénées Orientales*—(red wines), Bagnols, Coperons, Collioure, Torsenilla, Terrats; (white wines), Rivesaltes. *Basses Pyrénées*—(both red and white), Jurançon, Gan. *Vaucluse*—(red wines), Côteau-Brûlé, Clos de la Berthe, Clos de Saint Patrice. *Andes*—(both red and white), Limoux. *Alpes-Maritimes*—Gaude, Cagnes, Saint-Laurent-du-Var, Saint-Paul, Bellet. *Basses-Alpes*—Mées, Manosques, Valensalles.

The south-western district produces on an average 12,331,000 hectols of wine annually, and worth at the very least 406 millions of francs. The principal wines are:—*Gironde*—(red wines), Clos de Lafitte, Clos de Latour, Clos de Château-Margaux, Clos de Hautbrion, Clos de Rosan, Clos de Gorse, Clos de Léoville, Clos de Larose, Clos de Brane-Mouton, Clos Pichon-Longueville, Clos Calon, Pauillac, Pessac, Sainte-Estèphe, Saint-Julien, Castelnau de Médoc, Cantenac, Talence, Côtes de Canon; (white wines), Saint-Bris, Carbonieux, Pontac, Sauternes, Barsac, Preignac, Beaumes, Langon, Cérons, Pujols, Hats, Landiras, Virlade, Sainte-Croix-du-Mont, Loupiac. *Landes*—(red wines), Cap-Breton, Soustons, Messange, Vieux-Boûcaud. *Lot-et-Garonne*—(white wines), Clairac, Buzet. *Dordogne*—(red wines), La Terrasse, Péchermont, Des Farcies, Campréal, Sainte-Fois-des-Vigues; (white wines), Montbassillac, Saint-Nessans, Sancé.

In the eastern district the chief wine-growing departments are the *Jura*, which produces the following white wines:—Arbois, Château-Châlon, Pupillin, L'Etoile, Quintigny; and the *Drome*—(red wines), Côte-de-l'Hermitage, Croses, Merceurol, Gervant; (white wines), Côte-de-l'Hermitage, Merceurol, Dic, Vin de paille de l'Hermitage.

In the north-eastern district, the chief departments are:—*Marne*—(red wines), Verzy, Versenay, Mailly, Saint-Basle, Bousy, Clos Saint-Thierry; (white wines), Le Closet, Sillery, Aï, Mareuil, Hautvillers, Pierry, Dissy, Cramant, Avize, Oger, Le Mesnil, Epernay, Taizy, Ludes, Chigny. *Saône-et-Loire*—(red wines), Moulin-à-Vent, Thorins, Chenas, Fleury, Romanèche, La Chapelle Guinchet, Mercurey, Giary; (white wines), Pouilly, Fuissey, Solutré, Chaintré.

In the central and northern districts are:—*Côte-d'Or*—(red wines), La Romaneé-Conti, Chambertin, La Pierrière, Le Richebourg, Musigny, Clos Vougeot, La Romanée-Saint-Vivant, La Tache, Le Clos Saint-Georges, Le Clos Premeau, Le Clos du Tart, Les Porets, La Matroie, Les Bonnes-Mares, Clos de la Roche, Clos de Bèze, Clos de Saint-Jacques, Clos de Mazy, Clos de Versolles, Clos de Marjot, Clos de Saint-Jean, Vols, Nuits, Chambolle, Volnay, Pomard, Beaune, Morey, Savigny, Meursault, Gevrey, Chassagne, Alx, Blagny, Santenay, Chenôve. *Yonne*—(red wines), Côtes des Olivettes, Côtes de Pytois, Côtes de Perrière, Côtes des Préaux, Côtes de la Châinette, Côtes de Migraine, Côtes de Clairion, Côtes de Boivins, Quétard, Pied de Rat, Chopette, Judas, Rosoir, Irancy, Coulanges; (white wines), Vaumorillon, Les Griseées, Le Clos, Valmur, Grenouille, Bouguerau, Mont-de-Milieu, Chablis. *Aube*—(red wines), Les Riceys, Balnot-sur-Laigne, Avirey-Lingey, Bagneux-la-Fosse.

The culture of the grape in Algeria has developed slowly during the last twenty years, and, at the present time, several excellent wines are made in that country, the soil and climate of which are particularly favourable. Some of these wines were shown in the Paris Exhibition of 1878. The vineyards of Oran, Mascara, and Tlemcen furnish fine red wines; those of Bône and Douéra excellent dry white wines.

Austria produces annually, on an average, 3,242,146 hectols. of wine. The Austrian territory which produces the largest quantity is Lower Austria and Dalmatia. The Tyrol, Styria, Austro-Illyria, Carniola, and Moravia come next. The northern provinces also produce wine, but it is of an inferior kind. Austrian wines are both red and white, the latter being dry. Some localities produce liqueur wines, and sparkling wines are made at Vöslau, in Lower Austria and near Graz, in Styria. All these are made on thoroughly sound and good principles.

The production of wine in Hungary is estimated at 2,798,520 hectols. annually. The most celebrated Hungarian wines are Tokay, Szamorodni, Szalmabor, Ménes-Magyarat, Rust, Saint-George, Sopron, Sumlo; these are all fruity or liqueur wines. There are also many very highly esteemed dry wines, both red and white, made in Hungary and Transylvania; some of these are noted for their excellent bouquet. Hungarian wines are exported to Austria, Prussia, Poland, Russia, and England; a very small quantity only is sent to France. In the Exhibition of 1878, Hungary was represented by three hundred exhibitors, with more than 860 samples of choice wine: red, white, fruity, dry, and sparkling.

There is but little wine made in Switzerland, though there are a few vineyards which produce very superior wines. The red and white wines of Neufchâtel are much esteemed. In the canton of Vaud, there are three good brands, namely, those of Yvorn, Lavaux, and Lacote. The canton of Valais produces what are known as "Glacier" wines; and that of Zurich an excellent brand known as Neftenbach. Swiss wines are carefully prepared.

The soil and climate of Spain are in every respect admirably adapted for the cultivation of the grape. The wine produced by this country in the year 1878 amounted to 10,510,026 hectols., which, considering the extent of the country and its remarkable advantages, is not by any means a large quantity. Spain produces wines of many different varieties. The fruity wines of Spain have been noted for centuries for their exquisite qualities of perfume and flavour: the most celebrated are the wine of Xérès, or Sherry, Malaga, and Rota; the next in order are the wines of Montilla, Valdepenas, Cariñena, Peralta, and Sitges. Spain produces also some sparkling wines. Sherry, Malaga, and Montilla come chiefly from the province of Andalusia; the two Castiles furnish the wines of Toro, Rueda, Seca, Nava del Rey, Villarubia, Ocana, Yepes, Arganda, San Martin, and the celebrated Valdepenas. Saragossa, Catalonia, Aragon, and Navarre produce many esteemed red and white wines, of which the best known are those of El Campo and Cariñena. Finally, the provinces of Valencia, Murcia, Alicante, Caceres, and Badajoz furnish some very fine brands, amongst which may be mentioned those to which one of these provinces has given its name, the wines of Alicante. Spain was represented in the Exhibition of 1878 by 1536 exhibitors.

Portugal enjoys the same favourable conditions of soil and climate as Spain, and like the latter country is justly renowned for the quality of its wines. By extending the cultivation of the grape, however, Portugal might easily double its annual production, which during the years 1874, 1875, and 1876 inclusive, amounted only to about 4,000,000 hectols. The wine-growing districts of Portugal are the following:—Douro, Traz-os-Montes, Minho, Beira-Alta, Estremadura, Alemtejo, and Algarve. The average yield of the Douro is about 400,000 hectols., comprising the famous "Port," which is so largely consumed in England; and some other wines, as those of Muscat, Malvasia, Bastardo, &c. The second district, that of Traz-os-Montes, produces about the same quantity as the Douro; they are very light, dry, and aromatic. All the other districts produce more or less excellent wines.

The Portuguese island of Madeira has been celebrated for its wines for a very long period. Of the different varieties, the finest is that known as Malmsey, which is the produce of a particular vineyard; next in order come the wines of Tinta, Sercial, Bual, and Bastardo All Madeira wines increase considerably in quality and in strength by keeping. They are much esteemed in this country.

The situation of Italy is highly favourable to the cultivation of the grape and the production of good wines. The annual produce is about 27,000,000 hectols., but this quantity might be very considerably increased. In 1867, the produce of the whole of Italy was 28,879,908 hectols.; the average produce at the present time is rather less than this. The most celebrated Italian wines are those which are furnished by the vineyards in the neighbourhood of Vesuvius, one of which is the excellent liqueur wine called Lacrymæ-Christi. The wines of Piedmont, known as Barbera, Nebbiolo, Barolo, Gattinara, Malvasia d'Asti, &c., are also much esteemed. The Sicilian and Sardinian brands, however, constitute the most important produce of Italy. The former island is renowned for its Marsala, Malvasia, and Moscati, and for the wines called Etna-Madeira and Syracuse. There were 158 representatives of Italy at the Exhibition of 1878, and 417 samples were exhibited, each being accompanied by its analysis.

Greece has long been celebrated for the excellence of its wines. The dry wines of Corinth have special qualities of bouquet and aroma. Those of the island of Thyra are considered to be superior to all other Grecian brands; four-fifths of these are dry and acid, the remainder being very sweet red and white wines, known as Vino Santo. The island of Cyprus is celebrated for the liqueur wine to which it has given its name.

Australia is fast taking a prominent place among wine-producing countries. The soil and climate of many parts are well suited to viticulture. Some of the wines are richer and more alcoholic than those of Portugal; a few are of soft, luscious, delicate flavour, while others resemble the Sauternes.

BLACKING. (Fr., *Cirage;* Ger., *Wichse, Stiefelwichse.*)

Blacking is a pasty compound used for producing a polish on black leather surfaces, especially on the "uppers" and the edges of the soles and heels of boots and shoes. There are numerous methods of manufacturing this substance; but in nearly all, the base is a black colouring matter, usually animal charcoal, mixed with substances which acquire a gloss by friction, such as sugar and oil. The carbon employed should be in the form of a very deep, finely powdered black. Since it always contains carbonate and phosphate of lime, it is treated with a mineral acid in order to decompose these salts; a mixture of sulphuric and hydrochloric acids is frequently used, the salts produced being acid phosphate of lime, sulphate and chloride of lime. The sulphate of lime gives consistence to the pasty mass, and the two other salts being deliquescent help to keep the leather flexible. No more acid should be used than is sufficient to decompose these salts, or the leather will be destroyed. It is probably to prevent this that some makers add a small quantity of alkali to the blacking. Sometimes powdered gall-nuts, sulphate of iron, indigo, and Prussian blue are incorporated with the blacking in order to impart to it a good colour. Fatty or oily matters are also sometimes added in order to preserve the flexibility of the leather, and to neutralize any excess of acid which may remain. The consistence of different blackings varies widely; they may be classed either as liquid or as solid blacking.

The well-known liquid blacking of Day and Martin is composed in the following manner. Very finely ground animal charcoal, or bone-black, is mixed with sperm oil till the two are thoroughly commingled. Raw sugar or treacle, mixed with a small portion of vinegar, is then added to the mass. Next a small measure of dilute sulphuric acid is introduced, which; by converting into sulphate a large proportion of the lime contained in the animal charcoal, thickens the mixture into the required pasty consistence. When all effervescence has subsided, but while the compound is still warm, vinegar is poured in until the mass is sufficiently thinned; then it is ready to be bottled for the market.

The following are other ways of making liquid blacking:—

1. Animal charcoal, 5 oz.; treacle, 4 oz.; sweet oil, ¾ oz.; triturate until the oil is thoroughly incorporated, then stir in gradually ¼ pint each vinegar and beer lees.

2. Animal charcoal, 1 lb.; sperm oil, 2 oz.; beer and vinegar, each 1 pint, or sour beer, 1 quart.

3. Bryant and James's indiarubber blacking. Indiarubber in very fine shreds, 18 oz.; hot rapeseed oil, 9 lb. (1 gallon); animal charcoal in fine powder, 60 lb.; treacle 45 lb.; gum arabic, 1 lb., previously dissolved in vinegar, No. 24 strength, 20 gallons. The mixture is triturated in a colour-mill until perfectly smooth, then placed in a wooden vessel, and sulphuric acid added in small successive quantities amounting altogether to 12 lb. This is stirred for half an hour daily for fourteen days, then 3 lb. of finely ground gum arabic are added, and the stirring repeated for an additional fourteen days, when the blacking will be ready for use.

4. It has been proposed to treat the leaves and other portions of the mastic gum tree, *Pistacia lentiscus*, by decoction or distillation, principally to obtain from them a blacking which dries almost immediately after application, shines without the necessity of being brushed, and is much less liable to soil the clothes.

5. Acmé blacking. To rectified spirit, 1 gallon, is added blue aniline, 20·80 drachms, and Bismarck brown aniline, 31·20 drachms, the solution of the two last being effected by agitation within eight to twelve hours. After the solution is completed, the mass is allowed to settle, and the liquid portion is drawn off by spigots above the sediment, and filtered if necessary. The alcohol is placed in the apparatus first, then the colours, and the mixture agitated every hour for a space of ten to fifteen minutes. Of this liquid ¼ gallon is added to rectified spirit, 1 gallon, and in this are dissolved gum camphor, 11 oz.; Venice turpentine, 16 oz.; gum shellac, 36 oz. To benzine,

¼ gallon, add castor oil, 3⅕ fluid oz., and boiled linseed oil, 1⅗ fluid oz. The two solutions are then united by agitation, but should not be allowed to stand over two days in any vessel of iron or zinc, as in the presence of the gums the colours will be decomposed by contact with zinc in eight days, and with iron in eighteen to twenty-four days.

6. A quantity of ordinary starch is dissolved in hot water, and while still hot oil or wax is added, the mixture is stirred and allowed to cool. When cold a small quantity of iodine is added to give a bluish-black colour. To a gallon of this are added 8 oz. of a solution of perchloride or other per salt of iron, and a small quantity of gallic or tannic acid (or both), and sometimes about 2 drachms of oil of cloves with 8 oz. glycerine. The whole is thoroughly stirred.

Paste blackings are also made in a variety of ways, of which the following are the chief:—

1. Bryant and James's indiarubber blacking may be made in a solid form by reducing the proportion of vinegar from 20 gallons to 12. The compound then only requires stirring for about six or seven days in order to prepare it for use, and it may be liquefied by subsequent addition of vinegar.

2. Dr. Artus manufactures blacking from the following materials:—Lamp-black, 3 or 4 lb.; animal charcoal, ½ lb.; are well mixed with glycerine and treacle, 5 lb. Meanwhile guttapercha, 2½ oz., is cautiously fused in an iron or copper saucepan, and to it is added olive oil, 10 oz., with continual stirring, and afterwards stearine, 1 oz. The warm mass is added to the former mixture, and then a solution of gum senegal, 5 oz., in water, 1½ lb., and 1 drachm each of oil of rosemary and lavender may be added. For use it is diluted with three or four parts of water, and tends to keep the leather soft, and render it more durable.

3. All ordinary paste blackings require to be mixed with some liquid before application, causing considerable waste. It is claimed for the subjoined method of preparation, that by its means the blacking is rendered of such a condition that when merely dipped in water or other solvents the required quantity can be rubbed on to the article to be blacked without the cake crumbling or breaking up. The ingredients of the blacking are those in ordinary use, but it is brought to the required consistence by combination with Russian tallow, in the proportion of 3 per cent., and casting the mass into the desired forms. These may be cylindrical, &c., and may be enclosed in covers of cardboard, tinfoil, &c., in which the blacking can slide, so that when one end is pushed out for use, the remainder acts as a handle. The exposed end, when damped by immersion or otherwise, can be rubbed on the article without crumbling.

The ivory-black (animal charcoal) which has been used in the preparation of white paraffin, according to Letchford and Nation's patent, may be conveniently used for making blacking.

4. The addition of sulphuric acid to animal charcoal and sugar produces sulphate of lime and a soluble acid phosphate of lime, which make a tenacious paste. Thus: Animal charcoal, 8 parts; molasses, 4 parts; hydrochloric acid, 1 part; sulphuric acid, 2 parts. These are well mixed. A liquid blacking may be produced from this by the addition of the necessary proportion of water.

5. Fuller's earth, 8 oz.; treacle, 3 lb.; animal charcoal, 2 lb.; butter scrapings, 4 oz.; rapeseed oil, 4 oz.; strong gum water, ½ pint; powdered Prussian blue, ½ oz.; commercial sulphuric acid, 8 oz. If the blacking is required in a liquid form, add ½ gallon of vinegar.

6. To animal charcoal, 1 lb., add commercial sulphuric acid, 4 oz.; work them well together, and when the acid has done its duty upon the charcoal add fish or colza oil, 4 oz.; stir the mixture till the oil is thoroughly incorporated, then pour in gradually a strong solution of washing soda or other suitable antacid, and continue the stirring till ebullition ceases, or the acid is neutralized. Next add about 8 oz. treacle, and then pour in a solution of gelatine and glycerine, in quantity about 2 quarts if liquid blacking is required, but less will suffice to produce paste. The solution of glycerine and gelatine is made by dissolving the best size in hot water, in the proportion of 4 parts of water to 1 of size, and then adding to every quart of the liquid 1½ oz. of glycerine. The addition of the glycerine and gelatine preparation gives great brilliancy, depth of colour, and permanency to the blacking when applied to leather, and at the same time makes it damp-proof; besides which the antacid has the effect of neutralizing the sulphuric acid employed, and thus prevents the injurious action of that acid on the leather, as in the case of most ordinary blackings.

For application to dress boots the following composition is prepared:—Gum arabic, 8 oz.; molasses, 2 oz.; ink, ½ pint; vinegar, 2 oz.; spirit of wine, 2 oz. Dissolve the gum and molasses in the ink and vinegar, strain, and then add the spirit of wine.

Harness blacking is not made in the same way as boot blacking. The following are some of the methods of preparing the former kind:—

1. Glue or gelatine, 4 oz.; gum arabic, 3 oz.; water, ¾ pint. Dissolve by heat, and add of treacle, 7 oz.; finely powdered animal charcoal, 5 oz.; and then gently evaporate until the compound is of the proper consistence when cold, stirring all the time. It must be kept corked.

2. Mutton suet, 2 oz.; beeswax, 6 oz.; melt them, and add sugar candy, 6 oz.; soft soap, 2 oz.; lamp-black, 2½ oz.; finely powdered indigo, ½ oz. When thoroughly intermixed add oil of turpentine, ¼ pint.

3. Beeswax, 1 lb.; animal charcoal, ¼ lb.; Prussian blue, 1 oz., ground in linseed oil, 2 oz.; oil of turpentine, 3 oz.; copal varnish, 1 oz. Mix them well, and form the mass into cakes while it is still warm.

4. Add to No. 3, while still warm, soft soap, 4 oz.; oil of turpentine, 6 oz.; put into pots or tins while warm.

5. Isinglass, ¼ oz.; finely powdered indigo, ¼ oz.; soft soap, 4 oz.; glue, 5 oz.; logwood, 4 oz.; vinegar, 2 pints; ground animal charcoal, ½ oz.; beeswax, 1 oz. Infuse the logwood in the vinegar for some time with gentle heat, and when the colour is thoroughly extracted strain it, and add the other ingredients. Boil till the glue is dissolved, then store in stoneware or glass jars. Said to be very useful for army harness.

6. Melt 4 oz. mutton suet with 12 oz. beeswax, 12 oz. sugar candy, 4 oz. soft soap dissolved in water, and 2 oz. finely powdered indigo. When melted and well mixed, add ½ pint turpentine. Lay it on with a sponge, and polish with a brush. A good blacking for working harness, which should be cleaned and polished with it at least once a week.

7. Three sticks of black sealing wax dissolved in ½ pint of alcohol, and applied with a sponge; or lac dissolved in alcohol, and coloured with lamp black, answers the same purpose. This is intended for carriage harness; it is quick drying, and hard and liable to crack the leather, so should be applied as seldom as possible.

8. A good blacking consists of:—Hog's lard, 4 oz.; neat's-foot oil, 16 oz.; yellow wax, 4 oz.; animal charcoal, 20 oz.; brown sugar, 16 oz.; water, 16 oz. Heat the whole to boiling, then stir it until it becomes cool enough for handling, and roll it into balls about 2 in. in diameter.

9. Soften 2 lb. of glue in 1 pint of water; dissolve 2 lb. soap (Castile is the best, but dearest) in 1 pint of warm water: after the glue has become thoroughly soaked, cook it in a gluepot, and then turn it into a larger pot; place this over a strong fire, and pour in the soap water, slowly stirring till all is well mixed; then add ½ lb. of yellow wax cut into slices; let the mass boil till the wax melts, then add ½ pint of neat's-foot oil and sufficient lamp black to impart a colour; let it boil a few minutes and it will be fit for use.

10. When harness has become soiled it can be restored by the use of the following French blacking:—Stearine, 4½ lb.; turpentine, 6¾ lb.; animal charcoal 3 oz. The stearine is first beaten into thin sheets with a mallet, then mixed with the turpentine, and heated in a water bath, during which time it must be stirred continually. The colouring matter is added when the mass has become thoroughly heated. It is thrown into another pot, and stirred until cool and thick; if not stirred it will crystallize, and the parts will separate. When used it will require warming; it should be rubbed on the leather with a cloth, using but very little at a time, and making a very thin coat. When partially dry it is rubbed with a silk cloth, and will then give a polish equal to that of newly varnished leather, without injuring it in any way.

Liquid blacking is usually filled into small bottles of very coarse stoneware, closed by corks. Paste blacking is formed into cakes, which are secured in waterproofed paper, generally prepared by steeping the paper first in boiled linseed oil, and pressing, then hanging up to dry for from eighteen hours to a week. The following is an improved way of making a waterproof paper of superior quality, thinner, but equally strong, and capable of drying in less than a minute. The paper is steeped in a melted or fluid composition, consisting of paraffin, wax, or hard tallow, in combination with crude or other turpentine, in the proportions of two to one. It is then immediately pressed, and the surplus composition is removed by passing it between rollers heated by steam. By using paper in endless sheets, the whole process might be made continuous, the paper being finished for use or storing by the time it leaves the rollers.

It is obvious that the manufacture of blacking requires neither skill nor capital. It may be conducted on almost any scale according to the demand. The chief trade is, at the present time, in the hands of one or two very large firms; but smaller makers are scattered throughout the country. Though the consumption of the article is very considerable, its price is so low that it represents a small money value. It is neither exported nor imported in any appreciable quantity.

BLACKS. Several manufactured carbonaceous substances are known in commerce under the generic name of "Blacks." The most important of these are animal-black, bone-black, Frankfort-black, ivory-black, and lamp-black. They are usually obtained by carbonizing organic matter, particularly bones, in closed vessels or crucibles, or by collecting the soot formed by the combustion of oily, resinous, and bituminous substances. Other blacks than those enumerated are manufactured, but only on so small a scale as to be of no commercial importance.

Animal-black. (Fr., *Noir animal;* Ger., *Knochenschwarz.*)

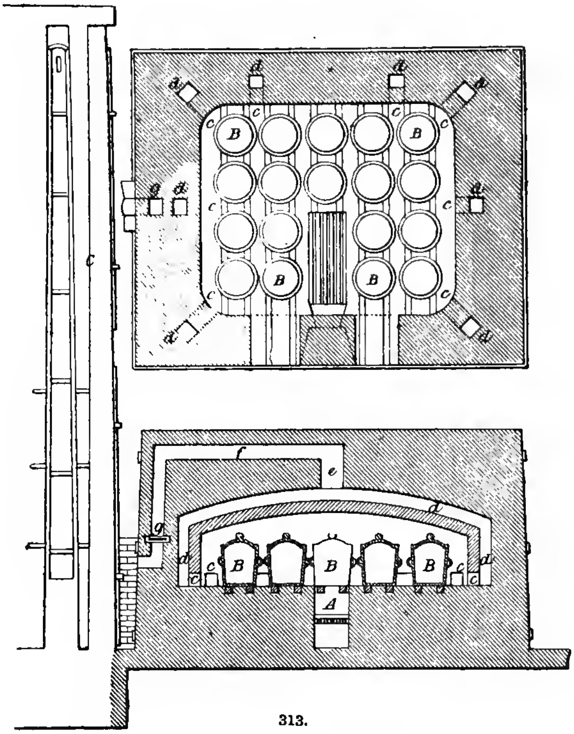
This substance is almost identical with bone-black, but is generally in a more finely divided state. Any animal refuse matter may be used in its preparation, such as albumen, gelatine, horn shavings, &c. These are subjected to dry distillation in an earthenware retort. An inflammable gas is given off, together with much oily matter, ammonia, and water, while a black carbonaceous mass is left behind. This is washed with water and powdered in a mill, the product being animal-black. It is largely used in the manufacture of printing ink (see Ink), and of blacking (see Blacking).

Bone-black. (Fr., *Noir d'os*; Ger., *Knochenschwarz.*)

When bones are heated in a retort or crucible, the organic constituents are decomposed and carbonized. A mixture of combustible gases is given off, which do not condense on cooling; and others, which condense in the form of a heavy oil, called bone-oil, and also much water containing tarry water and ammoniacal salts in solution. The residue in the retort or crucible consists of finely divided carbon in intimate mixture with the inorganic constituents of the bones: this mixture constitutes ordinary bone-black, or animal charcoal, as it is sometimes called. The inorganic portion may, if required, be removed by washing the residue in dilute hydrochloric acid.

The process, as worked on the large scale, is carried on in different ways, according as it is desired to collect the volatile condensable portion of the distillate, or to allow it to escape. In the latter case, when it is required to obtain only bone-black, the apparatus employed is of a very simple nature, and the amount of fuel needed is comparatively small. The carbonization is effected in fire-clay crucibles, 16 in. high and 12 in. in diameter. These are to be preferred to crucibles made of iron, which were much used at one time, since they do not lose their round form when subjected to a high temperature; in consequence of this, they fit more closely together in the furnace, less air can penetrate, and therefore less of the charcoal is consumed by oxidation. The furnace is an ordinary flat hearth, having a superficial area of about 40 square yards, and is covered in with a flat arch, all of brickwork. The fireplace is situate in the middle of the hearth; the crucibles are introduced through doors in the front, which are bricked up when the furnace is filled; each furnace holds eighteen crucibles. The crucibles, filled with the coarsely broken bones, are covered with a lid luted on with clay. To economize fuel, the furnaces should be in a row, and placed back to back.

312.



313.

The arrangement of the furnace and pots is shown in Figs. 312 and 313. A is the fireplace; B, the crucibles, eighteen in number, spread over the floor of the furnace in a single layer; *c*, *d*, *e*, and *f* are the flues for conducting away the heated gases arising from the calcination of the bones, as well as the waste heat itself; the last portion of the flue is fitted with a damper *g*.

The furnaces are intended to be built in fours, back to back, the waste heat serving in a great measure to conduct the operation of the revivifying apparatus placed in the centre and marked C.

When the furnace is filled and the doors are bricked up, the heat is slowly raised to redness, at which point it is kept for six or eight hours. The combustible gases are evolved and consumed in the furnace as soon as the bones begin to decompose, and by this means so much heat is produced that only a small quantity of fuel is needed to maintain the required temperature. When the carbonization is complete, the doors are taken down and the crucibles removed to cool, their place being immediately filled with fresh ones. The heat must be kept as uniform as possible throughout the process: if it be not sufficiently high, the bone-black will contain a portion of undecomposed organic matter, which renders it quite unfit for use; if, on the other hand, the temperature be raised too high, the bone-black will become dense and compact, whereby its efficacy as a decolorizer is much reduced. When the charcoal in the crucible has become perfectly cool, it is removed and crushed. When required for decolorizing or deodorizing purposes, it is only roughly broken up into small lumps, in which form it is most readily applicable. The crushing is effected by means of two grooved cylinders, consisting of toothed discs, alternately 10 and 12 in. in diameter. These are so placed that the 10-in. discs of one cylinder are opposite the 12-in. discs of the other, and thus, in revolving, the carbonized bones are crushed to fragments between them, but are not reduced to powder. They are passed successively through six of these mills, the cylinders of each couple being nearer to each other than the last. Finally, the crushed bones are carefully sieved; the powder is placed apart from the lumps, again passed through finer sieves, and sorted out into different sizes.

A furnace such as that described above will carbonize four charges of bones in one day, each charge being more than half a ton in weight. With careful work, the bones will yield 60 per cent. of bone-black, or more than one ton daily.

If it be required to condense the volatile gaseous products of the carbonization, this process is conducted in retorts similar to those used in the manufacture of acetic acid from wood; these are so arranged that the whole of the gaseous products are condensed and collected. The aqueous portion of the distillate is usually evaporated down to obtain salts of ammonia; the uncondensable gases may be employed for illuminating purposes. The manufacture of bone-black is usually carried on in the neighbourhood of large towns, where a good supply of bones may be readily obtained.

The principal use of bone-black, or animal charcoal, is to decolorize various solutions, particularly syrups; inferior qualities are used in the manufacture of blacking. The decolorizing properties of this substance are extensively made use of by sugar refiners in the purification of their different syrups (see Sugar). When it has become unfit for the clarification of the sugar liquors, the charcoal is purified for re-use by processes which will be described in the article on Sugar.

Ordinary bone-black has about the following composition: Phosphate and carbonate of lime, and sulphide or oxide of iron, 88 parts; charcoal, containing a small quantity of nitrogenous matter, 10 parts; silicated carbide of iron, 2 parts. The decolorizing properties of bone-black are due solely to the presence of the charcoal.

When intended for use as a deodorizer or decolorizer, bone-black should be kept carefully excluded from the air, for by exposure it loses this power to a great extent, and becomes almost inert. That which has been freshly burnt is therefore best for these purposes.

The cost of production of bone-black may be calculated as follows:—

	£	s.	d.		£	s.	d.
4 tons fat bones at 4*s.* per cwt.	16	0	0	Breaking up the bones	1	5	4
27½ bushels coal	1	3	9	Rent and taxes	0	8	0
2 firemen	0	4	9	Interest, repairs, and wear and tear	0	7	2
4 workmen	0	8	0	Contingencies and transports	0	2	4
1 carman	0	2	4				
2 horses	0	5	7		£20	7	3

Produce:—

	£	s.	d.	£	s.	d.
Black, 60 per cent., say 38 cwt. in grains, at 14*s.* 3*d.*	13	10	9			
10 cwt. fine, at 5*s.* 6*d.*	1	7	8			
Fat, 6 per cent., say 5 cwt., at 31*s.* 8*d.*	7	18	4			
	£22	16	9	22	16	9
Profit				£2	9	6

Frankfort-black. (Fr., *Noir de Francfort;* Ger., *Frankfurter Schwarz.*)

Frankfort-black is a black powder obtained from dried vine-twigs, carbonized to a full black and then ground very fine. On a large scale, it is prepared from a mixture of vine-twigs, wine-lees, peach stones, bone shavings, and ivory refuse. It varies in shade according as the animal or vegetable charcoal is in excess; when the latter predominates, the powder is of a bluish colour; but when there is an excess of animal charcoal, it has a brownish tinge. It is customary to wash the powder well when first made, in order to remove any soluble inorganic impurities. The finest Frankfort-black is probably the soot obtained from the combustion of the materials mentioned above. It makes an excellent pigment, and is extensively used by copperplate engravers in the preparation of their ink.

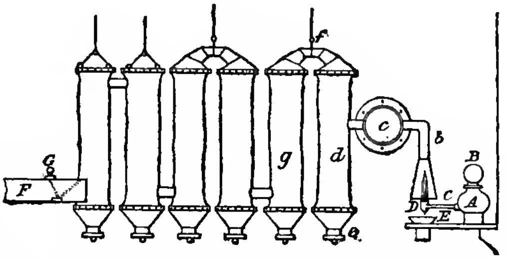
Ivory-black. (Fr., *Noir d'Ivoire;* Ger., *Elfenbein-Schwarz.*)

Ivory-black is a beautiful black pigment prepared by carbonizing waste fragments and turnings of ivory. These are exposed to a red heat for some hours in crucibles, great care being taken to avoid overheating or burning. When quite cold, the crucibles are opened, and the contents pulverized, the richest coloured fragments being kept apart for the best quality. The powder is then levigated on a porphyry slab, washed well with hot water on a filter, and dried in an oven. The product is of a very beautiful velvety black colour, superior even to that obtained from peach kernels, and quite free from the reddish tinge which so often characterizes bone-black. Ivory-black, like Frankfort-black, is employed by copperplate printers in the preparation of their ink. Mixed with white lead, it affords a rich pearl-grey pigment.

Lamp-black. (Fr., *Noir de Fumée;* Ger., *Kienruss.*)

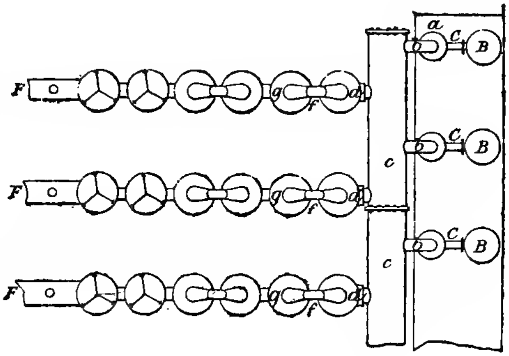
Lamp-black is an exceedingly light, dull-black powder, formed by the imperfect combustion of oils, fats, resins, &c. It may be prepared on a small scale by suspending a small tin-plate funnel over the flame of a lamp fed with oil, tallow, or crude naphtha, the wick being so arranged that it shall burn with a large and smoky flame. Dense masses of this light carbonaceous matter gradually collect in the funnel, and may be removed from time to time. The funnel should be furnished with a metal tube to convey the gases away from the room, but no solder must be used in making the connections.

314.



An especially fine quality of lamp-black is obtained from bone-oil, deprived of the ammonia with which it is always contaminated. It is manufactured on a commercial scale by means of the apparatus shown in Figs. 314 and 315. The oil is contained in the lamp A and kept at a constant level by means of the globular vessel B, which is also filled with oil and inverted over A. The oil flows from the lamp into the tube C, which is bent upwards at the further extremity on a level with the oil in the lamp. A cotton wick is supplied to the bent end of the tube, as well as a little spout D, for conducting away any oil that may overflow into the receptacle E placed beneath. A conical hood *a* surrounds the flame of the lamp and terminates in a tube *b*, through which are conveyed the sooty products of the combustion of the oil into the wide lateral tube *c*, arranged to accommodate the smoke from about a dozen such lamps placed at intervals of about 6 ft., as indicated in the figures. The effect of this wide tube *c* is not only to cool the smoke but also to collect the water and other liquids condensed. The smoke and vapours pass hence into *d*, the first of a series of sacks made of closely woven linen, about 10 or 12 ft. long and 3 ft. in diameter, closed at the bottom with a trap or slide *e*, and formed at the upper and lower ends of sheet-copper tubing made funnel-shaped. The upper one of these is prolonged into an additional pipe *f*, by means of which the smoke arrives at the second sack *g* in the series, thence finding its way to the third, and so on till the last sack of the row is reached. In connection with the last sack of each row is placed a horizontal flue F, in which are arranged frames covered with wire gauze and mounted on hinges. Their purpose is to retain the small remaining portions of lamp-black passing out with the smoke from the sacks. The meshes of the gauze are constantly getting filled up with soot, which

315.



necessitates a periodical checking of the draught for its removal. This is done by means of the rod G, which, when raised and allowed to fall suddenly, jerks the accumulated mass off the gauze. The current of air passing through the entire apparatus can be regulated by a damper placed at the entrance to the chimney in which the flue F embouches. At regular intervals, the mouthpieces in the lower ends of the sacks are removed, and their contents are shaken out separately and collected according to their various qualities. That gathered from the first sack in each row should always be kept apart from the remainder, as it is much contaminated by the presence of resinous and tarry matters.

A process has been devised by Messrs. Martin and Grafton for the preparation of lamp-black from coal-tar, which affords a very good product. The coal-tar is first stirred up energetically with lime-water in any convenient vessel, after which the mixture is allowed to stand until the coal-tar has subsided to the bottom, when the lime-water is drawn off. The tar is then well washed by decantation with hot water, and rectified in the ordinary naphtha still. Afterwards it is run into a long iron cylinder, which is placed over a furnace, and supplied with numerous large burners. Each burner has a metal funnel placed immediately above it, connected with a cast-iron pipe, into which all the fumes from each burner are conducted. The naphtha in the cylinder is heated almost to the boiling point by the furnace beneath. A series of smaller pipes lead away the fumes from the main pipe into a row of chambers, and thence into a series of large canvas bags, placed side by side, and connected alternately at top and bottom. The bags vary in number from fifty to eighty, the last one being left open to allow the smoke to escape, after traversing some 400 yards since leaving the burners. The best quality of lamp-black is found in the last bags, that near the furnace being much coarser and less pure. The bags are emptied whenever they contain a sufficient quantity.

The process employed in Germany for the manufacture of lamp-black is to conduct the products of the combustion of any resinous matter in a furnace into a long flue, at the end of which is placed a loose hood, made of some woollen material, and suspended by a rope and pulley. The lamp-black collects in this hood, and when a sufficient quantity has accumulated is shaken down and removed. In this manner about 6 cwt. of lamp-black may be collected in twenty-four hours.

In England, an inferior variety is sometimes obtained from the flues of coke-ovens. That known as *Russian Lamp-black* is made by burning chips of resinous deal or pine wood, and collecting the soot formed; but it is objectionable, owing to its liability to take fire spontaneously when left for a long time moistened with oil.

The lamp-black made in these ways is generally purified by calcination, in order to remove the empyreumatic oils which it invariably contains. This is effected in close vessels, and the product is called *burnt* lamp-black, and is especially useful as a water-colour. The particular virtue of lamp-black as a pigment lies in its state of extremely fine division, which could not possibly be attained by artificial means; this quality renders it invaluable as the basis of black pigments, all of which contain it in a greater or less quantity. Indian ink and printers' ink are also composed principally of this substance.

The transport of lamp-black is effected in barrels or bags; when in the latter, these should be previously soaked in water containing some clay in suspension, which stops up the pores of the sacking, and thereby prevents loss.

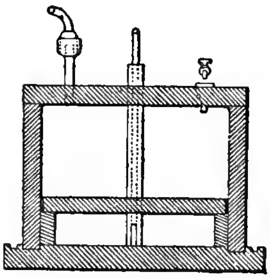
BLEACHING POWDER. (Fr., *Chlorure;* Ger., *Chlorkalk, Bleichpulver.*)—Synonym, chloride of lime; formula, $CaCl_2O_2 + CaCl_2$.

The exact nature of bleaching powder remains still a matter of doubt. It is sometimes regarded as a simple compound of chlorine with lime—whence its name—sometimes as an oxychloride of calcium, sometimes as a mechanical mixture, or as an absolute compound of oxychloride and hypochlorite of lime. For the various discussions upon this part of the subject, the scientific reader is referred to the writings of Millon, Fresenius, Kolb, Crace-Calvert, Schorlemmer, and a host of others.

Bleaching powder, as ordinarily manufactured, is a dull white powdery substance, often agglomerated into small round lumps readily friable between the fingers. It always contains a certain amount of free chlorine, which imparts a strong pungent odour, rather agreeable than otherwise, unless too powerful. A small percentage of moisture usually present keeps it feathery, and it readily absorbs a further amount of water when exposed to the influence of the atmosphere, finally turning into a dirty white paste. Under the influence of strong light—especially sunshine—decomposition takes place, with the formation of chlorate of calcium. The bleaching property of the compound is owing to the presence of chlorine, the most powerful bleaching agent known. The available amount of this gas contained in a sample of ordinary bleaching powder is about 36 per cent. Beyond this about 4 per cent. goes to form chloride and chlorate of calcium. Of the 36 per cent., probably 4 per cent. as a rule is free and disengaged during the various manipulations preceding the actual bleaching process. For this reason, it used to be customary to sell a 32 per cent. bleaching powder, and probably an article of this constitution would be as good for the consumer, and in every way better for the manufacturer, than the bleaching powder usually put upon the market. In the endeavour to secure a high strength, both loss and damage is caused, by the disengagement of free chlorine gas and the prolonged process of manufacture.

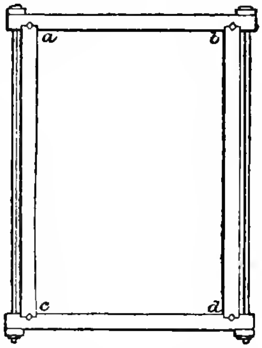
The art of bleaching is of very great antiquity, and until a comparatively recent date consisted of alternate treatments of the substance operated upon by various alkaline washings and exposure to the action of the sun and air. In this way, the oxygen of the air formed some combination with the colouring matter which could be extracted by water or an alkaline liquor. The use of chlorine was first suggested by Berthollet in 1785, and within a few years afterwards the process was worked upon a considerable scale in Scotland. The gas was generated in a glass or wooden apparatus by heating a mixture of salt, peroxide of manganese, and sulphuric acid, and passed into water. When a saturated solution was obtained, it was removed, and the goods bleached by being immersed in it and thoroughly boiled. The glass or wooden vessels speedily gave way to an apparatus constructed of strong sheet lead, encased in a metal jacket, with an agitator to effect a perfect mixture of the ingredients. Heat was applied by an underneath fire, or by a steam pipe introduced between the lead and the outer shell. This improved apparatus was used extensively for something like fifty years, an ordinary charge consisting of 120 parts of manganese to 150 of salt, and 185 of strong sulphuric acid. The chlorine gas was taken off by lutes and pipes in a manner very similar to that to be presently described.

316.



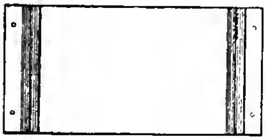
The addition of an alkali to the water—at first caustic potash—was made about 1792, and, in 1798, Charles Tennant, of Glasgow, patented the use of *lime*, to be employed as lime water. In this way, the article known as "bleaching liquor," still manufactured occasionally for paper-makers, was obtained. In 1799. the absorption of chlorine by *dry* lime was patented, and the commercial article now known as "bleaching powder" introduced.

317.



The process of manufacture, as at present carried on, is as follows:—Instead of mixing together the salt, manganese, and sulphuric acid, the liquid hydrochloric acid obtained by condensing the gases from the sulphate of soda process, in the manner fully set forth in a previous article (see Soda), is employed, and run upon a known weight of peroxide of manganese contained in a "still." The best form of still is shown in Figs. 316, 317, and 318, and will be readily understood. The bottom consists of one slab of stone (good free-stone, or, better still, "Yorkshire flag"), not less than 10 in. in thickness. Into it are set sides of similar material, about 6 in. thick. The grooves into which the sides are let are about 1 in. in depth, and a very little wider than the side, so as to allow of "stemming." At the four corners, *a*, *b*, *c*, *d*, Fig. 317, a diamond is cut and thoroughly stemmed with dry fireclay, fireclay just moistened with tar and heated, red lead and glass, or any other suitable compound. Sometimes the indiarubber rods described when speaking of hydrochloric acid condensers are used, but this construction is apt to be faulty. The whole still is securely bound together with 1 in. iron rods, which pass through the ends, and are screwed up against upright pieces of wood, Fig. 317. The cover of the still is formed of three stones, bedded in a mixture of tar and china clay. In it are various openings—a square manhole in the centre, through which the charge of manganese is also introduced, and round holes, to admit of steam column, acid, gas, and "dip" lutes. A false bottom—technically "tables"—is formed about 9 in. from the bottom stone, with stout slabs, about 12 in. wide and 5 in. thick, roughly dressed and resting upon stone or brick supports, running along the sides of the still, Fig. 316. Steam is introduced through a small iron pipe, protected from the action of the acid and gas by the stoneware column shown in Figs. 319, 320, and 321. This is set at the back of the still, and has an opening only underneath the tables. The hydrochloric acid is run in through the lute shown in Fig. 322, let into the cover near the steam column, while the "dip lute," shown in Fig. 323, likewise set in the cover, allows the workman from time to time to gauge the amount of acid he is running in. The stills are built in a range, and incline about 4 in. towards a gutter

318.

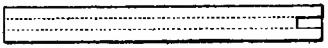


along the front, which conveys away the waste liquors, &c. A good size of still is 9 ft. by 6 ft. by 4 ft. 6 in. deep, the cost, complete, being about 160*l.*

A charge of manganese, about 6 cwt., is thrown into the still, and roughly spread upon the tables. The door is then replaced, and made tight with any convenient method of plastering, and the still is connected by the gas lute with the bleaching-powder chamber. Hydrochloric acid, of not less than 18° Twaddell, is then run in from the stock cistern, until the manganese is just covered. After being allowed to stand for a short time, good "strong" steam is introduced, at a boiler pressure of 45 lb., and kept at full blast for a quarter of an hour. A rapid disengagement of chlorine takes place, the gas passing away to the chambers, and a mixture of free hydrochloric acid, chloride of iron, and chloride of manganese is left in the still. Successive blasts of steam are pressed into this mixture from time to time until the operation is complete. The "bend" of the gas lute is then removed, and the contents of the still raked out, through a small opening in front, into the gutter. The reaction occurring is represented by the following equation:—

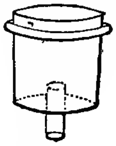
320.

319.

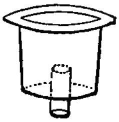


321.

322.



323.



$$MnO_2 + 4HCl = MnCl_2 + 2H_2O + Cl_2.$$

For this first part of the process—the generation of chlorine—various manganese ores are used. The best comes from Devonshire. It is soft, and therefore easily dissolved by the hydrochloric acid, and contains up to 72 per cent. of binoxide. The Spanish ores are of like strength, and sometimes as soft, but are more irregular in quality than the Devonshire. The German ores, as a rule, are weaker and smaller, 60 to 62 per cent., and often in a very finely divided state. Up to about 1857, the German qualities were chiefly used. The Spanish has now taken the lead. The following table gives the approximate composition of the various ores referred to:—

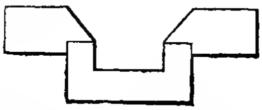
	Devonshire.	Spanish	German lumpy.
Manganese peroxide	70·00	72·00	69·00
Iron oxide	11·00	15·00	14·00
Carbonate of lime	0·25	0·25	1·50
Silica	15·00	10·25	13·00
Alumina	1·50	·50	1·50
Moisture	2·00	2·00	1·25
	99·75	100·00	100·25

Other descriptions occasionally used are imported from Virginia, California, and New Zealand. The Virginian is very irregular in quality. The best descriptions are very good, soft, and satisfactory in the working; the majority of the cargoes brought over, however, are hard, and contain a good deal of carbonate of lime. Hence they not only dissolve slowly, but waste hydrochloric acid. The Californian, as a rule, is very hard. The New Zealand is of recent introduction, and is well reported of. All these varieties come up to 70 per cent.—usually over.

The price of a good 70 per cent. ore is, at the present time, about 85*s.* per ton. Six years ago, it was 140*s.*, but the introduction of Weldon's recovery process has largely decreased the consumption.

The hydrochloric acid should not be too weak, in order that the manganese may be more thoroughly decomposed, and the still liquors kept as strong as possible. For this latter reason, the steam should also be as free from water as possible. With all precautions, a large loss results from undecomposed manganese. To make it as small as possible, constant supervision should be kept over the working of the stills. They should never be run off until perfectly "spent," and should be kept carefully clean by a thorough raking out before a fresh charge of manganese is introduced.

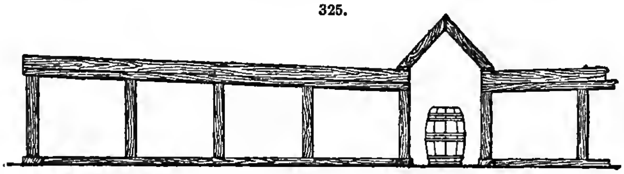
324.



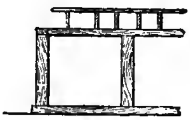
An efficient and economical form of still gutter is shown in Fig. 324. It will be noticed that the main body is formed of one balk of timber, to which are added sides of smaller pieces. This method of construction gives a gutter as good as if hollowed out of one large balk, costs of course much less, and can be made of a larger size than is readily practicable with one solid piece.

The next operation consists in bringing the chlorine gas into contact with the slaked lime in the chambers, or "boxes." Various materials and forms of construction of chamber have been from time to time adopted—wood, brick, stone, and sheet lead. The latter is now almost invariably used; but the old stone and brick boxes are still occasionally met with. When built of stone, the chamber is only about 10 ft. square by 6 ft. high, the best material being hard flag, and the method of construction somewhat similar to that of a manganese still. Sometimes a stone chamber has a lead top. A brick chamber is usually built in the shape of a long lime kiln—one great arch, about 9 ft. wide and 7 ft. high. The first leaden chambers were only small—packing about 2½ tons of bleaching powder each. The size has been gradually increased until the chamber of most modern and improved construction is about 60 ft. long by 30 or 35 ft. wide, and packs up to 12 tons of bleaching powder. The mode of erection is shown in Figs. 325 and 326. A wooden framework is first set up, of the size of the proposed chamber, consisting of 6 in. sq. corner posts, with stout uprights, about 7 ft. apart, of 7 in. by 3 in. deals, and the top or "crown" of 7 in. by 4 in. deals. Upon this framework, is hung a casing of 6 lb. sheet lead, the whole being burned by upright seams into one solid piece, and secured to the "crown" and uprights by straps of lead burned upon the sheet. The top is formed of similar sheets of lead burned together and strapped to joists, 11 in. by 3 in., set 14 in. apart. Two or three doorways are cut in the sides, and upon the top are formed two manholes—whence also samples can be drawn—and gas communication pipes. The doorways are about 5 ft. high and 4 ft. 6 in. wide, and are closed by stout sheet-iron doors swinging upon hinges and secured by cross beams and wedges. The workmanship must be of careful description to prevent any escape of chlorine. The height of a bleaching-powder chamber varies with the individual experiences of the manufacturers, but it should not average more than 7 ft. A slope of 12 in.—from 7 ft. 6 in. to 6 ft. 6 in.—is given to the top to prevent any accumulation of water. Various methods are adopted for connecting the side sheets with the bottom of the chamber and preventing any injury by the manipulation of the lime with shovels, &c. The best construction is shown in Fig. 327. An inner lining of lead, or skirting, 12 or 15 in. in height, is burned upon the sides and flanged 2 or 3 in. upon the ground or flooring. Over this flange, the bottom, formed of concrete or flags, is laid. A perfectly tight joint is thereby made, and if by any mischance the lead lining is cut, the gas has still no chance of penetrating the outer sheet. The older plan is to form a skirting of 1-in. deals round the chamber.

325.



326.



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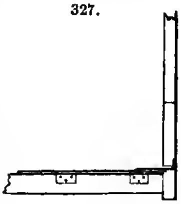
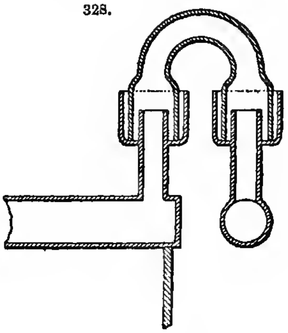


The gas from the still is carried for a short distance along earthenware pipes, on account of the heat and softening power of the steam. It is afterwards conveyed to the chamber in lead pipes of from 3 in. to 10 in. in diameter, depending upon the number of "mains" employed. Sometimes three or four stills are connected together; sometimes a whole range of stills plays into one large main pipe. By the former plan—*separated* mains, a more perfect command is obtained over the quality of gas served to the chamber; but the cost of repairs and the waste of gas are greater than when only one or two mains are used, and the strong and weak gases pass on to the lime indiscriminately. In any case the pipes from the stills must have a considerable fall, so as to keep all condensed steam out of the chambers, and allow it a free course back into the still. The best method of connecting the gas mains with the pipes leading finally to the individual chambers is shown in Fig. 328, and consists of two water lutes and a movable bend, or "elbow." The small vertical pipe is to carry off into any suitable cistern or drain the last products of condensation.

328.



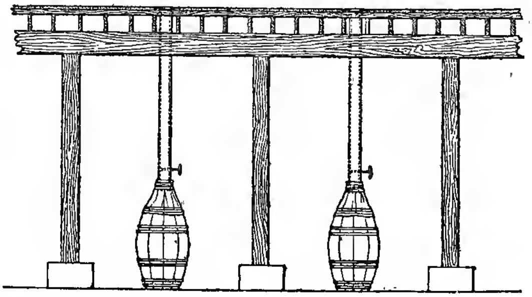
The lime employed is of two kinds—French "cliff," obtained from the banks of the Seine, and somewhat akin to the Dover chalk cliffs, and the pure limestone found in various parts of England

and Ireland, more particularly in Derbyshire and the neighbourhood of Belfast. Cliff varies considerably in its composition, from pure limestone to impure "chalk." Some English descriptions of the latter have indeed been often worked up into bleaching powder, the temptation being the lowness of cost; but in the long run, the operation does not pay, owing to the exceedingly uncertain composition of the chalk. Good limestone—the lumps that are usually burned for bleaching powder—has about the following composition:—

Carbonate of lime	98·25	Silica	0·50
„ magnesia	0·50	Iron and alumina	0·40
„ manganese	trace		
Phosphate of lime	trace		99·65

The stone is thoroughly calcined in any convenient form of kiln, care being taken to reject all portions not completely burned, and then slaked with water. This slaking requires considerable care and experience. Only a very slight excess of water should be used. If too great, a pasty mass is formed which resists the action of the chlorine; if, however, the whole is not thoroughly slaked, the absorption of the gas is incomplete, and raw lime goes through into the bleaching powder. The plan usually adopted is to spread the lumps of calcined stone in a layer about 12 in. deep, and to add the water through a rose pipe until the pieces fall into a fine powder. The portions of unburnt lime can be readily discovered and thrown out during the slaking process. The lime is next passed through a sieve of about sixteen meshes to the inch, and is spread upon the floor of the bleaching-powder chamber to a depth of about 8 in., the surface being slightly furrowed. If the depth of lime is too great, it is impossible to bring the chamber up to strength without frequent turnings, and consequent loss of gas. When the charging is completed, the manhole doors are luted on, the sheet-iron doors wedged up, and plastered round with lime or loam. The chlorine gas is now admitted from the stills, and the chamber "pressed" until a sample drawn from the top shows about 22 per cent. of chlorine. The gas is then turned on to another chamber, and the accumulated gas in the first box allowed to be thoroughly absorbed by the lime. When the green colour in the chamber has subsided, the doors are opened, and the charge is carefully and systematically turned over. The gassing operation is then repeated, occasionally a second turning is resorted to, and when a sample tests 37 per cent., the supply of chlorine is finally turned off, and the chamber is left to stand for six or seven hours. The doors are then opened, the manholes are removed, and the finished bleaching powder is packed into casks. Instead of allowing the unabsorbed chlorine to escape into the air when a chamber is opened, and to save the time necessary for the slow final absorption, it is very usual to have a communication with a freshly charged chamber, or a small antechamber, into which the gas is drawn when the bleach is finished, or when the box requires "turning." Various precautions should be observed in gassing the lime. A due proportion of "maiden"—i. e. pure—chlorine, and "spent" gas—gas mixed with steam—should be used. If the weak gas be brought into contact with the lime in too great a proportion—especially with fresh lime, a coating will be formed upon the surface, which resists the penetration of the chlorine. If a chamber be too rapidly pressed, a large proportion of the chlorine will remain in the powder only mechanically held, and will fly off when the bleach is packed. The common belief that the temperature of a chamber should not exceed about 80° or 90° F., while right in practice is probably wrong in theory, the mischief of a higher temperature arising not from the actual heat of combination, but from the presence of steam, of which the temperature is an indicator. Perhaps the best admixture of strong and weak gas is obtained by passing the product of a large number of stills into one main. The more usual plan is to have separate mains for about every three stills, and, *with careful management*, the gassing of a chamber can be more perfectly regulated by this method. The loss of chlorine during the operation of packing is about 0·75 per cent. When packed, the loss is at the rate of about 1 per cent. per month in hot weather, and 0·5 per cent. in cold.

329.



Instead of building the bleaching-powder chambers upon the ground, after the manner shown in Fig. 329, a very usual and excellent plan is to arrange them at a considerable elevation, upon suitable supports, to form a warehouse below. The packing is then performed by raking the bleaching powder into wooden spouts, countersunk in the floor, from which it falls into casks placed beneath. A closed connection between spout and cask is made by sheet indiarubber. This method of packing is less laborious and hurtful to the men employed; it is more quickly performed, and, although a seemingly greater loss of chlorine is apparent between the test in the chamber and the test in the cask, the bleach is more stable afterwards, the free chlorine being well shaken out of it by tumbling down the spout.

The usual bleach cask holds from 5 to 7 cwt. The powder should be packed as tightly as possible, both to preserve the quality and to economize the cost of casks. Owing to the disagreeable nature of the operation, this is a point which requires constant care and supervision on the part of the manufacturer.

The variations of the actual process of bleaching-powder manufacture are very few. The only important one has already been noticed—the preparation of liquor, by passing chlorine gas into lime water. Bleaching liquor is more esteemed upon the Continent than in this country, and is usually prepared by the bleachers themselves. The use of chalk, or carbonate of lime, has been proposed in place of the hydrate.

The question of yields is an important one, as there are many loopholes for loss. Upon an average, and in round figures, 13 cwt. of good 70 per cent. manganese ore, or 17 cwt. of 60 per cent., should yield 1 ton of bleaching powder. These figures refer of course to cases where the manganese is not recovered by Weldon's or some other process. A very great loss is incurred by the more finely divided portions of the ore being swept away with the waste liquors from the still, untouched by the acid. Further loss is sustained by the ore getting coated over, the acid being thereby prevented from penetrating to the centre. Sometimes an arrangement of washing and settling pits is made, and the waste manganese is restored to the still with a fresh charge; but it is doubtful if the result pays for the expense and trouble.

One ton of lime makes about 1¾ ton of bleach; but the quality varies considerably with the quality of limestone employed. About 2 tons of stone, or cliff, go to 1 ton of calcined lime. An experienced manufacturer can readily tell, from the appearance of the lime in the kiln when the fire has burned low, when the calcining operation is completed; and from the feeling and texture of the bleaching powder in the chamber, when the absorption of chlorine has been sufficient.

The chief uses of bleaching powder are, as its name denotes, for various bleaching processes, for the raising of metallic colours, and steam blues, and for the discharging of Turkey reds in calico printing. It is also used, but to a smaller extent, as a disinfectant. Its use in the latter capacity has been somewhat circumscribed of late years by the introduction of various other substances, such as carbolic acid, &c. It is, however, one of the best agents that can be employed for this purpose, a great merit being its harmlessness—the safety with which it can be handled and treated. The chief seats of the industry in this country are the districts of the Tyne, Lancashire, and Glasgow; the total output is about 70,000 tons per annum. The price fluctuates constantly and rapidly. In 1805, it was about 115*l.* a ton. From this point, with an increased output and better methods of manufacture, it gradually declined, until, in 1866, it ruled about 11*l.* a ton. Since then, it has risen to 17*l.*, fallen again to 5*l.*, recovered to 9*l.*, and, at the present time, remains steady at 5*l.* The cost price, when the recovery of the manganese is carefully carried out by Weldon's process—to be presently described, is about 4*l.* 15*s.* a ton. Under the old process it is fully 6*l.* a ton. Of course this variation in selling price by no means represents variation in profit. Owing to the different methods from time to time adopted in manufacturing sulphuric acid, it is difficult to give any reliable indication of the varying cost of this material; but the following table shows the approximate values of salt, since the commencement of the present century:—

Year.	Cost of Salt per Ton, delivered at Newcastle.			Year.	Cost of Salt per Ton, delivered at Newcastle.		
	£	*s.*	*d.*		£	*s.*	*d.*
1800	14	0	0	1835	1	0	0
1801	12	0	0	1840	1	0	0
1804	11	0	0	1845	0	17	0
1810	17	0	0	1850	0	17	0
1814	10	0	0	1855	0	16	0
1818	5	0	0	1860	0	16	0
1820	1	15	0	1865	0	15	0
1825	2	0	0	1870	0	13	6
1830	1	0	0	1875	0	15	6

It remains to notice the most important of the many processes devised for the recovery of the manganese, and for avoiding the use of manganese altogether. The consideration of these points has been reserved because the actual manufacture of the bleaching powder—the action upon lime with chlorine gas—is in all cases the same.

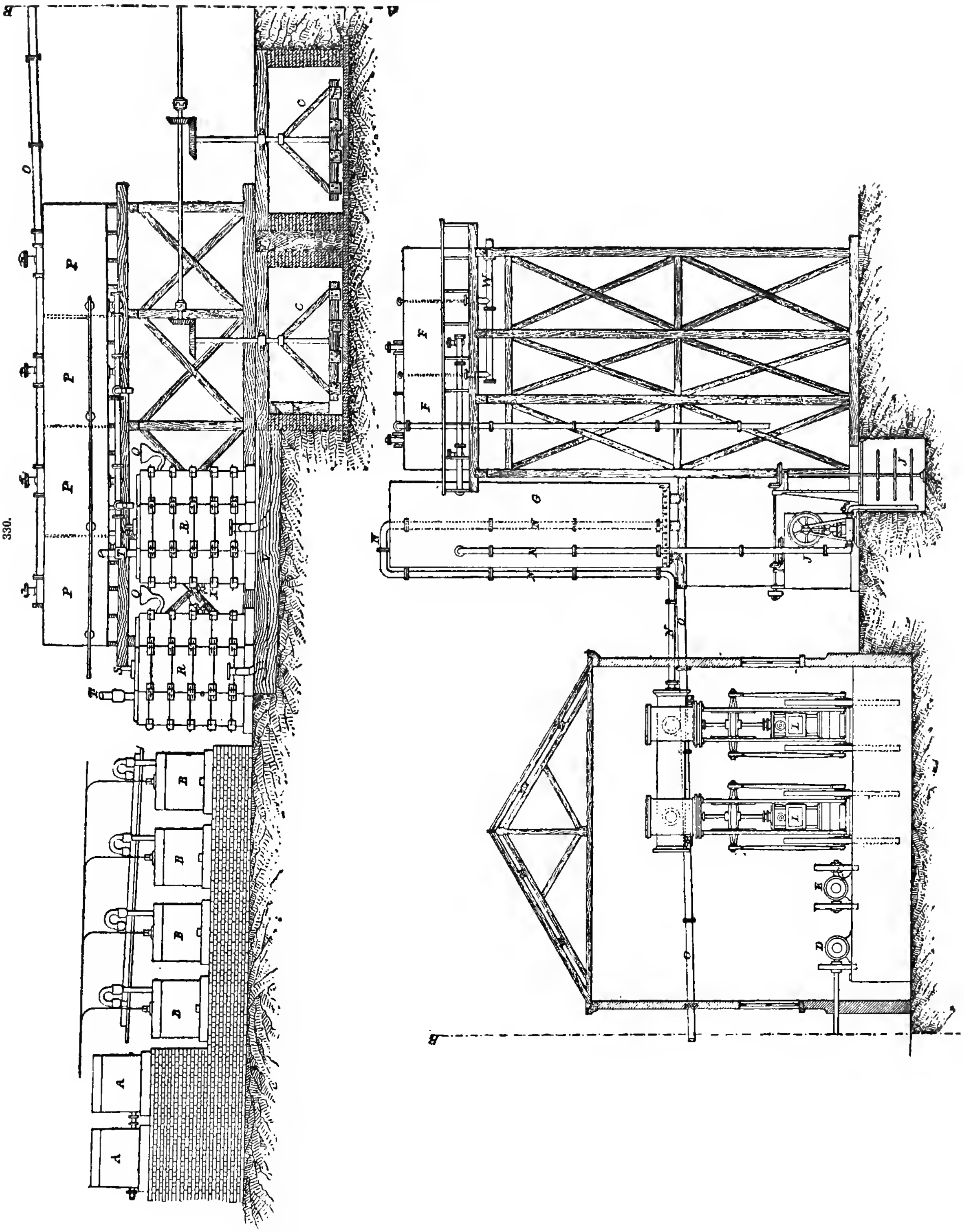
It will be at once apparent from the details given above, and from the chemical reaction in the stills—$MnO_2 + 4HCl = MnCl_2 + 2H_2O + Cl_2$, that the manganese is only an agent in decomposing the hydrochloric acid, issuing from the still, when its work is done, in the form of chloride of manganese, mixed with chloride of iron and free hydrochloric acid, and running off to waste. In addition to the expense entailed by so clumsy a process, the immense volumes of "still liquor," when run from the various works, forms a serious item in river pollution, and a nuisance to the surrounding neighbourhood. Of the processes of "regeneration" from time to time devised and carried out, those of Dunlop and Weldon alone deserve special mention. The former was first worked about 1855 at Messrs. Tennant's, St. Rollox Works; it consists in treating the still liquor with carbonate of lime, and decomposing the carbonate of manganese thus obtained by the simple action of heat. The liquors are first neutralized and allowed to settle, clear solution of chloride of manganese remaining supernatant. This is carefully drawn off, and run into a large boiler fitted with a shaft and agitator. Here it is mixed with ground chalk, or milk of chalk; steam is introduced under a pressure of about three atmospheres, and the whole is kept in constant agitation for three or four hours. The following reaction takes place:—

$$MnCl_2 + CaCO_3 = MnCO_3 + CaCl_2.$$

When the operation is complete, the contents of the boiler are left to settle, the clear supernatant chloride of calcium is run off, and the precipitated carbonate of manganese is drained and washed to remove all chloride of calcium. The expulsion of the carbonic acid and the oxidation of the manganese are effected in a long oven about 50 ft. in length, 12 ft. wide, and 9 ft. high. Four lines of rails traverse the sole of the chamber; heat is applied underneath by means of a flue passing down the centre, and returning on both sides. The carbonate of manganese is thrown loosely into sheet-iron wagons, which are slowly drawn backwards and forwards until the four lines of rails are traversed, the contents being subjected for something like forty-eight hours to a constant temperature of about 300° (572° F.). The water and carbonic acid are completely driven off by this process, and the residual manganese is converted by the action of the air—which is allowed to circulate through the oven pretty freely, through the loosely closed doors—into a mixture of peroxide and protoxide. Mr. Mactear reports well of this process, but it has not been worked on any large scale except at the St. Rollox Works. The expense of the plant is the chief objection. Some attempt has been made to utilize the chlorine lost in the chloride of calcium by substituting carbonate of magnesia for carbonate of lime, and obtaining hydrochloric acid from the resulting chloride of magnesium; but this refinement of Dunlop's process has not been found practicable.

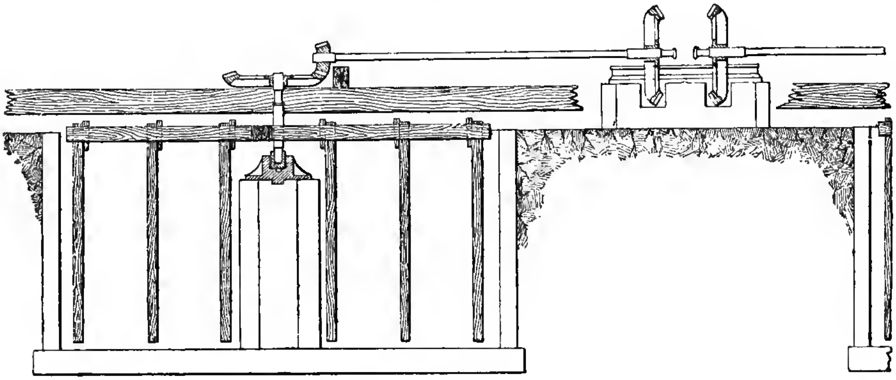
The second, and by far the most important, of the processes set on foot for the regeneration of the manganese, is that of Mr. Walter Weldon, which consists in the precipitation of the manganese as protoxide, and in peroxidation by an injection of air in the presence of an excess of lime. This improved form of an old patent has almost revolutionized the bleach and manganese trades. The old patents that dealt with this simplest of all the methods of regeneration, failed by employing only an equivalent proportion of lime, whereby only one-half of the manganese can be obtained as peroxide. Weldon's improvement consists in the addition of a *slight excess* of lime, which enables, practically, the whole of the manganese to be regenerated. The apparatus necessary for this process, some few minor details being omitted for simplicity's sake, is shown in the drawing, No. 330. A A represent hydrochloric acid cisterns, B B ordinary manganese stills, technically called "native," but set at such an elevation that their contents can, when required, be run by gravitation (the pipe of communication is omitted in the drawing) into R R, the "mud" stills, entering about half-way up. When the process is first started, the "native" stills are charged and worked precisely in the manner already described, until a good supply of still liquor is secured. This object having been attained, they are only worked to supply the 5 per cent. waste of manganese incurred during the ordinary working of the regenerating process. The still liquors are run off along the spout V into the neutralizing well *c*. To obviate the inconvenience of stoppage for repairs or cleaning, and to be able to neutralize a large quantity of still liquor rapidly, it is advisable to have *two* wells, as shown in the drawing, the spindles being thrown in and out of gear by the clutches upon the horizontal shaft. A cheaper form of neutralizer, and one largely employed, is given in Figs. 331 and 332; but it is not so satisfactory as the more elaborate apparatus shown in the drawing. In both cases the actual construction of the well is the same, and consists of a circular, or octagonal chamber, about 16 ft. in diameter and 7 ft. deep, built in the ground, with stone or firebrick sides and bottom. Still further to ensure perfect tightness, a good backing of slag is puddled in behind the stone or brickwork face. The agitating machinery shown in Fig. 330 consists of a cast-iron spindle with stout arms bolted on at right angles, from which project strong metal ploughs or scrapers. These, together with the wrought-iron bolts, require renewal about every two months, but the rest of the apparatus is thoroughly reliable and lasting. The agitators shown in Figs. 331 and 332 are of wood, and are constructed something like a gate, the driving part being set upon a stone centre, and thereby raised above the acid liquors. Occasionally strong chains are hung from the cross beam in place of the vertical arms; but these do not give efficient agitation. The wooden agitators require constant care and repairs, however strongly they may be made.

330.

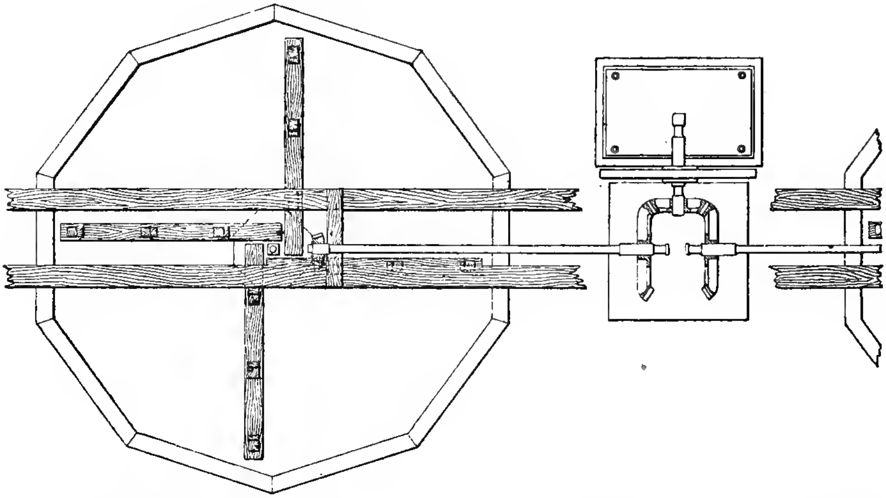


In the neutralizing well, the still liquors are mixed with roughly ground chalk, and agitation is kept up until the acid is thoroughly neutralized. This part of the operation requires care, that no injury may be done afterwards by the presence of an acid. Decomposition of the chlorides of iron and alumina is also effected by the chalk. The final liquors consist of chlorides of manganese and calcium, with excess of chalk and small quantities of oxide of iron and alumina, and of sulphate of lime. It may be stated in passing, that the liquor from the native stills is much more acid than that from the mud stills, as it is far easier to regulate the amount of acid in working the latter than the former. After being allowed to settle for a short time, the liquors are pumped, by the engine E, into the cisterns F, F. Here they are allowed to settle, until the supernatant liquor is perfectly bright and clear, of a slight pink colour. By means of any convenient form of siphon—indiarubber tubes, which float always upon the surface of the liquor, being perhaps the best, the clear liquors are next transferred to the "oxidizers," shown at G. These are of strong sheet iron, well riveted and transversely stayed; they should be not less than 10 or 12 ft. in diameter, and 30 to 35 ft. in depth. A large 10-in. iron pipe N passes from the blowing engines (which should be in duplicate) down the centre of the oxidizer, and terminates in a crosshead pipe, pierced with holes to effect perfect distribution of the air. Sometimes the air distributor is protected by a false bottom; but this is not necessary, as the blast of air keeps the holes well open. A smaller pipe is run down the centre of the oxidizer, for the injection of steam. The manganese liquor is run into the oxidizer to a depth of about 15 ft., and is raised by steam to a temperature of 55° (130° F.) or thereabouts. In the meantime, a carefully prepared milk of lime has been collected in the vessel J. The lime apparatus will be readily understood from the drawing. The milk is made in the upper

331.

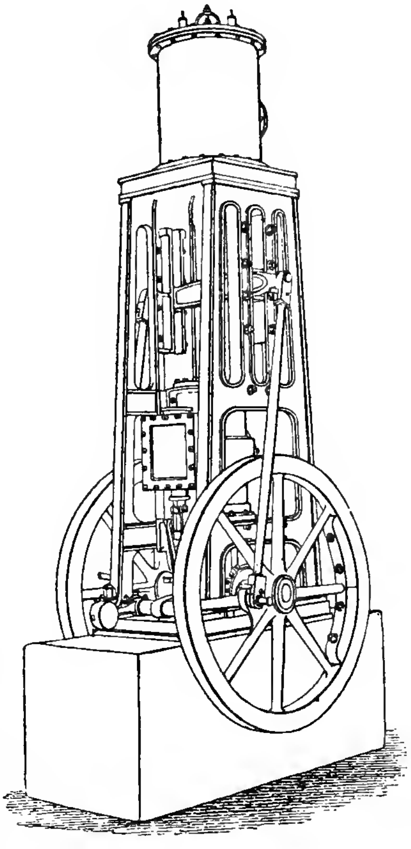


332.



of the two sheet-iron vessels, the lumps of calcined lime being placed in a wire basket to separate out all hard pieces and stones. Not less than 15 lb. of hydrate should go to the cubic foot of cream, and to ensure perfect fineness the liquor must be carefully sieved on its passage from the upper to the lower vessel. A revolving sieve turned by the small engine which agitates the liquor is the best form of apparatus. In many cases the milk of lime is pumped from the second vessel into a third, or "batch," cistern, placed above the oxidizers, to obviate the injury caused by any possible breakdown of the lime pump during the administering of the charge to the manganese liquors. Whichever system is adopted, thorough agitation of the prepared cream before using must be effected. The manganese liquor in the oxidizer having been brought up to a proper temperature, the milk of lime is pumped (see pipe K, Fig. 330), or run, in, and the blowing engine slowly set away to effect perfect admixture. The addition of lime is continued until the filtrate from a sample of liquor drawn from a small tap near the bottom of the oxidizer ceases to give a precipitate of purple permanganate of calcium with a solution of bleaching powder, showing that the whole of the manganese has been precipitated as oxide. A further quantity of milk of lime is then added, and the blowing engine set away rapidly, the injection of air being continued until peroxidation is complete. It may be mentioned here, that it is of the utmost importance to have oxidizers and blowing engine of ample capacity and first-rate quality, any serious hitch in the process spoiling the batch in course of operation. Several forms of blowing engine are employed, that shown in Fig. 333 being the best in the writer's opinion. It is the design of Messrs. Daglish, of St. Helen's, and is used now very extensively with the best results. Next to this the best form is a horizontal engine with wooden flaps, faced with indiarubber, in the covers of the air cylinder instead of the older form of valve. Although only one oxidizer is shown in the drawing, the smallest plant should have two, a batch of manganese liquor being prepared in one, while the charge in the other is being blown. Not only is a saving of time effected, but the risk of stoppage is guarded against by this plan.

333.



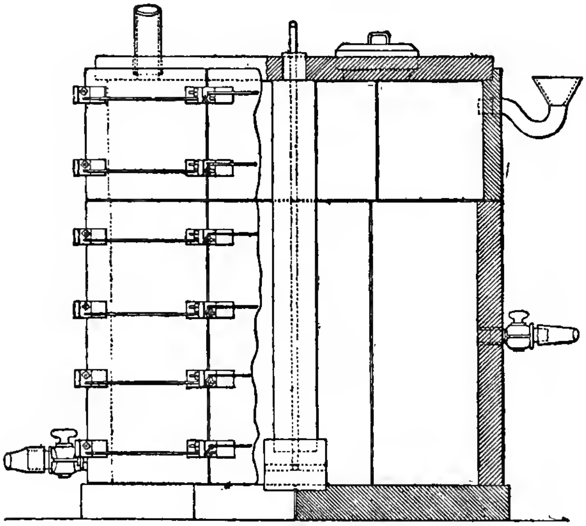
To return to the process. The amount of lime required for perfect precipitation varies considerably—varies with the quality of the milk itself, the presence of foreign matters and coarser particles, and the action of the liquor. Lime dissolves slightly in chloride of calcium, as also does protoxide of manganese, and these reactions render a varying amount of excess of lime necessary. Usually it is found necessary to add about 1·2 equivalents: the further amount introduced in excess, after precipitation has been ascertained to be complete, raises the quantity to 1·5 or 1·6 equivalents. On the other hand, too great excess of lime causes loss through the formation of compounds which neutralize the acid in the stills without liberating chlorine. The compound of lime and manganese thus formed is usually termed "base," and every finished charge is finally tested for "bases," with a view to keep them as low as possible. The amount should not exceed ·75 per cent. About two-thirds of the way through the operation of blowing, it is very usual to run into the oxidizer a portion of fresh manganese liquor. The lime of the "base" decomposes the chloride of manganese, forming a fresh portion of protoxide to be operated upon, and freeing a certain amount of peroxide before combined with it.

The length of time required for complete peroxidation varies with the size of engine, number of revolutions, and depth of charge. Not altogether, however, because if the air be injected at too great a speed, it simply passes through the liquor and is wasted. It is important to have as great a depth of charge as possible, as the surface presented to the action of the air is thereby increased and the absorption of oxygen more complete. The liquor is at first, after the addition of the lime, yellowish-white, but rapidly turns darker as the operation proceeds, and should finally be converted into a very thin black mud, consisting of solution of chloride of calcium, holding in suspension various compounds of manganese and lime—or "manganites,"—manganese and manganese—MnO and MnO_2—, and the peroxide. From the oxidizer, the whole mass is run into settlers, P, P, P, P in the drawing, and left to settle. Upon an average, about three and a half or four hours are required to complete the blowing operation.

After remaining in the mud settlers for four or five hours—or until a charge of mud is wanted —the chloride of calcium which floats clear on the top is drawn off by means of any convenient form of siphon, and run to waste. At the bottom of the settler will be found a layer of thick black mud to a depth of about 10 in.—a mixture of various manganese compounds and lime—which represents the finished and regenerated article. It is usual, after removing the chloride of calcium from the mud, to run in another charge from the oxidizers, and so collect a large quantity of the final mud. This is done, of course, to economize settler room, and also to prevent the drying and caking of the mud probably attendant upon a thin layer being left. From time to time the stock of mud in the settlers should be thoroughly agitated to ensure an even consistency. The settlers themselves are built preferably of stout sheet iron, well riveted, and supported by cross stays. Occasionally they are constructed of wood, like huge tubs, but any such form of apparatus is faulty.

From the settlers the mud is run, as may be required, into the stills R, R, Fig. 330, through the luted funnels Q. A section of Weldon still is given in Fig. 334, which will better show its construction. It is usually octagonal in shape—sometimes square—about 9 ft. deep, and each side 4 ft. wide. If square, the still may be 10 ft. wide, but stones of this size are very apt to crack. The octagonal form is both stronger and cheaper. Each side may be made of two slabs, to save expense; the lower piece in this case should be 5 ft. 6 in. high, and not less than 7 in. thick, and the upper portion 4 ft. high and 5 or 6 in. thick. The sides of the still are strongly bound up with 1¼-in. iron girders, and are jointed together with the indiarubber rods before described; or the flat surfaces are carefully dressed and bedded with china clay and tar, and a stemmed diamond run down the centre. The bottom may be of one solid piece, 12 in. in thickness, or formed in sections. The former is the better but more expensive plan. The sides should sit 1¼ in. into the bottom stone—or stones. The cover is usually formed of segments, and is let and stemmed into a ledge cut in the sides. These segments rest in the centre upon a strong stone shaft or pillar, 10 in. square, through the middle of which is drilled a groove for the injection of steam, which passes out near the bottom of the still at right angles to the axis of the steam shaft. Finally, a lute is set in the cover for the introduction of acid, a large 4-in. earthenware tap is let into the front, close to the bottom, to let off the spent liquors to the neutralizing well, and a small sample tap is stemmed into one side, rather more than half-way down. In the cover are also set a large pipe to convey the chlorine gas to the chambers, and a manhole.

334.



The still is first charged with hydrochloric acid, and the settled mud run in through the funnel. This mud should contain 5 lb. of peroxide of manganese to the cubic foot, the chloride of calcium being drawn off as closely as possible. It dissolves in the acid far more readily than native manganese ore, and requires comparatively little steam. About four hours is sufficient to work off a charge. The liquors are then run off through the large tap to the neutralizing well and treated with chalk in the manner before described. The amount of free acid, if the operation in the still has been carefully conducted, will not exceed 5 lb. per cubic foot of liquor. The more acid liquors from the "native" stills, if they are in operation, are now run into the mud stills, and so on to the neutralizing well. In this way the greater portion of the free acid contained is utilized in the treatment of the mud.

Although theoretically the whole of the manganese is recovered by this process, in practice there is a loss of about 5 per cent. The greater part of this loss is incurred in the liquor settlers. There is always an appreciable amount of mud escaping with the liquors from the stills into the neutralizing well, and this is pumped up with a quantity of chalk and sulphate of lime into the settlers. The deposit from here is regularly removed and washed in a special tank (omitted in the drawing), the resulting liquors being returned to the neutralizing wells; but nevertheless a considerable loss of both mud and chloride of manganese is incurred, and it would not pay to carry this part of the process out more delicately.

Two tests must be regularly made of the mud of the Weldon process—for peroxide and for "bases." In the former a sample is taken as the mud is run from the oxidizer, and to 1 cubic in. is added a solution, *in slight excess*, of a known quantity of iron protosulphate in hydrochloric acid. The mud dissolves promptly to a brownish yellow liquid, and the amount of iron salt left unoxidized is then determined by a standard solution of bichromate of potash, which is added until a drop of the liquid taken out upon a glass rod, ceases to strike blue with ferricyanide of potassium. If after adding the iron solution the mud does not completely dissolve, it is because an excess of protosulphate is not present. The original weight of iron salt being known, and the amount left unoxidized ascertained, the difference gives the amount acted upon, and this quantity divided by 25·88, gives the pounds of peroxide in 1 cubic foot of the mud.

After ascertaining the amount of ferrous sulphate peroxidized by the MnO_2 in 1 cubic in. of the mud, the amount of base is readily obtained. To the same amount of the mud sample a solution of a known weight of oxalic acid is added—*in excess.* The mixture is then heated gently, and the excess of oxalic acid determined by a standard solution of carbonate of soda. The difference between this and the original weight of oxalic acid gives the amount decomposed and neutralized by the mud. Then, as the number of grains of $Fe_2SO_4 + 7\,H_2O$ (crystallized ferrous sulphate) oxidized is to the number of grains of oxalic acid decomposed, so is 100 to a figure in column A of the subjoined table, against which in column B is the equivalent of base per equivalent of manganese peroxide.

A.	B.	A.	B.	A.	B.	A.	B.
69·00	1 044	65·75	·901	62·50	·758	59·25	·615
68·75	1·033	65·50	·890	62·25	·747	59·00	·604
68·50	1·022	65·25	·879	62·00	·736	58·75	·593
68·25	1·011	65·00	·868	61·75	·725	58·50	·582
68·00	1·000	64·75	·857	61·50	·714	58·25	·571
67·75	·989	64·50	·846	61·25	·703	58·00	·560
67·50	·978	64·25	·835	61·00	·692	57·75	·549
67·25	·967	64·00	·824	60·75	·681	57·50	·538
67·00	·956	63·75	·813	60·50	·670	57·25	·527
66·75	·945	63·50	·802	60·25	·659	57·00	·516
66·50	·934	63·25	·791	60·00	·648	56·75	·505
66·25	·923	63·00	·780	59·75	·637	56·50	·494
66·00	·912	62·75	·769	59·50	·626	56·25	·483

Besides these two tests, that must be made from every batch of mud in order to carry the process on well, it is usual from time to time to test for total manganese, by oxidizing the whole of the manganese present with bleaching powder, and ascertaining, in the manner above described, the amount of ferrous sulphate oxidized by the sample. A convenient quantity of mud is the 1 cubic inch already spoken of. This is dissolved in hydrochloric acid, in the least possible excess, which excess is neutralized with soda. The solution of mud is then heated and oxidized with bleaching-powder solution, complete conversion of all the manganese into peroxide being obtained when a slight purple coloration betrays the formation of a permanganate. After filtration and washing, the precipitate is added to the solution of a known quantity of ferrous sulphate in hydrochloric acid, and the total manganese calculated from the amount of ferrous salt acted upon.

There can be no doubt about the very great success of the Weldon process. Not only is the manganese recovered at a low cost, but a better yield of bleach is obtainable than by the old process.

One great reason of this is the facility for accurately gauging the quantity of acid necessary for the operation in the stills.

Many plans have been proposed for utilizing the chlorine wasted as chloride of calcium—two-thirds of the amount originally contained in the hydrochloric acid. Foremost among these is Weldon's own magnesia process. The liquor from the stills is neutralized with "Greek stone," a native carbonate of magnesium—preferably calcined and powdered—and the mixed chlorides of manganese and magnesium pumped into settlers, where the oxide of iron, alumina, and sulphate of lime are deposited. From here the clear liquor is run into an iron pot and evaporated by underneath heat until a temperature of 320° F., or thereabouts, is obtained. It is then drawn off into a double-bedded furnace, the two beds being separated by a sliding door in a manner similar to a "pot" and "roaster" arrangement. Here evaporation is continued to dryness, gaseous hydrochloric acid being driven off, together with a considerable amount of chlorine. The mixed gases are passed up a tower packed with coke, similar in arrangement to the ordinary hydrochloric acid condenser, and the resulting liquid acid utilized in the afterpart of the process for the evolution of chlorine. The residue left in the furnace after being evaporated, is broken up by a slice into cakes and transferred to the second bed. Here it is heated gently, so that the mass may not fuse but remain open, and a carefully regulated amount of air introduced. Oxidation of the manganese protoxide—formed when the chlorine is driven off from the mixed chlorides of manganese and magnesium—proceeds regularly, and a peculiar compound which has been termed manganite of magnesium ($MgMnO_3$) is finally obtained. This is put into the stills and treated with the hydrochloric acid from the condenser, as in the ordinary bleach process. By carefully regulating the proportions of manganite and acid, an almost neutral still liquor is obtained, which is treated with a little magnesia, settled, evaporated, and worked over again in the manner described. The gaseous product of the first part of the furnacing—the evaporation—consists chiefly of hydrochloric acid, a sufficient amount of water being present. Afterwards a more or less dilute chlorine is evolved. This may be conveniently passed into milk of lime to form a bleaching liquor, or may be mixed with the "maiden" gas from the stills.

It will be seen that by this process the whole of the chlorine is made available, and is actually utilized, so rendering possible an immense production of bleaching powder. A small loss of material is incurred from mechanical sources—leakage, &c.—but this may be reduced to 2 or 3 per cent. by a carefully constructed plant. The apparatus required is of simple description, and is in no way liable to get out of order. And yet, probably on account of the unremitting care required in conducting all the various operations, and the possible amount of mischief resulting from neglect or carelessness, the process has never been practically successful. It will be readily appreciated from the foregoing details that there are many points which are likely to prove veritable rocks of offence. If the proper proportions are not kept between the manganite and acid in the still, so much magnesia has to be added to the liquor, that the furnace product contains an undue amount of this substance, which is of course worse than useless in the still. Again, if the amount of protoxide in the manganite—answering to the "base" of the Weldon manganese recovery process—is large, a waste of acid results in the still operation. The regulation of the temperature of the furnace, and the admission of air, are likewise delicate matters requiring constant attention. The process has been worked by several manufacturers upon a fairly large scale, but is now entirely abandoned in favour of the more successful lime recovery process.

Other plans for the regeneration of manganese have been proposed by Hofmann, Kuhlmann, Schloessing, Elliott, and others, but have never got into the region of practical manufacturing upon a large scale.

Of the various processes for the production of chlorine without the use of manganese, that of the late Mr. Deacon deserves prominent notice. Beautifully simple in reaction, productive of an enormous yield of cheap chlorine, this process is not at all unlikely, in some revived and modified form, to supersede all others. At the present time it is practically abandoned on account of certain mechanical difficulties which militate against its continuous and effective operation.

Deacon's process originated probably in two already patented but unsuccessful methods of obtaining chlorine. The one was that of Laurens, and consisted in heating dry chloride of copper with sand. Cuprous chloride and chlorine gas are formed. The latter is utilized and the former reconverted into the cupric salt by treatment with hydrochloric acid and a current of air. The following reactions set forth the process:—

$$CuCl_2 = CuCl + Cl$$
$$2CuCl + O + HCl = 2CuCl_2 + H_2O.$$

The second process was that of Oxland, patented about 1845. He proposed to pass gaseous hydrochloric acid and air, in the proportion of one volume of the former to two of the latter, over pumice stone, bricks, or some other porous substance arranged in a reverberatory furnace, obtaining free chlorine and water.

These processes were never carried beyond an experimental stage. The first broke down through a certain and inevitable loss of copper; the second, through producing only a very weak chlorine. Deacon substituted sulphate for chloride of copper, finding that the decomposition of the hydrochloric acid is thereby effected at a lower temperature than when the latter salt is employed. His process consists in passing hydrochloric acid gas, from the salt-cake furnaces, over an arrangement of small clay marbles, broken bricks, coke, or some other hard but porous substance, saturated with solution of sulphate of copper, and having access of air. At a temperature of about 700° F. the hydrochloric acid is decomposed, with the formation of water and evolution of free chlorine. Mixing sulphate of sodium with the sulphate of copper has been found to facilitate the operation. The most important point in the process is the regulation of temperature. Below 500° the decomposition does not readily take place; above 800° volatilization of the chloride of copper which is formed ensues. When the operation is carefully performed and no loss of chloride by volatilization allowed, the sulphate of copper remains practically unchanged, and the whole of the chlorine of the hydrochloric acid becomes, theoretically, available for the manufacture of bleaching powder. The chief part of the apparatus is the "decomposer." This consists of a series of nine towers constructed of iron, and arranged in somewhat similar style to the Hargreaves cylinders, shown in Fig. 240. The first two towers are packed with bricks or drain pipes, with as open flue spaces as possible; the remainder are filled with small clay marbles, broken bricks, or coke, arranged above a grating. These materials are thoroughly soaked with the mixed solutions of sulphate of copper and sulphate of sodium. Preceding the decomposer is the "regulator," a brick or iron tower packed with bricks, up which the gases are passed before entering the decomposer. The object of the regulator is simply to ensure a constant temperature. Both regulator and decomposer are surrounded with a strong brickwork casing, in which are arranged vertical flues, communicating with a suitable furnace. To carry out this, the most important, part of the operation successfully, it is of the utmost importance that the decomposer be constructed of the best possible material and with every care. The gases are drawn through the regulator and decomposer by means of any convenient apparatus—a good chimney draught, or a Roots blower, &c.—a register of temperatures being made by a pyrometer. and samples of the gases entering and leaving the decomposer being readily obtainable by inserting a finger pump into the pipes and drawing a known quantity through an alkaline solution coloured blue with litmus. A considerable amount of dust—chiefly oxide and chloride of iron from the pipes or decomposing pans—collects in the cylinders, falls through the grating into the receptacles at the bottom of the towers, and is periodically cleared away. A more or less imperfect decomposition is effected, the gases leaving the decomposer consisting of chlorine, hydrochloric acid, nitrogen, unconsumed oxygen, and steam. By regulation of the draught and proper admission of air, great care is taken to reduce the amount of escaping hydrochloric acid to a minimum. These products are next passed up a condenser, whereby the hydrochloric acid is washed out, and then up a coke tower, where they are dried by coming in contact with strong sulphuric acid. Occasionally a chloride of calcium drier is also resorted to. The gas is now ready to act upon the lime. Owing to the enormous volume to be dealt with, the chambers are constructed in a different fashion from the ordinary bleaching-powder chamber. Outwardly they resemble the old flag or slate boxes, but the interior is divided into a number of compartments, and these are again intersected with a series of shelves, only about 9 in. space being left between each. Upon these shelves the carefully prepared lime is placed in thin layers, ¾ in. in thickness, and the gas is drawn from shelf to shelf and compartment to compartment, first over the lime most saturated with chlorine, then over that freshly charged. As each division, by testing a sample drawn, is ascertained to be brought up to strength, it is shut off, and the finished bleaching powder raked out.

The two great practical difficulties that have been met with in this very simple and ingenious process are (1) the irregular working of the decomposer—the liability of the copper salt to volatilize or choke up the interstices of the marbles, or whatever packing may be used; (2) the irregularity of the strength of the bleaching powder, owing probably to the dilution of the chlorine. To meet the uncertain volume of gas entering from the decomposing pans it is sufficient to organize alternate chargings, so that the amount shall be kept as uniform as possible. The activity of the sulphate of copper can be renewed from time to time by the injection of steam, after allowing the decomposer to cool down. A fresh solution of copper salt is made in this way, and distributed over the surface of the packing. The only hitherto insuperable objection to the process has been the uncertain character of the bleaching powder. Sometimes it will come well and rapidly up to strength; the next compartment or next charging will obstinately refuse to rise above 30 per cent. In the writer's opinion the solution of this difficulty will be found to lie in a better preparation of the lime, and more especially in regulating the amount of water in the slaking operation.

The exact character of the chemical changes that take place in the decomposer are still very imperfectly understood. Deacon and Hurter have been of the opinion that the sulphate of copper undergoes no change, but that its action is simply mechanical. They claim to have established,—

1. That with the same mixture of gases, and at the same temperature, the amount of hydro-

chloric acid decomposed by the aid of a molecule of the copper salt in a given time depends upon the number of times the molecules of mixed gases are passed through the sphere of action of the copper salt. Conversely, that the activity of a molecule of copper salt depends upon the speed with which fresh matter is presented to, and the products are removed from, it.

2. That in porous matters, the opportunities of action increase with increased velocities of the current of gas in nearly direct proportion.

3. That, other conditions remaining the same, the percentage of hydrochloric acid decomposed in any given time varies with the square root of the proportionate volume of oxygen to hydrochloric acid; and conversely.

4. That the chloride of copper formed bears no definite proportion to the chlorine produced.

5. That as the sphere of action includes molecules not in contact with the copper salt, hydrochloric acid must be decomposed under circumstances where the union of either element with the copper salt is impossible, i.e. that the decomposition must in part, if not entirely, be caused by the resultant of the forces engaged, and therefore direct from $2HCl + O$ to $2Cl + H_2O$.

Many other processes for the production of chlorine have been from time to time proposed, besides those to which prominence has been given. Those of Deacon, the acting upon salt with sulphuric anhydride and air—

$$SO_3 + O + 2NaCl = Na_2SO_4 + Cl_2—$$

Lalande and Prud'homme, Manghau, Tessié du Mothay, Thilbierge, Dunlop — decomposing a mixture of nitrate of sodium and chloride of sodium with sulphuric acid—and Shanks may be mentioned. None of these methods have, however, been worked to any successful issue upon a large scale, but those of Dunlop and Shanks deserve a few words of notice. The former is still in operation, the latter has only recently been abandoned. In Dunlop's process the materials were decomposed in a cast-iron cylinder, the following equation representing the reaction :—

$$2\,NaCl + NaNO_3 + 3\,H_2SO_4 = 3\,NaHSO_4 + Cl_2 + 3\,H_2O + NO_3.$$

A mixture of salt with the bisulphate—drawn off in a liquid state—yields, upon furnacing, ordinary salt-cake and hydrochloric acid. The gaseous products are conducted through a series of leaden Woulff's bottles, partly filled with strong sulphuric acid, which absorbs the nitrous acid while the chlorine is passed on to the bleaching-powder chambers to be absorbed by lime.

Shanks' process consists in decomposing chromate of lime by hydrochloric acid, yielding chlorides of calcium and chromium and chlorine. Thus—

$$2\,CaCrO_4 + 16\,HCl = CrCl_6 + 2\,CaCl_2 + 8_2O + Cl_6.$$

The residual liquors are neutralized with lime, as in the Weldon process, and treated with excess of milk of lime. They are then allowed to settle, the chloride of calcium is drained off, and the residual sludge furnaced at a low heat with access of air. Chromate of lime is re-formed and ready to be used over again in the stills.

BLEACHING. (Fr., *Blanchiment;* Ger., *Bleichen.*)

By the term "bleaching," is understood all those processes by which certain animal and vegetable products, more especially those used in the manufacture of clothing, are made white. Whatever the processes adopted, the impurities, natural or accidental, should be more readily affected by the chemical or mechanical means employed than the materials to be bleached; and, being thus either decolorized or removed, without appreciable injury to the texture of the materials themselves, the latter acquire the desired purity of white, which enhances their beauty and value, or, as in the case of textile materials sometimes, renders them more fitted for being dyed or printed. Hence the method of bleaching vegetable fibres is not at all applicable to animal fibres, the latter being readily destroyed by the chemical agents used for the former.

Bleaching is a very ancient process, its exact origin being unknown. The earliest methods must have been simple and tedious, and probably consisted in washing with water filtered through wood-ashes, and exposing to air, light, and moisture, after the manner practised by our laundry-maids to-day. All the earlier accounts of bleaching processes refer to linen, since the use to any notable extent of cotton goods in Europe only dates from about the middle of the eighteenth century. About this time, the principal seat of linen bleaching was Holland, where the process consisted in steeping the "goods" in a solution of potash for several days, then in buttermilk for about a week, and in spreading them on the grass, repeating the operations till the goods were deemed sufficiently white. One of the first improvements at this period, by Dr. Home, of Edinburgh, was the use of dilute sulphuric acid in place of buttermilk, by which the duration of the process, formerly about eight months, was reduced to four months. Lime, also used at this time by the linen bleachers, seems to have been employed from a very early date; but whether as a direct agent or only to render the potash caustic is not perfectly clear. The greatest improvement was the application of chlorine, suggested by Berthollet in 1785, and introduced shortly afterwards into Scotland by James Watt, the eminent engineer. It is interesting to note that the Clober Bleach Works, Milngavie, where chlorine was first applied as a bleaching agent in Britain, are still active. Dr. Thomas Henry introduced its use to Lancashire bleachers about the same time. Chlorine was at first applied in the gaseous form, the goods being exposed to its action while hanging up in a stove. Afterwards its solution in water, and later still, in dilute potash, were tried. The latter was known as Eau de Javelle, and, being almost without smell, relieved the workmen from the annoyance they formerly experienced from the gas. In 1799, Mr. Charles Tennant, of Glasgow, introduced the dry chloride of lime or "bleaching powder," now universally employed, especially in the bleaching of cotton. For the bleaching of animal fibres, wool, silk, &c., the use of weak alkalies, soap and sulphurous acid, seems to have been in vogue for a long period.

Cotton Bleaching.—Cotton is not bleached in the unspun state, but always in the form of yarn or thread, or of woven material or calico.

The most thorough and perfect kind of calico-bleaching is the so-called "madder-bleach," in general use with calico-printers and dyers; a detailed description of the various processes and machinery in actual use at the present time for this style is therefore given. For the madder-bleach, it is not simply necessary that the cloth be of snowy whiteness; it must in addition be thoroughly cleansed from all those foreign impurities which would resist the entrance of the dyes to be applied afterwards. For light and delicate plain dyes, the purer the white the better, but for dark shades this is not essential. When the fabric is to be printed and dyed so that some parts shall remain white, the bleaching must combine every excellence, and all those impurities which would attract colouring matter in the "dye-beck" must be entirely cleansed away, otherwise a tinged or bad white, destructive of the beauty of the print, will be the inevitable result. The term "madder-bleach" has been applied to this particular style of bleaching, because it is very specially requisite for those printed goods which have subsequently to be dyed with madder, or its present substitute, artificial alizarine. In practice, the whites do invariably become tinged to a greater or less degree during dyeing; but if the bleaching has been well done, the original purity of the white may be readily restored by a slight washing with soap and water, or by using a very weak solution of bleaching powder, without impairing, to any appreciable extent, the coloured parts of the design.

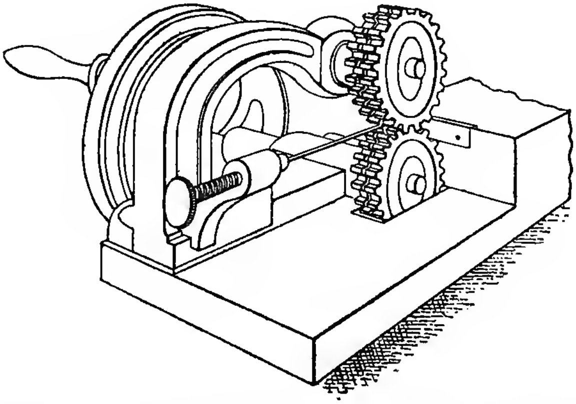
Madder Bleach.—As the cotton goods come from the weaver, they present a more or less greyish appearance, and are usually termed "greys." In this state, the cotton, in addition to its natural impurities derived from the plant, contains all those which it has acquired during the process of manufacture. These are the most important, and comprise the various matters introduced during the sizeing of the warps, such as china clay, magnesium chloride, and other inorganic substances, starch or flour, grease from the size, the machinery, and the hands of the workmen, and dust and dirt of all kinds. These impurities may vary from 5 to 30 per cent., or more. The natural impurities of the cotton are comparatively small, less than 1 per cent. Dr. Schunck has carefully examined the nature of some of these, and has shown the presence of fatty and waxy matters, brownish colouring substances, pectic acid, and albuminous matter. The complete removal of these impurities constitutes the madder-bleach.

Stamping.—To recognize subsequently the various lots of cloth and to trace damages, each grey piece, before bleaching, is stamped at the ends with numbers and letters. For this purpose, any colour may be used which will be sufficiently fixed to resist the bleaching process and remain legible afterwards. Thick gas tar alone, or mixed with a little turpentine, is the most generally used. Aniline black has been introduced; but owing to its liability to change, and its tendency to leave holes, it has not been much adopted.

Stitching.—The pieces are stitched together in lots or bunches of five or more. Formerly, this was all done by hand; now, stitching machines are universally adopted. Of these, the oldest is the so-called "donkey machine," still in use—especially in bleach-houses where rapid unstitching is a desideratum—for heavy goods and such as do not require heavy calendering. Fig. 335 represents this machine. It consists essentially of a pair of small cog-wheels working into each other and turned by a small winch handle. The centre of the teeth of both wheels is cut away, forming a groove in which the point of the needle rests, the eye end being supported by a small orifice in the end of a spring slide immediately opposite the wheels. The cloth to be stitched, being placed close up to the cog-wheels on the opposite side of where the needle point rests, is dragged in puckers into the latter, by turning the winch handle. When full, the needle is pushed still further through the cloth by the spring slide, taken from the machine, and the thread is drawn through by hand. If the machine is made with two pairs of cog-wheels and a pair of needles, two threads may be stitched together at a distance from each other of about half an inch. In this style of stitching, the ends of the pieces are made to overlap. The threads are not knotted, but left projecting 3 or 4 in. on each side of the pieces. The stitch is a simple coarse running stitch, and the thread is made of slackly twisted cotton, not liable to cut the cloth when subjected to heavy pressure.

In the bleach-houses of calico printworks, two more complicated machines are in general use, that of Rayer and Lincoln, generally called the American machine, and that of William Birch, Manchester. Fig. 336 represents Birch's machine. Without entering into details, it may be said that this machine makes the common flat chain stitch, easily drawn out again when required. It is simple in its working, and is so arranged that the attendant has simply to place together the two piece ends to be sewn, and to hook one corner on the tenter hooks of the guide arm, and the other on the hooks of the feed wheel; the machine will then start itself and guide the fabric across. The ends being sewn, the guide arm unhooks itself from the pieces, falls down, and stops the machine, which is then ready for another pair of piece ends to be attached. This machine may be driven by steam power, and will enable one person to do the work of three or four with the older machines. The thread is finer and the stitch is much closer than in the case of the donkey machine. Rayer and Lincoln's machine is an adaptation of Willcox and Gibbs' arrangement. In using it, the ends of the two pieces to be sewn are placed together, and fixed on to the pins of the vertical wheel. On starting the machine, this wheel revolves, the pieces pass under the needle, are stamped with numbers or letters, and the ends are neatly trimmed off. In the most complete machines, the goods are held both inside and outside the line of sewing, thereby securing and maintaining a perfect and even stretch of the goods. This latter point is very important, and whatever machine be used, the tension of the thread should never be too tight, or the seam will become puckered during the subsequent bleaching processes, and, when dried, the piece ends will be scrimped and creased to a considerable extent.

335.

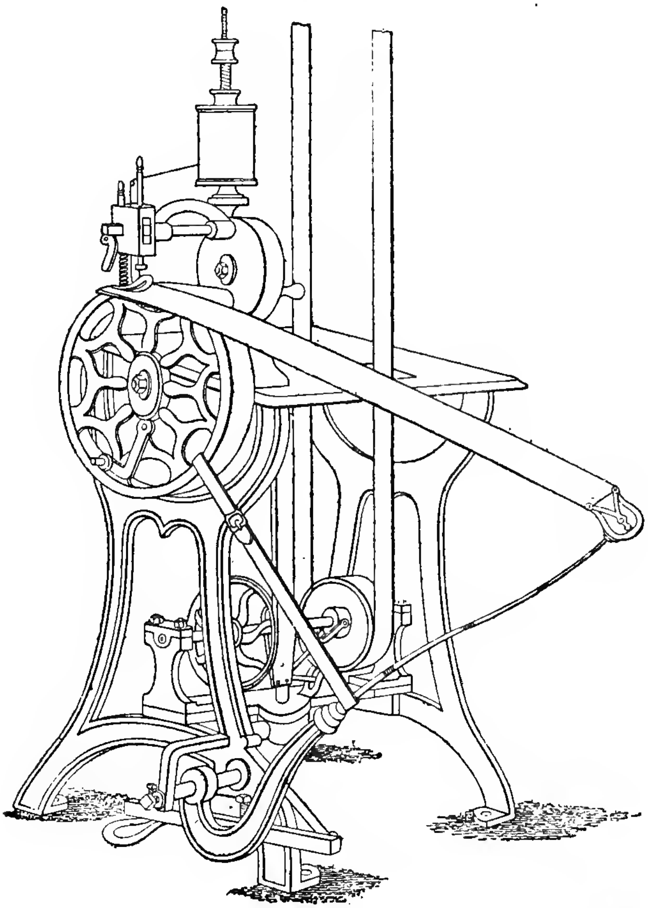


Singeing.—The next operation is "singeing," which consists in burning off the fine down on the surface of the cloth. It is essential for all those calico goods which are subsequently to be printed in good styles and to receive fine impressions.

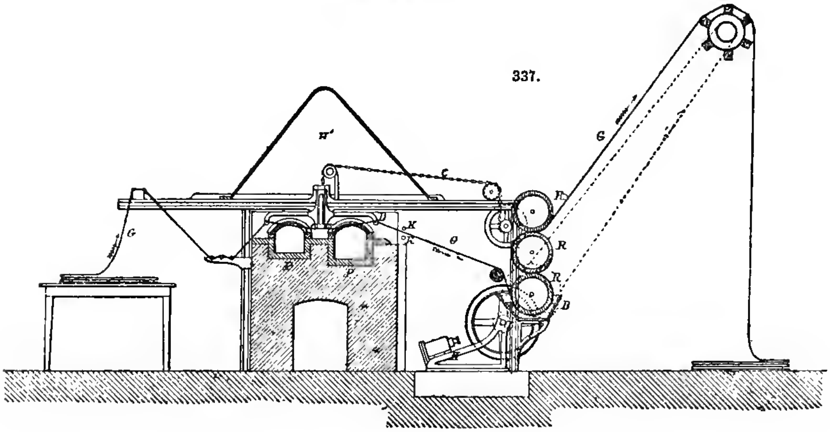
There are several methods of singeing in vogue, viz. by hot plate, by revolving hot cylinder, by coke flame and by gas flame. Fig. 337 represents the arrangement with two hot plates. The pieces are depressed on to and caused to pass rapidly over two red-hot plates P P. D represents an iron frame, carrying four bars for depressing the pieces, which can be raised or lowered by the chain C. G G is the passing piece. The two plates are heated by the same furnace, that which the cloth touches last getting the direct flame of the furnace, the other covering the return flue leading to the chimney. By this arrangement, the piece is only partly singed by the first plate, and so dried that the second plate completes the singeing to the best advantage. After passing the plates, the pieces are drawn between two rows of steam jets at K K, through a water trough B, and between the rollers R R, to extinguish any sparks which may adhere to the cloth. H′ is a hopper for leading away the products of combustion, and H is a small engine for driving the rollers R R. Formerly, thick cast-iron plates were used; they have been, however, almost universally replaced by cast-copper semi-cylindrical plates about 1 in. thick. These not only last much longer, being less liable to crack or get out of shape, but they are more easily kept free from the scales produced by oxidation, and present a smoother surface. With careful firing, such a plate may last several months without having to be mended. An essential point to be attended to is not to allow the edges of the plate to come into direct contact with the furnace flame; to avoid this, they should be made to rest well on the brickwork, or in a bed of clay. If clay is not used, a little sand along the exterior edge suffices to confine the flame beneath the plate.

A difficulty in plate singeing is to keep the plates at one regular strong red heat, the cooling action of the rapidly passing calico being very considerable. Hence, in some instances, the two plates are heated by separate furnaces. The difficulty is completely overcome by Worrall's revolving singeing roller, as fitted up in the bleaching department of Messrs. Edmund Potter and Co., and represented in Fig. 338. The ordinary semi-circular copper plate is here replaced

336.

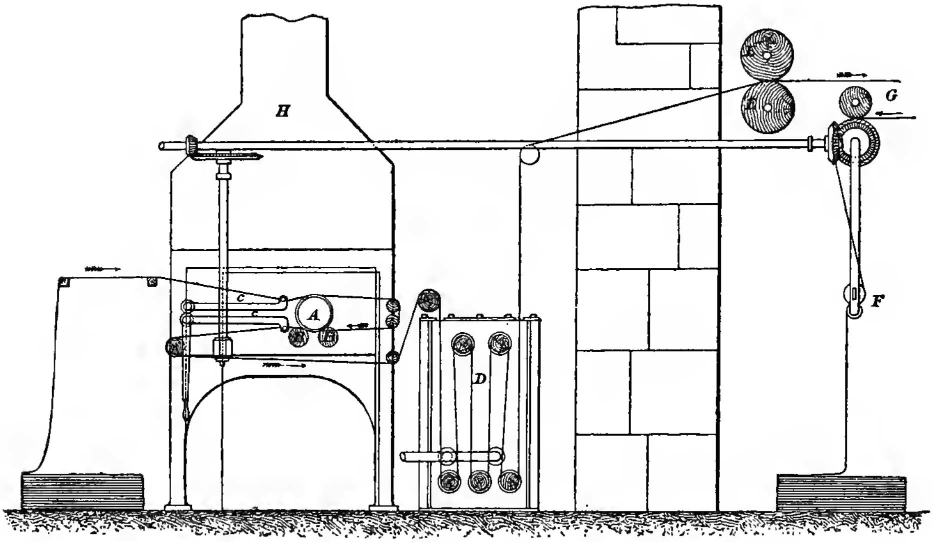


337.



by a cast-copper tube A, through which the flame from a furnace passes, heating its entire surface from end to end up to a good strong red heat. The tube rests with its bare weight on a pair of rotating pulleys B B at each end, from which it receives its own revolving motion by friction. The ends of the tube bear close up to the brickwork of the furnace and flues, and the draught is sufficiently strong to prevent the flame from appearing through the remaining chink. D is a steam box for extinguishing the sparks, E E a pair of traction rollers, F the folders. At G, the piece travels for some distance to cool, passes round a roller, and returns. H is the hopper leading to the chimney. If necessary, the pieces can be singed twice on one side with the same tube, by being made to pass above and below, and they can be made either to merely graze the tube or to wrap pretty considerably around it, by suitably arranged depressing bars C C. It is at once evident that the passing cloth comes continually in contact with a fresh surface of the revolving red-hot tube, and a regular even singe is the result. It may be remarked in passing that it is most economical to employ a system of mechanical stoking, such as Jukes'.

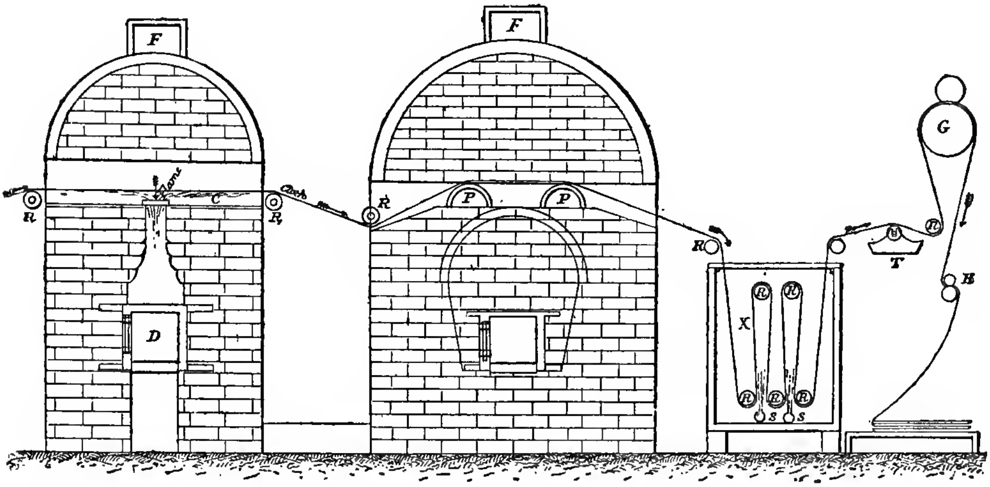
338.



A defect in the methods described is that, by being pressed against the plate or tube, the cotton hairs of the cloth are flattened down, which rather hinders them from being readily singed, and often necessitates a repetition of the operation. This defect is partly removed in the coke flame singeing arrangement, and wholly removed in that of the gas flame. Experience has shown that the coke flame alone is not sufficiently powerful; hence it is used, as at Messrs. Schwabe's bleach-works, in conjunction with the copper plate. Fig. 339 shows such an arrangement. It consists of a coke furnace D covered with a cast-iron plate having a long narrow slit in it, about 3 to 4 in. wide. By means of a fan, air is blown into the side of the ash-pit, all other openings to admit air being closed. When started, a sheet of clear, smokeless flame 1 to 3 ft. high rises through the slit, across which the grey cloth is rapidly passed, on to the hot plates P P, through the steam box X, over the damping roller at T, to be folded down at H. The flame is depressed and spread out at C, so that it covers 1 to 2 ft. in length of the passing fabric; and since the downy hairs are not flattened down, the dried and partially singed surface is thoroughly singed on the plates. In this, as well as in the arrangements mentioned previously, a hopper over both plate and flame leads off the products of combustion into the chimney by the flues F F. R R are rollers for guiding the cloth; G is a traction roller driven by an engine; S S are perforated steam pipes in the steam box.

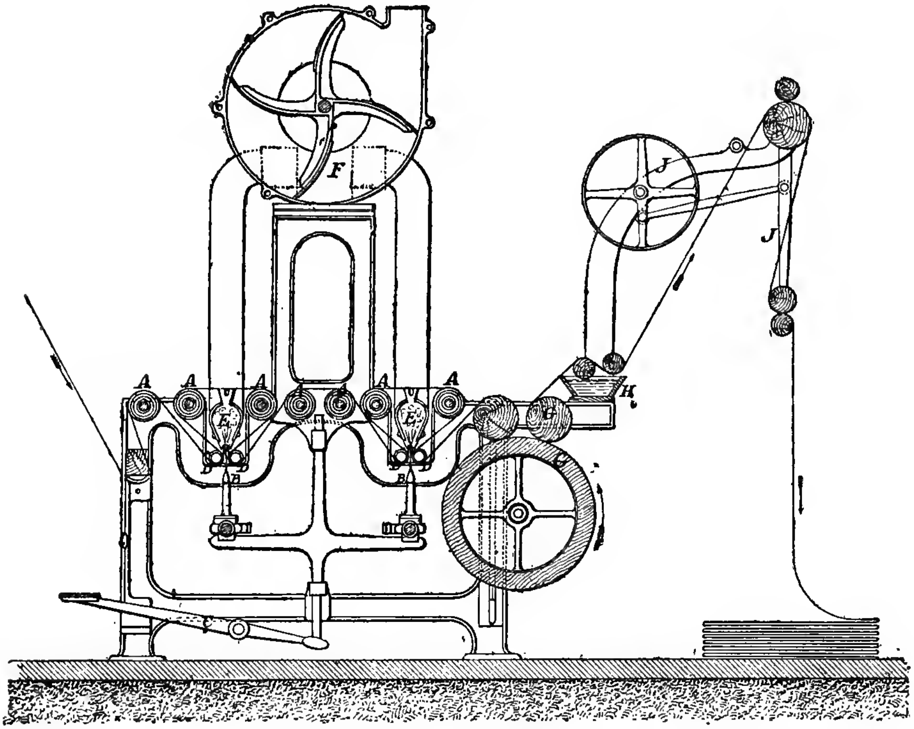
By far the most cleanly method of singeing is that with the gas flame. When first introduced, the flame was drawn through the passing cloth, and the general complaint was that the latter became too much impoverished, the nap in the centre of the fabric being burnt away. This defect is now completely removed, and the machine introduced by Tulpin, and further improved by Messrs. Mather and Platt, is a very effective arrangement. Fig. 340 represents this admirable machine. It consists essentially of two rows of ordinary gas burners B B extending across the width of the cloth to be singed. By means of two small metallic rollers D D, the cloth is brought into contact with each side of the flame, which is drawn up between the rollers by means of an exhaust fan F. The cloth is thus singed twice by the same flame, and, being presented to it while passing round the small rollers, the nap is made to stand up in the best possible condition for being singed off. The machine can be so threaded that the cloth may be singed twice on each side or four times on one side. The gas is mixed with air just previous to being burnt, and is so perfectly consumed that there is no deposition of carbon; the products of combustion also are carried off in a perfect manner by the canals E E. A A are guiding rollers, G G traction rollers; C is a lever, by means of which the gas flames can be lowered away from the cloth, in case of a stoppage; J J is the folding arrangement.

339.



As a rule, plate singeing is preferred for thick, heavy fabrics, and gas singeing for light cloths,

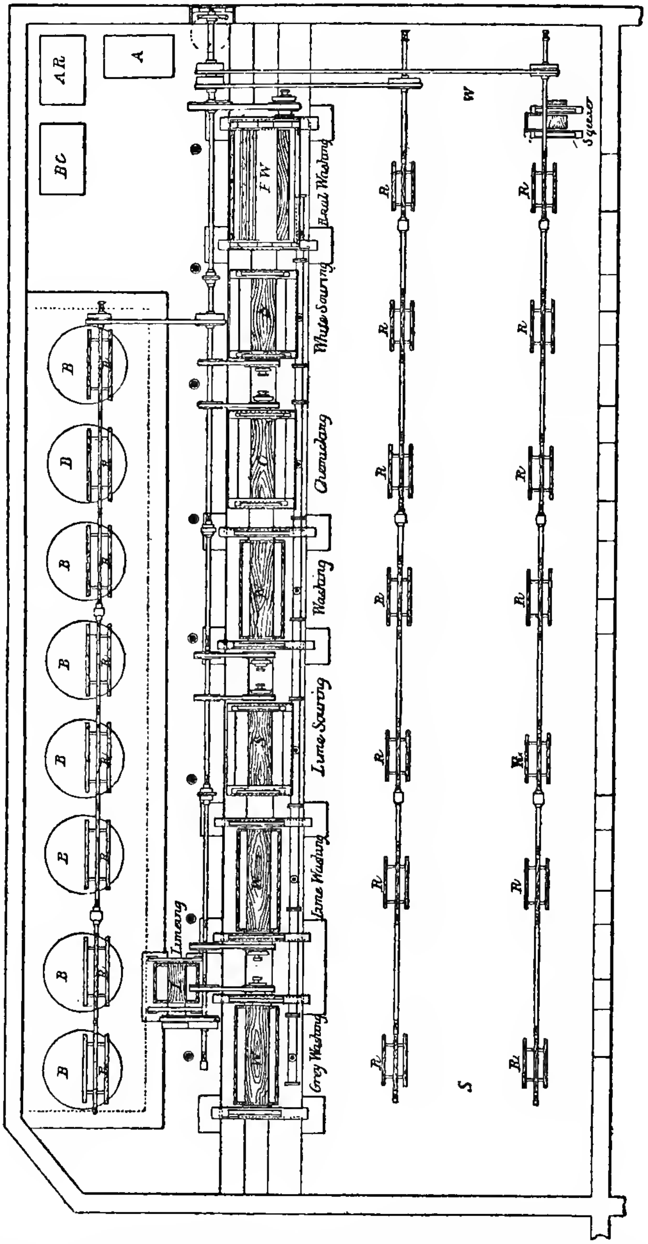
340.



such as muslins, jaconets, &c. The pieces may run at the rate of 150 to 200 single width pieces of 25 yds. each per hour, constant attention being requisite to regulate the speed for the different qualities of cloth, to prevent unequal, defective, or excessive singeing, and to guard against any accidents arising from fire. A very effective apparatus, in place of the water trough already mentioned for extinguishing sparks, is the small box fitted up in the interior with a few rollers and a perforated steam pipe. Through this box filled with steam, the cloth from the singe plates passes.

After working some time, a fine downy dust collects about the singeing machine and not unfrequently becomes ignited; hence every caution is necessary. The singeing-house should be frequently swept, and it is always safer to have the whole building fireproof and apart from the rest of the works.

341.



With regard to the consumption of coal in singeing, O'Neill states as the result of his experience with a double plate stove, heated by one fire and return flue, stove in good condition, and using ordinary engine coal, that 1 lb. of coal will singe fairly well 80 yds. calico $\frac{7}{8}$-yd. wide, two pieces going over at once. Schultz reports from Wesserling that 1 lb. coal singes about 65 yds. calico, with iron plate and once singed. Experiments conducted at Messrs. Salis Schwabe's works near Manchester, by Mr. Hill, with the coke flame and double copper plate, gave the following result:—

1 cwt. 3 qrs. 9 lb. coal }
1 „ 3 „ 0 „ coke } .. .. .. used per 1000 pcs. 25 yds. each.

This is equal to 1 lb. of coke and coal for 62 yds. calico, the singe being good and complete.

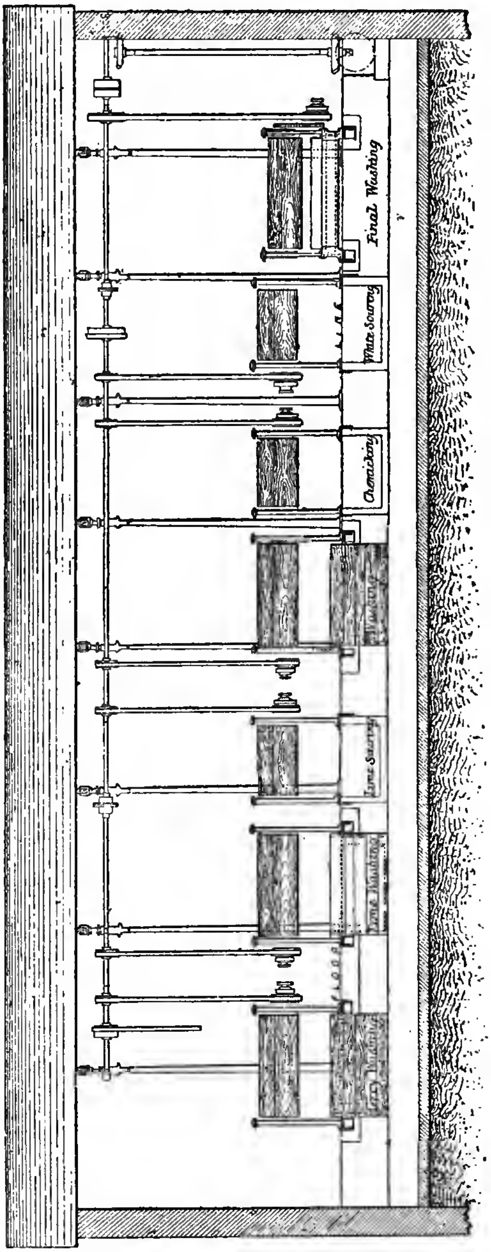
O'Neill gives the following data for the consumption of gas in Tulpin's machine:—

Works near Manchester	25,000 yds. $\frac{5}{8}$-yd. wide,	singed with	1330 cub. ft. gas.
Meyer (Steinbach Koechlin's) ..	25,000 „	„	„	1075 „
Schultz (Wesserling)	25,000 „	„	„	1192 „

Reckoning that 1 ton of coal yields 10,000 cub. ft. of gas, these figures show that 1 lb. of coal in the form of gas singes from 69 to 86 yds. of calico.

Before going into the details of the processes involved in bleaching proper, it will be well to describe the bleach-house and the machinery in use at the present time. Figs. 341, 342, and 343, show the ground-plan and elevations of a modern bleach-house for calico-printing in Lancashire, viz. that of Messrs. Alex. Drew and Sons. All the machines are driven by belting from an overhead shaft, by which means the noise from underground gearing, as used in many works, is reduced to a minimum, and the shafting is preserved from the corrosive action of weak acids, &c., splashing from the machines. This is probably the only bleach-house in Britain where the machines are driven in this manner.

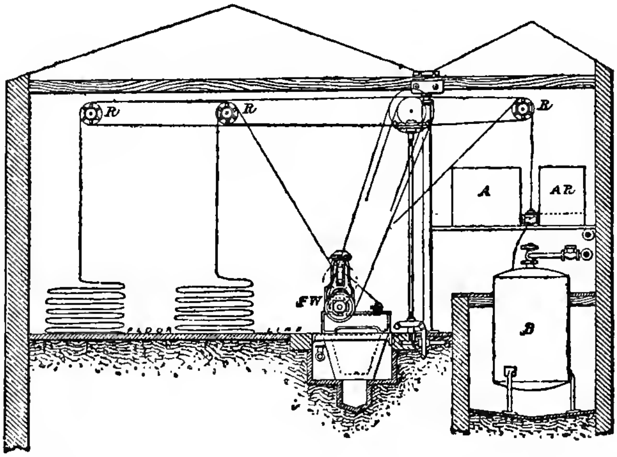
Another modern method adopted in establishments of good standing is to have each machine driven by a separate engine with double cylinders. It may be remarked in passing, that this plan of dispensing with shafting and gearing, and planting engines of this class to drive each separate machine, is carried out in all the departments of the bleaching and finishing processes. In this case, where steam pipes take the place of shafting, there is not the same liability of the whole works being suddenly brought to a standstill, as sometimes occurs when a main shaft breaks; and, besides the fact that each individual machine may be driven at the most suitable or productive speed, the occurrence of accidents to workmen engaged in oiling shafting is avoided, and it is reckoned that this method of distributing the motive power is ultimately more economical.



342.

In Fig. 342, B B B represent eight Barlow's kiers or boilers, which are worked in pairs. Behind these, running along the wall, are the steam, liquor, and water pipes, connected with the kiers, which stand surrounded by a high wooden stage to give easy access to the mouth of each kier, and to the various steam taps, &c. The boilers themselves are made of malleable iron plates, riveted together, and are supported upon cast-iron columns, sufficient in height to elevate the boilers from the ground and thus prevent corrosion. Above each boiler, is a winch R, with wooden spars, by which the pieces are drawn in filling the kiers; other winches are placed in suitable parts of the bleaching-house for piling the pieces on the floor. Here and there on the beams overhead, are fixed numerous so-called "pot-eyes"; these are rings about 4 in. in diameter, made of glass or glazed earthenware, fixed in wooden spars or otherwise secured, for the purpose of guiding the cloth, and preventing its coming into contact with iron pillars, &c. Close to the wooden stage surrounding the kiers, the various limeing, washing, souring, and chemicking machines are arranged, forming a single row, in the order in which they are required.

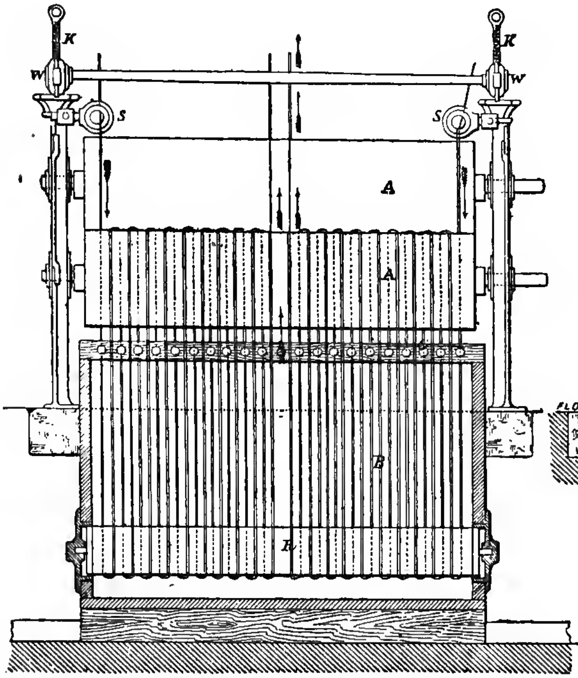
343.



The singed greys enter at the end S of the house, travel gradually, while going through the various processes and machinery, to the end W, and thence pass out in the bleached state, to be opened and dried elsewhere.

The "limeing machine" L consists essentially of a pair of heavy wooden squeezing bowls or rollers, set over a wooden trough fitted up with rollers; the set or pressure on the bowls is just sufficient to express excess of liquor, and thus prevent annoyance to the workmen when the pieces leave the machine. The pieces pass spirally through this machine, so that they are drawn four or five times (the more the better) between the squeezing rollers and through the milk of lime with which the trough is filled, thereby getting thoroughly saturated with the liquid. The dimensions of the trough are about 3½ ft. by 4 ft., depth 3 ft. W W are the washing machines, very similar in construction to the limeing machine, but much larger, the dimensions being about 9 ft. by 4 ft., depth 4½ ft. Figs. 344 and 345 give representations of this machine. A round roller R is fixed at a few inches from the bottom of the water-trough B below, the latter being provided with a plug-hole for emptying it, and two holes about a foot from the top at the sides for overflow. Two pieces simultaneously enter such a machine, at each end, and pass between the two squeezing bowls A A, down under the roller below, and up through the squeezing bowls again several times, being caused by guide pegs C to travel spirally towards the centre, and out. At the point of exit, the bowls are wrapped with a little lapping, to give the pieces an extra squeeze; a constant good supply of clean water flows into the trough at E, the overflow taking place where the pieces enter. To guide the pieces into the machine, there are two strong brass rings or "straining eyes" S, fixed to the framework above, but capable of being turned more or less obliquely, to give the proper degree of tension to the pieces on entering, a matter which must be well attended to, to avoid tearing the cloth, which is apt to occur if it is too slack; if too tight, on the other hand, the washing is not so complete. G is the water main, K and W are the screws, levers, and weights for regulating the pressure of the squeezing bowls against each other. C (Fig. 341) is the "chemicking machine," containing, when in use, a weak solution of bleaching powder or "chemick," and S S are the souring machines, in which the pieces are treated with dilute acid. Both these machines are identical in construction and method of working with the washing machines; they are, however, not quite so large, and the trough or pit below is made of stone instead of wood. The dimensions of the trough are about 6 ft. by 4½ ft., depth 3½ ft. For a final washing, the machine F W is excellent; it is known as Furneval's square beater, of which Fig. 346 is an enlarged section. In this, the pieces travel spirally as in the other machines; the water trough below, however, is much shallower, and larger in artificial area: 5½ ft. by 10 ft., depth 1¼ ft. It is fitted with two rollers, a square one A, immediately below the squeezing bowls; and a round one B with six ribs, at the other end. The square roller or "beater" revolves in a direction contrary to that of the pieces, which thus receive a violent flapping motion while moving in a state of tension along the surface of the water. In this manner, particles of dirt from the feet of the workmen, or which may have fallen accidentally on the pieces while piled on the floor, are effectually cleansed away. It may be remarked here that the floor of the bleaching house should be flagged, or of vitrified tiles, but never of wood; the roof should be well ventilated, especially immediately above the bleaching kiers. The "soda ash cistern," A, is a cast-iron tank 6 ft. by 3 ft. 10 in., depth 5 ft., capacity about 720 gallons, equal to 12 gallons per inch of depth. It serves for dissolving and holding in stock soda ash solution, made to stand about 50° Tw., equal to about 3 lb. soda ash 58 per cent. per gallon water. A R is the "ash and resin cistern,"

344.



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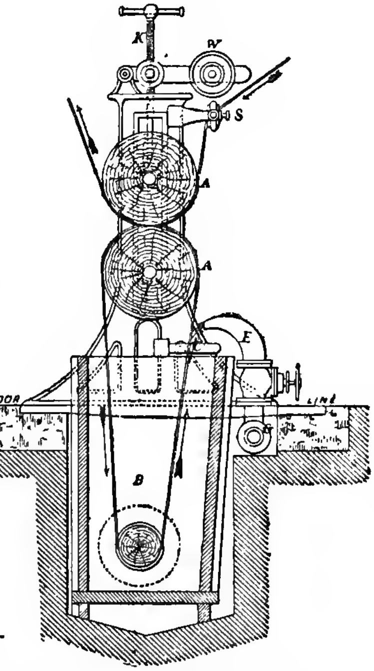

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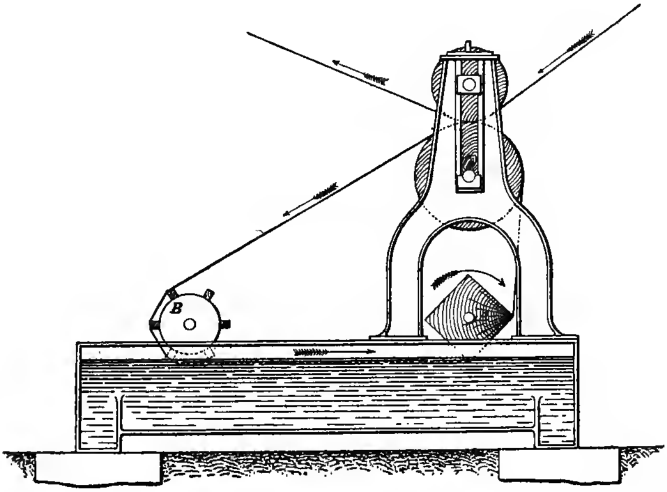
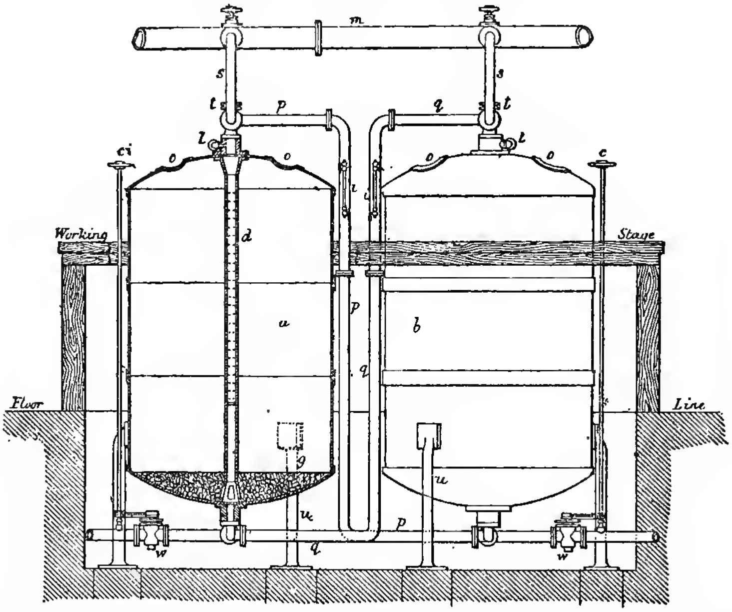


identical and connected by a pipe, with the soda ash cistern; it is used for making the "resin soap." Soda ash or caustic soda liquor from the cistern A is run into it, and the necessary quantity of resin is added; the cistern is filled to within a few inches from the top, and the whole is boiled by steam till the resin is dissolved. It is advisable to keep this liquor constantly at a gentle simmer, to ensure a perfect solution of the resin, and to prevent the solution from becoming gelatinous or separating, which it does if allowed to cool. It is usual to measure off the quantity of liquor required, both here and in the soda cistern, by means of an iron or wooden bar, marked with inch divisions. B C is the "batch cistern," similar to but larger than the two last, standing on a lower level, but still higher than the kiers. It serves for mixing each batch of resin soap or soda ash liquor with the necessary amount of water required to feed each pair of kiers. It is well to measure out even the requisite amount of water for the lime boil from this cistern. Though not absolutely necessary, the use of this cistern ensures regularity in the amount of liquid for each boiling, and any undissolved particles of resin or other irregularities may be readily detected, before running the liquors into the kiers.

Beneath these three cisterns, on the ground floor, are six stone cisterns: two for holding a solution of hydrochloric (muriatic) acid, two for sulphuric acid (vitriol), and two for a solution of bleaching powder (chemick). These cisterns are made of stone slabs, bolted together with iron rods on the outside. The joints of the hydrochloric acid cisterns are made tight by bands of indiarubber, let into grooves cut in the edges of the slabs; the joints of the sulphuric acid cistern are made with molten lead, and those of the chemick cistern with Portland cement. These cisterns are connected by pipes (iron for the chemick, lead for the acids) with the chemicking and souring machines, so that no carrying of the solutions is needed.

Fig. 347 shows the arrangement of a pair of Barlow's high-pressure bleaching kiers, one of which is given in section. *a b* are the kiers, of strong boiler-plate iron; *g* is the false bottom, consisting of smooth water-worn boulder stones, or a cast-iron grating, on which the pieces to be boiled are laid; *d* is the distributor, of wrought iron, acting also as a stay pipe; the upper portion is perforated and closed by a stop some distance from the bottom; the block *h* at the bottom is pigeon-holed to allow liquor to pass from the kier; above, the distributor is connected with the tap *t* (an ordinary two-way tap), by which steam is admitted from the main pipe *m*, and the reversing of which shuts off the steam communication and admits the liquor as it is expelled from the adjoining kier; *p p* is the pipe connecting the top of the kier *a* with the bottom of kier *b*, and *q q* is the pipe connecting the top of kier *b* with the bottom of kier *a*; *s s* are steam pipes from the main *m*; *l l* are the pipes and taps through which the liquors are introduced; *o o* are the manholes, through which the goods are entered and removed, and which can be closed by an iron plate held with two cross bars and screwbolts; *w w* are the draw-off taps connected with the pipes *p* and *q*, and which can be worked from the stage at *c c* in emptying the kiers of spent liquor, &c.; *i i* are glass gauges, by

347.



which it is seen when the liquor has passed entirely from one kier to the other; *u u* are short iron columns to support the kiers. The dimensions of these kiers are various. To hold each about 6000 lb. of cloth, the dimensions may be about the following: height, 10½ ft. at the side, with 10 in. bulge at each end, diameter, 7 ft. The distributors give an equal circulation of liquor or steam from the centre of the kiers through the goods all around, and prevent the goods from being pressed down into a compact mass, to which they are liable if the steam enters directly from the top; on the contrary, by this distribution, the pieces are kept rather in an open and loose condition, and the circulation of the liquors is thereby accelerated.

Without entering into every variety of detail which the fancy of each bleacher suggests, it will be sufficient to continue the description of the routine which the pieces to be madder-bleached have to pass through after singeing, premising that Barlow's kiers are used.

The following is a summary of the operations:—

1. Wash from the singe.
2. Lime into kier, boil with lime, and wash.
3. Sour and wash into kier.
4. Boil with resin soap, then with soda ash, and wash.
5. Chemick.
6. Sour, wash, squeeze and dry.

Washing.—The pieces are run direct from the usually adjacent singeing house into the bleaching house; guided, by means of the "pot-eyes," through the grey washing machine; and are piled on the floor. By this operation, the pieces, which till now have been in the open width, assume the rope or chain form, which they continue to have throughout the whole of the succeeding operations, till opened and dried. The friction of the squeezing bowls in the washing machine is sufficient to draw the pieces from a considerable distance, obviating the necessity of carrying them. A boy folds or plaits down the pieces on the floor, by means of a short stick, as they come from the washing machine. It is usual to allow them to lie thus in the pile over night to soften, though this is not absolutely necessary.

Limeing.—From the pile, the pieces are run through milk of lime contained in the "limeing machine" direct into the kier, being drawn by the winches immediately above the latter. Boys enter the kier, and continue to plait down the pieces with a short stick and to press them down with the feet till the kier is filled. The whole of the cloth in a kier is generally in two lengths, say 6000 lb. cloth, equal to about 1000 to 1800 pieces of 25 yds. each; by this arrangement, the kier is more quickly filled and emptied than if the pieces were in a single length. This plan of running two lengths of pieces at the same time is usual in working the washing and other machines.

When the pair of kiers are filled, the manholes are closed, and high-pressure steam is blown for about a quarter of an hour through both kiers, the pipes connecting the kiers being shut off and the draw-off taps below open. This drives out the cold water and air, and heats the goods through, only a small quantity of lime water being lost. On closing the draw-off and steam taps, and opening the liquor tap of one of the kiers, the necessary 1400 galls. of boiling water are drawn in from the batch cistern. In about twenty minutes, all the water has entered, and the liquor tap is closed. High-pressure steam is now again admitted into this kier (the two-way tap of the other kier being suitably arranged previously, to connect the two kiers), and the liquor is driven through the goods, out by the bottom, up the connecting pipe, and on to the goods in the second kier. In about twenty to thirty minutes, all the liquor is in the second kier. Both two-way taps are now reversed, steam enters the second kier, and forces the liquor through the goods in the same way back on to the goods in the first kier. This alternating process is continued for about seven hours, boiling with steam at 40 to 50 lb. pressure; the steam is then turned off, the manholes are opened, and the liquor is run off below. The two ends of the pieces are at once found, since they are tied to a piece of string, the end of which passes through the manholes and is attached outside.

Washing.—The pieces are now washed direct from the kiers through the "lime-washing machine," and piled down on the floor.

Lime Sour or Grey Sour.—They are then run from pile through the "lime-souring machine," and piled again on the floor, to remain in this state for from one to two hours. The souring machine is fed from the cistern with a solution of hydrochloric acid, at 2° Tw. If convenient, the pieces may be run direct from the lime boil, or "lime bowking," as it is often called, through the washing machine and at once through the souring machine without piling between. In this case, the two machines must run at exactly the same speed, and several yards of slack piece are allowed, before entering the souring machine, to drop on the floor, or preferably on to a travelling apron or endless band of wooden spars, driven in connection with the machines.

Washing after Lime Sour.—In this washing, it is most essential that every trace of acid be expelled from the cloth, hence the pieces are run from the pile through *two* washing machines successively, and direct into the kiers, to be boiled with resin soap.

Resin Boil or Ley Boil. First Boil in Resin Soap and Soda.—The pieces are admitted into the kiers exactly in the same way as for the lime boil. When the manhole lids are screwed on, steam is introduced to drive off air and cold water, and to heat up the cloth as before. The liquor tap of one kier is opened, and resin-soap liquor, equal to 770 lb. soda ash, 214 lb. resin, and 1400 galls. boiling water, is run in from the batch cistern. The quantity of cloth in the two kiers is supposed to be 12,000 lb. The kiers are worked by driving the liquor from one to the other, as before, for seven hours, with steam at 40 to 50 lb. pressure. The steam is turned off and the liquor is run out, its expulsion being aided by turning steam on again. When all the liquor is out, the steam and draw-off taps are closed, and the liquor tap is opened, to admit soda-ash liquor.

Second Boil in Soda Ash alone.—Soda-ash solution, equal to 120 lb. soda ash, and 1400 galls. water are run in from the batch cistern, and the boiling is continued, as before, for one or two hours. The steam is then shut off, the liquor is run out, and the manholes are opened.

Washing after Ley Boils.—The pieces are now run direct out of the kiers through the washing machine into pile. It is usual to pile the goods on a wooden stillage, to keep them clean.

Chemicking.—They are then passed through the "chemicking machine," which is fed from the chemick cistern with a clear solution of bleaching powder at $\frac{1}{4}^\circ$ to $\frac{1}{2}^\circ$ Tw., and are run into pile, in which state they remain two or three hours, or even over night. If convenient, the pieces may be run direct from the ley boil, through the washing and chemicking machines, without piling between.

White Sour.—The cloth is next run through the "white-souring machine," fed from the cistern with a solution of sulphuric acid at 2° Tw., and are again piled for two or three hours.

Final Washing.—The pieces are now washed thoroughly in the final washing machine, and are either piled on a wooden stillage, or, if convenient, are run direct through the squeezers, to be at once opened and dried.

It will now be well to inquire into the theory of the modern bleaching process as described above, and to notice slight modifications of details as practised in different bleach-houses, drawing attention, at the same time, to important points which must be remembered to ensure success.

Notes on Grey Washing.—Some bleachers omit the first washing, and run the dry greys at once through the limeing machine into the kier. Though not absolutely essential, this first washing is most advisable, especially where the limeing machine is small. Its principal object is to prepare the cloth for absorbing the milk of lime more evenly by making it thoroughly damp; at the same time, it removes some of the size and filling. Formerly, it was customary to steep the greys in a pit of cold water for two days or so and then to wash, before limeing, in order to ensure regularity in the lime boil; but this slow process has been gradually discontinued, and is not now usually practised. In this "rot-steeping," as it was called, the starchy matters of the size were rendered soluble by the fermentation which took place, and were thus easily washed out; there was, however, always the danger of "tendering" the cloth in this process, by the fermentation becoming too vigorous and attacking even the cotton fibre itself.

Notes on Limeing.—The chief point to be aimed at in limeing is to have the goods equally and thoroughly well saturated with the milk of lime; any defect in this respect is sure to give rise to stains that will be noticeable in subsequent dyeing. With some bleachers, especially where open low-press kiers are employed, it is usual to occasionally throw scoops-full of milk of lime over the pieces while being admitted into the lime kier, more particularly if the first washing has been dispensed with. The lime may be slaked immediately before using; the milk of lime as formed, and free from lumps, is gradually run into the limeing machine, during the passage of the pieces. The more preferable plan is to keep a stock of previously slaked lime in a stone cistern, from which the necessary quantity of pasty lime is ladled into a tub, there mixed with water, and run into the limeing machine. The quantity of lime used is variable according to quality of cloth. A good average amount is 5 lb. lime per 100 lb. cloth. The proportion of lime being absorbed by the cloth is readily ascertained by washing a yard or two of the limed cloth, and testing a given portion of the measured wash water with a solution of hydrochloric acid of known strength.

Notes on Lime Boil.—In filling the kier, the cloth should be evenly and well packed, especially at the sides, but not too tightly, so that the liquor may percolate as equally and easily as possible throughout the interior of the mass. During the boiling, the lime decomposes the greasy, resinous, and wax-like matters in the fabric, forming with them insoluble lime soaps; it also attacks the alumina, and modifies the brown colouring matter of the fibre, yet preserves the latter in a good, strong condition. The insolubility of the lime soaps formed is peculiarly advantageous, since the fatty matters are fixed the moment they become decomposed, and are thus prevented from floating about and accumulating irregularly through the cloth, thereby producing stains. In consideration of this property, coupled with the facts that the resinous matters are more energetically attacked by lime than by the caustic alkalies potash and soda, and that its price is low, lime is to be preferred for the first boil. When using low-press kiers with central puffer pipe, and with an insufficiency of water in the lime boil, the pieces at the top are liable to become tendered by the continued action of the heat and steam. In the same way, it may happen that the pieces lying at the bottom of the kier may be tendered, by the liquor having been forced up the puffer pipe to the top, and being so small in quantity as not to have time to circulate through the pieces to the bottom again. It is best to have the level of the liquor about 1 to 2 feet below the top of the pieces. With too much liquor, on the other hand, there is the risk of the pieces floating, and becoming entangled and damaged by tremulous boiling. During the lengthened boiling, water condenses and accumulates; care must therefore be taken not to run off too much or too little liquor. With Barlow's kiers, and with the injector kier to be afterwards described, when care is taken to add the proper measure of liquor at the beginning, there is not the same risk in this respect. During the lime boiling and subsequent washing, the cloth loses most of the starchy, insoluble and soluble, inorganic matters of the weaver's dressing. The resinous, fatty, and colouring matters still remain, but in an altered state, and the goods look even darker than before.

Notes on Souring.—The object of the souring after the lime boil is to decompose the insoluble lime soaps by removing the lime, besides dissolving out any excess of the latter adhering mechanically to the cloth. The acid also dissolves iron, copper, and other metallic oxides which may be present, and loosens the brown colouring matter of the fibre. Hydrochloric acid is preferable to sulphuric acid for this purpose, on account of the greater solubility of its lime salt; and care should be taken to keep up the strength of the acid to about 2° Tw., by having a regular flow from the cistern, since it is rapidly neutralized by the lime from the pieces. It is not advisable to add strong acid to the machine, for fear of its getting on to the cloth in its undiluted state, when, being more difficult to wash out, it might cause tender places. The following is an excellent method of keeping the sour at a regular strength, the hydrometer being of no use. A ¼ pint of the hydrochloric acid sour is taken from the machine while the pieces are running, and put into a small pot; a solution of caustic soda at 25½° Tw. is slowly added, from a graduated tube, with constant stirring, till a small piece of turmeric-dyed cloth, dipped in the mixture, shows, by its becoming slightly brown, that the acid is fully neutralized. The number of divisions of caustic soda required to effect this, gives the strength of the acid. The graduated tube should be a thick glass bottle of tubular form, each division showing ½ oz. measure of water. Divided in this manner, each ½ oz. measure of the caustic soda required represents 1° Tw. of hydrochloric acid, and the marks 1° Tw., 2° Tw., 3° Tw., &c., may be at once filed on the glass, beginning at the top. This testing is sufficiently exact, and can be performed in a few minutes by an ordinary workman. Soured goods should never be left lying long enough in a pile for the exposed parts to become dry, as the gradual concentration of the acid in such parts may tender them; hence exposure of the goods in this state to air currents should be avoided.

Notes on Resin Boil.—As already stated, the fatty matters remain in the cloth after the grey sour; but, being in the altered state of fatty acids, they are readily dissolved off, in the boiling with soda ash and resin soap, along with the brown colouring matters and everything else soluble in alkaline liquids. Formerly soap, soda, or potash was used. Soda ash or caustic soda alone is still used by those bleachers whose goods are sent white into the market; but for calico which is to be printed and dyed, the addition of resin soap is essential. Experiments made on the large as well as on the small scale, to be detailed afterwards, amply prove this. What the peculiar action of the resin is in this respect is not known. O'Neill states that he has used in its stead a coarse soft-soap made from sunflower oil, and with equal results. The subject is worth further inquiry. The date of the introduction of resin for bleaching purposes is not definitely fixed; from all accounts, it seems to have been about 1830. The usual amounts in vogue at present are: 1½ to 1¾ lb. of resin, and 4 to 4½ lb. soda ash (at 58 per cent.) per 100 lb. calico. With low-pressure kiers, steam at 8 to 10 lb. pressure, the boiling is continued twelve to fourteen hours; with Barlow's kiers, about seven to ten hours, according as the pressure of steam used is 50 lb. or 35 lb. per sq. in. With the new injector kier, three to four hours at 45 to 50 lb. pressure of steam is deemed sufficient. Some bleachers boil one to three hours with soda ash alone, both before and after the resin boil, using 1 to 2 lb. soda ash per 100 lb. cloth. The first soda-ash boil, though not absolutely necessary, is advisable, in order to neutralize any traces of acid accidentally left in the cloth through defective washing; and of course the soda ash liquor should be run into the kier without any previous heating of the goods by blowing steam through, as is the custom with Barlow's kiers, in admitting the resin soap and other liquors. Another plan is simply to run in the weak solution of soda ash till the goods are completely covered, and then to run it off again, before blowing steam through and introducing the regular liquor. This is called "sweetening" the goods. If the water of the bleach-house contains any considerable quantity of lime, a slight soda-ash boil, both before and after the resin boil, prevents the deposition of a lime soap on the cloth, and, in these circumstances, is advisable. The second soda-ash boil, though sometimes omitted, also ensures a complete removal of grease, and especially any particles of resin which might remain. That resin is not unfrequently left in the cloth is proved by its appearance on the scrimp rails, expanders, &c., in front of the white drying machines, after a large number of pieces have passed over; hence the necessity of seeing that the resin is well boiled with a sufficiency of soda ash previous to putting it into the kier. Another very good method of making the resin soap is as follows:—the resin cistern is made up with liquor in the following proportions; 33 gallons water and 33 gallons caustic soda at 70° Tw. are heated to the boil, 220 lb. resin are then added and stirred for a quarter of an hour or more, the boiling is continued for six hours till the resin is completely dissolved. The alkaline liquor is made strong enough to keep the undissolved resin afloat, otherwise the latter collects as a pasty mass at the bottom of the cistern, and is not so readily dissolved. The cistern is, of course, filled up in the proportions given, these only representing the amount required for one boiling of 12,000 lb. cloth, for which there would also be used, along with the resin soap just given, soda-ash liquor equal to 450 lb. dry soda ash.

When the goods have been boiled in soda ash, it is very important not to leave them lying in the kier for any length of time after the liquor has drained away; they should be washed as soon as possible, since they are very liable to get iron stains at this stage, either from the sides of the kier or otherwise. There is no fear of the goods being tendered during a soda-ash boil, unless, perchance, the ash contains caustic soda, and then, if there is a sufficiency of liquor, it is entirely prevented.

Notes on Chemicking.—It is the bleaching-powder solution which is essentially the whitening and colour-destroying agent, and its application is absolutely necessary, after the removal from the cloth of all fatty and other foreign matters, in order to destroy the slight creamy colour still remaining. Before its use was properly understood, it was often applied previously to the removal of the fatty impurities, and oxidizing these, and forming insoluble lime soaps, it produced stains which withstood even an acid bath. Olive and other oils, if boiled with a sufficient amount of bleaching-powder solution, give a white, solid, wax-like body totally insoluble in boiling caustic alkalies or in strong acids. Dry chlorine gas in the dark does not in general decompose dry colouring matter; light, and especially moisture, are necessary to produce reaction. The bleaching effect of the chemicking takes place principally while the goods are lying saturated with the weak solution of bleaching powder, which is partly decomposed by the carbonic acid of the air, as well as by the cotton fibre itself. The bleaching is completed on the subsequent treatment with acid, the disengaged chlorine gas destroying the very last traces of colour. It is advisable never to use the "chemick" so strong that chlorine or hypochlorous acid gas is evolved in any considerable quantity in souring, and the best method is to wash the goods between chemicking and souring. Care must be taken to have the bleaching-powder solution perfectly free from undissolved particles, otherwise holes in the cloth are sure to result; neither must it be too strong, too warm, nor too long in contact with the cotton, for the same reason. Goods which have been properly heated with lime, acid, and alkali, should only require a very weak chemicking to make them of snowy whiteness. Should a stronger treatment be necessary, it is better to give the goods two or even three treatments with weak chemick than to risk a strong solution. It is usual and best to chemick cold; with a luke-warm solution, a better white is obtained and more quickly, a warm weak bath acting as well as a cold strong one. If the bleaching-powder solution is only a little too strong, the cloth becomes rotten, and, if heated, it would be gradually quite destroyed, since, as Payen has shown, cellulose dissolves in such a solution with evolution of carbonic acid gas even at 50° (122° F.). The usual strength of chemick liquor is ¼° to ½° Tw. When the pieces have been running in this liquor for some time, the use of the hydrometer would be misleading, hence a rough and ready, but tolerably exact method of testing is adopted. The following test solutions are required:—

Arsenic Solution.—3½ grains arsenious acid are dissolved by boiling in 1 quart caustic soda at 16° Tw., then cooled.

Indigo Indicator Solution.—1 measure extract of indigo of good quality, 2½ measures sulphuric acid at 144° Tw., 5½ measures water, mixed well and filtered: 200 grain measures of this indicator should require 100 grain measures bleaching liquor at ½° Tw. to decolorize it.

Test Solutions for use.—(*a*) 2 measures arsenic solution, 7½ measures water, 4 measures indigo indicator solution, = 13½ measures. (*b*) 1½ measure arsenic solution, 11½ measures water, ½ measure cochineal liquor at 6° Tw., = 13½ measures. The cochineal liquor at 6° Tw. is made up with 1 measure of a watery solution of cochineal at 12° Tw. and 1 measure of methylated spirit, this is to prevent the solution from moulding. In testing, about ¼ of the chemick liquor is used to decolorize the cochineal. Either of these test solutions can be used with the same graduated phial, which should be of thick glass and cylindrical, about 8 in. long and 1⅜ in. in diameter. This phial should be graduated empirically by a chemist in the laboratory, so that each division shows $\frac{1}{10}$° Tw. of bleaching liquor, thus:—

Strength of Chemick Used.	Mark made on Phial.	No of gr. meas. Chemick required }	to bleach	{ No. of gr. meas. Test Solution.	Measure where Marks are made on Phial.
deg. Tw.					gr. meas.
$\frac{2}{10}$	2	1125	..	100	1225
$\frac{3}{10}$	3	750	..	100	850
$\frac{4}{10}$	4	562½	..	100	662½
$\frac{5}{10}$	5	450	..	100	550
$\frac{6}{10}$	6	375	..	100	475
$\frac{8}{10}$	8	281¼	..	100	381¼

The highest number, 8, is of course marked below.

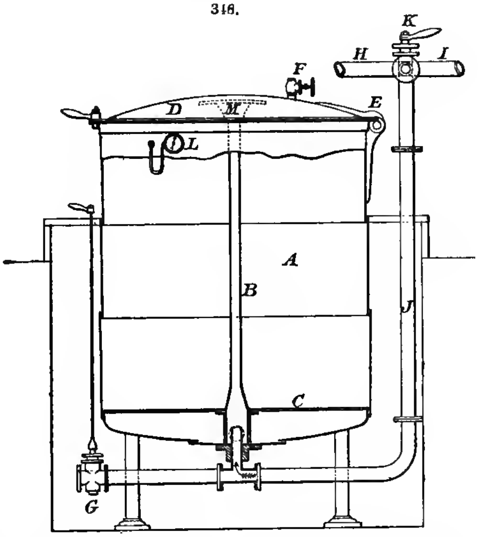
In order to test the strength of the chemick liquor of the machine, 100 grain measures of either of the test solutions is put into the graduated phial, and some of the chemick liquor is added by degrees (shaking the mixture after each slight addition), till the test solution is exactly decolorized. The number of the division at which the chemick liquor stands in the graduated phial gives the strength of the liquor in tenths of a degree Twaddle. The whole operation is extremely simple, and can be performed in half a minute or so, by the workman or boy attending the machine.

The most usual and rapid plan of applying the chemick is by means of the chemicking machine, as already described. Another method also adopted, principally by market bleachers and for fine cloths, muslins, &c., is to pile down the pieces in large stone cisterns provided with false bottoms. The chemick is pumped up by a lifting or a centrifugal pump from a well below, it flows into wooden perforated troughs or trays (drainers) placed above the cisterns, and is allowed thus to circulate through the cloth down into the well below, to be again pumped up, and so on during two to four hours.

Notes on White Sour.—For the "white sour," either hydrochloric or sulphuric acid may be used. Some bleachers prefer the latter, from its being less liable to contain iron. If this white souring is omitted and the goods are only washed after chemicking, they seem still to retain somewhat of a colourable substance, since such goods, when stored in the warehouse for some time, acquire gradually a yellowish or creamy tinge. To avoid this as much as possible, the last passage in weak acid is given, to dissolve the colouring substance which the chemicking has merely destroyed, together with any traces of iron which may still remain. It is needless to remark that the final washing must be thorough; here, as in all washing, a rapid change of water is more essential than volume.

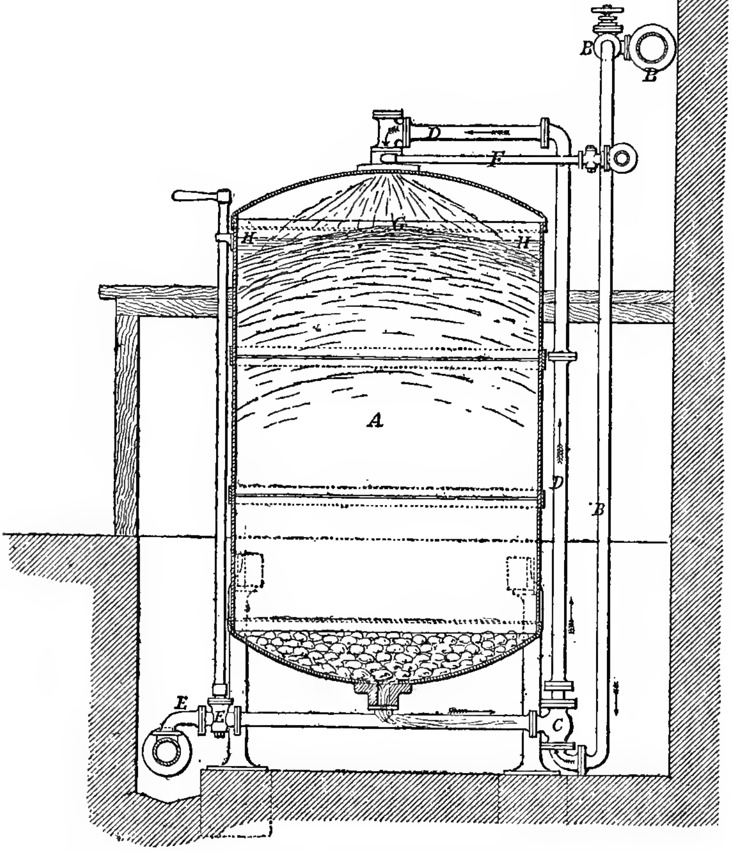
Referring to the boiling with lime, resin soap, &c., the great object sought after is to have every portion of the goods well boiled, and subjected to the action of the liquors; to effect this purpose, many varieties of boiler or kier have from time to time been invented. Besides Barlow's kier, already described, there is also Pendlebury's kier, identical in principle with Barlow's, and well adapted for bleachers on a smaller scale. The only difference is that one of the pair of kiers is smaller, so that a smaller quantity of cloth can be bleached at once; only the larger kier is filled with goods, the smaller one being required to contain the liquor between its passages through the goods. Still in use, especially for muslins, is the ordinary low-press kier, for working with steam at 3 to 10 lb. pressure. Fig. 348 represents this kier. A is the boiler, the lower part of which is given in section; B is the vomiting or puffer pipe, with "bonnet" M at the top; C is the perforated false bottom; D is the lid working on the hinge E and lifted up by attached

348.



chains, not shown in the figure; F is an air-valve; L is a steam-pressure gauge; H and I are the steam and liquor pipes, connected by a two-way valve K with the pipe J, leading to the bottom of the puffer-pipe; G is the draw-off valve. The usual method of working this apparatus is to blow steam through the goods for one and a half to two hours, then to enter the liquor and boil for ten to twelve hours. During this boiling, the liquor which collects below the false bottom is forced by the steam up to the top of the vomiting pipe and is there spread by the bonnet over the pieces. This action is of an intermittent character, since, after each ejection of the liquor, the force of the steam must accumulate till it is able to overcome the weight of the column of water in the puffer pipe. The most recently introduced is the injector kier of Messrs. Mather and Platt, Manchester, which bids fair to displace those mentioned. Fig. 349 gives a section of it; A is the

349.



boiler or kier, filled with cloth to G; H H is liquor collected on the top of the pieces; B B are the steam pipes, F the liquor pipe, D the circulating pipe; C is the injector; and E E the draw-off valve and waste pipe.

In the sense of there being a rapid continual circulation of goods through the bleach-house, without any long period of exposure on the grass, as was formerly the case, it may perhaps be considered that the bleaching process of to-day is continuous, though the term is not strictly correct, the operations being still intermittent. Attempts have been made in this direction; but with little or no commercial success.

Besides the bleaching agents at present employed, many others have at different times been proposed, e. g. silicate of soda, stannate of soda, petroleum oil, &c. Tessié du Mothay and Rousseau patented, in 1866, the use of permanganate of soda for bleaching, which, though in some styles of work it has had a share of success, has not by any means been able to supplant the bleaching powder. Various patents, too, have been taken out for the use of ozone, and, at the present time, (1879), a liquid preparation called "chlorozone," discovered by M. D. Brochocki, of Paris, is being introduced to the bleachers throughout Britain by the makers, Messrs. Nathaniel Holmes and partners, Warrington and London. Chlorozone is obtained by saturating a cold, caustic alkaline ley with a mixed current of hypochlorous acid and air. Its action in bleaching is similar to that of a solution of chloride of lime or soda; but it is said to possess a much greater decolouring power, without having any injurious action on the fibre. No doubt ozone has been the real bleaching agent, from the earliest times (when the cloth was exposed on the grass to air, light, and moisture) until now. It is known that ozone is constantly present to a greater or less degree in the atmosphere. In the rapid bleaching process of to-day, the general opinion is, that the really active agent is the ozone produced by the bleaching powder, the use of which simply replaces the old custom of exposing on the grass. According to this view, chlorine gas is evolved by the decomposition of the bleaching powder, it combines with the hydrogen of the water, and oxygen in the nascent state (ozone and antozone) is liberated. Where, however, the goods are washed between chemicking and souring (and this is decidedly the best plan), it is hypochlorous acid which is evolved, and, by its rapid decomposition into chlorine and oxygen (ozone), bleaches with double power, the chlorine liberating additional oxygen (ozone) from the water present. It must always be remembered that in these reactions there is a production of hydrochloric acid in the nascent state within the fibre, to which, probably, the tendering action of the chemicking is in a large measure due.

At one time or another, every bleacher has his attention involuntarily directed to the annoying occurrence of stains. Some of these are visible in the white cloth when dried, others only after being dyed. The former class may be simply dirt from the workmen's shoes, or other obvious causes easily remedied. Others may arise from dirty water being driven into the kiers along with the steam, from loose packing in the pipe-joints, grease, &c. This last may come from the stuffing-box of the piston-rod of the engine, from steam drying cylinder stuffing-boxes, &c. Iron stains often arise from rusty nails in the roof or on stillages, and from the inner sides of the kiers, to avoid which it is customary to whitewash the interior of the kiers with lime from time to time. Iron supports, brackets, &c., under the roof should be occasionally painted, and all wooden stillages should be pegged with wood instead of using nails. Holes, cuts, tears, &c., form another class of damages more or less frequent in all bleach-houses. As a rule, their occurrence to any large extent shows careless working or defective machinery. Some may arise from rubbing of the pieces against the sides of the kier through tremulous boiling, others may be caused by pebbles and cinders from the water, and even nails, becoming accidentally imbedded in the bowls of the washing machines. Cracked pot-eyes, and wooden rails worn to a cutting edge by the lengthened friction of the pieces in transit, are also occasionally a source of damage, and should be periodically examined.

With regard to the alteration in weight, length, and breadth of calico pieces during the present processes of singeing and bleaching, the following are the results of personal observation.

One piece best cloth, 72 reeds, 36 in. broad, 25 yards long, and weighing 5 lb. 4 oz., showed:—

Loss of weight in singeing	3 to 4 oz. =	3·5 to 4·7 per cent.
Loss of weight in bleaching	10 to 12 oz. =	11·9 to 14·2 ,,
Loss in breadth ,, ...	2½ in. =	6·9 ,,
Gain in length ,, ...	¾ to 1 yard =	3·0 to 4·0 ,,

As already stated, the loss of weight in bleaching may vary considerably, according to the quantity and quality of the sizeing which is in the warps.

O'Neill gives the following interesting results of experiments in testing the tensile strength of the cotton threads before and after bleaching, by measuring the strain required to break the thread. The calico experimented on was of good quality, and had sixteen to eighteen threads to the ¼ inch; the length of thread for testing varied from 0·25 in. to 2·1 in.:—

	Average Weight required to Break a Single Thread.	
	Before Bleaching.	After Bleaching.
	grains	grains
No. 1 cloth, weft threads	1714	2785
No. 1 ,, warp ,, ...	3140	2920
No. 2 ,, ,, ,, ...	3407	3708
No. 3 ,, ,, ,, ...	3512	4025

"It is seen," says the author, "that in two cases out of three, the warp threads are stronger after bleaching than before, and in one case a little weaker. All that can be safely concluded from numerous trials made, is that the tensile strength of the cotton yarn is not injured by a careful but complete bleaching, and probably it may be strengthened by the wetting and pressure causing a more complete and effective binding of the separate cotton hairs or filaments, the twisting together of which makes the yarn."

An idea of how little change has been made in the madder-bleaching process during the last thirty years, will be gained from the following sketch of the process as carried on at the celebrated print works of Messrs. Thomson, Clitheroe, Lancashire, in 1845 and 1850, in comparison with the process of to-day, as conducted at the equally famous print works of Messrs. W. Crum and Co., near Glasgow, and with two other processes also in actual use.

1845 *Process (Thomson's).* 12,000 *lb. Cloth. Low-press Kiers.*

1. Wash after singeing.
2. Lime boil, 430 lb. lime, 10 hours boil, wash.
3. Lime sour, hydrochloric acid 2° Tw., 1 hour steep.
4. First ash work, 215 lb. soda ash, 10 hours boil, wash.
5. First chemick, 137 lb. bleaching powder in solution at ½° Tw., 10 hours steep.
6. First white sour, sulphuric acid 2¼° Tw., 1 hour steep, wash.
7. Second ash work, 130 lb. soda ash, 10 hours boil, wash.
8. Second chemick, 70 lb. bleaching powder in solution at ½° Tw., 5 hours steep.
9. Last white sour, sulphuric acid 2½° Tw., 1 hour steep.
10. Wash, squeeze and dry.

1850 *Process (Thomson's).* 12,000 *lb. Cloth. Low-press Kiers.*

1. Wash after singeing.
2. Lime boil, 680 lb. lime, 10 hours boil, wash.
3. Lime sour, hydrochloric acid 2° Tw., wash.
4. Resin boil, 770 lb. soda ash, 214 lb. resin, 10 hours boil, wash.
5. Chemick, bleaching powder solution at ¾° Tw., 6 hours steep, wash.
6. White sour, hydrochloric acid 2° Tw., 2 hours steep.
7. Wash, squeeze and dry.

1879 *Process (Crum's).* 12,000 *lb. Cloth. Barlow's Kiers.*

1. Wash after singeing.
2. Lime boil, 500 lb. lime, 10 hours boil, 35 lb. pressure, wash.
3. Lime sour, hydrochloric acid 2° Tw., wash.
4. Resin boil: 1st. Sweeten with 120 lb. soda ash, 1600 gall. water.
   2nd. 450 lb. soda ash, 220 lb. resin, 33 gall. caustic soda at 70° Tw. (= about 120 lb. solid caustic soda at 61½ per cent. $NaHO$), 14,000 gall. water, 10 hours boil, 35 lb. pressure, wash.
5. Chemick, bleaching powder solution at ¼° Tw., wash.
6. White sour, sulphuric acid at 2° Tw., pile 1 to 3 hours.
7. Wash, squeeze and dry.

Another 1879 *Process.* 12,000 *lb. Cloth. Low-press Kiers.*

1. Wash after singeing.
2. Lime boil, 600 lb. lime, 10 lb caustic soda (solid), 10 hours boil, wash.
3. Lime sour, hydrochloric acid, 2½° Tw., wash.
4. Ley boils: 1st. 120 lb. caustic soda (solid), 3 hours boil.
   2nd. 560 lb. soda ash, 120 lb. caustic soda (solid), 320 lb. resin, 120 gall. water, 10 hours boil, water 16 in. above the false bottom.
   3rd. 120 lb. caustic soda (solid), 3 hours boil, wash.
5. Chemick, bleaching powder solution ½° Tw., wash.
6. White sour, sulphuric at 2° Tw., pile 1 to 3 hours.
7. Wash, squeeze and dry.

Another 1879 *Process.* 12,000 *lb. Cloth. Low-press Kiers.*

1. Wash after singeing.
2. Lime boil, 500 lb. of lime, boil 12 hours, wash.
3. Lime sour, hydrochloric acid 2° Tw., wash.
4. Ley boils: 1st. 170 lb. soda ash, boil 3 hours.
   2nd. 430 lb. soda ash, 190 lb. resin, 95 lb. caustic soda (solid), boil 12 hours.
   3rd. 190 lb. soda ash, boil 3 hours, wash.
5. Chemick, bleaching powder solution ¼° Tw.
6. White sour, hydrochloric acid 2° Tw., pile 1 to 3 hours.
7. Wash, squeeze and dry.

As there are differences in the quantities of stuffs used in the present bleaching processes, the following account of experiments carefully conducted both on the large and small scale will be of interest.

To test the effect of varying quantities of lime, several lots of cloth, each 2800 lb. weight, were boiled for 10 hours with: *a*, 100 lb.; *b*, 150 lb.; *c*, 160 lb.; *d*, 200 lb.; *c*, 260 lb. lime, in the usual way. The various lots were then soured, washed, boiled with soda ash, chemicked, soured, and washed, as usual. From each lot, a small piece of the cloth was taken and dyed in a madder bath for 2¾ hours, boiling during the last ¼ hour. All the fents became dyed a pink shade; *b*, *c*, *d*, *e*, were less tinged than *a*, there being little difference between *c*, *d*, and *e*. Result: use 150 to 160 lb. lime per 2800 lb. cloth.

Experience shows that light goods require less lime than this quantity. Cloth boiled on the small scale with lime for 5, 10, 20 hours, and treated as before, showed in subsequent dyeing no difference; hence 10 hours' boil may be deemed sufficient for a kier full of cloth, using low pressure.

To test the action of resin soap, the following experiments were made:—

1. On the small scale, the cloth was boiled with lime, soured, boiled twice with soda ash, each time for 12 hours; the first soda boil was with varying quantities of soda ash, viz. 8 oz., 4 oz., 2 oz., and 1 oz. soda ash per gall. water, then washed; and the second soda boil for all four trials was made with a soda solution at 2 oz. soda ash per gall. water. All the trials were then chemicked, soured, well washed, and dyed with madder. Result: all the fents dyed a reddish tinge.

2. Two fents, limed, soured, and washed, were boiled for 12 hours with solutions of caustic soda, containing 6 oz. and 3 oz. solid caustic soda respectively; both fents were then boiled in a solution of 2 oz. soda ash per gall. water for 10 hours, washed, chemicked, soured, washed, and dyed with madder. Result: the fents were tinged red even more than in the first experiment.

The above experiments showed that the cloth, when boiled with the strongest solutions either of carbonate of soda or caustic soda, dyed up deeper and redder in the madder bath than when boiled with the weaker solutions, and proved that whatever the proportion of soda used it is not able to remove that principle in the cotton fibre which attracts the dye in a madder bath. This result was completely confirmed by experiments made on the large scale, taking 2800 lb. cloth, and 50 lb., 100 lb., 150 lb., 200 lb. soda ash (without resin) for four separate trials.

If, in any of the foregoing experiments, a little resin soap was added to the soda boil, it was found that after chemicking, souring, and washing, the cloth no longer dyed in a madder bath, but became merely superficially soiled and tinged of a delicate pink shade. The resin soap, added to the soda, seems therefore not only to dissolve off better the free fatty acids; but also to dissolve off that waxy, resinous, or albuminous principle which attracts the dye of the madder bath, and which a boiling in soda alone does not affect.

3. In order to determine the best proportion of resin to employ, the following trial was made. Cloth which had been previously limed, soured, and washed, was divided into four fents, and each was boiled separately for 12 hours with the following solutions of resin and soda in 1 gall. water:—

a. 1 oz. soda, ½ oz. resin.
b. 2 oz. soda, 1 oz. resin.
c. 2 oz. soda, 2 oz. resin.
d. 4 oz. soda, 3 oz. resin.

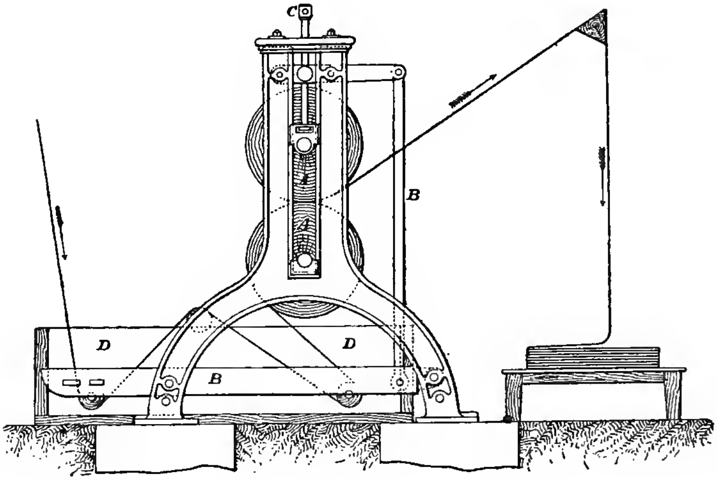
The fents were then boiled for 1 hour in a solution of 2 oz. soda per gall. water, washed, chemicked, soured, washed, and dyed with madder. Results: *a* was a pretty good white, *b* and *c* were the best white, *d* was brownish, not a good white. These were corroborated by experiments made on the large scale with 2800 lb. cloth. If 50 lb., 60 lb., 62 lb. resin were used, the dyed white was good, while the use of 75 lb., 80 lb. and more resin gave a dirtier and browner white after dyeing.

The final operations of the madder-bleach, viz. Squeezing, Opening, and Drying may now be discussed.

Squeezing.—The squeezing rollers or "squeezers," for expressing the greater part of the water retained by the pieces from the final washing, are represented in Fig. 350. This machine consists of a pair of hard wooden bowls or rollers A A, generally of birch or sycamore, about 18 in. or more in diameter, and about 18 in. in length; sometimes the bottom bowl is made of highly compressed cotton. Compound levers, weight, and screws B B and C serve to regulate the pressure of the bowls against each other; the latter are driven by cog-wheels connected with shafting, or preferably by an attached independent small engine. The pair of bowls are usually set over a small water trough D D, through which the piece passes before entering the nip. Through this machine also, two lengths of pieces generally pass at the same time, not spirally, as in the washing machines, but each getting only a single nip. One of the principal drawbacks in this squeezer is the comparatively rapid destruction of the bowls, the attendant inconvenience of stoppage, and the expense of renewing or turning up the bowls in a lathe.

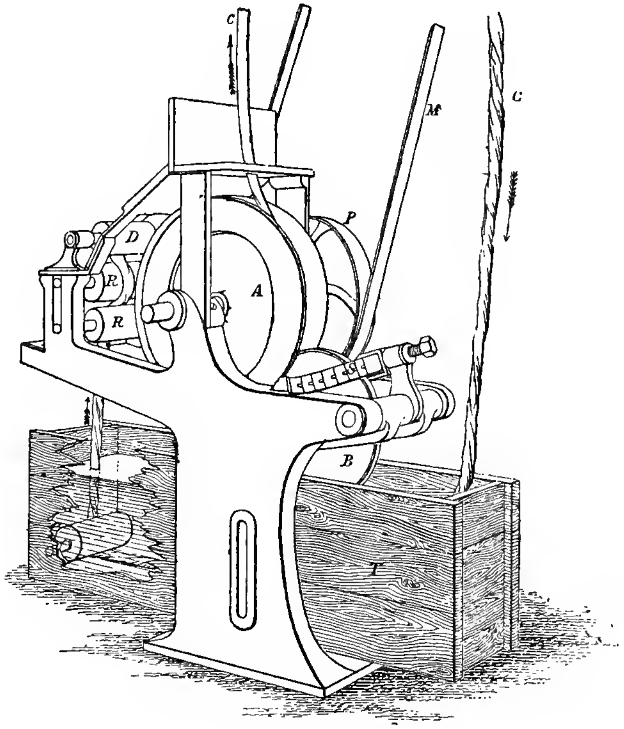
The above form of squeezer is being rapidly superseded by the more durable one introduced by Wm. Birch. The elasticity of the rollers, so indispensable when the cloth strand is spread out in a flat layer of necessarily uneven thickness, becomes superfluous when the strand is confined in a narrow groove, in which the layer of cloth must needs arrange itself evenly. This grooved form is the one adopted by Mr. Birch, the rollers being of brass, a material far more durable, of course, than wood or other elastic substances. This form of roller has further the very important advantage that the even layer of cloth thus obtained in it permits a reduced pressure to be used, since all the parts of the layer are evenly affected and do not, as in the above-mentioned squeezer, necessitate an over-pressure for the thick central part in order to get some little for the thin sides.

350.



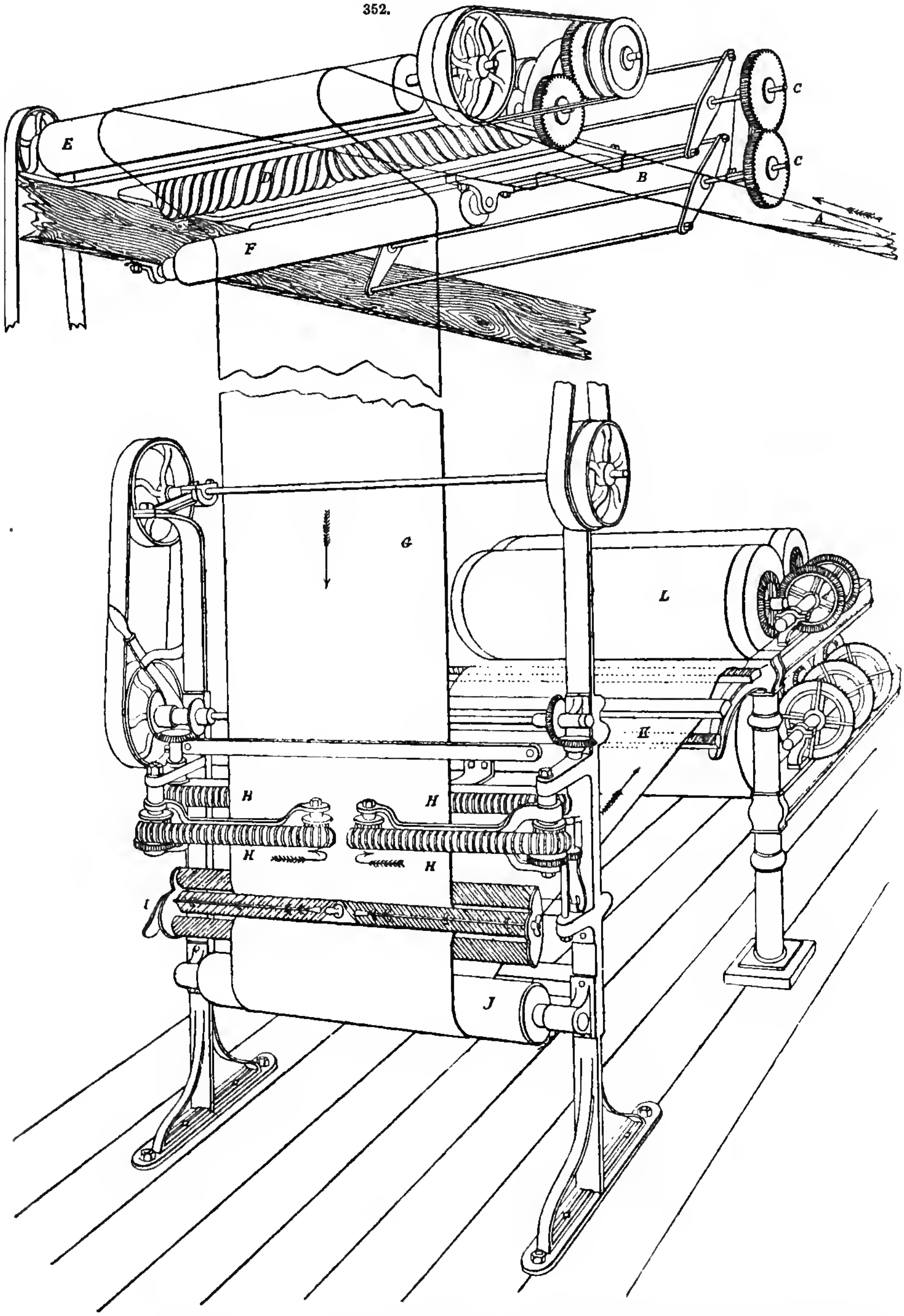
For thin material, however, Birch's machine is not adapted, unless two or three pieces can be run together, since there must be at least ¼ inch thickness of material to form a pulpy cushion at the bottom of the groove, otherwise the cloth will be cut. Fig. 351 represents this improved machine. T is a water trough through which the piece passes as it comes from the final washing, passing thence between the two brass rollers R R, the upper one of which simply rests on the

351.



lower one with its own weight. The use of these rollers is to express the excess of water, and to prevent its being carried round by the velocity of the squeezing rollers themselves. From these

352.



rollers, the piece passes over the wooden roller D, and enters the deep groove of the roller A, at the bottom of which it is pressed by the disc roller B; S is the spring for exerting the pressure of the disc roller in the groove; P and M are pulley and driving belt.

This machine as described was not found practically adapted to squeezing two pieces at the same time, without fear of tearing the cloth, owing to the tension of the two pieces being different, from their overlying each other in the groove. In the newest machines but recently introduced, this difficulty has been effectually overcome, by substituting for the rollers R R a pair of movable brass straining-bars, which can be fixed at any angle, and by adding a swinging guide-rail, round which the pieces pass before going over the straining-bars. With this arrangement, the tension of two pieces passing between the grooved squeezing-rollers at the same time is better regulated, and risk of damage is avoided.

The squeezed pieces are guided right away from the machine, by means of pot-eyes and small wooden rollers, from the bleach-house to the white drying-room, there to be opened and dried. The average time required for cotton bleaching is four to five days; the output of bleached cloth, using two pairs of Barlow's kiers, with regular work, boiling during the night and filling the kiers in the daytime, would be about 120,000 lb. cloth for five and a half days.

Opening and Drying.—By the old method, "opening" was effected by leading the squeezed pieces into large wooden vats standing on turn-tables on the ground floor; when full, an end of the piece was led up through the floor to the top of the drying-room above, where the piece passed over a large drum-roller, down to the drying-machine. Immediately before this drum-roller, a young girl or boy opened out by hand the twists of the long length of piece hanging down to the vats on the turn-tables, which required to be turned occasionally one way or the other to take out the twist as it increased. Just before the opened-out piece passed on to the cylinders of the drying machine, another young person was placed to take hold of each selvage of the piece with finger and thumb, and stretch it as much as was necessary to ensure the complete removal of every crease and fold, the piece then passing in a state of tension over the grooved scrimp rails and the revolving breadthener placed immediately before the first drying cylinder.

Fig. 352 represents Wm. Birch's scutcher and opener, which performs this work far more efficiently and cheaply, at the same time abolishing an unhealthy occupation for young people, who were perched close to the ceiling, where heat and vapour collect most. In order to convey an opinion of the quality of the work, it need only be mentioned that the machine operates by friction, which is uniformly distributed across the middle and over the whole length of the piece, thus giving it a uniform appearance; while hand labour, being only applied intermittently and to a comparatively small number of spots, was always liable to pull the piece more or less awry. As the piece comes from the squeezer, it is considerably twisted, like the strands of a rope, as shown at A; it then passes at B between the two double-armed scutchers or beaters geared together by the wheels C C, and driven by a belt at the other end, so that they revolve in the opposite direction to the cloth at the rate of about 300 revolutions per minute; these give a violent shaking to the twisted cloth and beat back the twist freely. The entire success of these beaters depends on the fact that, in a long length of pieces, there is about an equal number of right and left handed twists; before passing through the beaters, the strand of cloth must hang horizontally and freely for about 30 ft. From the beaters, the cloth runs over the spiral or scroll roller D. This is a wooden roller with copper sheeting fixed into it edgeways and spirally, so that a point on the thread of the screw travels outwards at about the same velocity as the piece which, passing over a guide, not seen in the figure, then goes over the roller E and behind the roller F. As shown

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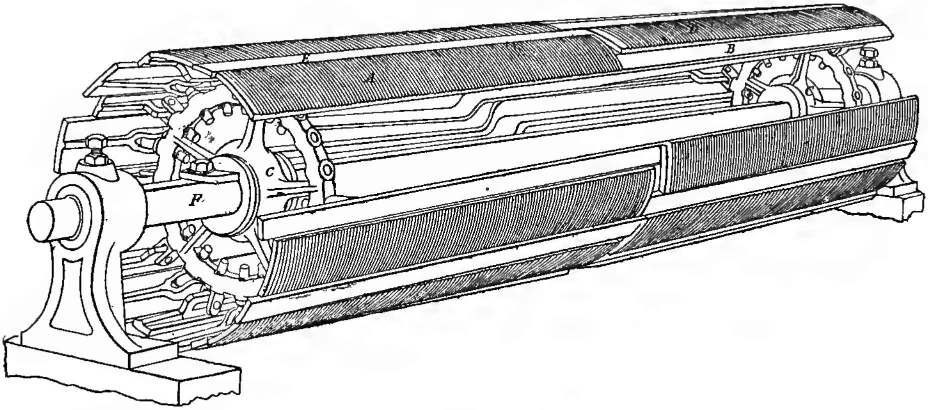
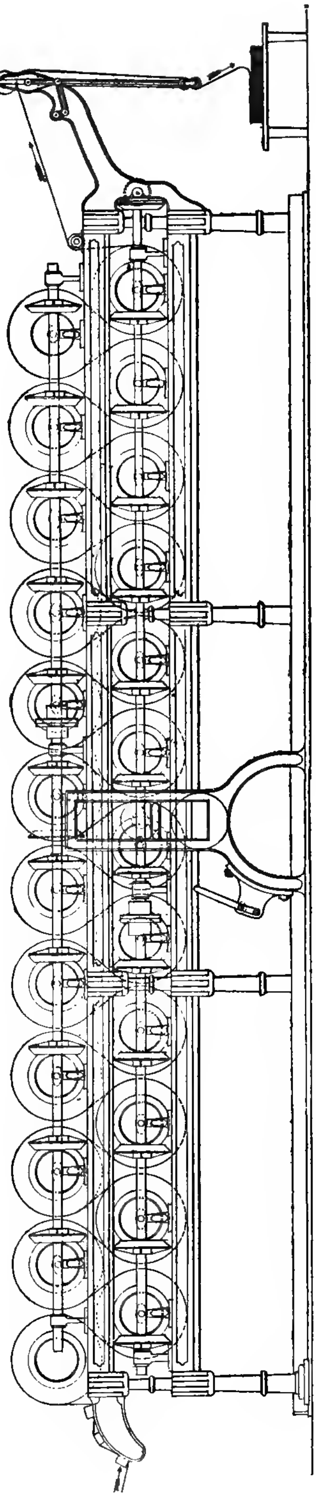


at G, the cloth is already pretty well opened out; it then passes to the opener or spreader placed below, and immediately adjoining the drying machine. The opener consists of four endless chains provided with projections; two work against the piece in front and two at the back, and, as one is placed slightly above the other, the fabric cannot be damaged by the close interlacing of their projections. These endless chains H H move, at the side next the passing cloth, from the centre of the fabric outwards, as indicated by the arrows, and exactly imitate the drawing out of the same with finger and thumb. Immediately on leaving the chains, the piece passes between the three corrugated friction-bars of the regulator I, which ensures that the calico shall run in the central line of the machine. Of these three bars, the middle one, appearing in front of the cloth in the figure, can be adjusted to produce any required tension of the cloth, by screwing it more or less between the other two bars; the latter are supported behind by a pivot at the centre, so that all three bars together can swing like the arms of a balance. As long as the passing cloth continues central with the machine, no change takes place; but directly it commences to swerve on either side, the regulator is called into action. This regulator is connected by levers with the framework carrying the endless chains. The moment the centre of the fabric moves in the slightest degree to right or left of the central pivot of the corrugated friction-bars, these swerve from their normal horizontal position, and, through the connecting levers, cause the pair of endless chains on the same side of the central line of the fabric to recede from each other; thus the friction on that side is reduced, while the pair of chains on the opposite side are caused to approach each other and grip the cloth tighter, the latter being thus drawn to the centre again. The corrugated surface of the regulator retains the absolute straightness of the cloth imparted to it by the chains; the cloth then passes over the corrugated scrimp rails at K on to the drying cylinders L. The guide referred to above, as being between the rollers D and E, is very similar to the regulator I, the only difference being that the two outside friction bars are replaced by spirally corrugated revolving rollers. The manner of suspension by a central pivot is the same, and the whole thus forms a perfectly independent swinging balanced frame supporting two rollers and a bar. If the piece swerves to either side, this guide of itself instantly brings it back to the centre. In the figure, the piece is represented as passing from the opener to the scrimp rails K, and at once on to the drying cylinders; in practice, however, a revolving breadthener is placed before the first drying cylinder, by means of which the cloth receives a last expansion; there being only a few inches between the breadthener and the drying cylinder, it is not drawn into the slightest crease by the tension.

Fig. 353 shows this breadthener or expander as improved by Messrs. Duncan Stewart and Co. It consists of a brass roller made up of segments A B, D E, half the surfaces of which are plain, as at B and E, and half obliquely corrugated, as at D and A. These segments are fastened by screws, joints, &c., to the two rings C C, which are set on the shaft F obliquely, so that they

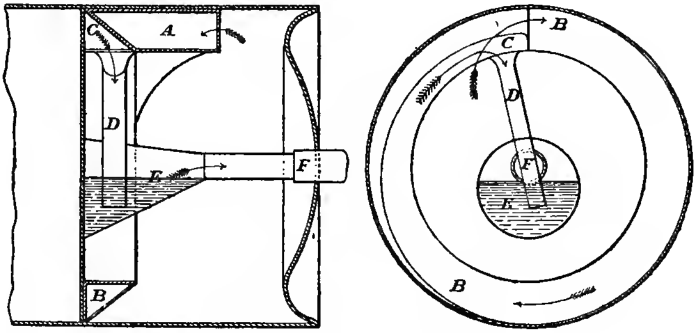


354.

diverge in the direction of the moving cloth. The whole revolves by the friction of the passing piece, and, at the same time, each corrugated segment moves and stretches the cloth from centre to selvage.

Fig. 354 represents the drying machine in general use. It consists of a series of nineteen to twenty-three hollow cylinders, about 2 ft. in diameter, made of tin or copper sheeting, generally driven by bevelled gearing, and properly strengthened by ring-stays in the interior. The axes are hollow, the steam entering by the one, the condensed water escaping by the other. The arrangement for effecting this latter should be of the most perfect kind, especially in the few front cylinders where the condensation of water is greatest. Fig. 355 represents a most effective yet simple arrangement as devised by H. Adam, of Bonhill. As the cylinder revolves, the condensed water is scooped up by the funnel A; it at once enters the triangular tube at B, and moves along to the other end C; here it enters the tube D, and is thus conducted into the conical reservoir E, whence its makes it exit by the hollow axis F. The whole of this interior arrangement is made of tin plate soldered together. The cylinders themselves are best made of copper, since experience proves that they dry considerably quicker than tin ones, owing to the difference in the heat-conducting power of the two metals.

355.



In starting the drying machine, it is *very necessary* to allow the cylinders to revolve for some time before turning on the steam; it is well also, when the day's work is ended, to allow them to revolve for some short time after the steam is turned off, in order to discharge the condensed water lying in the cylinders, otherwise the latter are very apt to collapse through the formation of a vacuum, caused by the steam being suddenly condensed by the cold water present. Both ends of each cylinder are provided with spring air-valves, opening inwardly, to avoid this as much as possible; but they must never be entirely relied upon, even when in perfect order. Another important matter, which it is well to note in connection with the drying cylinders, is that they should on no account be fed with exhaust steam from the engine, because the fatty matter used in lubricating the engine cylinder finds its way with the steam into the drying cylinders, and, being decomposed by the action of the heat and steam, produces fatty acids which act energetically and corrosively on the internal arrangements: if the cylinders are of tin plate, they will be themselves rapidly destroyed.

As the pieces leave the drying cylinders, they are plaited down by the folders. It will be seen from the above description, that from the final washing to the opened-out dried state, the pieces are never touched by hand.

Turkey-red Bleach.—When goods are to be dyed Turkey red, it is not necessary to give them a full madder bleach, because the die is plain, and no white requires to be preserved. The following is a summary of the operations:—

40 *cwt. Cloth. Low-press Kier.* 8 *lb. pressure.*

1. Wash (no singeing previously).
2. Boil in water 2 hours, and wash.
3. Ley boils: 1st. 20 gallons caustic soda at 70° Tw., 10 hours boil, and wash.
   2nd. 15 ,, ,, ,, ,,
4. Sour: sulphuric acid at 2° Tw., steep 2 hours.
5. Wash well, and dry.

The machinery is the same as that already described; for the souring, large stone cisterns are used; into these, when filled with pieces, the acid liquor is pumped till the latter are submerged.

Market Bleaching.—"Market bleaching" refers to goods which are bleached, and sold as finished white goods in the market. For these, it is only necessary that the white should please the eye. For heavy cloths, cambrics, shirtings, &c., the processes and machinery may be exactly the same as for the madder-bleach, though the use of resin soap is not necessary, and only soda ash or caustic soda may be employed for the ley boils. Subjoined is a sketch of two processes in use at the present time, each for 12,000 lb. cloth, and employing low-press kiers.

English Process.

1. Lime into kier.
2. Lime boil: 720 lb. lime, boil 12 hours, and wash.
3. Lime sour: hydrochloric acid 2° Tw., steep 2 to 4 hours, wash.
4. First soda boil: 120 lb. caustic soda (solid), boil 12 hours, wash.
5. Chemick: bleaching powder solution 1° Tw., steep 2 to 4 hours, wash.
6. Second soda boil or "white boil": 120 lb. soda ash, boil 12 hours, wash.
7. White sour: sulphuric acid 2° Tw., steep 2 to 4 hours, wash.
8. Blue, squeeze, and dry.

Scotch Process.

1. Wash.
2. Lime boil: 600 lb. lime, boil 10 hours, wash.
3. Lime sour: hydrochloric acid 2° Tw., steep 4 hours, wash.
4. Ley boil: 500 lb. soda ash, 40 lb. soft soap, boil 10 hours, wash.
5. Chemick: bleaching powder solution 1° Tw., steep 4 to 10 hours, wash.
6. White sour: sulphuric acid 2° Tw., steep 2 hours.
7. Wash, blue, squeeze, and dry.

This last process is for goods which weigh about 8 to 9 lb. per 70 yds.; when the cloth is heavier two ley boils are given, washing between. For muslins weighing about 5 lb. per 70 yds., 400 lb. lime and 400 lb. soda ash are used instead of the quantities given.

Sometimes it happens that the goods contain coloured threads, either at the piece ends, "headings," along the borders, or even throughout the piece, and which must be preserved. In such cases, slight modifications are made in the process; these can only be learnt by experience. If indigo blue or madder-lilac threads are present, the lime boil is omitted, and soda ash is used instead. If chrome-orange threads are present, the souring must be omitted. Green ornaments containing prussian blue require very careful treatment, and to be gently boiled for a short time with weak solutions of soft soap alone, followed by washing and chemicking.

For very light fabrics, such as book muslins, lappets, harness and Nottingham lace curtains, &c., the so-called continuous process or chain bleaching is not used, owing to the delicate texture of the materials. In the finest muslins, too, the warp threads are in pairs, owing to two threads having been passed through one division of the reed in weaving, and the grey muslin has consequently a somewhat stripy appearance. The chain bleaching process would not so readily separate the double threads of the warp, since the pieces, during the washing, &c., are always in a state of tension. Probably, however, the slack washing machines, to which reference will be made in speaking of linen bleaching, may be worth trying for fine muslin bleaching; in this case, the more rapid chain bleaching would, of course, be employed throughout.

Each piece of the above-mentioned fine materials is made up into a loose bundle and thrown into the kier (generally low-press), along with lime water or soda ash solution, as the case may be, for the boilings. The washing is performed in "dash-wheels." Fig. 356 represents one of these. It consists of a stoutly-made hollow wooden drum A, divided into four compartments, each quadrant provided with a hole B for putting in and taking out the pieces. Jets of water are admitted through openings C on both sides, and the dirty water runs off by small holes D in the periphery. E is the water main to supply the pipe F, which conducts the water through the openings C. The machine is so constructed that the water is turned on or off by the same leverage which throws the wheel into or out of gear. One or two bundles of cloth are put into each compartment, and, as the wheel revolves, are tossed from side to side. The dash-wheel is about 6 to 7 ft. in diameter, and about 30 in. wide. The speed should not be too slow, or the pieces will slide down the sides of the compartments; but if too quick, the centrifugal force will hold them stationary. This washing is one of the very best, and is very gentle; it has only been superseded by those described, wherever possible, on account of its slow and intermittent character. For chemicking and souring, the stone tanks with false bottoms and drainers, as described above, are employed.

Instead of the squeezers, the "hydro-extractor" is used. Fig. 357 represents the best description, as constructed by Messrs. Duncan Stewart and Co., Glasgow. It consists of a drum or cage made of close galvanized wirework, or of perforated copper sheeting, so supported by a spindle below that the whole can be made to spin like a top, but will stand upright when at rest. It is driven by friction from below, and can be made to revolve at the rate of about 1500 revolutions per minute, with a perfectly regular and smooth movement. The whole is protected by a strong cast-iron case. The wet bundles of goods are placed in the cage, as evenly and equally as possible, so as to balance it; when it is made to revolve, the water is expressed by the powerful centrifugal force through the perforations and into the outer case D, whence it escapes by the pipe P. When taken out after a few minutes, the goods have lost all excess of water, and the treatment is so gentle, that the most delicate fabric is not injured.

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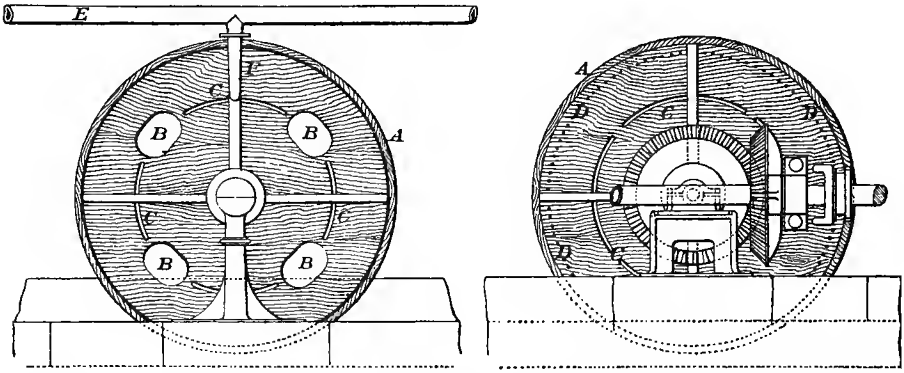

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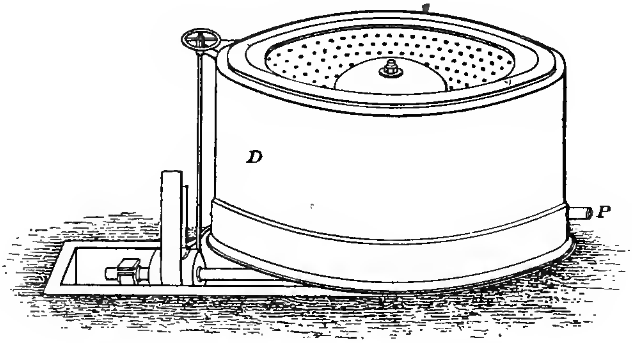

With respect to the method of bleaching such fine goods, it is very similar to those given, the amount of lime, soda, &c., being reduced to suit the texture of the materials. The following process for 1000 lb. cloth may be taken as a type, using low-press kiers:—

1. Wash, boil in water 3 hours, and wash.
2. First soda boil: 70 lb. soda ash, 20 lb. soft soap, boil 6 hours and wash.
3. Second soda boil: 50 lb. soda ash, 20 lb. soft soap, boil 3 hours, and wash.
4. Chemick: bleaching powder solution ½° Tw., steep 2 hours, wash.
5. Sour: hydrochloric acid 1° Tw., steep 2 hours, wash.
6. Third soda boil: 30 lb. soda ash, 20 lb. soft soap, boil ½ hour, wash.
7. Chemick, as before.
8. Sour, as before, and wash well.

With the market bleachers, a most particular part of their work, as important as the bleaching itself, consists in "finishing" the goods to suit the tastes of the various merchants and markets, and in imparting a fine appearance to the fabric. This embraces starching, damping, calendering, beetling, stentering, and folding, one or more of these processes being employed, according to the "finish" required.

Starching.—For the thicker fabrics, cambrics, &c., the so-called "starching mangle" is used in this process. It is very similar to the older kind of "squeezer," and consists of a pair of heavy rollers, one of compressed cotton yarn and the other of brass, the lower one dipping into a decoction of starch contained in a wooden trough below. The cloth is drawn at its full width between the rollers, acquiring an excess of starch, which is at once expressed; it is then generally run directly over the drying cylinders, and folded. There are other machines, so adapted that the starch is only put upon the wrong side of the cloth. This method is used when the cloth is of low quality; the starch is mixed with a large percentage of "filling" (china clay, &c.) for the purpose of filling up the pores, and giving weight and false solidity of appearance to the fabric. One arrangement by which this is effected consists of a coarsely pin-engraved copper roller, on to which the passing cloth is depressed. The copper roller revolves in a direction contrary to that of the cloth, and is coated with the starch mixture by a furnisher or wooden roller revolving in contact with it, or by dipping into the starch itself. The excess of starch on the copper roller is scraped off by a steel blade before it touches the cloth, so that the starch remains only in the engraved parts. In this manner, the starch is, as it were, printed, on to the back of the cloth. Another method is to depress the cloth on to a pair of rollers revolving in the starch mixture; the cloth is plastered with an excess of starch, which is then spread and partly scraped off, by passing the cloth over a steel blade. The two rollers can be adjusted at any distance from each other, so as to regulate the quantity of starch passing between them and coating their upper surfaces. Figs. 358 and 359 represent these two methods; R R are the depressing rollers, A A the starching rollers, E the pin-engraved roller, B B the steel blades, S S the starch boxes.

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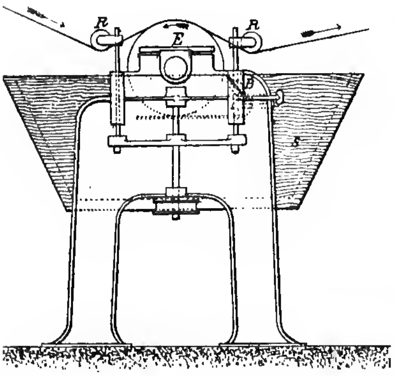

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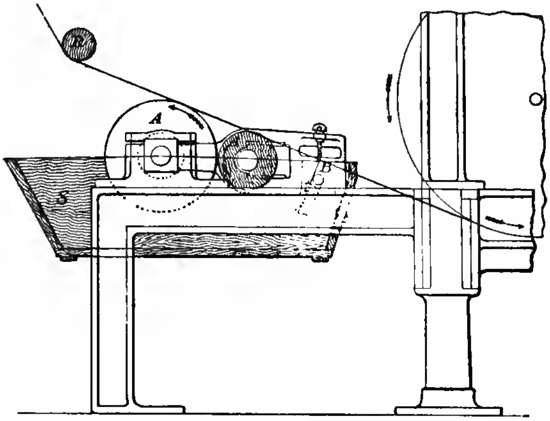
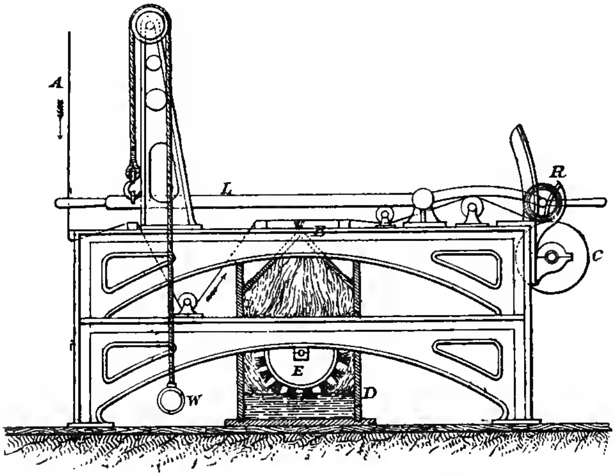


When the starching is done on one side only, it is usual to have the first few upper drying cylinders replaced by reels, and so to thread the cloth that only the unstarched side of the piece touches the drying cylinders, till the middle of the machine is approached, when the cloth is partly dried. This prevents the starch from sticking to the cylinders, and coming off again in lumps on to the pieces, thus spoiling their appearance. The same or a similar arrangement is used when the cloth has a raised woven pattern, e. g. brilliants, brocades, &c.; in this case the figured side of the cloth is not allowed to touch and be flattened against the drying cylinder; thus the raised figure is preserved.

The starch itself is a decoction of wheat, rice, sago, or other starches, according to the finish required, mixed with a little ultramarine, indigo, or aniline blue, to remove the yellowish hue of the white. If necessary, the "filling" already mentioned is added, also a proportion of soapy and waxy matters, which serve to render the goods soft to the feel, or capable of receiving a high lustre in the subsequent calendering.

Damping.—The damping process is required after starching, since experience shows that the cloth must contain a certain amount of moisture to subsequently acquire the proper feel and finish. Sometimes damping is rendered unnecessary, by regulating the speed of the drying machine, and allowing the pieces leaving it to contain the necessary amount of moisture; this is called "conditioning" the pieces. To gain speed, however, the pieces are generally hard dried, and a special "damping machine" is employed. Fig. 360 represents such a machine. D is a water box, with roller-brush E, which dips more or less into the water; in the upper part of the box, there is a narrow slit, across which the cloth passes at B, and there catches the fine spray thrown up by the rapidly revolving roller-brush. W is a weight attached to the lever L, to depress the loose roller R, on which the damped cloth is beamed against the driven roller C. The amount of moisture imparted to the cloth is determined by regulating the height of the water in the box. The pieces are allowed to remain on the beams for some time, in order to equalize the damping. There are other forms of damping machines, e. g. where the injector principle is applied as a spray producer; but the one described is the most general. According to the finish required, the goods, after damping, are either "calendered" or "beetled"; for a soft finish, this is done even without previous starching.

360.



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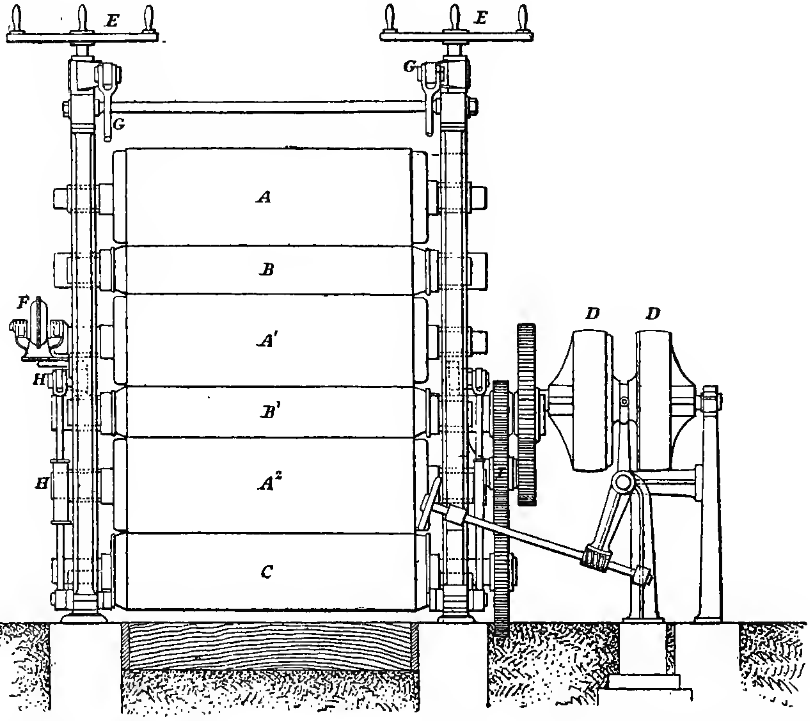

Calendering.—The beamed cloth from the damping machine is placed in front of the calender, passed between the rollers of this machine, and thus subjected to powerful pressure or friction, or both combined. Figs. 361 and 362 represent a six-bowled calender of the best description, as made by Messrs. Duncan Stewart and Co. A A^1 A^2 are bowls, made of highly-compressed paper sheets manufactured from linen rags. They are exceedingly hard and elastic, and not at all liable to crack or warp under the immense pressure to which they are subjected. B B′ are hollow iron cylinders, which can be heated by hot bolts, steam, or gas; F is a fan, to supply the air necessary for combustion when gas is used. D D are driving and friction pulleys, driven by a straight and a crossed belt respectively, from overhead shafting, and having reversible action; they are connected with the three lowest bowls by gearing, which is so arranged that the roller B′ may be made to revolve with a surface speed about a quarter greater than that of the rollers A^2 and C, which revolve at the same speed. E E are screws, for relieving at once the pressure of all the cylinders on each other, when the machine is standing. G G are levers, in action when all the six bowls are in use; H H are levers, employed when only the three lowest bowls are required. For common calendering, or "swissing," as it is termed, the gearing wheel I is withdrawn, and the whole six bowls revolve with an equal surface speed, no friction against the piece taking place. The hollow iron cylinders may be heated or not, according to the finish required; and the fabric is smoothed by simple pressure, or by pressure and heat combined. The dotted line in the figure shows the direction of the piece for "swissing." To give the pieces the highest degree of lustre, i. e. for "glazing," only the three lower bowls are used, with the wheel I in gear, the upper bowls being slightly raised, and the hollow cylinder B′ heated. The plain line in the figure gives the direction of the piece for "glazing," during which process the machine performs, in an intensely exaggerated degree, the effect of the "ironing" of the laundry-maid.

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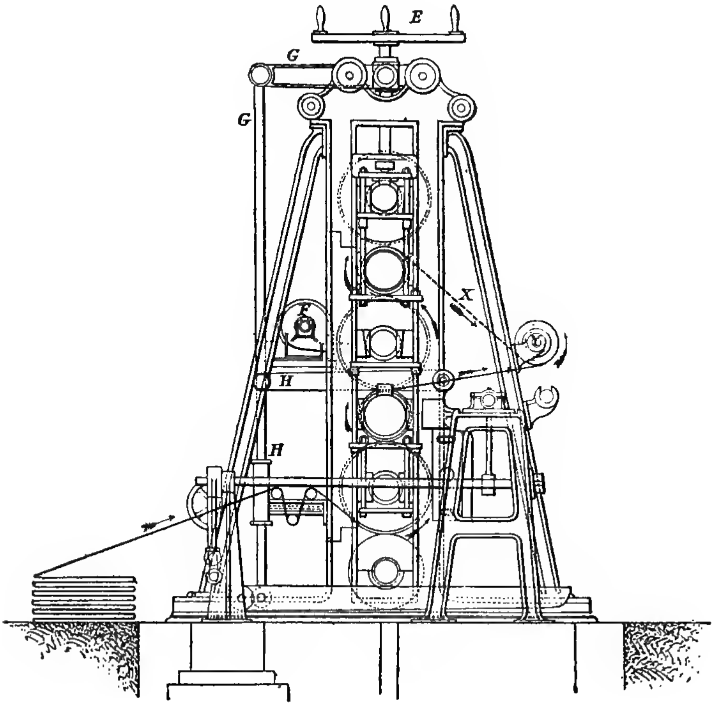

Beetling.—The "Beetling machine," Fig. 363, gives to the cloth a finish entirely different from that imparted by the calender. It consists of a row of heavy beams of hard wood A, about 5 in. square and 6 ft. long, provided with notches or projections, by means of which they are raised by cams or projections C on the revolving roller B, and are then allowed to fall with their own weight on a roller D or table below, on which the cloth is placed, several folds in thickness. By this repeated hammering, the cloth, which, if on a flat table, is constantly moved about by hand, if on a roller, by the revolving and lateral movement of the latter, becomes extended both in breadth and length; it acquires a certain lustre, and a thick and leathery feel. By the pressure of the threads of one layer of cloth on those of the other, a watered effect, similar to that of moire antique, is produced. The weft and warp threads are not flattened so smoothly as with the calender; the cloth still retains, at some stages, a thready appearance, and might almost be mistaken for linen, which it is in fact intended to imitate.

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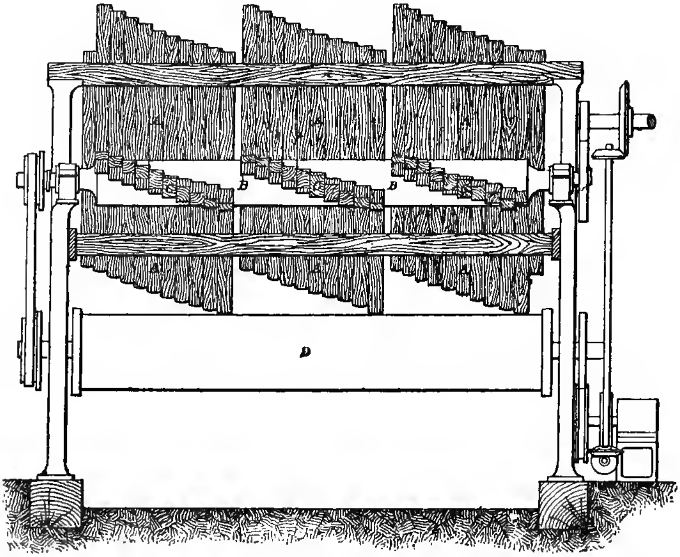

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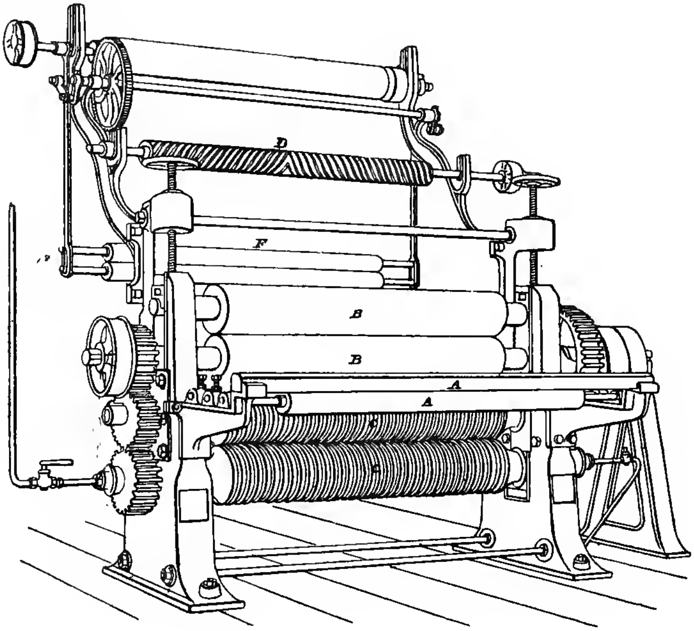
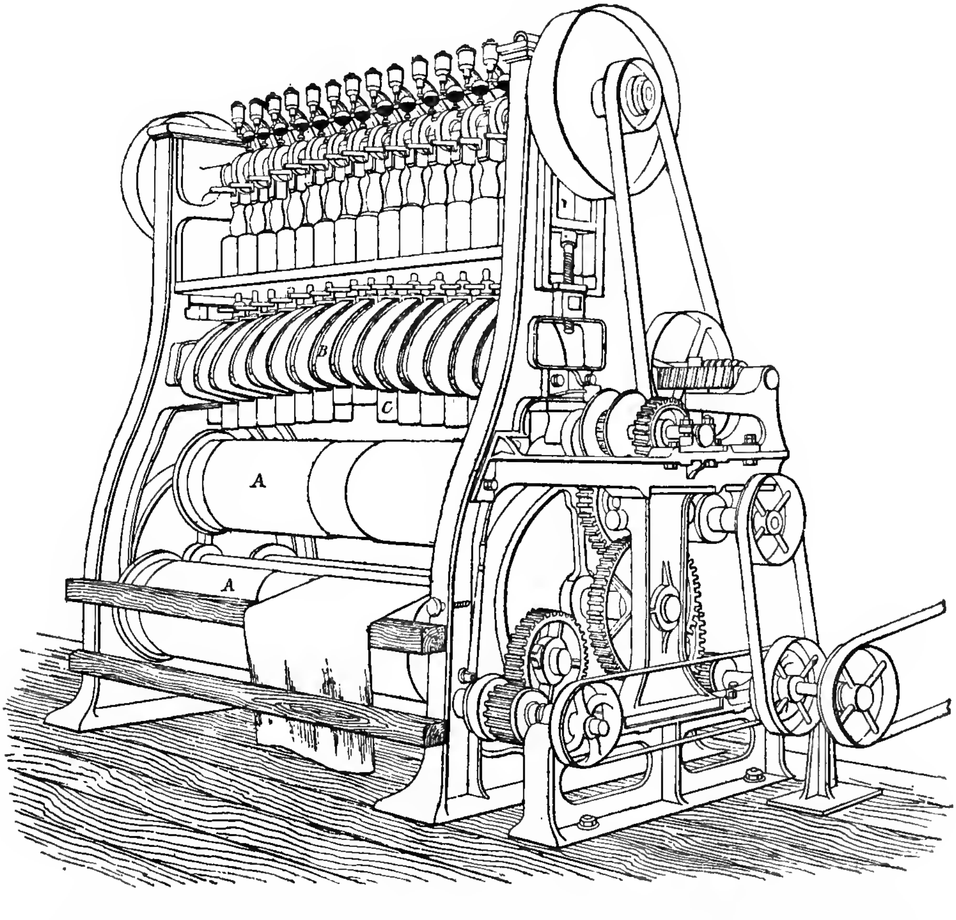


As has been said, the first effect of beetling is to stretch the cloth, and, in order to economize time in this respect, a novel machine has been made by Messrs. Duncan Stewart and Co., and has proved itself thoroughly efficient. Fig. 364 represents a front view of this machine. The damped cloth is led under and over the straining bar and rollers A A, between the wooden rollers B B, back between the middle rollers B and C, and then through the grooved metallic rollers C C; from here the piece passes behind, over the scroll roller D, over the roller E, and between the folding rollers F. The grooved rollers, which fit into each other, but without actually touching, stretch the cloth at once, thus saving time in the beetling. Another machine well worth notice here is the new "Beetling machine," Fig. 365, introduced by Patterson, and made by Messrs. Mather and Platt, of Manchester, and Messrs. Duncan Stewart and Co., of Glasgow.

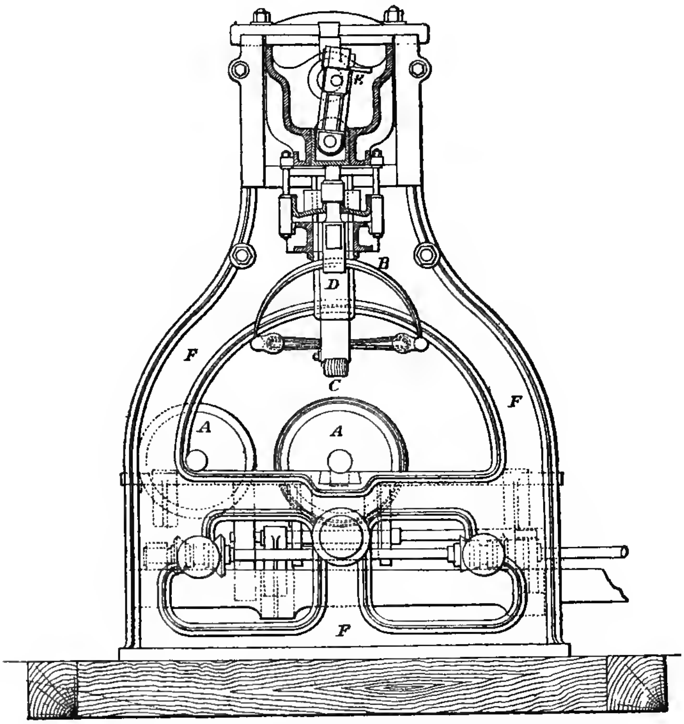
365.



In the older machine, the utmost speed at which the fallers or hammers can work is sixty blows per minute; with this new machine, the hammers work at 420 blows per minute. An elastic blow is obtained by suspending the hammer in a leather strap, attached to a semicircular steel spring, which receives its up and down motion from a crank. Fig. 366 gives a section of the machine, with another arrangement for supporting the beams of cloth. C is a wooden hammer, backed by an iron block, the whole being suspended in leather thongs. D is a guide to prevent the block from oscillating to the side. At E is the crank shaft; A A are the beams of cloth, and F F is the framework of the whole machine. It must be remarked, however, that these machines have not been able entirely to supersede the old kind. Experience has shown that they cannot produce the water mark, though they serve admirably for a preparatory beetling, thus saving time. This machine rough-finishes for five machines of the older kind, and for this purpose takes the place of seven of the latter. The whole process of beetling may last from a few minutes to several hours, according to the degree of finish required.

Folding.—This is the last process, by which the finished pieces are made up into folds of a uniform length, generally about a yard. Formerly this was done by girls, hooking one selvage of the piece backwards and forwards on to straight or only slightly curved steel hooks fixed on a wooden frame, or against a wall. One of the hooks was moveable, so that it could be fixed to suit any length of fold.

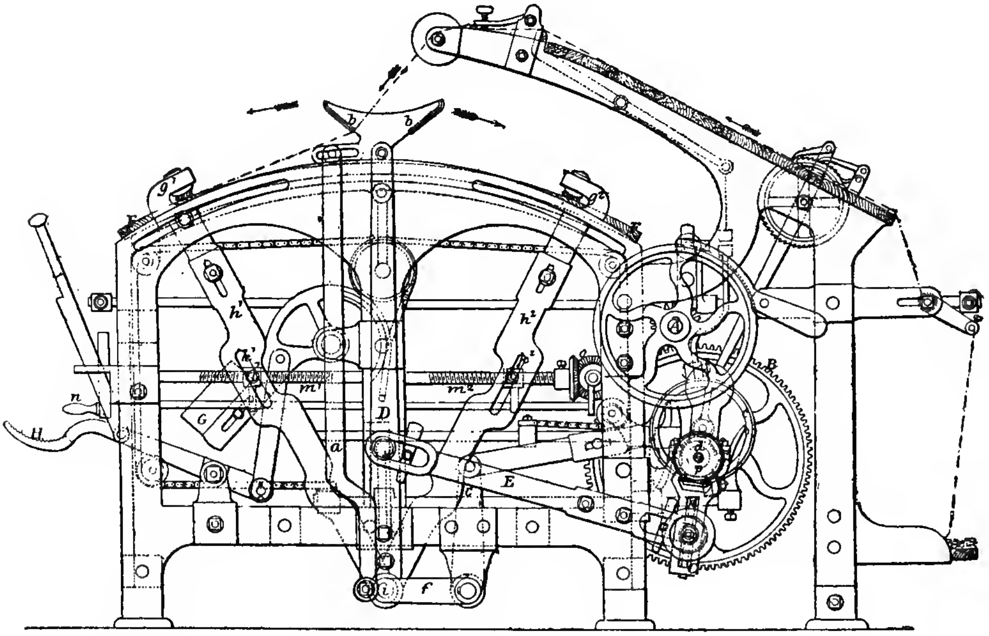
366.



Figs. 367 and 368 represent the modern folding machine of Messrs. Hacking, Bury, in general use. Fig. 367 shows a perfect machine, with all the working parts. The motion is imparted to the machine by means of pulleys fixed on the first motion shaft A; thence it is communicated to the crank shaft by the spur wheels B. At each end of the crank shaft, are cranks (one of which is shown at C), which give an oscillating motion to the side arms D, through the connecting piece E. At the top of the side arms D, there are carried knives or folding blades *b b*, which are for the purpose of laying the folds alternately under the holding rails $g^1 g^2$. The semicircular table F is made to press upwards by means of counterpoise weights G against the holding rails $g^1 g^2$, and so securely holds the cloth laid by the folding blades *b b*. To make the hold on the cloth more secure, the holding rails are generally covered with pin-pointed cards or with corrugated indiarubber. When the piece is folded, the foot lever H is depressed; this causes the table F to descend, and relieves the cloth from the holding rails $g^1 g^2$, so that the folded piece can be removed.

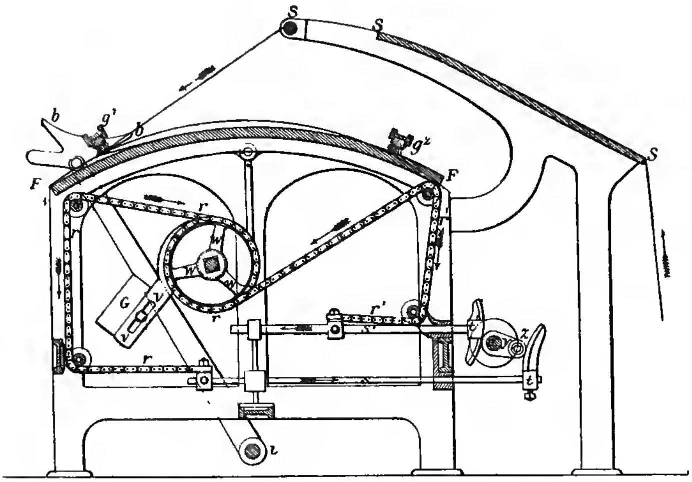
Such is a rough general description of the ordinary movements of this machine. The whole is, however, so complicated and ingenious that a reference to some of the special movements is necessary. The swivelling arm *a*, which determines the swivel of the knives or plaiter *b*, is worked by a cam *c*, placed upon the crank-shaft *d*, thus communicating (by means of levers *e* and *f*) the necessary amount of swivel to the knives without any alteration, at whatever length of plait the machine may be required to work. The altering of the position of the card-rails is effected as follows:—The card-rail brackets $g^1 g^2$ are extended, by means of the levers $h^1 h^2$, to the rocker shaft *i*. In the levers $h^1 h^2$, are made the slots $k^1 k^2$, in which work the studs $l^1 l^2$; these, being actuated by the right and left hand worm-shaft *m*, cause the levers $h^1 h^2$, bearing the card-rail brackets, to approach or recede from one another, as the handle *n*, upon the end of the worm-shaft *m* is turned round, either from left to right or *vice versâ*. This motion is communicated by means of the bevel wheels *o* to the opposite side of the machine, so that by turning the handle *n* the card rails are set parallel at any required distance, with the greatest ease. The top of the framing is marked in half inches, and a finger is attached to the card-rail bracket, so that the handle *n* must be turned round until the finger points at the required figure; the cards are then in a position to work. The regulation of the crank, to give the required sweep to the knives, is rendered very simple. On the square-ended shaft *d*, is placed a box key or handle, which, in being turned round, draws

367.



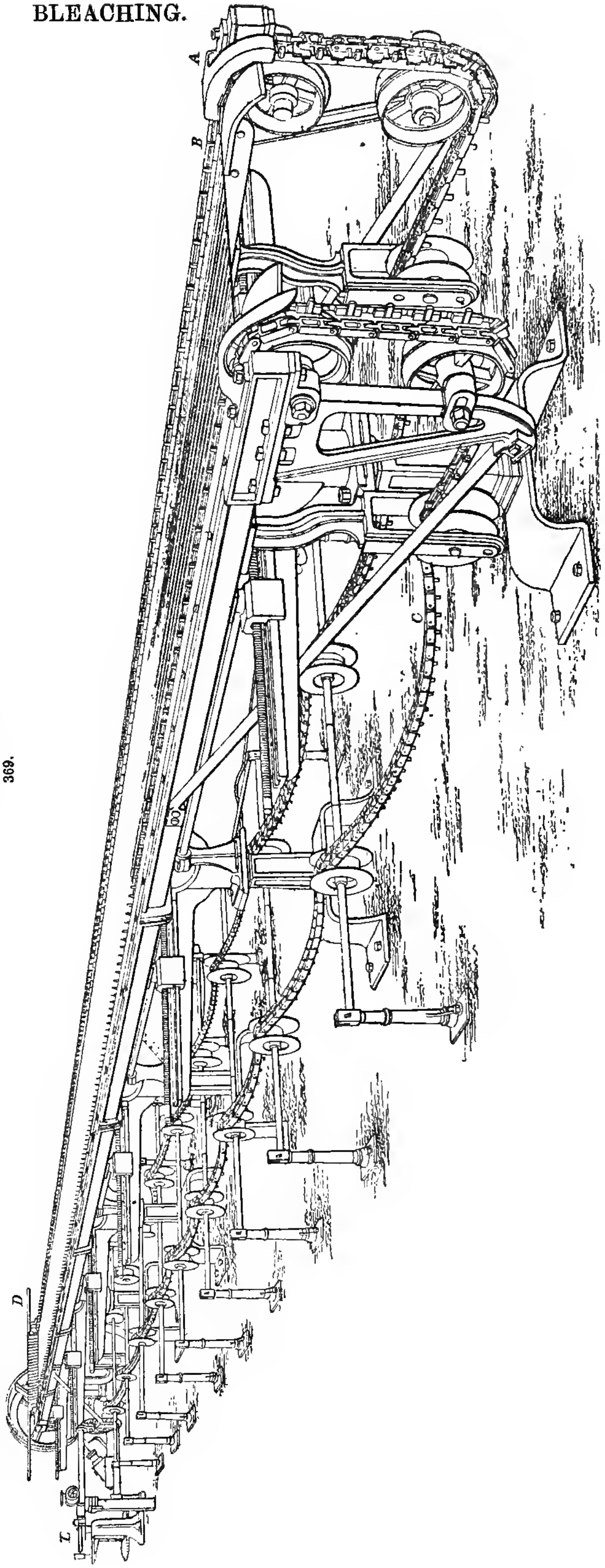
the crank arm towards or farther from its centre, by means of the bevel wheels *p* and the screw *q*; this motion is communicated also by the shaft *d* to the opposite side of the machine, so that by turning the handle on the end of the shaft *d*, the crank, which is also marked in half inches, is

368.



rapidly brought to the required point. Fig. 368 represents only such parts as are necessary to illustrate the special movement, to which reference will now be made. The object is to draw down the table F on which the cloth is being folded, at each side alternately, just as the folding knife *b* enters under the holding rails g^1 or g^2, and to let the table rise and secure the cloth immediately after the knife passes out. The knife thus passes under each folding rail without friction or wear, and the folded cloth is not pulled, rubbed, nor scratched. This is effected by means of the chains r and r', which are connected with the table, and are alternately drawn down by the cam and bowl y and z fixed on the crank shaft h, which, as they revolve, work against the curves t and t', and force them in opposite directions. The curves being connected with the chains by the rods s and s', cause the table to be depressed. The folded pieces are next re-folded into three by hand, pressed, and stamped ready for packing.

Muslin Finishing.—With the finest book muslins, the starching is still done by hand. Each single piece is dipped into the decoction of starch and blue, and well kneaded on a table. The starched piece is now taken to a moderately heated room and "aired." Two girls open out the piece, and, holding each end, sway it to and fro for a short time to dry it partly; it is then crumpled up again, pressed well together in the hands, and re-opened out, and the process is repeated till the starch is deemed to be sufficiently well worked into the fibres. The piece is now taken to two other girls in a cooler place, who, after opening it out, pass it lengthwise between them, holding each selvage, and, by a short rapid zigzag motion given to it every half-yard or so, straighten the weft and warp threads, so that they stand at right angles to each other. The piece is now taken to be stretched and dried on the stenter frames. Figs. 369 and 370 represent respectively the receiving and the delivering end of one of the most improved of these machines, as made by the patentees, Messrs. Duncan Stewart and Co. It is known as the "continuous clip stentering machine"; and consists of two somewhat parallel lines of framing, which guide the onward movement of two endless chains C C, made up of small brass clips which hold the selvages of the fabric. The cloth is introduced at



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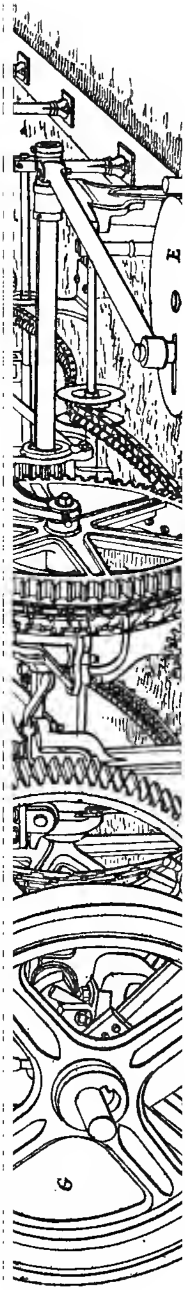

E
G

the end H of the machine, by two girls, each holding a selvage; here the clips open and close automatically, gripping the selvages very tightly. At this point, the machine is constructed so as to admit of the cloth being easily inserted; further on, however, the two lines of framing are fixed by means of screws at a greater distance from each other, and the cloth becomes stretched to the requisite breadth, at the same time moving along continuously, and is delivered dried and finished at the other end D; F is the cloth passing away to the folders; G is the engine for driving the whole machine.

In this manner, a "stiff finish" is given, the cloth feeling rigid and inelastic. The so-called "elastic finish," a special feature in certain varieties of muslin, is imparted to the pieces by the same machine, by moving the lines of selvage backward and forward during the drying and stretching on the stenter frame. This is effected by a crank motion imparted to the whole machine at E, which causes the weft and warp threads of the fabric to rub against each other till dry, thus preventing them from becoming united. Dried in this manner, the goods possess a characteristic and remarkable elasticity. The drying portion of the machine consists of rows of steam pipes situated immediately below the piece; or, as is very usual, a blast of heated air is driven against the piece from below, and fanners are placed above, at certain distances from each other. For this muslin-finish, fine wheat starch, boiled with water containing a small proportion of alum in solution, and a suitable quantity of smalts blue, is used; ultramarine is inadmissible, owing to its being destroyed by the acidity of the starch.

Nottingham lace, harness curtains, and similar materials, are starched by spreading them out on large tables covered with blanket and canvas, on which a thin layer of boiled starch and blue has been previously spread by means of brushes. When the fabric is extended on the table thus prepared, it is brushed over in order to press in the starch, which thus coats only one side, leaving the figured thicker portion to stand out clear and white from the more open groundwork, which is blueish.

Yarn and Thread Bleaching.—In the form of yarn and thread, cotton is free from size, grease, &c., and the process is consequently less severe than for cloth. The lime boil is entirely dispensed with, and there are slight modifications in the machinery employed. The yarn chains are "warps," used for weaving winceys, shirtings, ginghams, &c. As they come to the bleacher, they vary in length from 50 to 15,000 yds., but are usually plaited five-fold in a loose manner; the bleacher plaits them five-fold again, so that the chain is reduced considerably from its real length, and is thereby rendered more manageable. This plaiting is done very loosely and rapidly by hand, though there are machines which plait three-fold. If the yarn is in hanks, these are linked together in a simple manner, to form a long chain, though they are still, in many bleach-houses, handled as separate hanks throughout the process. If the yarn is in the form of "cops," ready for the weaver's shuttle, these are packed as carefully and tightly as possible into pure hempen bags, containing 16 to 20 lb. each, and are sewn up.

The following is a sketch of the bleaching process, as used for 3000 lb. of cotton yarn, employing open low-press kiers:—

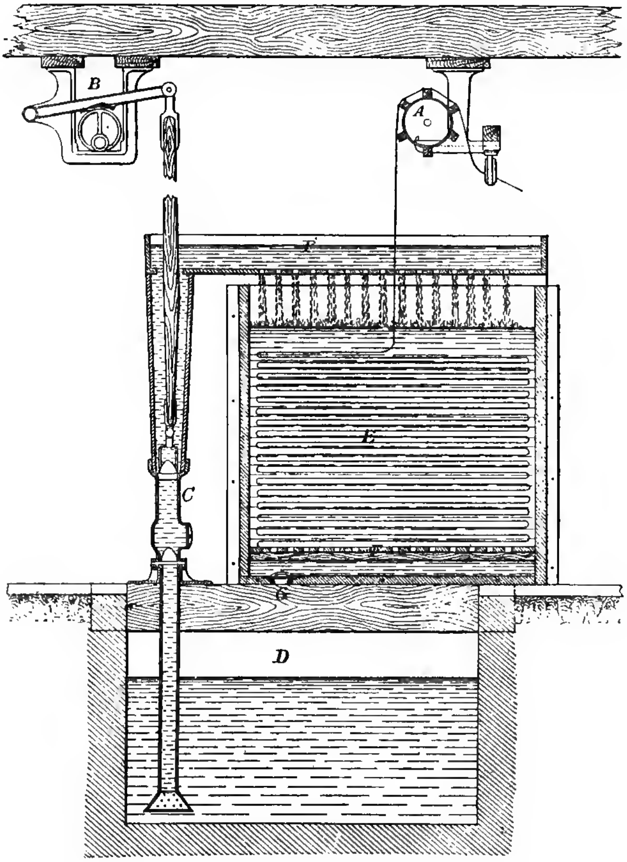
1. Ley boil: 60 galls. caustic soda, at 32° Tw., 400 galls. water, boil 6 hours and sweeten $\frac{3}{4}$ hour.
2. Wash through washing machine.
3. Chemick: bleaching powder solution, 2° Tw., 2 hours under sieve, wash $\frac{1}{2}$ hour under sieve.
4. Sour: sulphuric acid, 1° Tw., $\frac{1}{2}$ hour under sieve, wash $\frac{1}{2}$ hour under sieve.
5. Wash through washing machine.
6. Run through dumping machine, with hot soap liquor and blue.
7. Hydro-extract and dry.

Cotton thread is treated in the same way; but, on account of its closer and finer texture, the first five operations are repeated before passing to the sixth, using for a second ley boil about 8 galls. caustic soda at 32° Tw., or 30 lb. soda ash.

The chemicking, souring, and washing are performed in stone tanks having false bottoms and perforated drainers or sieves above, the liquors being made to circulate from a well below, by means of pumps. Fig. 371 shows this arrangement. E is the cistern with a false bottom F, and a valve G communicating with the tank D below; B is the shaft which drives the pump C, for raising the liquor up to the drainer F′; A is a winch for drawing the pieces into the cistern. The drainer may cover the whole surface of the cistern, and can be lifted up with hinges when introducing or withdrawing the cloth. For the sours, the drainer is made of wood; for the chemick, of sheet zinc. The washing machine referred to is similar to the one described under "madder bleach." The drying machine for the chains is also similar to those described, but is fitted up at each end with peg rails, to guide the chain spirally while it is moving several times from end to end between the drying cylinders. Just before drying, the plaiting is unloosed, so that the chain is dried in simple chain form. Hanks and cops are dried in stoves heated to about 71° (160° F.), the former being suspended on poles, the latter placed on trays made of galvanized wire netting.

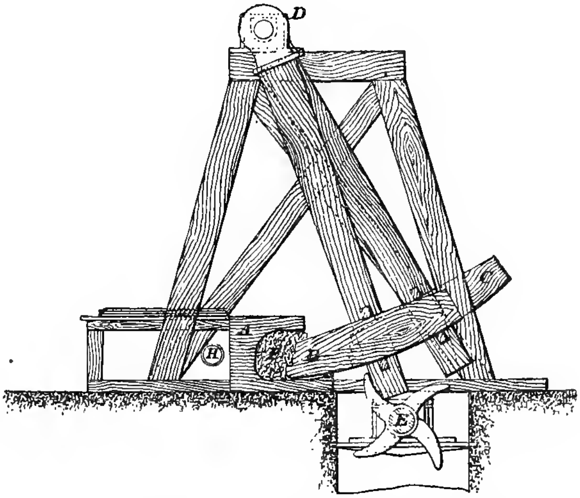
The "dumping machine" is rather a speciality in yarn and thread bleaching, where the chain form is used. It consists of a pair of heavy wooden rollers set over a large water trough. The upper roller is covered with close coils of cotton rope, to render it somewhat elastic. This roller rests with its own weight on the lower one, so that the knots or lumps produced by the plaiting or linking of the chain cause it in passing through to rise and fall with a jumping motion, thus squeezing the soap solution and blue into the very heart of the fibre. This part of the process adds very considerably to the beauty of the white. When the yarn or thread is handled in hank form, this treatment with soap solution takes place in the wash stocks, Fig. 372; A is the box or trough, made of a solid piece of wood, containing the yarn or thread at F, and fed with water from the pipe H; B and C are two heavy wooden hammers, working side by side into the same trough. They are supported by a strong loose iron bolt at D, and are raised alternately and allowed to fall again by the cams on the revolving shaft E. G is a table to hold yarn ready for entering the machine.

371.



A special washing machine also is required when the yarn is in hank form. Fig. 373 gives a representation of the ingenious machine devised by Gantert. It consists of an annular or oval-shaped trough A of any suitable size, in combination with a series of radial horizontal revolving arms working above the trough. A roller B is carried on the outer end of each arm which serves as its axis, and the several rollers revolve immediately over the trough. The hanks or skeins C to be washed are hung upon the rollers as indicated, and their lower ends dip into the water in the trough, in which a partition is fitted. The water enters on one side of this partition, where the hanks are taken off, circulates round the trough, and escapes on the other side of it, where the hanks are entered. By a complicated mechanism, the hanks are moved along, at the same time that the rollers B revolve, and cause them to vary their position in the water; in addition to this, the arms, rollers, and hanks have a backward and forward movement. The machine may be made of such dimensions that one circulation will give a sufficient wash; the hanks for washing are constantly put on to the rollers B by a workman on one side of the water-trough division, and are as rapidly taken off thoroughly washed by another workman on the other side of the division. The whole action imitates, in a striking manner, the washing of a hank as it is done by hand.

372.



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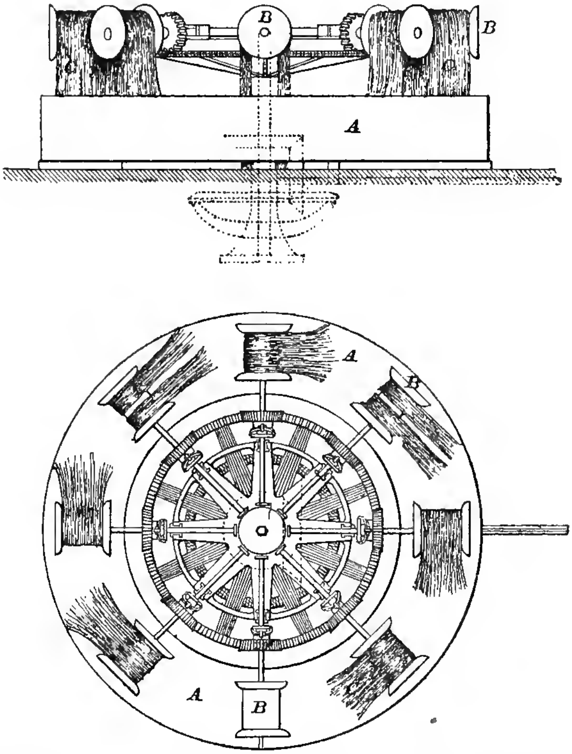


Woollen Bleaching.—As already mentioned, the bleaching of wool differs entirely from that of cotton, since their chemical and physical properties are dissimilar. Strong alkalies dissolve it, and bleaching-powder solution decomposes and destroys it, with evolution of nitrogen gas.

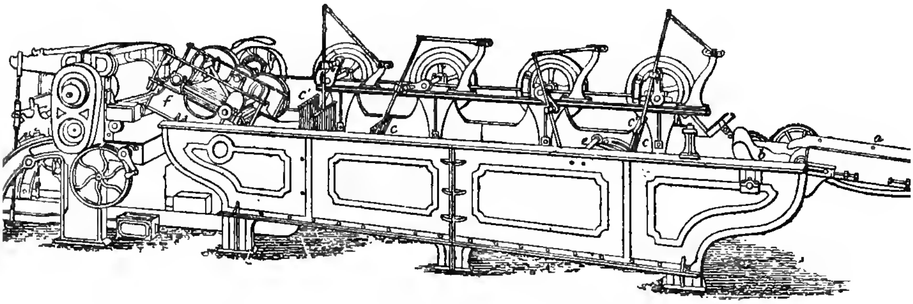
In general terms, the bleaching of wool consists in "scouring," or washing with water, solutions of soap, and weak alkalies; and in bleaching or whitening, by means of sulphurous acid. The use of sulphurous acid, and of ammoniacal liquors in the form of "lant" or stale urine, is known (from drawings on the walls of Pompeii) to have been practised by the Romans.

Wool Washing.—The preliminary step in woollen bleaching consists in removing, by washing, a portion of the suint and other adhering impurities. This may take place before shearing, in which case the animals are led into a running stream of suitable depth. Three to five men enter the brook, and the animals are washed by each successively, finishing with the man standing in the upper part of the stream. The loss in this operation may vary from 20 to 70 per cent. This first washing may also take place after shearing, in which case, the fleece is steeped in cold water, and is then washed in wicker baskets or nets in a running stream, or in large tubs. Fine wools are afterwards washed in warm water, drained, and spread on the grass or in stoves to dry. The drying machines recently introduced by Petrie and Fielden, of Rochdale, may be used with advantage.

Wool Scouring.—When the manufacturer or dyer receives the wool, it is further washed or "scoured" with the following detergents: for fine long wools, soft soap; for short wools, coarse or fine, stale urine, alone or mixed with soda ash, also soda ash alone, silicate of soda, and mixtures of alkaline carbonates and soap. When stale urine is used, the loose wool is plunged into a large tub, containing about 1 measure of stale urine to three or four measures of water; after being worked about with a stick or stang for five or ten minutes, it is lifted out with a fork on to a drainer or scray. When sufficiently drained, the wool is thrown into a cistern provided with a perforated false bottom; here it is well washed and worked about in cold water two or three times, the water being let off below between the washings. This method requires, of course, an abundant supply of water; by it, one man can scour from 500 lb. to 600 lb. per day. An improvement upon this method, used in some places, is to have a perforated sheet-iron box swung on a crane. The perforated box is let down into the scouring tub, and the wool is worked about in it; it is then raised, and allowed to drain, after which the wool is tilted into the washing cistern, to be washed two or three times as before. This arrangement requires two men; but more work can be got through. Long-stapled wools are worked about with forks in the scouring liquor. When soap is used, the wool is passed between squeezing rollers, before washing off in water. An excellent scour is also obtained by using resin soap made with soda ash (see Cotton Bleaching).

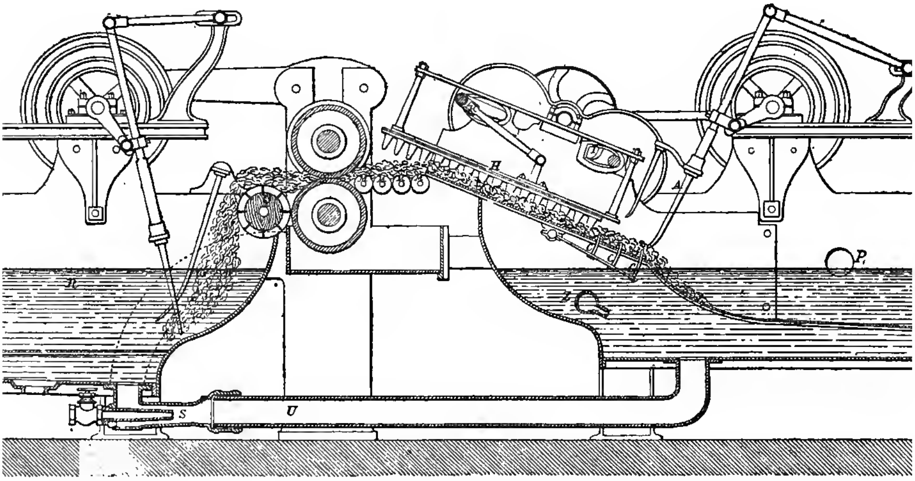
Though the above methods are in general use in small works, they are superseded in large establishments by the wool-scouring machines. Fig. 374 shows a "single four-rake" machine, made by Messrs. J. and W. McNaught, Rochdale. It consists of a large cast-iron trough, fitted up with an ingenious arrangement of forks or rakes. The loose wool is introduced by a boy at one end of the trough; by the movement of the rakes, it is well worked about in the scouring liquor and carried gradually forward to the other end of the trough, there to be lifted out of the liquor by a special mechanism, passed through a pair of squeezing rollers and thrown off, by a fanner, in a semi-dry condition. The wool is then brought back from the delivery to the entering end, and is passed through twice or thrice, using either fresh scouring liquor or water, as required. With a complete machine of three troughs, ranged in a line, the wool is passed by self-acting machinery from one trough to another, and is finished at one operation. If the scouring-house be small, one of the troughs may be made angular, to fit into the corner.

374.



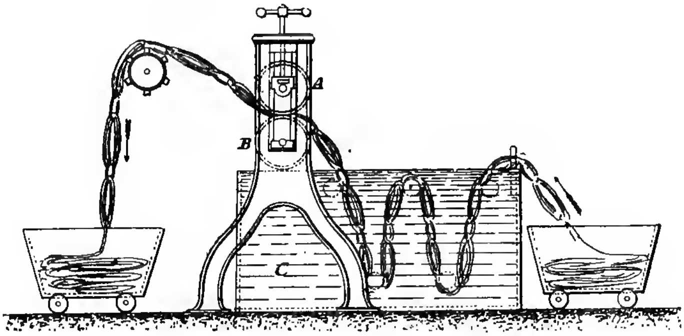
The wool to be scoured is placed upon the apron or feeder *a*, which carries it to the trough; it is then pressed into the liquor by the rotating immerser *b*, and passed forward by the reciprocating rakes *c c*; *e* is a stationary rake, which the reciprocating rake intersects; its use is to prevent the wool from passing forward too quickly. The stationary rakes are hung on pivots, and are adjustable to any angle, to suit the various qualities of wool. After having been carried forward by the washing rakes, the wool is lifted out by a swing rake at the other end of the trough, and is carried on to the second trough, by a very ingenious contrivance, represented in section on a larger scale in Fig. 375. A is the swing rake with a double row of prongs, which work close to the end of the trough, being of the same curve as that traced by the point of the prongs. The wool is, by this means, lifted out of the liquor, and deposited at the bottom of the inclined plane. In order to prevent the wool from being washed back into the trough by the surge of the liquor, a number of retaining prongs *c*, at the bottom of the incline, shoot up from beneath the incline directly the wool is landed on it. H is a flat rake or frame, with short prongs projecting below (similar to a harrow as used for agricultural purposes); this rake is worked by the cams I upon which it rests, and by the crank K, and is so actuated that, after the wool has been deposited at the bottom of the incline, it drops upon it and drags it up the incline, to the extent of its stroke (about 13 in.); it then rises, and returns over the wool, to drop upon it and drag it up again, the retaining prongs withdrawing immediately that the rake drops upon the wool. The rake H works stroke for stroke with the lifting rake A, and drags up the incline all the wool which is deposited at the bottom. The wool, being pushed by the rake over the end of the incline, emerges upon a series of metal rollers M, about 3 in. in diameter, all revolving in one direction, which carry it forward to the squeezers. These rollers M are so driven that each succeeding roller shall revolve quicker than the one before it; this continual increase of speed effectually prevents any wool from getting down between the rollers, distributing it evenly, and enabling it to enter the squeezers in a continuous sliver, without losing even the shortest fibres. The squeezing part N is strong, and is fitted with escapement motion, to ensure equal surface speed in the two rollers. P is the inlet of the liquor expressed by the squeezers, and conveyed back to the trough by a pipe. After passing the squeezing rollers, the wool is cleared from them by the roller Q revolving in the same direction, with a slightly increased surface speed. The wool falls from this "clearer roller" directly into the second trough, to be carried forward by the washing rake as before. At the end of the third trough, a delivery fan, about 2 ft. in diameter, is placed behind the squeezing rollers, and, after passing between them, throws off the wool in a semi-dry condition. Each trough is fitted with a perforated false bottom, with space underneath to allow the dirt and mud to settle; Z is a water-pipe for swilling the mud away. The bottom of the trough slopes downwards from the delivery to the feed end, and a large outlet valve is placed at the lowest point. Between and beneath each two troughs, is placed an injector S; a jet of steam, introduced into the connecting pipe U, causes the liquor to pass quickly from one machine to the other; by this arrangement, all the troughs may work together on the same level. The first trough contains a strong scouring liquor; the second, a weaker one; and the third may contain running water. Besides the one described, there are other good machines by Petrie and Leech, each possessing special features. The loss in this scouring may range from 35 to 45 per cent. The temperature of the scouring liquor is about 54½° (130° F.). The active principle in stale urine is the carbonate of ammonia, produced by fermentation; this forms an emulsion with the fatty matters. When carbonate of soda is used, the strength of the solution should be about ¼ lb. to ½ lb. soda, per 10 galls. water. For fine wool, soap and soda is sometimes used. It is seldom that loose wool is sulphured.

375.



Yarn Scouring.—When wool has been spun, it comes to the manufacturer or dyer in the form of hanks, and contains in this state about 10 to 15 per cent. of rape, olive, or other oils, or oleic acid, which have been added to facilitate the operations of spinning. The detergent used is generally carbonate of soda, or a mixture of soap and soda, or of soap and ammonia, the latter for better class wools. Before scouring, it is usual with some kinds of wool, in order to prevent the felting of the yarn, to steep it in hot water for about five minutes, and then to leave it to cool. The scouring is done in large wooden boxes, heated by a perforated steam pipe. The hanks of yarn are hung on sticks placed across the box; they are worked to and fro, and frequently turned over by two men standing on each side, for ten to fifteen minutes, then lifted, drained, transferred to a second box to be worked in a similar manner, and finally washed in cold water. The temperature of the scouring bath is about 60° to 66° (140° to 150° F.). In some establishments, the scouring of hank yarn is also done by a machine very similar to the cotton yarn washing machine, Fig. 373, p. 508. By another method, the hanks are worked about by hand in scouring liquor standing in a small box or tub, and are carefully placed on a travelling endless band, which leads them through a pair of squeezing rollers, and drops them into a box behind. The process is repeated, and a wash in cold water finishes the operation. A good and rapid method of scouring woollen yarn is by means of the machine represented in Fig. 376, which is extensively used in the Paisley dye-works. A great advantage gained by employing this machine is that the scoured and dyed yarn becomes less tangled, and will wind very much better, than when scoured by hand. It consists of two iron squeezing rollers A and B, both covered about 1 in. thick with some soft, durable material, e.g. silk noils, in order to make them elastic. These rollers are set over the delivery end of the wooden trough C, which is about 8 ft. long and 2 ft. wide, and is fitted up internally with wooden rollers above and below. The hanks of yarn are previously linked together, end to end, by means of a small knotted and twisted loop of cotton cord, the knot being buttoned, as it were, in the end of the twisted loop. The hanks thus form one continuous chain, and the whole operation of linking is rapidly performed by a boy. The knot is always left between the hanks, to prevent its cutting the yarn, on passing through the squeezing rollers. By this method, one man and eight boys can scour 3000 lb. yarn a day, using two machines, one for the rough, and the other for the finishing scour. By placing three machines in a row, and feeding the last one with a continuous supply of clean water, the scouring may be performed at one operation, and with fewer attendants. The advantage of this is obvious.

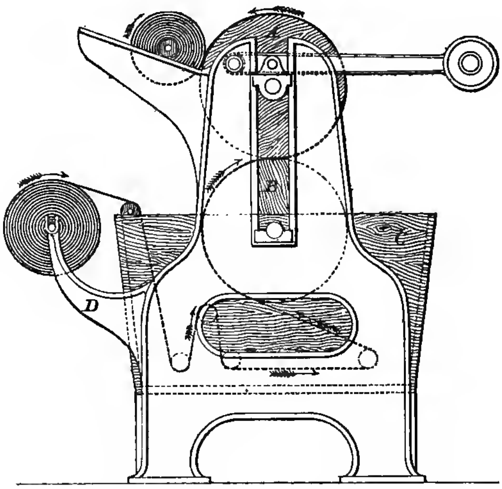
376.



Yarn Sulphuring.—Yarn to be dyed in dark shades needs no further bleaching; but when certain delicate and light shades are to be subsequently dyed, or if the yarn is required white for weaving purposes, the damp scoured yarn is hung on poles, and exposed in a sulphur stove to the action of sulphurous acid gas. Finished white yarn is blued in the last washing with a little neutral indigo extract, or with a mixture of aniline blue and aniline violet, before sulphuring. The common dimensions of a sulphur stove for this purpose are:—Height of the walls without roof 12 ft., breadth 12 ft., length 27 ft. It is built of brick, with a tiled floor, and is provided with a closed window at each end, and with a door, made simply but well. In the interior, there is at each corner a furnace whereon to burn the sulphur, and opposite each furnace is an iron door opening outwards. Two of the furnaces have a small chimney 6 ft. to 8 ft. high, to facilitate the rising of the vapours to the upper parts of the stove; the other two have none. The yarn is hung on poles, resting on a wooden framework; the entrance door and a trap-door under the ventilator are then closed, the necessary quantity of sulphur is placed in little cast-iron pots, lighted, and put in by the iron doors, and all is closed up. As the oxygen in the air of the chamber becomes exhausted, the burning sulphur is extinguished. The yarn is left in from six to eight hours or overnight; then all the doors are thrown open, and, as soon as the place is well ventilated, the yarn is taken out and hung in the open air, to allow the absorbed fumes to escape. The amount of sulphur burnt is about 6 lb. to 8 lb. sulphur to 100 lb. yarn. After sulphuring, the yarn is well washed in cold water, and dried.

Cloth Scouring.—In general, this is very similar to yarn scouring; but, of course, the machinery is different, and there are slight variations in the time occupied and in the quantities of stuff used, according to the different qualities of the material. Fig. 377 represents one of the machines used. Four such machines, called crabbing machines, are usually placed one behind another. Each consists of two bowls, the upper one A of iron, the lower one B of wood, working in a wooden box or trough C, of the following dimensions:—breadth above, 28 in.; ditto below, 21 in.; depth, 16 in.; length, 45 in. At the bottom of this box, there are a few wooden rollers, under and over which the cloth has to pass, as well as a steam pipe, for heating the scouring liquor. The bowls are arranged to be driven in either direction, in order to roll or unroll the cloth on either bowl. The beamed pieces for scouring rest on the bracket D, and, after passing through the liquor, they are re-beamed on the loose beaming roller which rests on the inclined supports at E, and against the roller A. The pieces are singed by plate or by gas, before scouring; they are beamed on rollers, about fifteen pieces of 36 yds. on a roller.

377.



The following is the process for bleaching muslin-de-laine with cotton warp; it consists of three passages through soap and soda liquors, sulphuring, mangling, and drying on steam cylinders or in the drying shed. The cotton warp threads will have been bleached before weaving, so that the present bleaching has reference only to the woollen weft. The first machine is set, when commencing, with 2 lb. soap, and 6 lb. soda; but generally it is set with the old soda liquor from the third machine, sometimes with half of this old soda liquor and half of the soap liquor from the second machine. The pieces run through at a temperature of 60° (140° F.). Three sets of fifteen pieces each are scoured before letting off the liquor. The pieces are beamed on the top bowl, and the beam is transferred to the next machine.

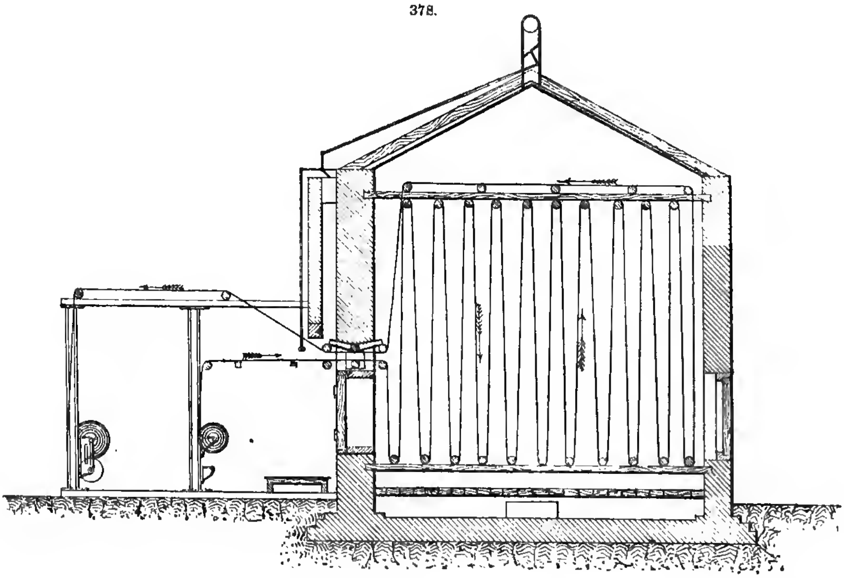
The second machine is set for the first fifteen pieces with 1 lb. soap and 3 lb. soda. The pieces from the first machine are run into this second liquor at 71° (160° F.), and are beamed on the loose roller. To the two following sets, 1½ lb. soap is added.

The third machine is set with 2 lb. soap for two sets of fifteen pieces each. Temperature, 71° (160° F.). The beamed pieces are then taken to the sulphuring stove.

The point aimed at in the above process is the complete exhaustion of the scouring effect of the liquors. At the same time, the cloth on leaving the third machine should be fully scoured, and without a trace of grease; the operation may be considered well performed when a trace of soap remains in the cloth at this stage. It may also be remarked that the greatest care should be taken to prevent the pieces from crimping or creasing, as these defects cannot be removed, owing to the fibres becoming broken. The pieces are rapidly stitched together, by means of thin iron wire. The second and third machine have a small roller in front, to diminish the tension of the cloth, and hinder its running up in breadth.

Cloth Sulphuring.—The cooled pieces are run through Thom's sulphuring stove, Fig. 378. This stove consists of a chamber about 6 ft. long, by 5¾ ft. wide, built with a double brick wall, and roofed with sheet lead; height of walls, 5 ft.; elevation of lead roof, 15 in. Right under the roof, and fastened to it, is a serpentine steam pipe ¾ in. diameter, which heats the top and inside of the chamber, thus preventing condensation or the formation of drops. The sulphur is burnt outside the chamber, in a small furnace adjoining one of the side walls of the stove. Through an aperture in this wall, the sulphur fumes enter a small canal (inside the stove), which is covered with perforated tiles, so that the fumes may be equally diffused in the stove. On the top and just in the middle of the lead roof, is a 1-inch lead pipe connected with the chimney of the works, for regulating the draught necessary for the combustion of the sulphur, and for leading its fumes into the stove. A wooden frame, with rollers at top and bottom, is fixed in the stove; the pieces, in open width, are run in over these rollers and led out on the opposite side, the stove being completely filled with sulphurous acid gas. It is preferable to lead them back over rollers, so that they may come out at the same slit by which they entered, and be beamed at once. The space between the two walls in front is connected with the chimney, and serves to lead away the gas carried out by the pieces.

378.



After beaming, the pieces are run through again. Twenty-four muslin-de-laine pieces of 36 yds. each can be run twice through this machine in one hour. The quantity of sulphur used is nearly the same as in the chambers for yarn, or about 7 lb. sulphur for sixty pieces of 36 yds. each.

Mangling or rincing in cold water.—Three bowls, a brass one in the centre, and two of wood, with levers, weights, &c., form the mangling machine. The bottom bowl is placed in a box or trough, filled with water. The sulphured pieces are run open through the water box, then between the bowls, and, before receiving the top nip, are passed under a continuous jet of pure water. They are beamed on this machine, and dried on the steam cylinder drying machine.

Bleaching muslin-de-laine, all wool.—For this purpose, the same machines may be used; but, as a rule, less strain, less soda, and lower temperature are required.

First Machine: 3 lb. soap, 1 lb. carbonate of soda, or the old soap bath with an addition of ½ lb. soda. Temp. 49° (120° F.).

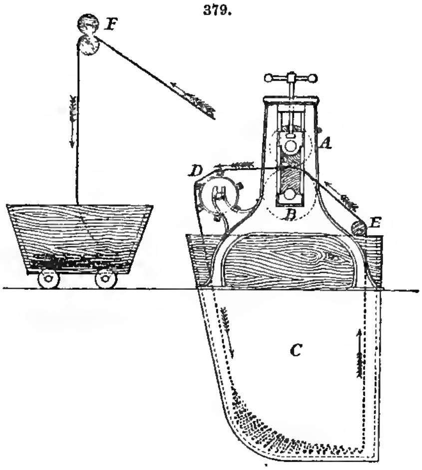
Second Machine: 5 lb. soap for the first roll of sixteen pieces, and 1 lb. soap is added for each sixteen pieces following. Temp. 65° (150° F.). French all wool pieces are about 80 yds. in length; in this case, only eight pieces are put on a roll. The liquor is renewed after six rolls, or forty-eight pieces of 80 yds. each.

Third Machine: 2 lb. soap. Temp. 60° (140° F.). The pieces are beamed, well stretched, both in length and breadth, on the rollers, and left to cool.

Fourth Machine: 2 lb. soap. Temp. 49° (120° F.). The liquor is run off and a fifth passage is given in water at 43° (110° F.). The pieces are left to cool again on the rollers, then sulphured twice, rinced in cold water through the mangling machine, and dried. They are singed, either on plate or by gas, previous to scouring. Fine goods, or those to be dyed in light, delicate shades, are only singed after having been treated with soap and soda. Flannels generally require stronger soda baths, since they contain more oil.

Fig. 379 represents another kind of woollen cloth scouring machine, called a "dolly," suitable only for certain kinds of woollen goods, e. g. flannels, merinos, &c., the creasing of which during scouring is of little consequence. It consists of two wooden bowls A and B, set over a wooden box C, 5 to 6 ft. deep, 4 ft. broad, and 5 ft. long, divided, by perforated wooden boards, into four compartments. Each division holds eight pieces of 50 yds. each, and weighing 20 to 30 lb.; they are all stitched together end to end, so as to form one endless band. This band, guided by the rollers D E, is drawn by the two squeezing bowls in the direction indicated by the arrows. When the scouring is finished, an end is loosened and led between the traction rollers F, in order to draw the pieces out of the machine. The box C is filled with a mixed solution of soap and soda, so as to form a good lather, say 2 lb. soda to 1 lb. soap. The pieces are run from fifteen to twenty minutes, then taken out, and washed in cold water in a similar machine; afterwards they are scoured again for fifteen to twenty minutes in a good solution of soap only, then washed, hydro-extracted or mangled, sulphured, and washed. The number of scourings and sulphurings depends greatly upon the quality of the material, and upon the degree of whiteness required.

379.



Goods which have to remain white are blued, by being run through a padding machine containing 1 gall. boiling soap solution (1 lb. soap per gallon of water), 9 galls. water, 1½ to 2 pints indigo blue pulp (precipitated from a blue vat). The soap is required to keep the blue in suspension; with less than the quantity given, the blueing might be uneven. The blueing process precedes the sulphuring. "All wool" goods require about half the given quantity of indigo blue pulp; they are sometimes blued by using a weak aqueous solution of indigo extract (sulfindigotic acid) after scouring, and, when sufficiently blued, are rinsed in cold water, to wash off the blue adhering superficially.

The method of bleaching by burning sulphur, as above described, is known as "gas bleaching," to distinguish it from "liquid bleaching," in which are employed a solution of sulphurous acid, or solutions of alkaline sulphites from which the sulphurous acid is expelled by a mineral acid.

Good results may be obtained by using a solution of bisulphite of soda, acidified with hydrochloric acid; in this, the woollen goods are steeped for several hours and then thoroughly washed. Large crystals of bisulphite are used, so that their solution and decomposition may take place gradually. A more rational method, however, is that in which the treatment with hydrochloric acid takes place in a separate bath, whereby the sulphurous acid is generated within the fibre, and, being in the nascent state, acts more powerfully upon the colouring matter of the wool. Liquid bleaching, when properly done, gives a more permanent white than gas bleaching, as may be inferred from the remarks, which will presently be made, on the theory of sulphurous acid bleaching.

After sulphuring with gas, the goods should be washed with a weak solution of carbonate of soda or ammonia; after a final sulphuring, especially if they contain cotton, with water only; this is in order to remove the small quantity of sulphuric acid generated in the fibres, and which would otherwise be liable to render the goods tender. The treatment with soda after sulphuring has, also, the effect of restoring the suppleness of the wool, which the latter process has destroyed.

The sulphurous acid acts, by combining with the insoluble colouring matter fixed on the wool, to form an easily soluble compound, which, as it happens, is in itself almost colourless, but which must nevertheless be washed away if the white is to be permanent; hence repeated treatments with soda, soap, sulphurous acid, and water, suffice to eliminate every trace of this colouring and colourable matter. Since the last trace of any colouring matter remaining would necessarily be precipitated by treatment with soda, and thus leave the wool with a yellowish hue, it will be readily understood that the washing after the final sulphuring should be done with water only, if a pure white is desired. Imperfectly bleached woollen goods, from which the colourless compound of colouring matter with sulphurous acid has not been entirely removed by washing, become slightly yellow after lengthened exposure to air.

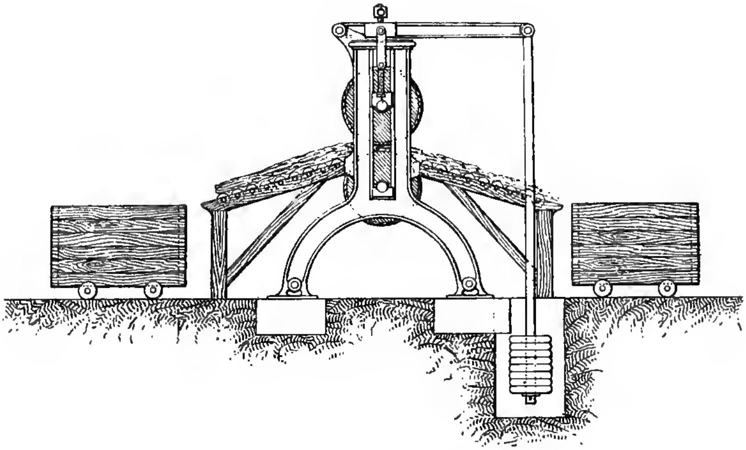
With respect to the quality of the water suitable for scouring woollen, the freer it is from lime and magnesia salts the better, especially when soap is employed, since in this case insoluble soaps are formed, which cling with great tenacity to the fibre, and have an injurious effect on subsequent dyeing processes. When an alkaline carbonate, or urine is employed, the bad effects are not so great, as, from the powdery nature of the precipitates produced, they are more readily removed by washing.

Linen Bleaching.—The bleaching process to which linen is subjected has for its object the destruction and elimination from the pure cellulose of the linen fibre all its impurities, the principal of which are insoluble pectic matters, occurring to the extent of 25 to 30 per cent.

Linen is bleached in the form of yarn, of thread, and of cloth. In the case of yarn, it is very usual to bleach it but partially, for reasons to which reference will be made hereafter. Thread and cloth are generally bleached white. The operations of linen bleaching are, on the whole, very similar to those of cotton bleaching; but the details vary from the latter in some points, and the whole process is very much more difficult and tedious, owing to the larger percentage of natural impurities which adhere with great tenacity to the fibre. The process comprises—boiling with dilute caustic or carbonated alkalies, washing, chemicking, souring, rubbing, and "grassing," or exposing.

Some of the machinery too, as used at the present time, differs from that employed in cotton bleaching. For yarn and thread, it is very usual to have the false bottom of the bleaching kier, or pot, movable and attached by ropes to a crane, so that after draining away the liquor, the whole potful of hanks can be lifted out at once. For washing, Gantert's machine is well adapted. For expressing the water after washing, either the hydro-extractor or the squeezers are used, preferably the latter. These squeezers are made somewhat differently from those already described, and are shown in Fig. 380. They are provided with endless bands or aprons, on each side of the bowls, for entering and taking off the yarn, which is placed upon the entering band in a thick layer, the hanks overlapping each other. The levers, &c., are arranged so as to give the bowls considerable play up and down.

380.

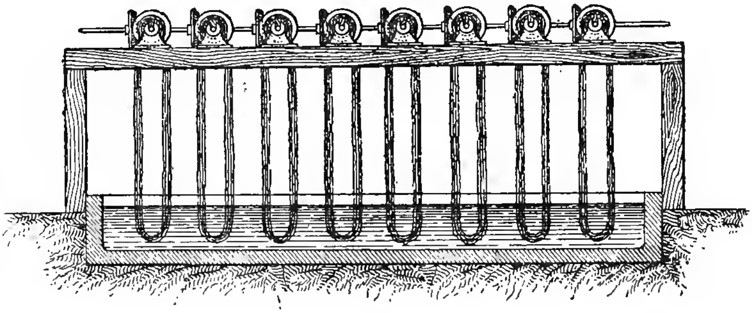


The chemicking machine, seen in Fig. 381, consists of a large stone cistern, about 15 to 25 ft. long, 5 to 6 ft. wide, and 3 ft. deep, provided with a framework holding twenty or more square reels, on which the hanks of yarn or thread are hung, their lower ends dipping into the bleaching powder solution. The reels are driven by a series of bevel wheels placed along one side of the cistern, and having reversible gearing. Each reel rests loosely in its bearings, and can be readily detached while the machine is in motion. When necessary, e. g. at the end of the operation, the framework and all the reels can be raised out of the liquor at once, by means of chains attached to the four corners of the frame. With this machine, a whole kierful of yarn or thread is chemicked at once and with great equality; it is generally run for from one to three hours, and, during the whole of that time, each portion of the hanks is successively exposed to the action of the liquor and of the air.

The machines for souring are identical with those used for cotton yarn.

With regard to the machines in use for linen cloth bleaching, it may be remarked that the washing machines, as described under "madder bleaching," have not been found at all adapted for linen, since the latter does not possess the elasticity of cotton (probably owing to the absence of the spiral character of the fibres), and the goods are liable to be "cracked" or torn, especially at the selvages, by a slight increase of tension. Many classes of goods, too, e. g. towelling, are of very uneven thickness, owing to the divisions between each towel (i. e. the jeep forming the fringe), containing only warp threads, thus differing very much from the woven central portion. This inequality alone would make the cotton washing machines quite inapplicable, since such goods would readily be torn. The machines in general use are the wash stocks, identical in construction with those described in the bleaching of cotton hank yarn. For many qualities of goods, it is more than likely, however, that success would attend the adoption of slack washing machines, similar to those in use with calico printers. In these machines, the washing trough is divided, by wooden spars or by perforated plates, into compartments, corresponding to the number of nips received by the cloth, so that each compartment can hold several yards of slack cloth before it is drawn again between the squeezing rollers.

381.



The chemicking and souring of linen cloth consists, as a rule, in merely steeping the goods in stone cisterns containing the liquors, and then lifting them, after nine hours, on to drainers placed over a portion of the cistern. A preferable method, however, is to use pumps, and cisterns with false bottoms and wells below, as mentioned in "market bleaching," so that the solutions can be circulated through the goods, and a more even action of the reagents be obtained. A more recent and approved plan is to use a machine similar to the slack washing machines just referred to, with a continuous flow of liquor, as described in "madder bleaching."

A special feature in linen cloth bleaching establishments is the "rubbing machine," a representation of which is given in Fig. 382. It consists of a pair of heavy wooden boards A B, about 2 to 3 yds. long, 1 ft. broad, and 3 in. thick, resting on each other, and one of which is moved lengthwise to and fro, by means of a crank shaft D, while the pieces are led laterally between them. Where the pieces pass between the boards at c, are fixed pot-eyes, and the boards have their rubbing surfaces corrugated in order to increase the friction.

By the term "grassing," or exposing, is understood the spreading of the goods in a field to subject them to the influences of air, light, and moisture. This is a characteristic of the present general method of linen bleaching; practical experience has proved that it cannot conveniently be dispensed with.

The following is a

Modern Irish Process for 3000 lb. Brown Linen.

1. Lime: 250 lb. lime.
2. Lime boil: 14 hours, low pressure, 3 to 8 lb.; wash 40 minutes in stocks.
3. Sour: hydrochloric acid 2½° Tw., steep 2 to 6 hours; wash 40 minutes in stocks, "turn hank," and wash 30 minutes in stocks.
4. Leyboils: 1st. 60 lb. caustic soda (solid); 60 lb. resin; previously boiled and dissolved together in water; 400 galls. of water; boil 8 to 10 hours, run off liquor, and add
   2nd. 30 lb. caustic soda (solid), dissolved; 400 galls. water, boil 6 to 7 hours. Wash 40 minutes in stocks.
5. Expose in field, 2 to 7 days, according to the weather.
6. Chemick: chloride of lime solution, ½° Tw., steep 4 to 6 hours; wash 40 minutes in stocks.
7. Sour: sulphuric acid 1° Tw., steep 2 to 3 hours; wash 40 minutes in stocks.
8. Leyboil or "scald": 3rd. 15 to 25 lb. caustic soda (solid), dissolved; 400 galls. water; boil 4 to 5 hours. Wash 40 minutes in stocks.

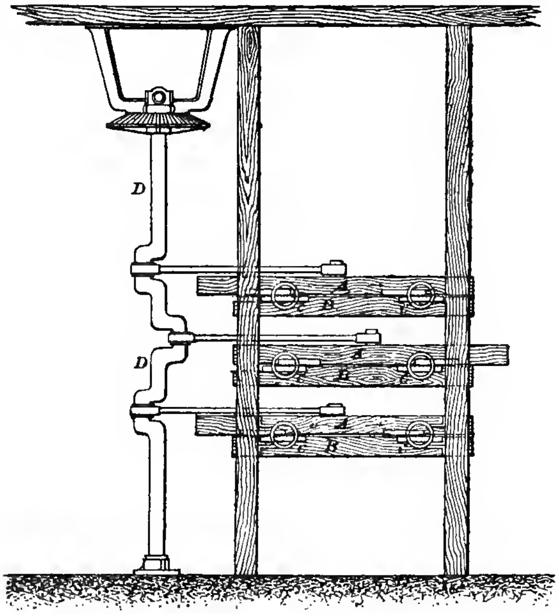
9. Expose in field, 2 to 4 days.
10. Chemick : chloride of lime solution ¼° Tw., steep 3 to 5 hours. Wash 40 minutes in stocks.

The goods are examined at this stage; those which are ready are soured and washed, and those which are not perfectly white are taken to the next stage of the process.

11. Rub with rubbing boards and a good solution of soft-soap.
12. Expose in field, 2 to 4 days.
13. Chemick: chloride of lime solution ⅛° Tw., steep 2 to 4 hours. Wash 40 minutes in stocks.
14. Sour : sulphuric acid 1° Tw., steep 2 to 3 hours. Wash 40 minutes in stocks.

The above process is suitable for all those goods, e. g. lawns, shirtings, handkerchiefs, which are made of brown yarn (i. e. linen yarn which has had no previous bleaching), and which never contain coloured yarns. It is, however, customary, as has been said, to bleach linen yarn, before it is woven, to various degrees of whiteness, which have special technical names, e. g. exposed duck, house duck, cream shade, &c. This preparatory bleach is specially advantageous for thick heavy goods, and such as have coloured borders, figures, &c., since, in this case, a milder bleach may be given, and there is a better chance of preserving the bloom of the interwoven colours. Such semi-bleached yarn is, for example, used for table linen, towelling (damasks, diapers, huckabacks), &c.

382.



For these goods, the following process is sufficient :—

Modern Irish Process for 3000 lb. Cream Linen.

1. Lime: 160 lb. lime.
2. Lime boil: 10 to 12 hours, low pressure, 3 to 8 lb.; wash 40 minutes in stocks.
3. Sour: hydrochloric acid, 2½° Tw., steep 2 to 4 hours; wash 40 minutes in stocks; "turn bank," and wash 30 minutes in stocks.
4. Leyboil: 1st. 200 lb. soda ash and 60 lb. resin, previously boiled and dissolved together in water; 400 galls. of water; boil 6 to 7 hours; wash 40 minutes in stocks.
5. Expose in field, 2 to 7 days, according to weather.
6. Chemick: chloride of lime solution ¼° Tw., steep 3 to 4 hours; wash 40 minutes in stocks.
7. Sour: sulphuric acid 1° Tw., steep 2 to 3 hours; wash 40 minutes in stocks.
8. Leyboil, or "scald": 2nd. 400 lb. soda ash, 400 galls. water, boil 4 hours; wash 40 minutes in stocks.
9. Rub with rubbing machine and good solution of soft-soap.

10. Expose in field, 2 to 4 days.
11. Chemick: chloride of lime solution $\frac{1}{8}$° Tw., steep 3 to 4 hours; wash 40 minutes in stocks.
12. Sour: sulphuric acid 1° Tw., steep 2 to 3 hours; wash 40 minutes in stocks.

It is possible to bleach some goods without limeing, and, when it can be avoided, they are much softer. What is known as "brown holland" is a plain woven linen cloth which has had little or no bleaching, but only a slight boiling in water, or a weak soda-ash solution, with, perhaps, a little souring. It therefore has the natural colour of the linen fibre.

During the limeboil, a portion of the brown colouring matter (pectic acid) is dissolved. Dr. Kolb finds that for every hundred parts so dissolved, 48 parts of lime enter into solution. The same precautions as are mentioned under "madder bleach" must be even more rigorously attended to here.

The boiling with alkali removes still more of the pectic acid, also the fatty and greenish matters present. Carbonate of soda seems to dissolve more of the greenish and less of the fatty matter, hence linen yarns boiled with soda ash are somewhat softer than those treated with caustic soda.

After the leyboils, the goods should never be allowed to lie exposed to the air too long before washing, otherwise they are apt to be tendered in places, by the crystallization of carbonate of soda within the fibres, which are cut or burst during the formation of the crystals.

The loss in weight by the boilings with lime, and caustic (or carbonate of) soda varies from 15 to 36 per cent., according to the origin and previous treatment of the yarn. Unbleached yarn boiled with water alone for a week, under a pressure of 75 lb., loses about 18 per cent. In all these cases, the insoluble pectic acid is changed into soluble metapectic acid, which combines with the alkali, driving off the carbonic acid when soda ash is used (Kolb).

After a number of successive boilings with alkali, the brownish colour of the fibre disappears, and the goods only retain a pale grey shade, which varies in hue according to the process of retting employed. In this case, the pectic matters have been thoroughly discharged, and the remaining grey colouring matter is readily bleached, by steeping in a weak solution of chloride of lime, without injury to the fibre. The brown pectic matters are only bleached with great difficulty, and even then only by using a chemick solution of such a strength that the fibre itself is attacked; hence this agent must never be relied on, in the earlier stages of the process, to remove the brownish colour of the fibre; and, since scarcely more than 10 per cent. of the pectic matters are ever removed in practice by a single leyboil, it is only by repeated treatments with alkali that the whole of these matters are eliminated.

The great excess of pectic matters prevents the "chemick" from decolorizing the whole of the grey matters at one operation; hence the necessity for alternating the alkaline boilings with more and more dilute chloride of lime treatments. If the "chemick" is used at too early a stage, the brown colour becomes fixed or "set," and can then only be removed with the greatest difficulty, if at all.

The quantity of "chemick" used in practice for linen is always greater than that required for cotton; but its use is nevertheless restricted, and alternated with exposure in the field. This plan is adopted from the fact that linen, although mechanically much stronger than cotton, does not possess an equal resistance to chemical decomposition. For the same reason, the necessity for washing well between chemicking and souring, and after souring, cannot be too strongly recommended, in order to avoid the evolution of chlorine gas within the fibre. Prolonged contact, too, with hydrochloric acid even at 2° Tw. has a weakening action on the fibre.

The object of the rubbing, which is so essential for many qualities of goods, is to remove small specks of brownish matter called "sprits," which may appear here and there throughout the piece. The "turn-hanking" referred to in the above processes consists in loosening and refolding the pieces so that every part may be exposed to the action of the hammers of the wash stocks, and the operation is introduced at various stages of the bleaching process, according to the appearance of the goods.

In order to see if the bleach has been successful and complete, a good test is to dip a sample of the goods in a weak solution of ammonia; well bleached linen will not be affected by it, whereas such goods as are white, but still contain pectic matters, will be tinged yellow, and will always be liable to become so if stored for a lengthened period.

The usual period required for bleaching brown linen is from three to six weeks, though it is quite possible to bleach many classes of goods in much less time.

Silk Bleaching.—Silk is bleached either as yarn or as woven material, the operations on the whole being very similar to those of Woollen bleaching. One of the great centres of the silk dyeing and bleaching industry is Lyons. Following is a *résumé* of what M. Marius Moyret, of Lyons, says on the subject, in his excellent 'Traité de la Teinture des Soies.'

Silk-yarn Bleaching.—The first operation is that of "scouring," which can be performed in different ways and with different substances, e. g. with weak caustic alkalies, alkaline carbonates, soap, or acids. The object of this scouring is to remove, to a certain extent, from the raw silk, some of its envelope of glutinous matters, in order to render it lustrous, soft, and supple, and fit for being dyed.

Scouring with weak Caustic Alkalies.—These, viz. caustic potash and soda (caustic ammonia has no action), are the most active, but, at the same time, the most dangerous, to employ, since with prolonged action, especially in the case of fine silks, the fibre itself is attacked. They are used, however, and with success too, for scouring the coarser and fancy kinds of silk. The hanks of silk are hung on sticks, and worked in a tub containing the scouring liquor, as described under woollen yarn scouring. For 100 lb. silk, a solution of 3 to 4 lb. solid caustic alkali in about 300 galls. water heated to 60° (140° F.) is used, and the yarn is turned during half an hour. It is then well washed and beaten. This plan is advantageous for coarse fancy silks, since it dissolves off the fine down of the fibres. For these qualities, the total loss in scouring is 10 to 12 per cent. of the weight of raw silk.

Scouring with Alkaline Carbonates.—This method, still used in China, has, notwithstanding its economy, almost entirely disappeared from European establishments, on account of certain practical difficulties. The silk yarn is worked for from one to one and a half hour, in a bath heated to 85° (185° F.), containing for 100 lb. silk, 10 to 12 lb. soda crystals. At first, the silk swells up and becomes gelatinous, then the outer envelope dissolves off; the fibre thereby becomes finer and more lustrous. It is sufficiently scoured when it produces a rustling noise on being rubbed with the nail; it is then washed two or three times with tepid water. The loss varies from 18 to 28 per cent. Besides the delicacy of this method, it is inconvenient not to be able to boil the silk without great risk, while experience has shown that boiling will give in many respects a better article.

Scouring with Soap.—This is pre-eminently the best method, since it preserves and even increases the valued properties of silk, such as feel, brilliancy, &c.; the soap used, however, should always be of the best quality. In the north of Europe, soft potash soaps, generally made from linseed oil, are used; in the south, hard soda soaps made from olive and other oils are preferred. Of late years, soap made from oleic acid has been more and more employed. Those soaps are to be preferred which wash off best and leave an agreeable odour. In general, those made from oleic acid and linseed oil wash off best; then follow the soaps made from olive oil, suet, &c. (containing stearic and margaric acids); last, and worst in this respect, comes palm-oil soap, which, on this account, has been almost entirely given up, notwithstanding its agreeable odour. For scouring silks which are to be subsequently dyed, oleic acid soap may be recommended; but for those destined to remain white, a good olive-oil soap is best. In the latter case, two operations are necessary, "ungumming" (*dégommage*), and "boiling." For "ungumming," a boiling solution of 33 lb. soap to 100 lb. silk is used, the yarn being worked in this, from a half to three-quarters of an hour. Previous to placing the silk in this bath, however, it should be softened in a weak solution of soda crystals, or better still, of hydrochloric acid, and should be washed. For "boiling," the same bath may be used (if not too strongly charged with silk-glue), except for the purest whites, or when the raw silk is coloured; in these cases, a fresh bath is imperative. The yarn is lifted from the ungumming bath, and allowed to drain; the hanks are then wrung, sewn up in coarse hempen bags or "pockets," and boiled, during two to three hours, with a solution of 17 lb. soap per 100 lb. silk. The yarn is then rinsed in a weak, tepid solution of soda crystals, to avoid the precipitation of any fatty compounds on the silk, after which it is rinsed in cold water. For Japanese and Chinese silks, the loss may vary from 18 to 22 per cent.; for European silks, 25 to 27 per cent.

Scouring with Acids.—M. Moyret finds that an aqueous solution containing 5 per cent. of phosphoric or arsenic acid, has an action similar to that of the weak alkalies. Silk, previously moistened with dilute tepid hydrochloric acid to free it from lime, is ungummed, after boiling for three hours in the pockets with the above solutions. The process, however, has not been adopted, owing to the fact that the silk is not rendered so white, and is not so capable of being properly weighted afterwards.

Silk Yarn Bleaching and Tinting.—After scouring, the yarn is opened out, to be hung on sticks, and worked in a bath containing 10 lb. soap per 100 lb. silk, at a temperature of 49°–60° (120°–140° F.); it is then drained and straightened out, ready for being sulphured. The total amount of good olive-oil soap required to scour silk for white, varies from 50 to 60 per cent. of the weight of the latter in the raw state.

Sulphuring.—For this purpose, the hanks, while still damp and well straightened out, are hung in the sulphur chamber (which is of the same construction as that described under Woollen bleaching), and are there exposed to the fumes of burning sulphur for five to six hours, or even over night. Afterwards, the silk is well rinsed in a weak tepid solution of soda crystals, in order to wash out the sulphurous and sulphuric acids absorbed by the fibre. To ensure the thorough expulsion of the former, it is customary to hang the rinsed hanks, after wringing out the water, in a stove heated to 29°–38° (85°–100° F.). With reference to the bleaching of silk by sulphurous acid, M. Moyret's opinion seems to be that probably it does not act directly in destroying the colouring matter of the fibre; but that along with the formation of sulphuric acid there is also a production of ozone, to the bleaching properties of which reference has been made in Cotton bleaching

Tinting.—This operation is necessary to hide the faint yellow hue which the silk still retains.

Unlike the analogous operation in use with cotton and wool, the question here is not always one of simple blueing; to suit the tastes of the merchants, the silk is actually dyed in various delicate shades, e. g. milk white, snow white (pure white), azure white (blueish white), Chinese white (orange, yellowish and purplish whites). To obtain pure white, a very weak neutral bath of ammoniacal cochineal and indigo carmine is used, care being taken that the dye should not too rapidly fix itself on the fibre; to prevent this, a little ground chalk is added to the bath. A cold or slightly tepid solution of aniline violet, with addition of a little soap, is also very much used for this shade. To obtain Chinese white, a weak soapy solution of annotto may be employed. After tinting, the silk is rinsed in fresh water and dried in a moderately warm stove, admitting as little light as possible. A passing reference must here be made to the wild or Tussah silk, which it is not possible to bleach in the ordinary way; the process of Tessié du Mothay, however, already described, yields very fair results.

Scouring and Bleaching Woven Silk.—Before scouring, the goods are singed with the gas flame (see Cotton bleaching). The scouring machine consists simply of a winch set over a wooden box or tub. As with the silk yarn, so here, there are two operations, "ungumming" and "boiling," both of which can be done with the same machine. For ungumming, the piece is simply winched backwards and forwards, for about an hour, in an old boiling liquor at 100° (212° F.). After winding the piece on to the winch and allowing it to drip, the liquor is run off and the tub is refilled with fresh liquor, containing 30 to 40 per cent. of white soap, and heated to incipient boiling. The piece is then unwound, and again winched backwards and forwards for about two hours; it is then rewound on to the winch, and allowed to drip for half an hour, when it is ready to be rinsed for dyeing in dark shades, or to be bleached for pale or white shades. Sometimes, in order to save time, the boiling is done in pockets as in the case of silk yarn. For rinsing, the winch with the silk wound on it is transferred to another tub containing a weak solution of soda crystals, where it is unwound and winched for a quarter of an hour, after which it is removed to be streamed in running water, and beaten, till thoroughly clean and ready for dyeing. If for sulphuring, a fresh weak soap bath heated to 49° (120° F.) is given, instead of rinsing; and, after draining, the pieces are hung in the sulphur stove. According to the degree of purity of white required, this soaping and sulyhuring is repeated several times. J. J. H.

BOGWOOD.

Deeply buried in the peat bogs of Ireland, have been found the relics of primeval forests; specimens of oak, fir, deal, and yew have been dug up at intervals, and used by the peasants for firing and other domestic purposes. The oak thus found is as black and as hard as ebony, and possesses considerable value as an article of turnery. That best suited for carving is brought from the counties of Meath, Tipperary, Kerry, and Donegal. A load of it as disinterred costs only about 30*s.*; but a considerable portion of it is unfitted for carving, by the presence of flaws and splits. It is first cut into suitable pieces, and is then worked on the end of the section, or across the grain, and not on the length of the grain or plankwise. The process employed resembles that adopted in the case of ivory. The more experienced workmen can carve designs without having any pattern to work from, earning from 40*s.* to 50*s.* per week. The wages of the less expert vary from 10*s.* a week upwards, women earning nearly as much as men. The total number of persons employed in this industry is said to be over 200. Many of them work on the premises of their employers, others at home.

About fifteen years ago, a method of stamping the design in the wood was devised; this permitted the production of very fine effects, without incurring the great cost of skilled hand labour. According to this plan, the piece of wood, cut to the required size, is placed on the top of the die, which latter is heated by means of a hot plate of metal on which it stands. Over the wood, a similar hot plate is laid; upon this a powerful screw press descends, and the wood receives the impression of the dies as freely as wax, the bitumen in it preventing the fibre from cracking or crumbling. In this way, objects of exquisite delicacy and very high relief (almost to the height of 1 in.) can be produced in a few moments. The designs thus obtained by the die are readily distinguishable from those wrought by the carver's tool; they want the extreme sharpness of the carving, but, on the other hand, they are capable of showing more minute figuring and more elaborate details. The dies, some of which are very beautiful in design, and all sharply cut, are made in the establishments where the carved objects are produced. The designs are not conspicuous for great variety of conception; they take the form principally of antique sculpture crosses in high relief, round towers, abbeys, antique brooches, fibulæ, harps, shamrocks, and other national emblems, besides a multitude of articles used in the boudoir and drawing room.

There are three or four dealers in such articles in Dublin, each of whom sells, perhaps, 5000*l.* worth per annum.

The wood has been utilized as fuel, for centuries past; but its application to artistic purposes dates only from George IV.'s visit to Ireland in 1821.

BONES. (Fr., *Os*; Ger., *Bein*, *Knochen*.)

Bone consists of a dense cellular tissue of membranous matter known as *periosteum*, rendered hard and stiff by incorporation with certain insoluble earthy salts, of which phosphate of lime is the most important. Bones form the solid framework or skeleton of the bodies of animals, enclosing and protecting the most vital parts from external injury, and themselves clothed with softer parts called flesh. They differ greatly in form and character, some being hollow and filled with marrow, while others are solid and contain no marrow. In composition, they exhibit equally wide diversity, especially with regard to the proportions of the two principal constituents, viz. the organic (osseous cartilage or *ossein*) and the inorganic (earthy salts). The former, through which the nerves and blood-vessels find their way into the bone, is antecedent in growth to the latter, and is composed of modified gelatine. The earthy portion consists essentially of phosphate of lime, with carbonate of lime and small proportions of some other salts; it is built up slowly and gradually during the whole lifetime of the animal, so that from the relative earthiness of the bone, some idea may be formed of the age of the animal. On an average, it may be said that the weight of green bones is about equally divided between the organic and inorganic components, or, when dry, about 30 to 40 per cent. of the former to 60 to 70 per cent. of the latter. It has been observed that bird bones are more earthy than animal bones, and contain a greater percentage of carbonate of lime in proportion to the phosphate of lime. The bones of amphibia, again, are less earthy than those of mammalia; in fish bones, the inorganic ingredients vary between 21 and 57 per cent. The composition of fossil bones depends, in a great measure, on the conditions under which they have been preserved, and much irregularity is to be expected. Sometimes the organic matter is abundant, as in fish bones; in other cases, it is altogether wanting. Carbonate of lime is usually more strongly developed, which may be owing to the phosphate being in some degree converted by the infiltration of carbonic acid or its salts.

The economic uses of bones are manifold and important. In the first place, they contain a large amount of nutritious food, which may be extracted by continued boiling in water, or by "digesting." In treeless countries, such as Iceland, Tartary, and the Pampas of South America, they are commonly used as fuel; and among many savage tribes, they form the points of arrows and other weapons of war or the chase. But these are rather domestic than industrial applications.

Whether coming from the slaughter-house or battle-field in a raw state, or from the domestic kitchen after having undergone one or more cookings, bones always contain an amount of fat, which must be extracted as a preliminary to any other process needed to fit them for their various uses. The elimination of the grease is usually effected by subjecting the bones to gentle ebullition, for about twenty-four hours, in water in large open coppers, and skimming off the fat as it floats. All kinds of bones should not be boiled indiscriminately together, both because the bones themselves will be devoted to different purposes, and because the quality of fat produced will likewise be various. The hollow bullocks' shank-bones are generally boiled alone, yielding the primest fat, which is sold to the soap-makers, and to the manufacturers of "butterine" and other curious compounds with which science provides our breakfast tables, at about 35*s.* to 45*s.* per cwt. Ordinary butchers' bones are chopped into pieces about the size of the sticks composing the bundles of London firewood, and in such a manner with regard to grain, &c., as will best expose the fat-impregnated cells of the bone to the dissolving action of the hot water. The grease from these is less in quantity and inferior in quality to the last named, and sells at 25*s.* to 35*s.* per cwt., the price varying with the more or less brown colour. Common house-bones yield still less fat, whose general character and price do not differ materially from those just mentioned. Horse bones contain so little fat as not to be worth boiling for its extraction, and are comparatively useless for any purpose save manuring the ground; they are only indifferently valuable in that sphere, as the great percentage of lime they contain precludes their being economically treated with sulphuric acid before application to the soil. Fish bones are usually pressed, to remove the valuable oil which is present in considerable amount, and are then administered as a manure, without any further preparation.

One of the principal uses of bone is the manufacture of knife handles, toothbrushes, babies' gum-rings, and a great variety of such small articles of turnery. Almost the only kinds of bone employed for this purpose are the shin and buttock bones of oxen and calves. They are first boiled, as described above, to remove the fat, and this process robs them, at the same time, of some of their bone cartilage, thus rendering them rather more brittle. Next they are bleached, by laying them in the sun, or by other means, and are sawn and turned into shape as required. When finished, they are soaked in turpentine for one day, boiled in water for about an hour, and then polished, first with glass paper, second with Trent sand or Flanders brick on a wet flannel, third with whiting on a damp woollen rag. Finally, a small quantity of wax is rubbed on quickly with the object of filling up the tiny pores of the bone, but very little must be allowed to remain on the article. Common articles, such as cheap tooth and nail brushes, are often polished, by simply using a little slaked lime on a damp flannel or woollen rag. An excellent method of cleaning bones is to soak them for twenty-four hours in a solution of 1 lb. soda ash and ½ lb. calcined lime in three quarts of hot water, then wash them thoroughly and put them to bleach. Bone shavings, scrapings, and sawdust are in considerable request among pastrycooks and others, for making jelly.

In some bone-producing countries, notably South America, whence enormous quantities of bones are imported to this country and a few Continental ports, the bones are commonly calcined in the open air before shipment, an operation which greatly reduces their bulk, by eliminating all the moisture they contain, and rendering them a friable mass. In this form, they are known as "bone-ash," and are consumed chiefly in the manufacture of high-class artificial Manures (which see), while about 4500 tons per annum are employed in the china manufactories of this country. Less important applications of the substance are for the making of cupels used in assaying, and for case-hardening small articles of steel.

Another product derived from bones is "sal-ammoniac" or "chloride of ammonia." This is produced by subjecting bones, which have previously been boiled to remove the fat, to a process of distillation in large retorts, by which is drawn off a vapour composed of carbonic acid, various hydrogen-carbon compounds, water (steam) holding carbonate of ammonia in solution, and a peculiar oil which is collected separately and afterwards burnt in specially constructed lamps for the purpose of depositing "lamp-black." Towards the conclusion of the distillation process, chloride of ammonia and sulphate of soda are formed; the former is separated by sublimation, and the latter is dissolved in water and crystallized. The mass left in the retorts represents the earthy portions of the bone, blackened by the carbon of the organic matter and known as "Ivory-black," "Bone-black," or "Animal charcoal" (which see). By exposing this last to an open fire, the carbon is consumed, and the bones are rendered almost white. They are then reduced to powder (bone-ash), and are used for cupel making, as a polishing powder for plate, &c., and by the phosphorus-match makers.

The purification of ammonia salts from the waste of bone-gas and animal-charcoal works is rendered difficult by the presence of empyreumatic organic matters (Dippele's oil). The cost is much increased by the necessity for re-subliming the crude products, while the neutralization of the condensation waters with hydrochloric acid creates a nuisance, by reason of the ammonia sulphide and cyanide present. Mr. J. V. Divis has elaborated a mode of purification, which he thinks may be used even in sugar-works making their own animal charcoal, 8 to 10 per cent. (according to the quality of the bones) of ammonia water being obtainable, containing 7 to 9 per cent. of actual ammonia, the yield of bone oil being 1·7 to 2 per cent. The ammonia waters are collected in old petroleum barrels and allowed to stand two days, when the floating oil is skimmed off. The waters are then gently heated and just neutralized with hydrochloric acid, after being mixed with concentrated solution of chloride of lime, to decompose the carbonate of ammonia, without which there would be a liberation of gas. Carbonate of lime is abundantly deposited, and its precipitation clarifies the liquor. After some hours, the clear liquid is decanted, and the sediment remaining forms a good manure. The chloride of lime must be slightly deficient—never in excess. The clear but yellowish decanted solution is heated to boiling in sheet-iron tanks, which causes the rest of the impurities to separate out, and admits of their being skimmed off. The boiling liquid is then filtered through a mixture of wood charcoal, animal charcoal, and coke, in a double-bottomed cask. Finally, it is evaporated in shallow pans, the vapours arising being forced through the ash-grates of the furnaces. The sal-ammoniac thus produced contains 95·3 per cent. of true chloride of ammonia and 4·2 per cent. of water.

Before detailing the important part played by bones in the manufacture of gelatinous substances, such as gelatine, size, &c., it will be necessary to refer for a moment to their composition. After undergoing the preliminary fat-extracting operation, there remain the two essential constituents—cartilage and lime-earths. And here it might be well to remark that the fat is not really a *constituent* of bone, but an accessory, for varieties of bone exist identical in other respects, but quite free from grease. A portion of the cartilage is sure to be dissolved out of the bones while they are being boiled to removed the fat, and in the large dyeing works at Manchester and other places, this is often utilized for making "size." After removing the fat, the bone liquor is boiled down in another vessel till it is strong enough for stiffening the heavy goods to which it is applied. When the size-liquor is too weak for further use, it still possesses a value as a fertilizer, and the exhausted bones are also bought up by the farmers and manure makers for a similar purpose. A modification of this plan consists in crushing the bones, treating them with steam at high pressure, and adding to the semi-gelatinous mass thus formed, a proportion of hydrochloric acid (2 per cent.) and reboiling. The fat then separates and floats on the liquor, to be easily collected and purified, by being treated first with boiling water and a very small quantity of caustic soda, and next with animal charcoal, and finally filtered.

The osseous cartilage may be removed from bones, by suspending them in a vessel with weak nitric or hydrochloric acid (1 part acid to 9 parts water) at 10° (50° F.). The acid causes an effervescence, by acting on the carbonate of lime, and dissolves out the whole of that and the other earthy constituents without affecting the cartilage, which, while retaining the form of the bone, soon becomes soft and translucent. It is then washed in two or three changes of cold water, to remove all traces of acidity. It shrinks and darkens on drying, becoming hard and strong, but somewhat brittle, and losing none of its transparency. It now forms gelatine. It has been proposed to obtain gelatine from bones, &c., by means of benzine and other hydro-carbons. Sometimes it is found advisable to treat the material with lime before adding the hydro-carbon, but only rarely. After the bones have remained for a considerable time under the influence of the hydro-carbon, the fatty matters are dissolved, and the pure gelatine is found at the bottom of the vessel. The two products are thus easily separated, in order to be treated in the usual way, and the hydro-carbons are recovered by evaporating with steam, and condensing.

The following is a German plan for preparing gelatine from bones. The bones are exposed to the sun and air for about six weeks, and, in dry weather, are moistened several times daily with water. Quantities of 10 to 15 cwt. are put into vats and soaked with a solution of hydrochloric acid at 4° (? Beaumé), which is drawn off when saturated, and replaced by a fresh solution, repeating till the bones are softened. These are washed in fresh water and placed for fourteen days in a solution containing a small amount of lime, then taken out and thoroughly rewashed in fresh water, and laid out upon large plates to dry in the air. The product at this stage is raw gelatine. About 300 lb. of this is laid in running water for twenty-four hours, which makes it soft and easily broken up; it is then left for several days exposed to the open air, after which it is put into an immense kettle with 40 gallons of river water; a fire is made, and it is slowly cooked, the mixture being stirred every half hour, and 4 oz. of alum added, which helps to liberate the fatty particles, and thus materially to purify the gelatine. After cooking for eight to ten hours, according to the state of the mass (which may be tested by filtering some through a linen cloth, from which it should come clear and free from all impurities), the whole is put into a vat containing 3 gallons of fresh water acidulated with sulphuric acid. It is stirred, two quarts of acetic acid are added, and the mass is left to stand for one hour, when it is again filtered through linen cloth and put into wooden vessels, where the mass gradually attains a solid state. Before becoming thoroughly hard, it is cut by machine into thin sheets and laid out to dry in an airy and dry spot under an awning. The very best brand of gelatine is said to be made in this way. Should it be desired to produce coloured gelatine, the following modification is needed: On completion of the last filtration through linen cloth, a small quantity of gall is added, and then the required colouring matter. The most common colour is carmine, dissolved in *aqua ammoniæ*, and stirred into the mass. Aniline colours may also be used. The proportions are generally 1 oz. of colouring matter to 4 lb. of liquid gelatine, the former being first thoroughly cleaned by repeated straining through linen cloth, then added to the diluted gelatine, and the whole well mixed while warm and poured out on large frames or sheets of glass placed in a cool, dry, airy place. The sheets are taken off when dry, or just before if they are to be stamped with patterns.

In the method of manufacture known as Rice's, the bones are placed in dilute phosphoric acid, by which the earthy matters are dissolved and removed from the cartilage, which latter can be turned into gelatine by any ordinary process. The acid is recovered from the earthy matter for re-use in the following way:—About two-thirds or more of the solution of acid phosphate of lime is submitted to the action of sulphurous or sulphuric acid, which precipitates the lime as sulphite or sulphate, either being easily removed, and leaving the acid or acid phosphate (according to the amount of acid used) in an available condition for further use on fresh bones. By extracting the phosphates originally held in the bone, this process yields an actual surplus of phosphoric acid, so that it is claimed that almost 50 per cent. can be gained on each treatment. The residues are used for manure. The cost of production is said to be greatly reduced by this plan. Phosphoric acid alone is found to be best; but it may also be used in conjunction with other acids, in such proportions that the mixture will dissolve and remove the earthy matters.

Efforts have been made to obtain white gelatine from low products, and to whiten dark-coloured gelatines, such as those got as a secondary product in the manufacture of neat's-foot oil, and which sell with difficulty. One proposed way of surmounting the difficulty consisted in digesting the raw material—hoofs, bones, &c.—in water or superheated steam at a pressure of three atmospheres. After three hours' digestion and half an hour allowed for settling, the strongly ammoniacal solution of gelatine is concentrated, the supernatant oil having been previously removed. A dark, brittle gelatine was thus obtained, which it was tried to bleach, without success, by means of sulphurous acid or a sulphate in presence of hydrochloric acid. The duration of the digestion was then diminished, and, instead of drawing off all the liquid at the end of three hours, it was drawn off three times, from hour to hour. The solution was then supplied with some wood charcoal mixed with 25 per cent. of animal charcoal, and after standing for twelve hours, was treated as above. The product was a gelatine of good quality, appearing yellow only in large masses, tasteless, scentless, and fit for all purposes. The solution requires 4 per cent. of the charcoal mixture.

The principal use of gelatine is in the manufacture of various alimentary substances. It has proved very useful for taking casts of delicate and intricate objects, without showing seams. Its use among dyers has already been noted. Recently a new demand has been created, by the discovery that gelatine, in presence of a salt of chromium, is rendered insoluble by the chemical action of light. The most important application of so-called chromatized gelatine hitherto has been in the heliotype process, which is virtually a new art of lithography. If paper coated with a solution of bichromate of potash and gelatine be exposed to the light, the gelatinous film becomes to all intents and purposes a lithographic stone, from which an indefinite number of copies of photographic negatives may be taken. The compound is also used in a new process for rendering woven fabrics waterproof; cotton and linen that have been soaked in a weak solution of gelatine (or glue) and bichromate of potash become waterproof on exposure to daylight, without being impervious to air.

Probably a larger quantity of bones is applied to the fertilization of the soil than is consumed in all the other ways together. They are applied raw, calcined, or dissolved in sulphuric acid. Since the growth of Australian meat-preserving companies, a plan has been tried for reducing the enormous bulk of bones, and their consequently heavy freight, between that country and this. The bones are crushed fine, and then moulded into cakes resembling flooring tiles, measuring about 6 in. square and 3 in. thick, and weighing about 6 lb. each. They are sufficiently adhesive to be handled freely, while they are rapidly dissolved by water. A ton weight can be got into 29 cub. ft.

The price of bones varies between about 5*l.* and 8*l.* per ton, according to cleanness, size, and fatness. Bone-ash sells at 7*l.* to 8*l.* per ton.

The following are the latest procurable statistics concerning the imports and exports of bones to and from the United Kingdom :—

Imports.

	1873.	1874.	1875.	1876.	1877.
Tons	79,559	92,158	104,971	95,648	112,195
Value .. £	537,531	633,535	704,715	623,371	741,899

Of the total quantity imported in 1877, the proportions (in tons) used for manufacturing purposes other than manures were, from France, 1877; Uruguay, 1106; Brazil, 1033; Australia, 780; United States, 762; Holland, 426; Belgium, 252; Germany, 157; other countries, 1062. For manures only (in tons), from the Argentine Republic, 33,217; Uruguay, 15,090; Russia, 14,235; Brazil, 7452; France, 6416; Italy, 6388; Turkey, 4941; Germany, 3227; Holland, 3177; United States, 2490; Spain, 2242; Denmark, 2204; other countries, 3661.

Exports.

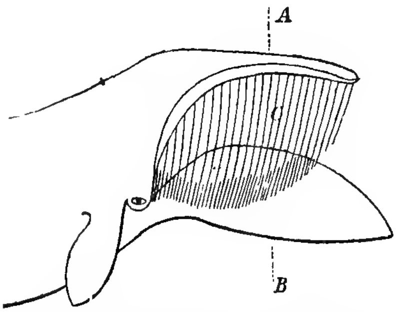
The quantities of bones exported from the United Kingdom in 1877 to all countries were, for manufacturing purposes, 26 tons, value, 292*l.*; and for manure only, 226 tons, value, 1469*l.*

See Blacks, Buttons, Celluloid, Cements (Glue), Ivory, Manures, Pottery.

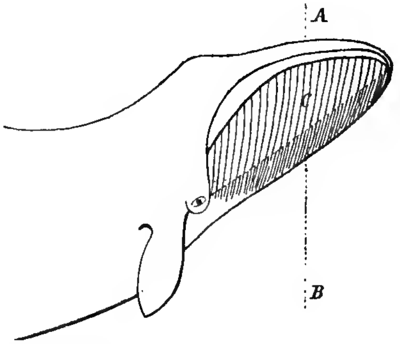
Whalebone, or Baleen. (Fr., *Baleine;* Ger., *Fischbeine.*)—In deference to popular misconception regarding this substance, attributable partly to its unscientific name, it has been judged advisable to introduce it here, despite the fact that it does not possess a single feature in common with bone. The method of growth of the whalebone is a modification of the system of the rabbit's tooth or the elephant's tusk; it contains no bone whatever, but resembles rather a number of hardened hairs, cemented together by a sort of gum, its chemical composition, according to Brande, being a basis of albumen hardened by a small proportion of phosphate of lime. It forms a substitute for teeth in certain species of whales, especially the *Balæna mysticetus* (Greenland whale), and *B. australis* (Southern whale). The very diminutive nature of the creatures on which these animals feed—scarcely larger than a common house-fly—renders teeth unnecessary, and requires a kind of sieve, in which the prey may become entangled and crushed, and thus the interior of a whale's mouth has the appearance of being furnished with a forest of bristles.

The baleen is a depending growth from the sides of the upper jaw, and consists of a number of flat plates, or "blades," as they are technically termed, separated by gum, and fringed with coarse hair to assist in securing the food. The position of the baleen is shown in the accompanying illustrations. In Fig. 383, the mouth is represented open, as when the animal is feeding; A is the crown-bone whence the baleen depends; B the lower jaw; C the baleen or whalebone. Fig. 384 indicates the mouth closed, and the blades of baleen packed away by the action of the lower jaw. The number of blades on each side is commonly about 300. They are longest in the middle, reaching a maximum of 15 ft., but generally not exceeding 12 or 13 ft.; their breadth at the root is about 10 or 12 in., and thickness, 0·4 to 0·5 in. A full-grown Greenland whale yields about a ton of the substance. As imported from the Greenland seas, which are its chief source, it is generally divided into handy pieces of 10 or 12 blades each; but sometimes the sailors have had time during the voyage to strip off each blade separately, and to divest it of its hairy fringes. Before cutting up the blades for use, they are cleaned and softened, by boiling for about two hours in long coppers, and are then fixed, while still hot, in the large wooden vice of a carpenter's bench, in a convenient position for being planed or shaved into the required strips by means of the tool shown in Fig. 385. It consists of two handles A D, an iron plate C D, with a guide notch E, and a semicircular knife F, which is screwed firmly to each end of the iron plate, and adjusted with its cutting edge on a plane exactly so much lower than the bottom of the notch as will represent the desired thickness of the slice to be stripped off. The notch of the tool is applied at the end of the "blade" farthest from the operator, and is then drawn towards the person, so as to cut always in the direction of the fibres, and never across them. These slices are dried, and planed smooth on their other surfaces. Whalebone is polished in different ways. According to one plan, it is first scraped with pieces of glass, or steel scrapers, then rubbed with emery paper, and finally with tripoli or rotten-stone on a woollen cloth; or in another way, it is rubbed with ground pumice, or wet felt, and finished with dry quicklime, spontaneously slaked and sifted.

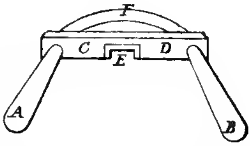
383.



384.



385



It possesses the valuable qualities of elasticity, flexibility, lightness, and strength combined. Heated by steam or in a sand-bath, it softens, and may be bent or moulded into various shapes, which it will retain if cooled under compression. When boiled, it becomes harder and darker coloured. Unlike tortoiseshell, it cannot be soldered. Its industrial applications are multifarious and important. The fibres detached in slicing the blades are used as a substitute for bristles in common brushes, and instead of hair for stuffing mattresses. From the thick parts of the blades, are made knobs for walking-sticks, and snuff-boxes. It is also used in the framework of hats, and in making ladies' bonnets, and even artificial flowers have been made from white whalebone, which will take many bright and durable colours. Narrow strips, grooved or made into ribs by being drawn through an aperture in a steel plate, are used for covering pocket telescopes, &c., being wound around the tube and tucked under the rings at the ends; broad, flat slices of parti-coloured whalebone are sometimes similarly used, the light portions being dyed green, and the dark remaining unchanged. Solid pieces of mixed colours are occasionally made into walking-sticks, and plaited strips of black and white are often employed on whips. A considerable quantity is still consumed in the manufacture of ladies' stays, but not nearly so much as formerly, and probably the principal demand now is for making the stretchers of umbrellas, &c.

The price of whalebone fluctuates exceedingly, and may be put roughly at 50*l.* to 150*l.* per ton.

The imports of whalebone were, in:—

	1873.	1874.	1875.	1876.	1877.
Cwts.	3,544	2,911	1,871	1,799	1,969
Value .. £	64,618	54,920	42,240	47,144	82,987

The quantity for 1877 was contributed as follows:—

The northern whale fisheries, 987 cwt.; United States, 380 cwt.; other countries, 602 cwt.

The exports of whalebone in 1877 were, to Germany, 251 cwt., value, 15,216*l.*; France, 126 cwt. value, 4700*l.*; other countries, 96 cwt., value, 456*l.*

BORAX, or BI-BORATE OF SODA. (Fr., *Borax, borate de soude;* Ger., *Borax, Borsäuresnatron.*)

The word Borax forms a convenient heading for this article, as the term is universally known; but, having regard to the fact that various other borates, as well as native boracic acid itself, are utilized either in the production of, or as substitutes for, borax, it is felt that a description of each will be welcomed, especially as the subject has been but very narrowly treated of hitherto.

First of borax. This salt is an acid or bi-borate of soda, $Na_2B_4O_7$, forming transparent crystals of the rhombic system, whose surface becomes efflorescent on exposure to the atmosphere. Its sp. gr. is 1·705; it is soluble in water, giving it a weak alkaline reaction. When heated, it melts in its water of crystallization (ten molecules), which is given off, leaving a spongy mass of "burnt borax." When an aqueous solution of borax, sp. gr. 1·245, is allowed to crystallize at about 79° (174° F.), octahedral crystals are obtained, combined with only five molecules of water. This latter is known as "octahedral" borax; the former, as "prismatic" borax. Octahedral borax crystals are commonly said to be stable only at a relatively high temperature; but Gerney has found that both the prismatic and octahedral forms can be produced at a low temperature, and that 56° (133° F.), which has been indicated as the inferior limit for the production of prismatic borax, is in reality only a temperature near the higher limit at which the production of prismatic borax has been observed, since this salt loses a part of its water at this temperature. Borax absorbs hydrochloric and sulphurous acid gases, and is decomposed by sulphuric, hydrochloric, and nitric acids. Melted borax dissolves almost all metallic oxides, whence its greatest industrial utility. It fills the most important place in the list of boracic compounds, and contains:—

Boracic acid	36·58	per cent.
Soda	16·25	,,
Water	47·17	,,

Its manufacture will be described in due course. In a natural state, it exists in great abundance in California and in Thibet, being locally known in the latter country as *tinkdl* (*anglicé* "tincal").

Second on the list in point of importance, is native boric (boracic) acid (Fr. *acide borique, boracique;* Ger. *Borsäure, Boraxsäure*), H_3BO_3, containing boracic acid 56·38, water 43·62 per cent. It forms white, scaly, shining crystals, which yield all their water on heating, melting to a transparent mass, which, on cooling, solidifies to a colourless glass. For solution, it requires 25·6 parts of water at 15° (59° F.); but only 2·9 parts at 100° (212° F.). Its aqueous solution has only a very slight acid taste; it colours blue litmus, purple; and turmeric, reddish brown. Boric anhydride expels almost all other acids from their compounds at a red heat. The greatest natural source of this acid is found in the well-known *lagoni* of Tuscany; but it is a common product of volcanic action, and forms a constituent of both sub-aërial and sub-marine hot-spring waters in many parts of the globe.

Next worthy of attention are the variously named and as variously constituted borates of lime, and double borates of lime and soda, known as borocalcite, boronatrocalcite, tincalzite, ulexite, Hayescine, &c. They occur in reniform masses, varying in size from that of a hazel nut to that of a potato. Their outer crust is hard and chalky looking; but they are easily broken, and inwardly present a mass of crystalline needles, intersecting each other in all directions, and of brilliant white satiny appearance. These borates are generally associated with reddish or yellowish crystals of glauberite or gypsum, as well as with a certain proportion of common salt, which imparts a brackish flavour. The whole mass is almost completely soluble in strong acids; but is very slightly soluble in water. These minerals are of such variable composition that no formula can express it with any degree of accuracy. The approximate percentages of the principal ingredients of a number of samples are thus variously stated:—

	1.	2.	3.	4.	5.	6.	7.	8.	9.	10.	11.	12.
Boracic acid	46	34¾	45½	37	46	41	41½	31½	25	39¼	8½	31
Lime	15	14½	14½	14	18	7½	13	11¼	12¾	13¾	2½	10
Soda	5	12	9½	10	..	12	4½	5	..	2½	1¼	5

The varieties of this mineral occur principally in the nitrate of soda beds of South America.

Boracite, or borate of magnesia, is one of the richest native boracic salts, containing, when pure, about 70 per cent. of boracic acid and 30 per cent. of magnesia. It crystallizes in the cubic system, and is pyro-electric and double-refracting. It is found generally in association with deposits of rock-salt, gypsum, and potash-salts (kainite and carnallite), usually in nodules, rarely in strata. The variety found in the German potash beds is called Stassfurtite. When washed until the water which passes no longer precipitates with nitrate of silver or chloride of barium, and then dried at 100° (212° F.), these minerals give respectively the following composition:—

	Boracite.	Stassfurtite.
Chlorine	8·15	8·02
Magnesium	2·75	2·71
Magnesia	25·24	26·15
Protoxide of iron	1·59	0·40
Boracic acid	62·91	60·75
Water	0·55	1·95
	101·19	99·98

The formula for boracite will then be $2(3MgO4BO_3) + MgCl$; Stassfurtite contains one more equivalent of water.

Howlite, or silicoborocalcite, is a hydrous borosilicate of lime, containing about 43 per cent. of boracic acid. It occurs in a nodular form in gypsum and anhydrite, in Nova Scotia and in the copper region of Lake Superior.

Cryptomorphite is a hydrated borate of lime and soda, with 58½ per cent. of boracic acid.

Boracic acid exists in a number of other minerals as a subsidiary ingredient; but only the borates of soda, lime, and magnesia, besides the native acid, have yet been found in sufficient abundance to be economically employed in the preparation of commercial boracic compounds.

The industrial importance of borax and its allies may be inferred from the fact that the monopoly of the market, enjoyed by the Tuscan producers in 1855, evoked a petition from the consumers, praying the Government for information concerning the resumption of the trans-Himálayan export, which had decayed under the influence of the policy pursued by the Tuscan monopolists. Their address represented the article as one of prime necessity for porcelain and pottery manufacturers, and enlarged on the mischief resulting from its excessive price, and the consequent employment of inferior substitutes.

Having adverted to the principal forms under which boracic compounds are met with in nature, the next consideration will be their geographical and geological distribution, together with the native methods of preparing the raw product for exportation. Afterwards, will be added a description of the treatment of the imported articles, by which they are fitted for use.

1. *Europe.*—The preparation of native boracic acid in Tuscany dates from 1818, and now forms one of the chief branches of Italian chemical industry, and an important factor in the sum total of the production of boracic compounds. The occurrence of the acid is as vapour emitted with steam from fissures in the earth, and as a solution in water. The locality in which this curious phenomenon is developed is of comparatively limited extent, chiefly in the neighbourhood of the villages of Monte Cerboli, Castelnuovo, and Monte Rotondo, lying between Massa Marittima and Volterra. The sides of many of the valleys of tributaries of the river Cecina are studded with vapour vents (*sôffioni*), and with ponds of boiling muddy blue water (*lagoni*). These have the same general direction as the axis of the Appennines, are in close proximity to Miocene serpentine eruptions, and are intimately connected with recent earthquakes. Boracic acid has never been found in a solid state at any depth to which search has been made; its origin is, therefore, somewhat a matter of speculation. Two distinct theories have been adduced to account for its presence as an absorbed gas at or near surface :—(1.) It may result from the double decomposition of water and a volatile boracic salt; in support of which view, the acid appears only when water is present. (2.) It may be caused by the reaction of sulphuric acid on mineral borates, such as tourmaline (containing 1·9 to 4·2 per cent. of boracic acid). This supposition is strengthened by the fact that the neighbouring granite is so rich in this mineral as to be named "tourmaliniferous." It is to be noticed that until water is introduced into the vapour vents, the presence of boracic acid is not manifest. Mineral borates existing at a depth in the earth would remain unaffected by the contact of sulphurous, or even sulphuric, acid in presence of a high temperature; but the admission of water would lower the temperature, and call into play the influence of the sulphuric acid, by which the boracic acid would be liberated from its compounds, and would be ejected in combination with the water and steam. The presence of sulphuric acid is abundantly testified by the frequency of such minerals as sulphates of ammonia, and of lime, alum, gypsum, &c., around the *lagoni.*

It is now necessary to repeat in a few words the threadbare history of the utilization of this apparently inexhaustible source of boracic acid. The discovery of the acid in the waters of the *lagoni* of Monte Rotondo and Castelnuovo was made about a century ago, and in 1818, the first attempt was made to recover the acid from its aqueous solution. About 3¼ tons of very crude crystalline acid was obtained as the result of nine and a half months' working, and was exported to

France. For nine years the undertaking was continued, but with very little profit to the proprietor, on account of the immense outlay needed for firewood, which was naturally very scarce in such a volcanic district. The turning-point in the success of the industry was the happy idea of economizing the heat contained in the steam which escapes from the *soffioni*, for the purpose of concentrating, by evaporation, the very dilute solutions of boracic acid represented by the waters of the *lagoni*.

There are about a dozen places where the production of boracic acid is now carried on.

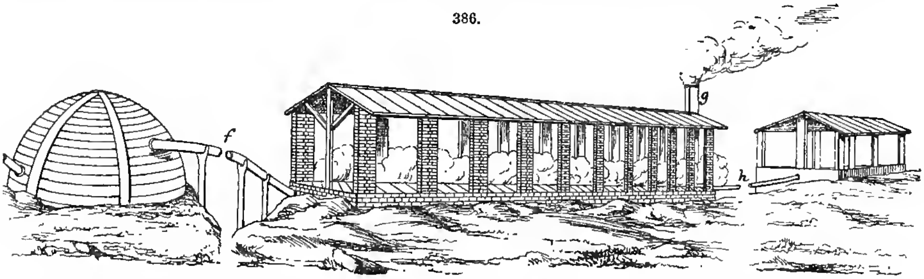
1. Lardarello, or Lagoni of Monte Cerboli.
2. Castelnuovo, Val di Cecina.
3. Lustignano, Lagoni Rossi.
4. Serrazeano, Lagoni Solforei.
5. Sasso, Lagoni di Acquavita.
6. Monte Rotondo, Lagoni della Pianacce.
7. Il Lago, including San Federigo, San Eduardo, and La Collachia.

These all belong to Count Lardarel, and are situated within a few miles of the little commune of Castelnuovo, in the government of Leghorn. Lardarello is the principal establishment, and the produce of the other works is taken there for preparation.

8. Il Lago Solforei di Vecchiena, at the Lake of Monte Rotondo, the property of M. Durval.
9. I Lagoni delle Galleraje, at Travale, the property of an Italian Company, the Società Ammonia Borica Travalese.

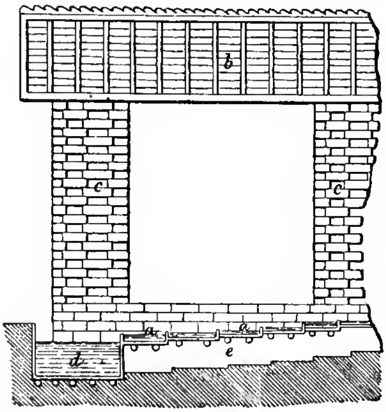
The system of working is practically identical at all the establishments, except the last named. A description of Lardarello, the principal, will therefore suffice for the others. A little to the south of the village of Lardarello, groups of half-a-dozen or more *lagoni* are seen pitted about on the hill-slopes. These *lagoni* are formed in the following way. A space is chosen where several *soffioni* are situated in convenient proximity to each other. A quantity of clay is then dug out, so as to leave a hollow of more or less circular shape, enclosing the orifices of the *soffioni*. The sides of this artificial basin are strengthened by rough masonry, but the bottom requires no such lining. The depth varies from 4 or 6 feet to nearly as many yards, the capacity of the basin requiring to be carefully adjusted to the force of the vapours issuing from the *soffioni* which it includes. Whilst the workmen are engaged in excavating the basin, they are protected from the scalding influence of the vapours, by means of small wooden chimneys, placed over the vents, so as to conduct the steam, &c., into the atmosphere at a sufficient height above them. Chains of basins are thus made on the hill-sides, the members of each set of half-a-dozen or so being arranged in terrace-like order, and connected by little canals. Having completed a series of basins, the next step is to transform them into *lagoni* or pools, by introducing water. This is conducted, by a channel, from any suitable source to the topmost of the series of basins. Percolating through the natural fissures in the bottom of the basin, it comes into contact with heated gases and rocks, and is immediately converted into steam, which is re-ejected with considerable force, and is recondensed in the body of cold water lying in the basin. After remaining in the basin for twenty-four hours, constantly agitated by the escape of subterranean vapours, the water acquires a slate-blue colour, and is thereupon run from the first basin, by a little channel, to the next lower in the series. Thus the second basin assumes the character of a *lagone*, and is made to furnish its due proportion of boracic acid. Here, also, the water remains for twenty-four hours, and so on with each basin of the series, a fresh supply being admitted to the topmost as fast as it is run off to the next. Additional portions of boracic acid are absorbed by the water during each stage of its journey, till finally it contains about 0·50 per cent. of the acid in solution. The temperature of the liquid is above 100° (212° F.), and dense volumes of steam are given off in its passage. While still boiling, it is conducted by a pipe *h* to the *vasco* (see Fig. 386), a tank about 66 ft. square and 18 in. deep, covered by a tiled roof supported on slight brick pillars. Here it is allowed to settle; the impurities held mechanically in suspension—clay and insoluble sulphates—soon precipitate themselves, and the water is run off from the tank in a clean state.

386.

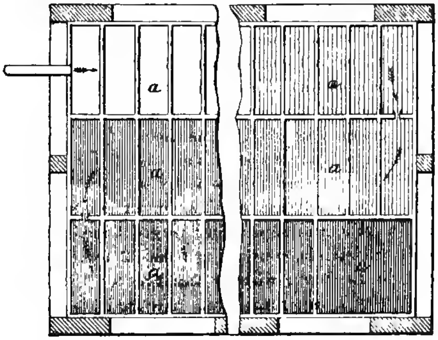


The next step is the concentration of this dilute solution of boracic acid, which is performed in a series of evaporating pans, in an adjoining building, shown in elevation in the same figure. These "Adrian evaporators," as they are called, Figs. 387, 388, consist of three parallel rows of shallow leaden divisions, named *scanelli*, each one of which is $\frac{1}{8}$ in. lower than that preceding it, and separated only by a leaden partition $\frac{1}{2}$ in. broad and of about the same depth. These *scanelli*, or pans, *a*, are about 200 ft. in length by 8 ft. 4 in. to 10 ft. in breadth, and are arranged under a roof *b*, supported on light brick pillars *c*, which suffices to keep out the rain, without impeding the process of evaporation. The divisions of the *scanelli* run transversely, and measure about 2 ft. 7 in. to 3 ft. 4 in. in width; the partitions are about 2 in. high, and the pans are placed at a slight inclination, to favour the flow of the water. By a reference to Fig. 387, it will be seen that the *scanelli* rest on beams over a low vaulted steam chamber *e*, lined with hydraulic cement, to protect the masonry and retain the heat, derived through pipes, from *soffioni*. The supply of heated vapours was first obtained by vaulting over a natural *soffione* with a rough stonework dome, Fig. 386, about 10 ft. high, firmly bound with wrought-iron bars. The admission of a little water produced a considerable head of steam, which was led by the pipe *f* into the vaulted chamber *e* (Fig. 387), and, having traversed it, was allowed to escape by the chimney *g*. It was soon found, however, that these domes were liable to be undermined by the action of the vapours, and in place of them, the plan is adopted of connecting steam pipes with the tube of an artificial boring, which renders the apparatus more convenient, neater, and easier of control. These artificial *soffioni* are bored, with the tools shown in Fig. 389, to a diameter of 10 or 12 in., and are lined with sheet-iron tubing. The evaporating process is conducted as follows:—At the same time that steam is admitted to the chamber *e*, a tap is opened, by which the dilute aqueous solution of boracic acid flows from the *vasco* into the first *scanello*, the quantity being nicely regulated. As it passes slowly from one pan to another, much of the water is evaporated, the colour of the liquid changes gradually to a bright yellow, a peculiar odour is generated, and the solution becomes much more concentrated. This constitutes the secret of the success of the undertaking; what occupied sixty-two hours to evaporate with artificial fuel, is effected in twelve hours by natural means, at infinitely less cost.

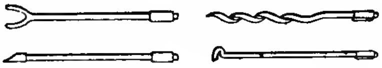
387.



388.

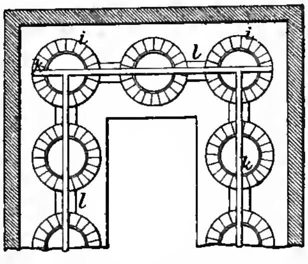


389.

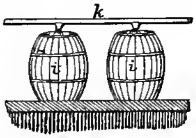


Being thus concentrated, the liquid is run into a large, deep reservoir, the *caldaja a sale*, *d* (Figs. 387, 388), whence it is pumped up every twenty-four hours, and conducted by a wooden pipe to the *bollajo*, or crystallizing house, in which are arranged a number of large *tonne* or vats *i* (Figs. 390, 391), about 3 ft. 4 in. in diameter. When they are to be filled, the plugs situated over the centre of each vat are removed from the pipe *k*, which runs round the room. The liquor remains here for four days, during which time the boracic acid crystallizes at the bottom and sides

390.

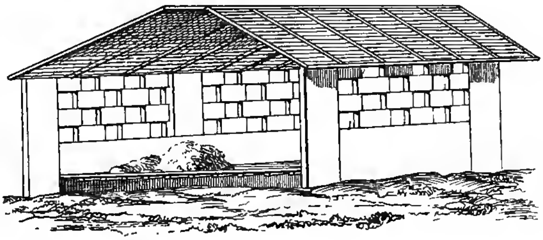


391.



of the vats, to a thickness of some inches; the remaining liquid is then drawn off, by removing a second plug near the bottom of each vat, and finds its way along a drain to the evaporating house. Fresh liquid is then admitted to the *tonne*, and the process is repeated, till they are filled with hexagonal crystals of boracic acid, having the size and appearance of wafers, with a pearly lustre. As these crystals retain a large quantity of water, on removal from the vats, they are placed in large wicker baskets, called *corbelli*, to drain, and are afterwards spread in thin layers on the floor of a large airy chamber, the *asciugatojo*, or drying room, Fig. 392. The floor is formed of brickwork, and is heated, like the evaporators, by a steam chamber beneath. The crystals are repeatedly stirred with a wooden rake, losing their sharp angles, and separating in great measure from each other. When dry, they are shovelled up into large barrels, containing from 12 to 13½ cwt. (about 600 kilos., or 2000 Tuscan lb.), and conveyed to Leghorn, whence the greater part is exported to England. The boracic acid produced in this way is far from pure. An analysis of it, in 1842, gave—

392.



Crystallized boracic acid	76·494	Chloride of ammonium	0·298
Sulphate of ammonia	8·508	Water of crystallization of these salts	6·557
,, magnesia	2·632	Silicic acid	1·200
,, lime	1·018	Sulphuric acid combined with boracic acid	1·322
,, soda	0·917	Organic matters	traces
,, potash	0·369		
,, iron	0·365		
,, alumina	0·320		

Latterly the amount of foreign salts has much decreased, and the impurities do not now exceed about 13 per cent., chiefly sulphate of lime, ammonia, alumina, and magnesia. The acid crystals are imported in their crude state, and are here purified by repeated crystallization.

At the Lardarello works, there are twelve evaporating sheds, containing thirty-five evaporators. The average daily production is about 3 tons, sometimes reaching as much as 4 tons. At Castelnuovo, the average production is about 27 tons a month, and at the other works still less. The total annual production of Count Lardarel's property is now about 3000 tons. From 1818 to 1845, it averaged about 900 tons per annum ; from 1846 to 1850, about 1000 tons ; between 1857 and 1859, it rose gradually from 1100 to 2000 tons a year.

M. Durval's property at the lake of Monte Rotondo is about 18 acres in extent. The water contains about 0·002 per cent. of boracic acid. The prepared acid has a maximum of about 15 per cent. of impurities, chiefly sulphates of ammonia, alumina, and magnesia, with hydrochloric acid, free sulphuric acid, and traces of organic matter. The process employed is identical with that at Lardarello. The produce is sent almost exclusively to French markets.

The waters of the *lagoni* at Travale contain boracic acid in much less proportions than in the districts already described. The pools are situated at a short distance from the village of Travale, in the valley of the Sajo, a little stream feeding the Teccia and Merse, tributaries of the Ombrone. All the *soffioni* here have been produced by boring, some of the bores having a diameter of 16 in. Water is usually met with at a depth of 50 to 70 ft., though in one place a depth of 560 ft. was reached before the subterranean springs were tapped. At the Lagoni delle Galleraje, the waters contain sulphate of ammonia, in the proportion of about 1 grain to the pint, associated with the boracic acid. These products are extracted from the waters by an evaporating apparatus heated by the vapours from the *soffioni;* but the profit derived from the manufacture of the sulphate of ammonia is very small, as the cost of production equals that of the boracic acid, while the commercial value is only about one quarter. The boring of Il Foro Carlo, 240 ft. deep, yields per twenty-four hours about 132,144 gallons of water, at a temperature of 96° (205° F.), containing in solution about 260 milligrammes (say 4 grains) of boracic acid per litre (1·76 pint). The water rises to the surface as in an artesian well ; only about one-sixth of the supply is at present utilized. There is no basin, the water being led away directly, by cast-iron pipes, from the bore-hole to the precipitating tank, 60 ft. long, 45 ft. wide, and 1 ft. 8 in. deep. An improvement lately introduced here consists in heating the water in the tank, by pipes fed with vapour from a dry *soffione*, Il Foro Filippo, by which means a certain amount of water is evaporated from the tank, and the solution is thereby concentrated to 400 milligrammes (6 grains) per litre. The boring of Il Foro Filippo is 210 ft. in depth, and the temperature of the water in the tank is maintained at 94° (202° F.). The solution, having a specific gravity of 11° Baumé, is conducted in the usual way to the evaporators, which resemble those at Lardarello, the temperature being retained at 76° (169° F.). Having traversed the entire length of the pans, the liquid is received in the tank at the lower end with a density of from 12° to 50° Beaumé, and is crystallized, dried, and packed in the ordinary manner. The evaporating house contains three rows of evaporators, 207 ft. in length and 10 ft. in width. The produce is about 57½ lb. per diem.

The crater of Vulcano, one of the Lipari group, is the seat of similar volcanic phenomena, by which a large amount of boracic acid vapour is generated. Till within a few years of the present time, the products from this source were very crudely gathered, by means of convict labour; but since the property has passed into the hands of a British capitalist, proper appliances have been erected for collecting and concentrating the acid, and utilizing the other substances produced. There is nothing in these constructions which calls for detailed description. England annually imports some few thousand pounds of the crystallized acid from this source.

The great potassic salt-beds of Prussia, Anhalt, and Saxony, representing in all probability the upper deposit of a large lake, and resulting from natural evaporating and crystallizing processes protracted over a space of some thousands of years, are another source of boracic minerals. The borders of this vast deposit are composed of the less soluble potash salt called kainite, which is a double sulphate of potash and magnesia; while in the interior, the minera clarnallite, a double chloride of potash and magnesia, is met with. It would seem from this, that the less soluble salts were first deposited, while the more soluble still remained in solution in the deepest parts of the basin.

The extensive boring operations, successfully undertaken here by the Continental Diamond Rock-boring Company, afford valuable and interesting details of the strata constituting the formation. The first bore was put down at the supposed edge of the ancient salt lake. It penetrated New Red Sandstone (about 680 ft.), then gypsum and anhydrite (97 ft.), to the salt clay layer which is the characteristic overlying stratum of the potash salts, and generally supposed to have been the means of preserving them from denudation. Next came a layer of impure coloured salts, forming the transitory covering of the valuable potash salts, and at 835 ft., the pure kainite layer was struck, and sunk through for about 50 ft. In this kainite bed, are found not inconsiderable quantities of boracite, chiefly in small nests or nodules in the upper part of the bed. It also occurs in nodules in the carnallite.

When in a pure condition, this so-called Stassfurtite, or Stassfurt boracite, consists of boracic acid, magnesia, and chloride of magnesium. In its raw state, however, it is usually much contaminated with foreign salts, sometimes to the extent of 50 per cent. The following analysis is stated, by Dr. Krause, to fairly represent the composition of the raw product as brought to market:—

Boracic acid	52·39 per cent.	Chloride of soda	1·28 per cent.
Magnesia	23·13 „	Sulphate of magnesia .	0·87 „
Chloride of magnesium ..	12·14 „	Sesquioxide of iron ..	0·71 „
„ potash	3·46 „	Water	6·02 „

In other words, the percentage of borate of magnesia present is about 85. In order to extract the boracic acid from the mineral, it is washed and dried, then coarsely ground; about 237 lb. (105 kilos.) are then placed in a leaden pan, with so much water as to render the mass pasty, but not sufficient to cover it. The pan is built in over a grate, so that it can be heated from below without the flame coming into actual contact with it, and rests on fire-clay slabs, or (less advisedly) on cast-iron plates. Several pans are placed in a row, and heated by the same fire. The paste is constantly stirred with a wooden spatula, and after one to two hours, the solution is run out through a 1¼–1½-in. hole in the bottom of the pan. This opening is fitted inside with a strainer, whose mesh does not exceed 0·04 in., which holds back the powder; it is closed on the outside with a wooden plug, or, better, by a leaden valve made air-tight with indiarubber. The first muddy portion of the outflowing liquid is thrown back, to prevent any waste of materials. When the liquid has thoroughly drained off, 20–30 pints of water at a time are passed over the surface of the sediment, and allowed to run rapidly through. The outlet is again closed and the sediment is well mixed with about 66 gallons (300 litres) of water; after which is added 330 lb. (150 kilos.) of crude hydrochloric acid of 1·16 sp. gr., and the whole is well stirred. The pans are again heated, care being taken that the contents of the first do not reach a temperature above 66° (150° F.). Before solution takes place, an occasional stirring is necessary; but as soon as it has finished, the fire is withdrawn, the liquor is allowed to settle for a few minutes, and is then let out, through the opening, into stone or iron crystallizing vessels. The impurities will have been deposited in the pan, and the outflowing liquor should be clear. While the solution is becoming perfectly cool, the pans are cleaned out and refilled. When the boracic acid has crystallized out, which it does at a temperature of 15°–20° (59°–68° F.), or less, the lye is let off; the acid is pressed between cloths, rinsed with a little clean water, again pressed, and dried. Instead of pressing the acid, it may be drained, to free it from the lye. The first and most important crop of boracic acid crystals are thus got quite clean. The lyes are mixed and evaporated as often as any boracic acid crystallizes out. The last small proportion thus extracted, containing 5–10 per cent. of foreign salts, is either placed separately from the clean product and valued accordingly, or is thrown into the next panful of solution. The final lye is allowed to run away, or it may be evaporated down to 45° B. (1·321 sp. gr.) and an impure chloride of magnesia be obtained from it. In the latter case, the solution, while still hot, is run into strong vessels, where it will form a solid mass after several hours' rest.

The cost of the manufacture, as above described, is estimated to be as follows:—

	£	s.	d.
231 lb. (105 kilos.) Stassfurtite (about 45*s.* 10*d.* per cwt.)	4	14	6
Carriage, grinding, and loss		1	6
330 lb. (150 kilos.) hydrochloric acid (about 3*s.* 5*d.* per cwt.)		10	0
Coal, labour, and wear and tear		5	0
	£5	11	0

Yielding:—

	£	s.	d.
176 lb. (80 kilos.) boracic acid (about 91*s.* 8*d.* per cwt.)	7	4	0
330 lb. (150 kilos.) chloride magnesium (about 1*s.* 4*d.* per cwt.)		3	11
	£7	7	11

giving a profit of 36*s.* 11*d.* It is probable that a greater yield of boracic acid would be obtained in practice.

The following attempt was made to manufacture borax direct from Stassfurtite. About 231 lb. (105 kilos.) of the commercial mineral were treated as in the first stage of the process for extracting boracic acid. The washing out of the foreign salts was performed in a cast-iron retort, walled in after the manner of the leaden pan before mentioned. The direct play of the fire on the retort must be avoided, otherwise it is impossible to prevent the powdered mineral from burning on to the bottom. After the lye was run off, through an opening at the bottom of the retort fitted with a strainer, the hole was reclosed, and over the paste was poured 660 lb. (300 kilos.) of crude caustic soda lye of sp. gr. 1·33. The whole was thoroughly mixed with a wooden spatula, and heated up. It was necessary to stir up the mixture from time to time, to ensure the complete decomposition of the mineral. After an hour, about 44 gallons (200 litres) of water were added, the mass was mixed, and allowed to boil off again, and the fire was then withdrawn, or rather, allowed gradually to die out.

As regards the density of the solution: for making prismatic borax, it should be about 20°–22° B. (1·161–1·180 sp. gr.) at 27° (80° F.); for octahedral borax, 1·263 sp. gr. at 76° (169° F.), the addition of more alkali to the solution being necessary. For this purpose, soda will do equally well. The contents of the retorts are allowed to settle for three to four hours, whereupon the liquid is removed, either through an opening in the top, or by means of a siphon. It is then poured through felt into iron (or lead-lined wooden) crystallizing vessels. The lye remains for eight to fourteen days in these; it is then drawn off, and again evaporated. The crystals of borax finally obtained are almost chemically pure.

The remaining sediment is collected, and treated in bulk with hot water, the lye is run off after the powder has settled, and fresh water is again applied. The united liquors are evaporated. The then remaining sediment contains hardly any borax. In making borax direct, much more attention has to be paid to the conduct of the operation than is the case with extracting the boracic acid.

The cost of the manufacture is thus stated:—

	£	s.	d.
231 lb. (105 kilos.) Stassfurtite (about 45*s.* 10*d.* per cwt.)	4	14	6
Carriage, grinding, and loss		3	0
660 lb. (300 kilos.) caustic soda lye (about 20*s.* 4*d.* per cwt.)	6	0	0
Coal, labour, and wear and tear		5	6
	£11	3	0

The value of the 202 lb. (92 kilos.) borax (say 6*l.* 9*s.*), and of the magnesite produced is more than a third less than the above estimated cost. In order to derive any profit from the manufacture, it would be necessary, if possible, to reduce the consumption of caustic soda lye to the equivalent (say 110–150 kilos.), and it may be more economically manufactured than purchased. Efforts may be made, too, in the direction of replacing the caustic soda lye entirely or partially by carbonate of soda.

Among the minor occurrences of boracic acid or minerals in Europe, which are not the subject of commercial undertakings, may be mentioned boracite at Lüneberg in Hanover, and at Halberstadt in Transylvania. The acid, either free or combined, is present in a great number of mineral waters, though not in sufficient abundance to be a source of manufacture; allusion may especially be made to Vichy, Carlsbad, and Fachingen (Nassau). During a long stay in Iceland, one of the most volcanic islands in the world, the writer made particular search for borax, analyzing some scores of samples of water from the mineral springs and boiling mud wells which characterize it; but the results were singularly disappointing and contrary to expectation.

2. *Asia.*—Borax (borate of soda) has been imported from Asia, from the earliest times, under one of its local names, *tinkál.* Before the utilization of the Tuscan boracic acid, no other source than Asia was known, and even the now familiar word borax is of Arabic origin. The modern discoveries of boracic compounds in less inaccessible parts of the world have done much to cripple the growth of the Asiatic product; but we still import considerable quantities from our Indian Empire. By many authorities, the salt is stated as an Indian product; this is not the case, it is entirely of trans-Himálayan origin. Stretching from Leh eastwards along the course of the Sutlej and the Brahmaputra, is a line of lakes, about a thousand miles in length, more or less explored. Many of these lakes are salt in a marked degree, have no outlet, lie at a high altitude, and are fed in a great measure by subterranean infiltration. Those situated in Ladák and Great Thibet, are the source of the so-called "East Indian tincal."

The most westerly deposits are those found in the uninhabited lake-plain of Pugha, in the former country. It lies at an elevation of over 15,000 ft. above the sea, on the Rulangchu, a small stream full of hot springs, joining the Indus on its left bank. The portion of the valley where the tincal is found may be roughly stated at 2 miles in length by ¾ mile in breadth, and, if not watered by, it is at least under the influence of, hot springs, whose temperatures in four places vary from 54° to 75° (130°–167° F.), while the temperature of the stream fed by them reaches 13° (56° F.) in July. A sulphur mine exists on the banks of the stream, and numbers of coarse garnets are found in the neighbourhood. The deposit of impure borax, locally known as *sohaga*, has a thickness of several feet. It does not effloresce on the surface of the soil, as has sometimes been said; nevertheless a saline efflorescence, composed principally of sulphate and sesqui-carbonate of soda, with more or less chloride of sodium, always indicates the existence of the subjacent beds of borax. The natives exhibit considerable skill in removing the valueless efflorescence and collecting the borax beneath, employing a kind of wooden spoon or spatula. The gathering of the mineral cannot be carried on at all times; on the contrary, each crop, as it may be termed, is dependent upon a catalytic action resulting from wet and subsequent evaporation, and having the effect of separating the borax from its impurities. The borax appears as a greasy substance, in a confused crystalline mass, of yellowish-green to dirty-white or grey colour, and is divided by the natives into three qualities. These, according to somewhat untrustworthy evidence, have about the following composition:—No. 1. Pure borax, from 68 to 85 per cent.; chloride of sodium, 4 to 5 per cent.; sulphate of soda, traces to 6 per cent. No. 2. Pure borax, 50 to 72 per cent.; chloride of sodium, 5 to 6 per cent.; sulphates of soda and lime, 10 to 20 per cent. This latter is in a powdery form. These two qualities are said to be generally mixed together, so as to yield an average of 70 to 72 per cent. of borax. The third quality is too impure for removal, and is left at the surface to cleanse itself by the natural process already mentioned. As artificial flooding has never been resorted to, the harvesting operation must be postponed till the occurrence of a natural downfall, which, at this elevation, usually takes the form of snow. The moisture sinks into the earth, taking up the impurities in its passage, as they are much more soluble than the borax. Under the influence of the sun, the soil dries up again, and the dissolved salts effloresce on the surface, while the borax, thus naturally (partially) purified, remains below. About ten or twelve days are allowed to elapse, after the downfall ceases, before the gathering of the crop is commenced. During the hot months of July and August, the production could probably be much increased or hastened by artificially flooding the ground. Frost causes a total suspension of operations for a great part of the year. The depth to which the borax-yielding earths extend has never been ascertained; but there is no doubt that they must exist in enormous, probably inexhaustible, quantities. The thickness of each crop of borax does not exceed about 2 or 3 in., the effect of the catalytic action being limited to that depth; the lower portion of the deposit, which is still impure, is exposed to the surface by the removal of each crop. The quality of the borax earth is roughly judged by its hardness and weight. One man can collect a *maund* (about 80 lb.) in a day; it is filled into little woollen bags, holding about 25 to 30 lb. each.

The people who engage in the *sohaga*—thus the crude borax is termed in the plain dialect, and *tchalleh* by the Thibetans—trade are chiefly Kanáwaris and Khampos, a class of wandering traders of Lahaul, Thibet, and Spiti. In the summer, they resort to the Pugha and similar districts, and there load their sheep and goats with the mineral, returning in the autumn, before the passes are closed, to the lower hills, where they remain during the winter, pasturing their flocks, refining the sohaga, and bartering it for goods which they carry back in the following summer. All traders have a right to collect borax on payment of a fee of 1 rupee (nominally 2*s.*) in coin or goods for every three bags of about 25 to 30 lb. The total production of this district has been placed roughly at 20,000 *kucha maunds* of 32 lb. each, or say nearly 30 tons annually. In 1850, the price paid for the *sohaga* in barter was only 1 rupee for a *pucka maund* (80 lb.), or about 56*s.* per ton; but two years later, under the stimulus of export, it reached about 62*s.* 3*d.* per ton. These are the prices *in loco.* The difficulty, danger, and cost of transport raise the latter figure to 24*l.* 18*s.* per ton of *sohaga* at Kulu, and to 42*l.* per ton of cleaned borax at Kudli, Sisova, or Teki, in the lower hills.

The purification of the crude *sohaga* from this district is carried on chiefly in the neighbourhood of Sabatha, Bhaji, &c., in the lower hills, where wood, and winter grazing for the carriers' flocks, is procurable. The native processes of purification will be described further on.

Passing eastwards from the Pugha district, the next important source of borax is the lakes of Rudokh, where a superior quality, locally termed *chú tsalé* (water borax), is found. The interval between this point and the large lake of Tengri-Nur is not much known. The Pangong lake is reported saline; near Lumadodmo, are several small saline lakes, and in the vicinity are hot springs possessing medicinal properties; the Pursng Cháka lake is saline, and great quantities of borax, locally termed *bul*, are found lying all around it, in beds varying from 2 to 10 feet in thickness, and of light, loose consistency; at Hissik Cháka, is a small saline lake; and, at Tong Cho Cháka, a much larger one. It is impossible to say whether any borax will be found in those lakes which are simply recorded as saline. The chain of saline lakes is terminated on the east by the Tengri-Nur, lying to the north of Lhasa (nearly 100 miles), and at an elevation of over 15,000 ft. The lake is of very considerable size, and is encompassed on all sides by rocky hills. Very few streams flow into the lake, whose waters are principally supplied by springs, and are subject to very little rise or fall. There is no outlet. The crude borax, or *tshoochal*, as it is called by the Thibetans (*teliya* in the plains), is deposited in the bed of the lake, never in dry ground nor in high situations, nor universally distributed over the lake bed even, but only on the borders of the lake and in the shallowest depths. The bed of the lake is said to deepen gradually towards the centre, where great quantities of common salt are found, the depths being as completely monopolized by that substance as the shallows are by the borax. This latter is dug up in large crystalline masses, which are afterwards broken for convenience in transport. Here, as elsewhere, the supply seems inexhaustible, inasmuch as the holes from which the mineral is extracted soon become refilled. The lake is frozen as early as October, and remains so for a great portion of the year, during which, operations are suspended. Borax is also found by the lake Bul Cho, a little to the north of the Tengri-Nur. It measures about 6 miles by 5 miles, and has no outlet; geysirs or spouting hotsprings are found in the neighbourhood. The same saline deserts are found in Tartary, on the territory of the Mongols of Tsaidam. Holes 2 or 3 ft. deep are dug in the arid, sterile soil, wherein the tincal collects and is periodically gathered. Southwards again from Lhasa, is another lake, the Yamdok Cho or Palte, over 13,000 ft. above sea-level, whence borax has been obtained from time immemorial.

The raw tincal is sometimes submitted by the carriers to a refining process, and is then known as "refined East Indian borax." This process generally consists in dissolving the crude substance in two parts of hot, or ten parts of cold, water, and then allowing it to crystallize. The *tshoochal* has to be broken up first, on account of its hardness. Formerly the crude tincal used to be covered over with ghee (clarified liquid butter from buffalo milk), to prevent deliquescence in damp weather; but this practice has been partially, if not entirely abandoned. An improved process of purification adopted at Jagádri is as follows:—One *maund* of tincal is mixed with double its weight of water, placed in an iron pot over a fire, and then boiled for two to two and a half hours; when the whole has boiled down to a fourth of its original bulk, it is removed from the fire and poured into earthen jars (*sabúcha*); after three days, the impurities settle at the bottom, and the borax crystallizes above; the water is then poured off, and the borax is taken out separately from the impurities, and dried. The product of refined borax obtained will depend upon the character of the raw material; if of good quality, the yield will be four-fifths; if moderate, one half; if inferior, two-fifths only. Part of the production from the western lakes finds its way down towards Bombay, but the bulk of it, together with all from the more eastern sources, goes to Jagádri (where it is purified), and thence *viâ* Furruckabad or Mirzapúr to Calcutta. The transport from the lower hills to Jagádri was, and probably still is, effected on pony or mule back; thence to Furruckabad, in hackeries or Indian bullock carts, 25 *maunds* being a load; and finally by river craft to Calcutta. Thence it is shipped in double gunny-bags, containing 2 *maunds*, or 164 lb. each; sometimes, in empty beer-casks. Before packing, it is often bulked, and mixed with mustard or rape oil and curd of milk, to prevent efflorescence during the long voyage, otherwise it is said to heat and crumble into powder. The tincal as imported into this country consists of a mass of little, hard, loose crystals, varying in size from small shot to lentils, dirty white in colour, and more or less translucent. The "refined East Indian borax" comes in thin cakes of crystals more or less crumbled, whiter and more transparent than the tincal. Some manufacturers prefer the finest tincal to the purified borax, as the former will often give 98 to 99 per cent. of pure borax, while the latter seldom reaches above 85 per cent., on account of containing large quantities of soda and moisture.

The importations of Asiatic borax now bear but a small proportion to our total consumption. No doubt new sources will be opened up as the country becomes explored and new trade routes are made, and the production of already known sources could doubtless be much increased by scientific treatment; but there remain the terrible passes of the Himálayas to be crossed, by which the trade must for a long time be heavily handicapped in the competition with other countries.

Among other Asiatic countries, Ceylon and China are said to produce borax; but the amount is so small that it never finds its way to foreign markets. Future explorations may reveal larger deposits. Turning to Turkey, we find that in Asia Minor have been discovered important deposits of boracite (borate of magnesia). This valuable mineral occurs in nodules of 3 lb. and upwards, regularly disseminated through beds of gypsum. It has already become an article of export, though the industry has hardly had time to develop itself. Boracite is one of the richest boracic minerals, and it is hoped that it may be found in sufficient abundance to become the subject of systematic mining.

3. *Africa.*—Africa is not known to possess any deposits of borax; but it is possible that the rhodizite, or "African tincalzite," as it has been called, a kind of boracite found on the west coast, may be discovered in such quantity as to repay working expenses.

4. *America (North).*—It is from the New World that the greater part of our supply of borax is at present drawn. The principal occurrence of boracic minerals in North America is on the Pacific slope, notably about the Sierra Nevada, and the Slate Range of California. In the State of Nevada, considerable beds have been worked. The Columbus district, Esmeralda County, contains, it is said, some 20,000 acres of rich borax land, besides some thousands of acres of less rich deposits, which will only pay for collection during the driest seasons. The Columbus Valley, where the deposit is richest, is about 10 miles in length and 7 miles in width, and entirely destitute of all but saline vegetation, being covered principally with light briny incrustations, though near the borders of the valley are wide stretches of drifting sands. Water is usually found at a depth of 2 ft., and, on the west side of the valley, is fit for drinking. Borates of lime are found in small quantities in all parts of the valley, but chiefly at the northern extremity, where the wash from the hills is collected. Here they form a large bed, covered with a coating of salt. The accumulation varies in thickness with the moisture of the ground, increasing in warm, dry weather, and decreasing under the influence of cold and wet. The whole surface is elevated several inches in the early part of the summer, and augments continually till the arrival of the first autumn rains. Its rise and fall are likened to the movements of a huge pan of dough. Each alternation of weather adds to the thickness of the actual deposit, the process being evidently analogous to that already recorded of the Ladák beds. Where, in 1869, pieces of mineral only as large as walnuts were taken out of the prospecting holes, there is now said to be found a deposit varying from lumps as large as potatoes to a solid stratum 2 ft. thick. A layer of salt a few inches thick underlies the borate bed, and is again underlaid by a band of sulphate of soda, beneath which, beds of clay and sand alternate to unknown depths. Borate of soda is also found in the marsh. The deposit lies at an elevation of about 3500 ft. above the sea, and is surrounded by mountains of old volcanic formation, principally obsidian, basalt, and trachyte. Saline efflorescences containing borates are common throughout, and doubtless form the source of the deposits in the basin, which receives the wash and percolation from the hills. The borate of lime is probably formed *in situ* by a process of double decomposition. It usually occurs in long, brilliant filaments in nodules; but also in amorphous masses mixed with sand, and salts of soda. The borate of soda is said to be found on the surface as a crystalline efflorescence, resembling very fine snow, but yellowish white in colour; it is sometimes a foot thick.

The company working here have hitherto used only the borate of soda. This is raked together in heaps, with shovels of thin steel, made sharp at the edge for cutting off the saline herbs which grow abundantly on the spot. Care is taken to avoid the patches of salt, and sulphate of soda. The first is easily recognized by its taste, but the second is much more difficult of distinction by that means; these salts, however, form crystals quite distinct in character from borax. The gathered borax is transported in carts, and spread on a large platform placed above wooden vats of some 385 bushels capacity. These are filled with water, which is heated to boiling by an injection of steam. The crude borax is added by degrees, till the density of the mass reaches 1·241 sp. gr. —a concentration which would be much too great if borax alone were introduced; but the sulphate of soda, and salt, as well as the mud, and borate of lime in suspension, help to increase the density. When the boiling solution has reached this degree of strength, it is left; the herbs floating on the surface are removed with a skimmer, and the liquor is run into crystallizing pans, by means of indiarubber tubing. The removal is performed with great care, so as to keep the liquid as clear as possible. The crystallizing tanks are large vats about 10 ft. long, 3 ft. 4 in. wide, and 6 ft. 8 in. deep. There the liquid cools slowly down to about 25° (77° F.), occupying six to ten days, according to the weather. When the temperature sinks below 28° (82° F.), the crystallization is carefully watched, that the mother-liquor may be run off before the sulphate of soda is deposited; no fear need be entertained of the precipitation of the salt present, as it requires a much lower temperature for crystallization. The point 77° F. being reached, a cork is withdrawn from the bottom of the vat, to allow the mother-liquor to escape. Mud, mixed with numerous crystals of borax, flows out at the same time; these crystals are washed with the mother-liquor from a subsequent vat, and preserved for refining. This is a delicate operation, and soon gives the workmen rheumatism, from standing in the mud. A crust of borax, sometimes 6 in. thick, forms at the bottom of the vat, and is removed by picks. The presence of borate of lime makes the crystals adhere strongly to the sides of the vat. The borax is placed to dry on platforms, and, at the end of four or five days, is put into old coffee-sacks holding 1½ cwt. The raw product yields about 30 per cent. of borax, and the cost of manufacture at these works is placed at 8*l.* per ton. The cost of transport to rail is about 10*l.* per ton, and thence to San Francisco about 3*l.* 10*s.* more. There it sells at about 1*s.* 9*d.* per lb. Matters containing less than 50 per cent. of borax cannot be worked profitably here.

The utilization of the borate of lime found in these deposits has been but little developed. When found pure, or nearly so, it is best shipped in a raw state, as the materials necessary for its conversion into borax, or for the extraction of its boracic acid, cannot be got *in loco* at a reasonable cost. Nevertheless an attempt was made to manufacture boracic acid from the mineral, in the following way. The borate is evaporated with sulphuric acid in leaden pans to the consistence of a thick paste, then run out and allowed to cool, by which it hardens. The mass is now placed in cast-iron cylinders heated to redness, while a current of steam passes through. The boracic acid is volatilized with the steam, and condensed in chambers lined with lead. To remove the sulphuric acid, the vapours are passed through a layer of coke arranged in the upper part of the cylinders, which reduces the sulphuric acid to sulphurous. No fault was found with the process; but the cost of material was excessive, and left no profit. Should the discovery of native sulphur or pyrites in the neighbourhood permit the manufacture of sulphuric acid on the spot, operations might be profitably renewed. A sample taken from 14 tons of borate of lime from this district yielded:—

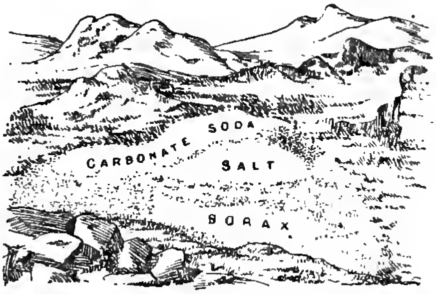
Boracic acid	36·24 per cent.	Sulphate of soda	2·70 per cent.
Lime	11·10 „	Sesquioxide of iron and alumina	2·25 „
Chlorides of sodium and potassium	6·25 „	Water	29·35 „
		Insoluble residue	12·15 „

Fourteen miles north-west of this valley, in the same county, is a second borax field of several hundred acres. Native borax, in large white monoclinic crystals, is found in the mud near the surface of a marsh, which in rainy weather is covered with water. The layer of borax (with other borates in less proportions) is from 6 in. to 1 ft. in depth.

In Churchill county, are several extensive borate beds, the principal one being over 1000 acres in extent and covered with a deposit of borates of lime and soda which, though not heavy, can be gathered at little cost. Works have been put up to manufacture a ton of borax per diem. Smaller deposits are found throughout the neighbourhood. In the same county, is a lake about 1½ mile in circumference, whose water is supersaturated with salts, principally borax. The basin of the lake is symmetrically oval, and lies 150 ft. below the level of the plain. It is probably an extinct crater; it possesses neither outlet nor inlet, and is fed entirely by subterranean springs. By pumping out the water and evaporating it, the crude borates might be extracted.

The neighbouring State of California contains saline lakes reaching to the southern boundary line of the United States. Of these, perhaps the best known is the great Borax Lake in the Slate Range, about 400 miles south of San Francisco, and 140 miles north-east of Bakersfield. This wonderful formation was first explored by Mr. Arthur Robottom, an energetic and persevering pioneer of commerce, who has searched half the world for borax, and to whom the writer is indebted for much valuable information. The lake is about 15 miles long, and 8 miles across; it contains immense saline deposits, which are also spread over part of the surrounding valley, forming snow-white incrustations. The appearance of the neighbouring formation is said to indicate that the sea was once 60 ft. deep here over a large area, the ancient beach being plainly visible. Here, too, the borax and other salts seem to have quite distinct habitats. In one portion of the lake, is a reef of carbonate of soda, and near it, are a number of pyramids of the same product about 4 ft. high and 1 to 2 ft. thick. In the centre, is a ridge of common salt about 5 miles long and 2 miles wide; on one margin of the lake, is a bed of borax about 1000 acres in extent and 3 ft. thick; and beneath this, a stratum composed of sulphate of soda and borate of soda, combined to form a solid mass almost as hard as stone, and varying in depth from 1 to 3 ft. The borate of soda is dirty coloured; but the salt, lying above the level of the entire deposit, in some places to a thickness of 7 ft., is as white as snow. Between the borax bed and the salt ridge, are a few hundred acres of shallow water, very warm and filled with variegated crystals, which give the water a particoloured appearance. Fig. 393 well illustrates the disposition of the various salts. The preparation of the borax found on this property is conducted as follows:—The crude borax is gathered, as free as possible from other salts, in cowhide baskets, which are emptied into carts, and their contents are thus conveyed to the boiling-establishment on the shores of the lake, which is the only building within many miles. The mineral is here deposited in vats of boiling water, and kept boiling for five hours, to remove the impurities. The liquor containing the borax in solution is run into large zinc-lined coolers, where it crystallizes around the sides, and is then scraped off, packed in bags, and dispatched by mule teams to the nearest station on the Southern Pacific railroad, *en route* to San Francisco.

393.



Borax has also been found in Death Valley, about 32 miles farther east; but many years will probably elapse before it is utilized, on account of the natural obstacles presented by a waterless, treeless, salt-desert, which has proved the grave of many an emigrant.

The second most important borax deposit of California is in Borax Lake (or Lake Kaysa, as it is called by the Indians), a pond covering 200–400 acres according to the season of the year, situated a short distance east of, and separated by a Cretaceous ridge from, the Clear Lake, about 110 miles north of San Francisco. According to John Arthur Phillips, Esq., F.G.S., who made a careful examination of this property, the borax occurs chiefly in the form of crystals of various sizes imbedded in the mud of the bottom of the lake, which is found to be most productive to a depth of 3 to 3½ ft., though the earth brought up by a boring rod, put down near the centre to a depth of 60 ft., is said to have afforded proportions of the salt throughout. The crystals are most abundant near the centre, and over about one-third of the surface; but they are also met with in the muddy deposit of other portions of the basin, some—in the richest part—being over 1 lb. in weight. The largest crystals are generally imbedded in a stiff blue clay, at a depth of 3 to 4 ft.; a short distance above them, is a nearly pure stratum of smaller ones, 2½ to 3 in. in thickness, in addition to which, crystals of various dimensions are found disseminated through the muddy bottom. Besides the borax thus existing in a crystalline form, the mud itself is highly charged, and when dried, yields (including the enclosed crystals) 17·75 to 18·86 per cent. of borax. These figures refer to the portions of ground now being worked; but the unworked portions also, though less productive, contain a large amount of borax. It has further been ascertained, by making pits on the lake shore, that clay containing a certain proportion of borax exists in the low ground, at a distance from the water's edge. The borax is at present manufactured extensively from the native crude crystals, while the mud in which they are found is returned to the lake, after the mechanical separation of the crystals by washing, the mud being raised by sheet-iron cofferdams and a small dredging machine. It is evident that in this way only a portion of the borax is recovered. As to the extent of the deposit and its capabilities of production, Mr. Phillips furnishes the following data. The total extent of the muddy deposit consists of more than 300 acres; but supposing only 100 acres to be rich enough to pay for working, and that the depth is only 3½ ft., there will be 565,000 cub. yds., or at least 565,000 tons of wet mud, or say (allowing 60 per cent. of water) 226,000 tons of dry mud, containing, according to mean analyses, 18·29 per cent. of borax; but granting that only 12 per cent. is got out in practice, there will be a yield of 27,120 tons of crystallized borax, without considering some (estimated) 6000 tons existing in solution in the waters. But even this does not include the total productive capability, for it is evident that borax is constantly being formed, through the decomposition of the carbonate of soda abundantly contained in the waters of the lake, by boracic acid emitted from the sources beneath its bed, since large volumes of carbonic acid gas constantly escape from the surface. Another authority believes that the deposit would renew itself every two or three years. The borax, after boiling and crystallization, is packed in boxes of 114 lb. weight for transport to San Francisco. Mr. Phillips estimated the production here at 2500 lb. to 2800 lb. per diem, at a cost of about 18*l*. a ton.

There is every probability that the dry lake beds farther towards the south-eastern extremity of the State will also be found to contain borax. Among the minor occurrences of boracic compounds in North America, may be mentioned Howlite, near Lake Superior and in Nova Scotia; Ulexite, in Nova Scotia and Nevada; cryptomorphite, in Nevada and Oregon; borax, in Canada. Boracic acid exists as a constituent of mineral waters in California, Colorado, Nevada, Wyoming, Maine, and Nova Scotia. Very appreciable quantities of borates, apparently in the form of borate of soda, and perhaps of lime also, are found in the waters of the Pacific, from San Diego to the Straits of Fuca, becoming hardly perceptible beyond Oregon, and reaching a maximum near San Diego. Their presence cannot be traced seawards beyond the submarine ridge running parallel with the coast. Dr. Veatch considers their source as undoubtedly volcanic, and looks for the seat of the volcanic action in this submerged mountain range.

5. *America* (*South*).—An important source of boracic minerals has been found in the *salinas* of South America, notably those on the Pacific face of the Cordillera of the Andes, in Peru, Bolivia, and Chili. These *salinas* are later in age than the Tertiary deposits, and appear at intervals scattered over the whole of that portion of the western coast where no rain falls, stretching more than 550 miles north and south, but exhibiting the greatest development between latitudes 19° and 25° south. They are generally superficial; but occasionally reach to some slight depth below the crust, and may then be entirely covered over with diluvial detritus, always, however, giving signs of their existence by a saline efflorescence on the surface of the ground, which often covers vast plains as a white crystalline incrustation. The salts forming these *salinas* present combinations of the following minerals, in a more or less pure state:—Common salt, Epsom-salt, glauber-salt, thenordite, glauberite, soda-alum, magnesia-alum, gypsum, anhydrite, chloride of calcium, iodide and bromide of sodium, carbonate and nitrate of soda, and, in some places, borate of lime and of soda. The boracic acid compounds are ascribed to volcanic causes, while all the other mineral substances present are such as would be left on evaporating sea-water, or by the mutual reactions of the saline matter (thus left by evaporation) on the organic matters and constituents of the adjacent rocks. In the presence of abundant evidence of the recent elevation of the coast, and the fact that no rain falls in these regions, it seems very reasonable to attribute the origin of these *salinas* to lagoons of salt water, cut off by the rising of the laud.

The *salinas* are met with at three very different altitudes above the sea, viz.:—about 2500 ft. to 3500 ft.; 7000 ft. to 8000 ft.; and 12,500 ft. The first include the important beds of nitrate of soda, running from lat. 19° southwards into the northern part of the Desert of Atacama, showing themselves, according to the configuration of the country, at distances varying from 10 to 40 miles inland. The boracic acid compounds met with are believed, by Professor Forbes, to be due to volcanic exhalations; and the borate of lime, occurring in large quantities, appears to be indirectly produced by the condensed vapours of volcanic *fumaroli*, many of which are still in full activity in the district. The borate of lime is found only in the more elevated part of the *salina*, on its eastern side, where the rising ground begins to form the western slope of the adjacent cordillera. As volcanic action is developed on a grand scale in this range, such *fumaroli* forming lateral vents are very common, and it is to be expected that the waters coming down the slopes carry with them in solution the boracic acid contained in the condensed vapours of the *fumaroli*, which, coming into contact with the lime of the decomposed rocks of the plains below, would readily combine to form the nodules of borate of lime here found. Moreover, the borate deposits recede from the coast as they advance south, following the eastward trend of the volcanic formation. The second series of *salinas* are developed on a grand scale in the northern part of the Desert of Atacama, the principal one with a length of more than 100 miles, and a width of 20 to 30 miles, and a smaller one farther south, about 30 miles long and 12 miles wide. The third and highest series occur in a number of swamps, commencing at Laguna Blanca, and more or less developed all the way to Oruro, and thence past Sora-Sora far to the south.

A section of the *salina* where fully developed shows the following strata:—

1. The *costra* or crust, composed of earthy matters, angular pieces of rock-salt, and other saline matters.

2. *Caliche*, composed of granular layers of nitrate of soda, containing salt, other saline and earthy substances, and angular pieces of stone, often accompanied by much sulphate of soda and some magnesia-alum, mixed with earthy matters, as silica, alumina, carbonate and sulphate of lime; also iodine, bromine, chlorine, and the boracic acid mineral locally known as *tisa* or *tiza*.

3. *Coba*, the general loose, earthy covering to the silico-calcareous and porphyritic rocks, in which the borate is found in nodules, from the size of a pea to 2 ft. in diameter; or in thin striæ, with sulphate of lime.

The best borate-bearing ground is flat, and its surface is free from salt, the *tisa* making its appearance in nodules of all sizes, but generally that of a large potato. They are sparsely or plentifully imbedded in a now dry saline mud, which is, however, damp and even wet in some places from the percolation of water. Much glauberite, in large and small crystals, is sometimes combined with the borate; while at other times, the strata is made up entirely of borate. Pure borate is found only in a few places; that occurring under the *salitres* is accompanied by glauberite.

As has been already remarked, the grade of the borate varies exceedingly, so that no general average composition can be given. This seems to be owing to the fact that where it occurs, are numerous deposits of chloride of calcium and sulphate of lime; and, though no rain falls in the district, the deposits retain sufficient moisture to keep them quite soft, like half-dried mud. The constitution of any compound resulting from a mixture of solutions of these salts must necessarily vary with their proportions. There is every probability that the formation of the mineral is due to precipitation, the after shrinking of such a gelatinous precipitate accounting for the nodular form in which it is found. It is easy to collect specimens with composition varying from almost pure bi-borate of soda to none at all, as in samples 5 and 9 (p. 526), which have evidently been formed from sulphate of lime, and an indefinite compound of soda with boracic acid, only a small part of the resulting sulphate of soda having drained off. The richest specimens are probably formed, in the opinion of Mr. Walker, from chloride of calcium and a sodio-boracic salt, the resulting chloride of sodium, owing to its solubility at ordinary temperatures, draining off more readily than sulphate of soda under the same conditions.

Strata of borate of lime, calculated at over 3,000,000 cub. yds. in extent, have been found in the dried-up lake bed of Maricunga, situated to the north-west of Copiapo, on the western slope of the Andes. The lake is situate at 12,000 ft. above the sea, and is entirely shut in by mountains of volcanic formation, abounding in trachyte and pumice. Borate of lime, in the form of white silky flakes, has been discovered suspended in the waters of the hot springs called Baños del Toro, in the Cordillera of Coquimbo.

On the authority of Dr. Phipson, it forms an excellent flux for metallurgical purposes, and has been employed with success in the porcelain manufactories of Sèvres; it appears capable of effectually replacing borax in all the applications of that salt. The boracic acid may be extracted from the mineral, by saturating the pulverized substance in boiling dilute hydrochloric acid. The clear solution is decanted while hot, and, upon cooling, the liquid throws down the boracic acid in large quantities.

Test for Boracic Acid.—Macerate a small sample of the suspected mineral in alcohol, adding a little strong sulphuric acid, ignite the solution, and allow it to evaporate; the merest trace of boracic acid, whether free or combined, will colour the flame green.

Preparation of the Imported Articles.—The boracic compounds as imported are seldom in a fit state for use, and are therefore submitted to a preparative process after arrival in this country. The process of course varies with the substance; thus, the boracic acid of Tuscany has to be converted into borax; the tincal from Asia needs purification; and the borates of lime require cleansing, or transformation into borate of soda.

The manufacture of borax from the Tuscan boracic acid is performed in the following way:—About 23 cwt. of carbonate of soda crystals are placed in a large copper, or wooden vessel lined with lead, containing such a quantity of water as will raise the total weight to 2 tons. Heat is then applied, by the introduction of steam from a perforated coil lying at the bottom of the vessel, and the mass is then kept at the boiling point till all the soda is dissolved. The crystals of boracic acid are then added, in instalments of 10 to 12 lb., till there is sufficient to complete the decomposition of the sodic carbonate—usually about 1 ton. Carbonic acid is disengaged with lively effervescence, and borate of soda (borax) remains in solution, the liquor exhibiting a specific gravity of 1·66 (33° Tw.) at the conclusion of the operation. The heating is then suspended, and the vessel is tightly closed, and left to stand for ten to twelve hours, at the end of which time the clear solution is run into shallow crystallizing pans. In cool weather, the crystallization usually occupies three or four days. The mother-liquor is siphoned off, and is put back into the copper to assist in the solution of more carbonate of soda. The resulting crystals of borax are redissolved in boiling water, to which is added about 1 cwt. of carbonate of soda for each 2½ tons of borax. The solution is heated to the boiling point and is run into lead-lined inverted cones. These are covered with matting, in order to conserve the heat as long as possible, to produce large and well-defined crystals. At 30° (86° F.) the mother-liquor is run off, and the crystals, after standing a few hours to prevent their becoming friable, are carefully detached by means of a chisel.

To avoid the tedious nature of the above operation, it has been proposed to calcine the native acid, with perfectly dry carbonate of soda, in a furnace at a red heat; the result is a hard, spongy borax of excellent quality. But as the impurities inherent in the acid can only be eliminated by crystallizing the borax, the improvement on the older plan is not apparent.

In making octahedral borax, the liquor must be run off to crystallize at 75° (167° F.), when the sp. gr. is 1·3; the mother-liquor is removed when its temperature is 55° (131° F.). The product is harder than ordinary borax, and contains only half as much water. It is preferred for soldering purposes.

The refining of tincal is performed by placing the crude mineral in pans, covering it with cold water to a height of 2 or 3 in. above the surface, and leaving it to stand for some hours. Recently slaked lime is then added, in the proportion of 1 part to 400 parts of tincal; the mixture is stirred, and left to stand for twelve hours; it is then again strongly agitated, and the muddy supernatant liquor is decanted. This liquid is not thrown away, but is preserved to wash the impure borax, the solid matters in suspension being first separated by settlement and decantation. The washing is continued with the same liquor, clarified by subsidence as often as applied, till it is no longer rendered turbid. In this way, a great portion of the fatty matter is washed away as an insoluble soap of lime. The salt thus purified is dissolved in 2¼ parts of boiling water, to which has been added a solution of chloride of lime, containing 2 parts of that salt to 100 parts of tincal. A precipitate is thereby produced, consisting chiefly of insoluble soap of lime. The liquor is separated from the precipitate by filtration, and is evaporated down to a density of 1·14 or 1·16; it is then run off into crystallizing vessels, and is cooled very gradually, in order to produce large crystals.

Borate of lime in a raw state has been used with fair success, as a substitute for borax, in porcelain manufacture; but it is liable to spoil the colour. When treated by the following process, however, it is found to be quite equal to the sodic salt. The mineral is levigated in a manner similar to that adopted in colour works, and a small jet of steam is admitted into the dolly tub to promote purification. The sand and coarser impurities are separated in the dolly tub, while the finely divided borate of lime flows on through spouts into tanks; there it subsides, leaving the soluble impurities in solution in the supernatant liquor, which is siphoned off. The borate of lime is dried in dishes in stoves, or in reverberatory furnaces, with a gentle surface heat, and is occasionally stirred about. For coarse ware and inferior glass, it suffices to wash off the sand, &c., adhering to the crude nodules of mineral. In using this substance as a "fret" for potters, the consumption must be regulated so as to have the same proportion of boracic acid as would be represented by a specific quantity of borax.

The extraction of boracic acid from borates of lime has been already described. There only remains to be mentioned a process sometimes employed for converting the borate of lime directly into borate of soda. This is effected in two ways, known respectively as "wet" and "dry"; the first is peculiar to France, as the second is to England. The former closely resembles the manufacture of borax from Tuscan boracic acid, already detailed. The finely-powdered mineral is heated with water in a similar way, and a quantity of carbonate of soda is added, sufficient to neutralize the previously determined boracic acid present. Under the influence of the heat, a double decomposition takes place, and when completed, the copious precipitate of carbonate of lime is allowed to subside, while the clear solution of borate of soda is decanted, concentrated, and crystallized. According to the second plan, a mixture of powdered borate of lime and carbonate of soda, with the addition of a little sand or other siliceous substance, is heated, in a reverberatory furnace, to a state of incipient fusion, and is then left to cool, after which the semi-fused mass is powdered, and the borax is extracted by lixiviation.

Uses.—The uses of borax are already very numerous, and they will doubtless increase in number and importance as the price is reduced by competition. Its chief application is for the glazing of all descriptions of pottery and chinaware, as well as for enamelling clock and watch faces, iron plates, &c. In welding processes, it is employed by blacksmiths, brass-founders, and electroplaters; it is consumed in the manufacture of beads, glass, and cement. Dentists find it valuable in making the plates for artificial teeth; plumbago pots will last much longer if first annealed in the oven, and then painted with a strong solution of borax. The antiseptic and disinfecting properties of borax have been, perhaps, too little appreciated, and its application in this direction may be extended indefinitely, especially for the preservation of meats, &c., and for the destruction of insect life on fruit trees. For household purposes, it is of unlimited value, and may with advantage be applied to most of the uses where soda is commonly employed. Its medicinal applications are very numerous; and to the analytical chemist, it is an absolute essential. This part of the subject cannot be passed over without referring to Major Ross's discovery ("Pyrology") of the invaluable assistance rendered by borax in distinguishing the presence of the three natural alkalies—potash, soda, and lithia.

The market prices of the various boracic compounds are approximately as follows:—

Tincal, 28*s.* per cwt.; refined East Indian borax, 28*s.* to 30*s.*; Californian borax, 32*s.*; Tuscan boracic acid crystals, 32*s.*; Tisa, 14*s.*; English refined borax, 35*s.*; ditto ground, 38*s.* to 40*s.*

As the imports of borax are no longer made a specific item in the Custom House returns, statistics on the subject are somewhat meagre and irregular. The total production of the Tuscan lagoons is estimated at 3000 to 4000 tons of boracic acid annually. The yield of the German boracite beds, from 1864 to 1874 both inclusive, was, at Stassfurt, 3141 cwt., and at Leopoldshall, 203 cwt., or a total yearly average of but little over 300 cwt. of that mineral. The imports of borax from Asia into this country, in 1873–74, were 19,013 cwt., at an average value of 58*s.* 8½*d.*; and, in 1874–5, 8,604 cwt., at 51*s.* 6*d.* The export from Bengal ports, in 1874–5, was 8493 cwt., value 21,835*l.*; and, in 1875–6, 11,490 cwt., value, 22,533*l.* According to American statistics, the export of borax from San Francisco, in 1873, was estimated at over 80,000*l.* worth; and the total production, in 1876, was 46,258 cwt., of which England took 17,961 cwt.; the Atlantic States, 15,161 cwt.; Germany, 1261 cwt.; China and Japan, 890 cwt. In 1877, the shipments to the Atlantic States were 31,571 cwt.; England, 14,058 cwt.; Germany, 385 cwt.; China and Japan, 232 cwt.; South America, 14 cwt. In the last-mentioned year, arrangements were made for turning out 200 tons per mensem from the Californian lakes; but this excessive production overcharged the markets, and in August, 1878, the two chief works in California agreed to limit their production to 120 tons each for the following year. The returns of South American exports are a little startling. In 1874, Chili exported 53½ cwt. of borate of lime; and in the succeeding year, Peru exported 3240 cwt. of boracic minerals, valued at 12,474*l.* or at the rate of 3*l.* 17*s.* per cwt.

C. G. W. L.

BROMINE. (FR., *Brome;* GER., *Brom.*)—Symbol, Br. Combining weight, 80.

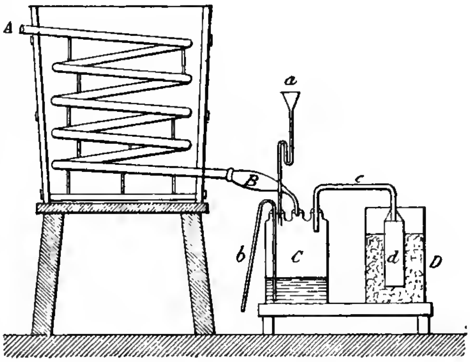
This element was discovered in the year 1826, by Balard, of Montpellier, in the mother-liquor of the water from the salt marshes of that place. It is, at ordinary temperatures, a deep brown-red coloured liquid, possessing a powerfully pungent and irritating odour, similar to that of chlorine, but more suffocating and offensive. Its aqueous solution bleaches like that of chlorine, but not so powerfully, and it bears a close resemblance to chlorine and iodine in many of its other properties. It is very volatile, speedily filling with deep red vapours any vessel in which it is placed. It is highly poisonous. At 15° (59° F.) its sp. gr. is 2·98; at – 22° (– 4° F.) it solidifies, forming a hard, brittle, laminated mass, of a dark, leaden-grey colour, and semi-metallic lustre. It boils at about 63° (140° F.). It is sparingly soluble in water, more readily in alcohol, and abundantly in ether. With hydrogen, it unites to form hydro-bromic acid; and with bases, to produce the salts called "bromides."

Bromine occurs in small quantities in sea-water, one litre containing about 0·061 grm. The mother-liquor of sea-water, and of the water of many saline springs, contains such quantities of it as to admit of its extraction from these sources with considerable profit. After the removal, by crystallization, of the greater portion of the salts of potash and soda, the bromine remains behind, chiefly as bromide of magnesium. A current of gaseous chlorine is passed through the uncrystallizable liquor, by mixing it with peroxide of manganese and hydrochloric acid in stoneware retorts, and distilling the mixture. In this way, the bromine is liberated from the magnesium, the liquor becoming at the same time of a deep orange-colour. The bromine then distils over into the receiver in the form of a heavy, dark-red liquid, surmounted by an aqueous solution of bromine.

At Stassfurt, from the salt springs of which place by far the largest quantity of commercial bromine is obtained, the manufacture of this substance was commenced by Frank in 1865, when its price was very high. A year later the price of bromine was reduced to one-half, in 1867 to one-sixth, and during the three following years it still steadily declined. The production was at first 3000 lb. per annum, from which it rose quickly to 15,000 lb., and has, since that time, increased considerably. The *modus operandi* employed by Frank at the present time is as follows. The raw material is the mother-liquor which remains after removing, by crystallization, the chlorides and double chlorides of potassium and magnesium from the solution of raw Stassfurt salt. This liquor contains from 0·08 to 0·15 per cent. of bromine; the later salt deposits sometimes contain much larger quantities.

The apparatus used consists of a stoneware pan or retort, of a capacity of about 80 to 100 cub. ft., set in brickwork. It is heated inside by means of a perforated leaden steam-pipe, passing through the lid of the still and reaching to the bottom, so as to deliver numerous small jets of steam. The remainder of the apparatus is shown in Fig. 394. The delivery tube of the retort is connected with a condensing worm A, surrounded by cold water; the end of this worm communicates, by means of a glass adapter B, with the middle neck of a Woulfe's bottle C, holding about 18 pints, and furnished with a safety funnel *a*, and a siphon *b*, for drawing off the bromine. The third neck of the bottle contains a bent tube *c*, leading to a stoneware jar D, which is filled with moist iron filings; this tube terminates in a glass cylinder *d*, which prevents it from becoming stopped up by the formation of ferrous bromide. The joints are made with lutes of clay and oil, bound round with parchment. The still is charged with the mother-liquor, peroxide of manganese, and sulphuric or hydrochloric acid, and the mixture is heated rapidly to the boiling point, by passing steam through it. The vapours of bromine passing over are condensed in the worm, and are run into the Woulfe's bottle C, where two strata are formed, the lower consisting of pure liquid bromine, and the upper, of a solution of bromine in water. The uncondensed vapour contains a little bromine, which renders it very offensive; this is entirely absorbed by the iron filings. The first portion of the distillate is toler-

394.



ably pure; but as soon as the green colour of chlorine gas is observed in the adapter B, the distillation must be stopped, and the retort recharged.

The bromine in the Woulfe's bottle is always more or less contaminated with chlorine, bromide of lead (formed in the condensing worm), and other substances; it must, therefore, be refined or rectified before it is fit for use. This rectification is effected by redistilling the bromine in large, glass, tubulated retorts, the necks of which are luted into glass receivers; the incondensable portion is carried from the receiver into a Woulfe's bottle, containing caustic potash or soda solution, and thence into a vessel containing moist iron filings. The retorts are heated by means of sand baths; these have double sides, between which steam is passed. The first products of the several retorts contain much chlorine; they are, therefore, mixed together, and redistilled in the same manner. When this portion has been removed, pure bromine distils over, and is collected in other receivers. From these, the bromine is run off into glass cylinders, having a cock near the bottom, by means of which it is transferred into the final receptacles—strong glass bottles, fitted with ground glass stoppers, and holding from 4 to 5 lb. of bromine. The stoppers are coated on the outside with rosin, over which is placed a layer of clay luting secured with parchment paper. Four of these bottles are packed in a wooden box of four compartments. For the transport of bromine by sea, Frank evaporates a solution of ferrous bromide to dryness, and packs the dried salt in bottles. When required for use, the salt is dissolved in water, and chlorine gas is passed through the solution in order to liberate the bromine. By this means, all danger of leakage or of loss from broken bottles is avoided. The bromine made in this way at Stassfurt has an advantage over all other kinds of commercial bromine in that it is entirely free from iodine.

In 1866, a patent was taken out by Leisler for obtaining bromine from the mother-liquer left by operations with kainite or carnallite, or from the water of the Dead Sea, which contains, according to an analysis by Lartet, in 1 litre, taken from a depth of 300 metres, 7·093 grm. (0·7 per cent.) of bromine. In this process, bichromate of potash and an acid are added; heat is applied, the bromine is volatilized, and is collected in a condenser filled with iron or steel filings. The means employed is a distilling apparatus; the acid used is hydrochloric, diluted with four times its volume of water. To 100 parts by bulk of the mother-liquor, 1 part of the acid is added, the bichromate being introduced as a saturated aqueous solution. The bromide of iron formed is dissolved by the aqueous vapour, and is condensed in the receiver. From it, bromine or any of its compounds may be obtained.

The mother-liquor of varec contains iodine and bromine in about the proportions of 8 parts of the former to 1 part of the latter. In order to obtain bromine from this source, the iodine must first be separated. This may be effected by throwing down the iodine, either by passing chlorine gas through the liquor till a sample taken out gives no precipitate with chlorine water or iodide of potassium; or it may be separated as free iodine and iodide of copper by adding sulphate of copper. The liquor, after this treatment, is mixed with peroxide of manganese and strong sulphuric acid, the proportions being first determined by experiment with small quantities, and the mixture is distilled precisely in the same way as in Frank's process, already described.

Another method of purifying commercial bromine consists in saturating it with baryta, or hydrate of barium. By this means, the chlorine contained in the impure bromine is converted into chloride and hydrochlorite of baryta, and the bromine itself into bromide and bromate of baryta. The mixture is evaporated and ignited, in order to decompose the oxygen salts, and the residue is treated with alcohol, which dissolves the bromide of baryta and leaves the chloride. The pure bromide is then distilled with manganese and sulphuric acid in order to obtain bromine.

Bromine in the form of bromide of potassium is used as a medicine, its medicinal properties being very similar to those of iodine. It is also administered in the form of an aqueous solution, composed of 1 part of bromine to 40 parts of water, in cases of scrofula and similar diseases; five or six drops is the common dose. The solution is used also as a lotion. Bromide of potassium is extensively used in photography. Bromine itself is sometimes employed as a disinfectant. Its use in the preparation of aniline dyes, in the form of bromides of ethyl, amyl, and methyl, has now been almost superseded. According to Reichardt, bromine may with advantage be substituted for chlorine in the manufacture of potassium ferricyanide.

The total annual production of bromine in Europe and America amounts to about 1150 cwt., of which 400 cwt. are made at Stassfurt, and 300 cwt. in Scotland, from the mother-liquor of varec.

BROOM-CORN. (*Sorghum dura.*)

Broom-corn is a species of grass which is largely cultivated in the United States, for the manufacture of brooms. It is closely allied to the *Sorghum saccharatum*, a sugar-yielding grass, which is another variety of the same species. Broom-corn was originally brought to the United States from the East Indies, and its cultivation has since rapidly extended in North America. It is cultivated for its "brush," the dried panicles cleared of the seed. The grain is used for feeding cattle and poultry. The stalks make a good manure, and are sometimes employed as fodder. Large quantities of the broom-corn "brush" are imported into this country, chiefly for making carpet-brooms and clothes-brushes.

The corn used in this manufacture is grown principally in the valleys of the Mohawk and the Connecticut. The soil of the bottoms along these rivers possesses certain characteristics highly favourable to the growth of this agricultural product Although the labour attending its cultivation is great, it is considered a valuable crop, being more hardy than maize, and less liable to injury from frost. It was a good deal cultivated in the Genesee Valley some years ago, and is still to some extent; but the product goes to supply western and local markets. The crop has become one of the most decided importance, and it will no doubt attract the attention of farmers more generally than it has done; while to its manufacture into brooms, mechanical ingenuity and capital will be turned. In 1860, 2585 tons of broom-corn, worth 85 dollars a ton, were sent away from Chicago.

In Saratoga County, 60 acres of broom-corn yielded from 600 to 700 lb. of brush per acre, and on two acres, as much as 800 lb. per acre were obtained. The expense of cultivating and securing the crop is about 10 or 12 dollars per acre. In Montgomery County, the raising of this crop is on the increase, more than 1500 acres being planted. It brings from 20 to 30 dollars per acre on the field, when ready to cut. About one-fourth of the brush is made up in the county. In Ohio, broom-corn has been introduced into some of the rich vales, and has produced, in favourable situations, about one-third of a ton of cleaned brush, ready for market, per acre, worth from 33 to 43 dollars. The cost of cultivation is considered to be one-fourth greater than that of Indian corn. The yield varies with the season; sometimes as many as 600 brooms per acre are produced, with 20 bushels of seed, worth as much as oats for horse-feed.

On a farm belonging to the largest manufacturers in Schenectady, the cultivation of the corn has been simplified to almost as great a degree as the broom manufacture. The seed is sown with a seed-barrow or drill, as early in spring as the state of the ground will admit, in rows 3½ ft. apart. As soon as the corn is above ground, it is hoed, and shortly afterwards thinned so as to leave a space of a few inches between the stalks. It is only hoed in the row in order to get out the weeds that are close to the plants, the remaining space being left for the harrow and cultivator, which are used frequently in order to keep down weeds. The cultivation is finished by running a small double mould-board plough, rather shallow, between the rows. The corn is not left to ripen, but is cut while quite green, and the seed not much past the milk. It was formerly the practice to lop down the tops of the corn, and let it hang for some time in order that the brush might straighten in one direction, but it is now the custom to leave the tops until the brush is ready to cut, which, as before stated, is while the corn is green. A set of hands goes forward, and bends the tops to one side; another set follows immediately and cuts off the tops where they are bent, and a third set gathers the cut tops into waggons, to be taken to the factory. Here they are sorted out into small bunches, each bunch being made of brushes of equal length. The seed is then taken off by a toothed apparatus resembling a hatchel. The machine is worked by horse or steam power, and cleans the brush very rapidly. It is then spread out on racks to dry; in about a week's time, it is dry enough to bear being packed closely. The stalks of the corn, after the tops have been cut off, are 5 or 6 ft. high; they are left on the ground, and ploughed in the following spring. It is found that this assists in keeping up the fertility of the soil, so that the crop is continued for several years without apparent diminution. (See Brushes.)

BRUSHES. (Fr., *Brosse;* Ger., *Bürste.*)

There is, perhaps, no domestic utensil in such common and constant demand as the brush in its various forms, and a great variety of substances have been introduced into the manufacture to meet the demand. Brushes intended for scrubbing metallic surfaces are made of wire; those for use in contact with acids, of spun glass. For coarse work where elasticity is not required, twigs of broom, rattan, whalebone, wood, rushes, and other plants are employed. The Shakers of New York State cultivate a kind of sorghum, or broom corn, which they use extensively in making brushes. The shafts of quills also are prepared and split up; and even horn, which is softened by steeping in an infusion of sage leaves, then flattened, rolled out, extended and moulded so as to break up into threads. Old rope, cocoa-nut fibre, and the roots and fibres of many other tropical plants are in constant use for the same purpose. For the smaller kinds of brush known as pencils, feathers are employed, and the carefully-selected hair of the camel, badger, squirrel, goat, fitch (polecat), sable, bear, horse, and other animals. For artists' pencils, the hair of the ichneumon, and a portion of that which grows within cows' ears, is reserved. Bears' fur, being coarse and stiff, is principally consumed in varnishing brushes; badgers', long, soft, and elastic, in graining and gilding brushes; sable-tail, which is very long and very elastic, makes the finest and dearest artists' pencils; camels' hair comes next in value to sable; cow's ear hair is useful for striping and lettering brushes. The greatest care is taken to prevent loss when working up the valuable hairs, as a double handful of sable is worth 20*l.*, and camel hair nearly as much. But the consumption of the products above-mentioned does not approach that of hogs' bristles, which really form the mainstay of the manufacture. The best of these are procured from the wild hog of northern Europe, about five-sixths of the total coming from Russia and Poland. During the Crimean war, the imports of these fell off very considerably, and split whalebone was attempted to be substituted, but with very indifferent success, as it splits and wears much more rapidly. The whitest and best hogs' bristles are used in hair, tooth, clothes, and hat, and the best paint brushes.

The bristles as received by the manufacturer, though apparently well washed and clean, have still to go through an elaborate cleansing process. Then, or before being washed, they are assorted according to their colour (unless obtained already assorted), being classified into black, yellow, grey, white, and lilies, or pure white. The "whites" are then bleached by means of sulphurous acid or other agent, and again assorted according to quality, length, and size. A bunch having all the large ends pointing the same way is taken in the hand and "dragged" through a kind of comb, which catches and removes the coarsest ones. A number of these combs are arranged on a bench, each one of the series having finer teeth and placed nearer together. The "dragging" is repeated through each finer comb in succession, the result being a number of heaps of bristles of various sizes. This combing makes the bristles more elastic, and polishes them. When assorted, the bristles are ready for the brush-maker. Each operator makes his own special variety of brush, the entire process being carried out by a single hand without any division of labour, except when the brush has afterwards to go to a cabinet-maker, to be finished for the market by having the back glued on, &c.

Brushes are primarily divided into two classes, simple and compound. The former consists of a single tuft; the latter, of many. Compound brushes are also capable of several subdivisions; those with a number of tufts set side by side on flat boards (like a scrubbing-brush) are known as "stock" brushes; and again, these may be either "pair-work" or "set," i. e. the bunch screwed up and twisted into the hole, and held there by the application of cement; or they may be "drawn-work," the bunch being doubled up and *drawn* into the hole by means of a wire through the loop.

Simple Brushes (*a.* Round).—Of these, the most common are round paint-brushes. In arranging the fibres or hairs for paint-brushes of all kinds, the chief object is to place them so that their ends shall come to a central point, and in the finer kinds, especially artists' pencils, much skill is required to do this. The brush is made by inserting a bunch of full-length bristles between two projecting prongs on the handle, and securing them by a wrapping of twine, which is afterwards covered with a coating of glue mixed with red-lead. In large paint-brushes and painters' dusters, the handle is secured by driving the small end first into the bristles placed in an iron cup, which holds them fast. A new binder for bristles of paint-brushes consists of a continuous piece of soft india-rubber, attached by a cylindrical band in the bristles below the ferrule, and by connecting the perforated yoke part with the ferrule and handle. An improved method of ensuring the firm setting of the bristles in the handle is as follows:—The bristles are bound firmly with string in addition to cementing, a socket is turned in the periphery of the handle, to receive them, and on the periphery at the socket end, a shallow rebate is formed, to receive the binding string. The opposite sides of the socket are then chamfered off down to near the flat bottom of it, so as to leave a shallow socket for a cylindrical bunch of bristles; the two prongs are curved on their internal periphery. In the walls of the socket, are transverse saw-cuts, in order to allow of the walls yielding to the pressure of the external binding-string, which thus tightens the hold on the bunch. The handle thus made is said to be cheaper, the bunch of bristles is shorter for the required elasticity, and the whole structure is more durable.

For making artists' "pencils," the delicate hairs from the furs of animals are taken, and first washed in clean water, then soaked in warm water, dried, combed, and assorted. They are then arranged in bunches, so as to form a point, without leaving a blunt or scraggy end when the brush is wet. This is done by women and children, as a very delicate touch is required. The bunch is next fastened, and drawn through the large end of a quill, till the hairs project sufficiently beyond the other end. The quill, having been soaked beforehand in hot water in order to enlarge it, shrinks sufficiently, on drying, to hold the brush securely. Quills from geese, turkeys, ducks, pigeons, quails, larks, and other birds, are used. Brushes of this kind are also often mounted in metallic cups.

(*b.* Flat.)—In making flat simple brushes, such as whitewash brushes, annular bands of copper or brass are prepared by spinning the metal from the flat, so that it shall have no joints. This ring or band is of smaller diameter at the front edge than at the back, and is strengthened in front by a lip or bead. It is then pressed into an oval form, and the bunches are inserted; but, before pushing the bristles quite in, a wedge of wood is introduced in the middle and pushed in along with the bristles, till their roots are at some depth from the back of the ring, the dovetail shape of the front part causing considerable pressure. The ring is then squeezed in a vice whose upper edge is grooved, and holes are made for pins or screws to go through all. It is then warmed, and cement is run into the hollow of the ring behind the roots of the bristles. The wooden handle is then inserted and secured by nails or screws, or the handle is dovetailed and, after insertion, the sides of the ring are squeezed down on the sloping sides of the dovetail.

Compound Stock Brushes. (*a.* Set.)—In this class are included scrubbing, clothes, nail, and hat brushes, and hair brooms, dusters, &c. Such brushes are made by inserting tufts of bristles or other material into a "stock" or "head" previously bored for their reception. These stocks are cut from pieces of board of the requisite thickness in such a way as to get two out of each width. The holes are drilled through a pattern board to ensure uniformity, this being either flat or rounded according to the brush stock used; the holes are often bored angularly to the face, or the face itself is rounded so as to give an outward splay to the bristles or hairs. These latter are usually set in by one end, giving the full length; but where stiffness is required, as in hair-brushes, the tufts are doubled and then cut off square and even, forming a very hard brush when doubled near the root ends. One end of the bunch, or the loop when it is doubled, is dipped into hot pitch or glue, then tied, dipped again, and quickly inserted, by a twisting motion, in the hole prepared for its reception; here it is securely held by the pitch on hardening. In making nail-brushes, it has been proposed to form an oblong hole in the brush back, with the sides dovetailed or undercut so as to hold a piece of pumice similarly shaped, and placed in the hole before the back is secured to the block of the brush.

(*b.* Drawn.)—The distinctive feature of "drawn" brushes is that the tufts or bunches of bristles, or other materials, are bent double, so as to form loops through which wires are passed, for the purpose of "drawing" them into place in the holes of the stock. There are two ordinary methods by which this is done. According to one plan, holes large enough for the bunches are made part of the way through the block, while much smaller ones are continued from the bottom of the larger ones quite through the block. The block being thus prepared, one end of the wire is passed through the loop of the first bunch, which is drawn into place; the other end of the wire passes out through the block, and is ready to receive the next bunch in a similar manner. This process is repeated till all the holes have been filled with bunches, when the ends of the drawing wire are secured, and the whole wire is neatly covered by a veneer back being glued or screwed on; this strengthens and improves the brush, and prevents the wires from scratching the hand and from rusting. After this, the brush is finished up with spokeshave and scraper, sand-papered and varnished. The "drawing" is done by clamping the drilled stock to a table. When a row is filled, the tufts are cut off to gauge by a shear, or, when the bristles are very short, this is postponed till the brush is finished. An expert will "draw" 500 holes per hour, but the average number does not exceed 100. For the best tooth-brushes, silver wire is used, and string is sometimes substituted when the brush is liable to come in contact with substances which would corrode wire.

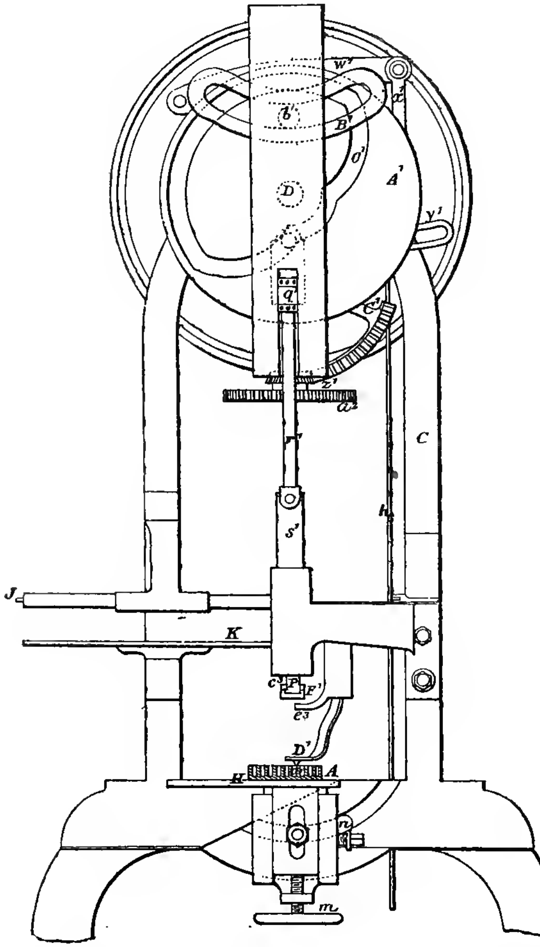
By the other method, which is known as "trepanning," the holes for the reception of the bunches are bored not quite through the stock, and these are crossed by other holes bored transversely through the sides; the bristles, being then inserted, are secured by wires put through the transverse holes. These last are then stopped up with plugs of the same material as the stock (which is also the back), so that they are invisible, and the brush looks to be made of one solid piece.

The Woodbury Machine.—Quite a revolution in the manufacture of some kinds of "compound" brushes was caused by the invention of the Woodbury brush machine, whose object is to produce a brush having its bunches of bristles firmly bound and securely held in the back, without the use of any cement or independent fastening beyond that employed in binding the bunches together, the back remaining in one solid piece. The backs, which are introduced to the machine ready made, are prepared in the following way:—The position of the holes is marked by punching with a simple machine and the back is then placed in the boring machine, which consists of a two-spurred bit of suitable size, made to revolve very rapidly and which drills the holes as fast as the back can be adjusted, the process being facilitated by a hooked arm whose bent end inserted in a punch mark draws the back just far enough forward to bring it in position under the bit, to have the succeeding aperture made. One such machine easily bores 50,000 to 60,000 holes per day. A (Fig. 395) represents a portion of the back of a brush, furnished with the usual holes *a* for the reception of the bristles. These are collected into suitable quantities so as to form, when doubled or bent over as usual in the manufacture of other brushes, bunches B of a size to fit the holes *a*. A wire *b* is then passed through the loop formed by the doubling of the bristles, and is afterwards bent spirally around the bunch B, so as to bind it and form screw-threads on it, in order that when the bunch of bristles is screwed into one of the holes *a*, the wire *b* will secure the bunch of bristles in the back by forming corresponding female threads in the hole, or by fitting into similar threads previously made there.

395.

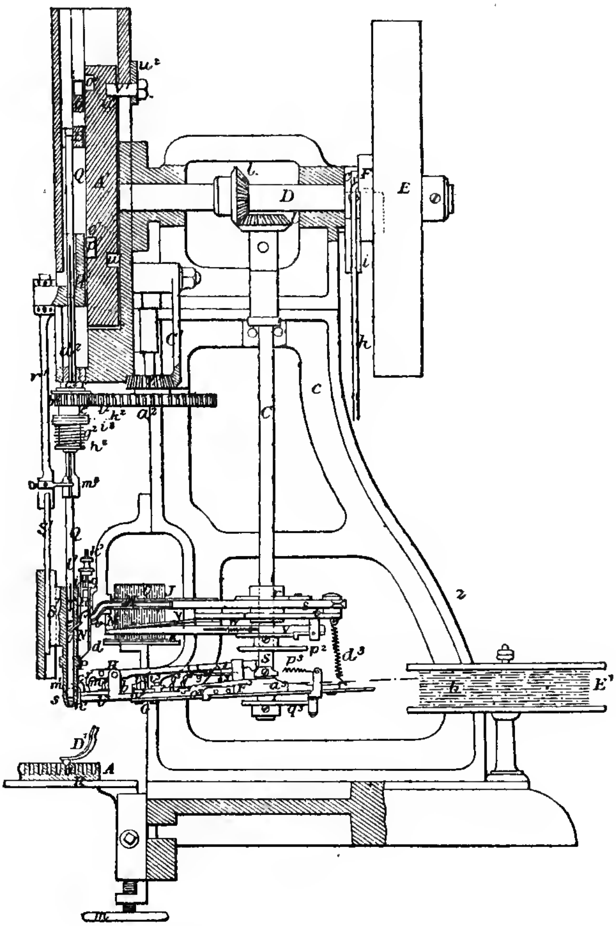
The two ends of the wire *b* are either carried around the bristles separately from each other so as to form double screw-threads, or are carried around it side by side. The ends of the wire *b* serve, upon any tendency to unscrew the bunch, to prevent the backward motion of the bristles, and thus retain them in place, by reason of their (the wires') abrupt termination, or by their being formed so as to ensure engagement with the sides of the hole.

396.



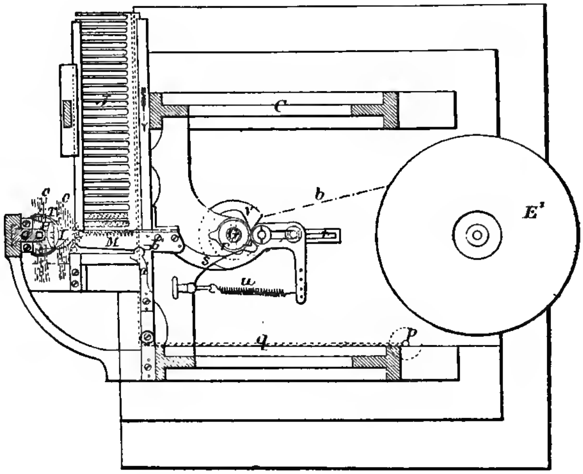
The figures representing the machine are:—Fig. 396, front elevation; Fig. 397, partially sectional side elevation; Fig. 398, sectional plan mainly on line *z z* on Fig. 397; Fig. 399, section of device used in connection with a treadle, for stopping and starting the machine without arresting the motion of the driving pulley; Fig. 400, elevation as seen from rear of principal mechanism and devices for inserting bristles; Fig. 401, enlarged section of doubling and outer plungers and certain attachments working in concert with them; Fig. 402, view of brush-back centring mechanism detached; Figs. 403, 404, and 405 show respectively enlarged plan of wiring apparatus, elevation of lower portion of doubling plunger, and sectional view of internally threaded screw-nut or mouth-piece at the lower end of the hollow or outer plunger. C is the main frame of the machine, carrying at its top a main horizontal driving shaft D, which receives its motion from a driving pulley E fitted loose on the shaft. The hub *c* of this pulley is notched at *d* (Fig. 399), and works against a disc F which is fast on the shaft D. Pivoted to this disc is a double-armed pawl *e*, which engages with and disengages from the notched hub *c* by a spring *f* on the face of the disc when pressure is removed from the back of the upper arm of the pawl *e*, which is done by working a crank lever *g* by the application of the operator's foot to a treadle connected by a rod *h* with the lever. On releasing pressure from the treadle, a spring contrivance *i* throws up the treadle, and bears the lever *g* against the upper arm of the pawl *e*, till arrested by a stop *k* on the disc. The pawl is thus thrown and held out of gear with the notched hub *c*, and the machine is stopped without arresting the motion of the driving pulley. This arrangement forms a very simple, smooth, quick and efficient stopping and starting device. C is a secondary shaft arranged vertically within the machine and deriving its motion from the main shaft D by bevel gear *l* (Fig. 397). The shaft serves to work the devices by

397.



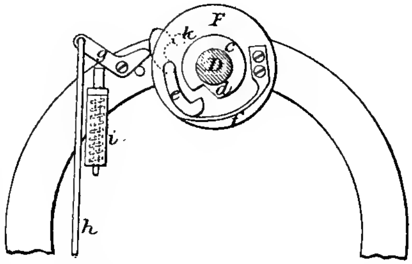
which the bristles are fed to the plungers that effect their doubling, their binding by the wire, and the introduction of the bunch into the brush-back, as well as the devices by which the wire is fed to and through the bristles after doubling, and the mechanism for centring the brush-back under the bunch-inserting devices. These last are worked by the main shaft D; H is a bed on which the brush-back A lies. This bed is adjustable up and down by means of a slide working in a guide frame and operated by a screw *m* to set the brush-back to its work, the guide frame also being adjustable laterally in a curvilinear direction by a slot or groove *n* (Fig. 396), to give the bed various angular positions to suit backs of different shapes. J is a horizontal comb arranged over an upper table K, which is situated some distance above the bed or table H, but a little to one side or in the rear of it. This comb, whose teeth face the front of the machine, has an intermittent travel in the direction of the arrow (Fig. 398), a tooth or space between two teeth at a time, when feeding the bristles to the bunch-forming and inserting devices. The bristles *o*, represented by lines and dots in the figures, are placed within the teeth of the comb, so that they stand in an upright position, projecting for about half their height or length above the comb, and resting at their lower ends on the table K. Each intermittent movement of the comb, which is effected by a weight *p* and cord *q* passing over pulleys, causes a space between two contiguous teeth in the comb to be brought opposite a twisted receiver or gauge L (Fig. 401), into and down through which the bristles in the comb space are passed, by the action of a cross intermittently reciprocating saw or feeder M (Fig. 397). This saw feeder has its motion communicated to it in one direction by a toe cam *r* (Fig. 398) on the shaft C, working against a roller carried by a rod or arm *s*, which is guided in its course by travelling along a fixed slot *t*; and in the reverse direction is worked by a spring *u* pulling on the arm *s*. Each forward motion of the saw feeder projects a certain quantity of the bristles in the comb space facing the spiral receiver L into the receiver, the discharge being aided by a crowding fork N (Fig. 397) operating on the bristles on either side of the receiver, through whose sides they project. This crowding fork receives a reciprocating motion for the performance of its work from a cam *v* on the shaft C, and a spring *w*; also an up and down motion, at the end of its back stroke and when starting forward, by an incline *x* on the rear sliding portion of the fork stem, working through a slotted guide and a spring *y*, which latter also serves to hold the fork down during the remainder of its travel.

398.



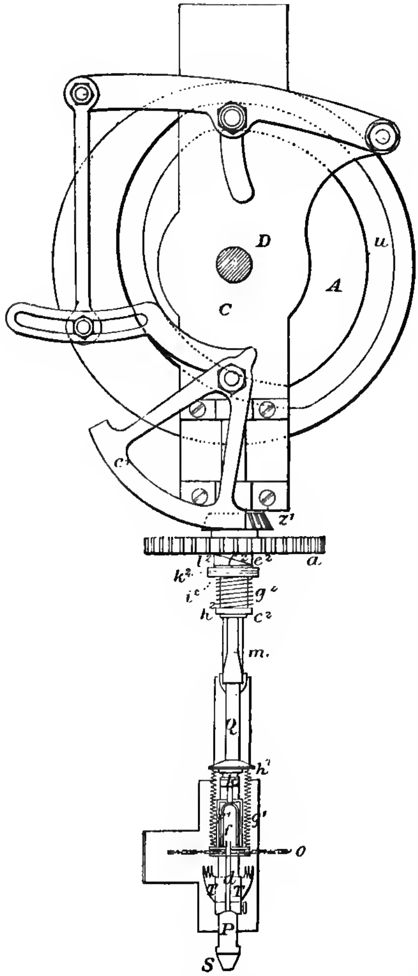
The up and down movement of the crowding fork is to enable the latter to get a proper hold on the bristles when commencing its feeding stroke. The bristles *o*, as they are crowded down and through the twisted receiver L, are turned so as to occupy a horizontal position across the path of a vertically reciprocating bristles-divider and conductor N* (Fig. 401), attached to the outer or hollow plunger P of the inserting device, which has arranged in it the doubling plunger Q. Before describing the action of the devices which operate upon detached quantities of the bristles as taken by the divider and conductor N from the twisted receiver L, in size or amount corresponding to the bunches to be made, it may here be stated that the resistance of the bristles in the comb space opposite the receiver L serves to restrain the saw feeder M from making a full forward stroke under the action of the spring, and while the saw feeder is thus limited in its stroke it holds a spring stop *a'* in locking position on the comb J to prevent it from moving forwards; but, on the comb space being emptied of its bristles, by the action of the saw, the latter is free to move further forwards, and, by an incline *b'* on its face, is caused to temporarily lift the spring stop *a'*, so that the comb J is at liberty to move forward a tooth or succeeding bristles-holding space under the action of the weight *p*, to keep up the supply to the receiver, and so on in succession for each comb space till the comb J is emptied, when it is drawn back to be refilled.

399.



The bristles-divider and conductor N*, which passes through the delivery end of the receiver L, has combined with it an independent follower or gate R (Fig. 397), arranged above the divider N* and serving in conjunction with it to limit the supply of bristles from the twisted receiver L, and to shut off the discharge from it at the periods when they are not required to enter the hollow plunger P, to which they are conducted by inclined upper edges *c'* of the device N*, in rear of the dividing knife *d'* and in line with an oblique slot *e'* in the hollow plunger, within and through which latter the bristles lie and project crosswise. The gate R has the lower ends of its side *f'* the converse of the upper edges *c'* of the divider and conductor, so as to form an inclined passage down into the hollow plunger P. This gate is made capable of sliding up and down a fixed frame *g'* under control of the plunger P and of the springs *h' h'* (Fig. 400). The position of the gate when the plunger P is down to the work is such that egress is shut off from the receiver L, the gate being drawn and held down to its closing position by the springs *h' h'*, and being slightly tilted from a vertical position, so that when the hollow plunger P rises from its work, a projection on the upper end of it will catch under the back of the gate R and lift the latter in common with it for a brief interval until ears on the side of the gate come opposite recesses in the edges of the fixed frame *g'*, when the gate will fall out of the way of the plunger, by the ears dropping into the recesses. This locks the gate R while the plunger slides freely up over its back. The lift of the plunger P on the gate R is such that it establishes a clear space between the top edge of the dividing knife *d'* (Fig. 397) and the bottom edges of the gate R for the passage of the bristles from the receiver L as the divider passes up through, the size of the opening being regulated if necessary by an adjusting nut *k'* on a screw stem of the gate. In the re-descent of the hollow plunger P, so soon as its upper projection passes the back of the gate R, the latter has its side ears thrown out of lock with the recesses in the edges of the fixed frame *g'*, by the contraction of the springs *h'*, to effect which, the lower edges of the side ears on the gate and corresponding edges of the recesses in the fixed frame in which they fit are made bevelled, so that the springs *h' h'* in pulling down on the gate will first throw the latter to a slightly oblique position beyond the fixed frame, to ensure projection *i'* catching it again in the ascent of the hollow plunger P. The side ears on the gate R being then released from the locking recesses in the fixed frame *g'*, the completing contraction of the springs *h' h'* next draws down the gate so as to close egress from the receiver L, such closing action following in the wake of the dividing knife *d'* as it passes down or out of the receiver. A deposit of bristles having been made in the oblique slot *e'* of the hollow plunger P, the latter remains stationary for a time, while the doubling plunger Q comes down within it. This last-mentioned plunger (Fig. 401) is made bifurcated at the lower end and with longitudinal grooves *l'* up its sides, so that in the early portion of its descent it catches on or over the bristles lying across and through the plunger P, and, as it continues its descent

400.



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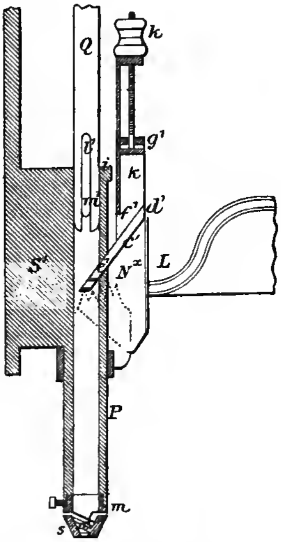
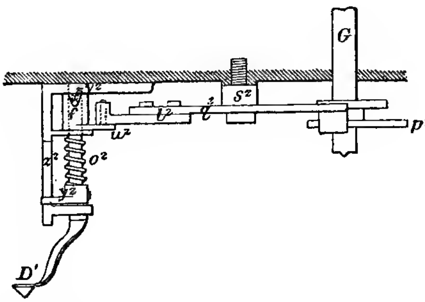


alone towards a nut or mouth-piece *s*, at the bottom of the outer plunger P, it folds or doubles up the bristles into the side grooves *l'*. The bristles, in being thus drawn out of oblique slot *e'* by the descent of the plunger Q, and formed into a bunch, are straightened by being drawn through a comb T (Fig. 398) attached to, and arranged to partially surround the outer plunger P. After the inner plunger Q, in its solitary descent, has entered the nut *s* (which is of tapering configuration internally), and the bottom of the plunger Q of corresponding shape, the wire *b* for binding the bristles is introduced (through the loop formed by doubling them), by way of cross passages *m'* made through the nut *s* and the bifurcated portion of the plunger Q, being of a suitable length to project beyond the passages on opposite sides of the nut. The two plungers P and Q then move down, in common, on to the back A and over a hole *a*, and during the descent, or as the end of the downward stroke is reached, the doubling plunger Q is revolved, so as to lap the wire spirally around the doubled bristles, aided by female threads *n'* made in the nut *s*. The plunger Q continuing to revolve in the same direction, the wire-bound bunch is projected through the bottom of the nut, and, by its wire binding, is made to screw its way into the hole *a* in the brush-back. The plunger is then slightly and slowly rotated in the reverse direction, to take the twist out of the bristles, and the two plungers P and Q move back to their raised positions for similar action on a succeeding lot of bristles, and so on till the brush is finished.

402.



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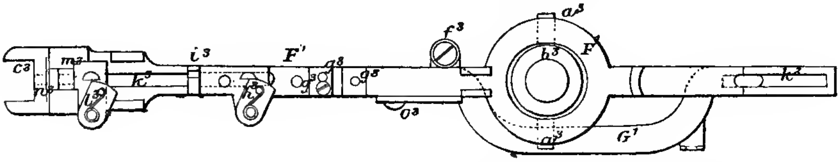
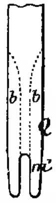
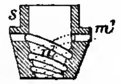


The means adopted for securing the necessary motions and pauses in the plungers P and Q are as follows:—On the main shaft D (Fig. 397), is a disc A', having in its front face a cam groove *o'*, whose configuration gives the requisite movements and pauses to the hollow plunger P, the connection with the latter being established by a pin or roller *p'*, travelling in the groove *o'*, and carried by an arm *q'*, in adjustable attachment by screw nuts with a vertically moving and guided rod *r'*, working a vertical slide *s'*, that carries the hollow plunger P. The inner and doubling plunger Q is worked by an eccentric pin *t'* on the face of the disc A', the pin moving, as the disc revolves, in and along a slotted cross-head B', mainly of a shape corresponding with the circle in which the pin *t'* travels, and guided so as to have an intermittent vertical sliding action under the operation of the revolving eccentric pin *t'*. The upper end of the plunger Q is attached to the cross-head B' by a screw and annular groove, in order to admit of its having the necessary intermittent rotary as well as vertical movement. The rotary motion is given for the purpose of wrapping the wire spirally around the double bristles, and to screw the bunch into the hole in the brush back, also to take the twist out of the bristles when the plungers retire. The groove *u'* in the back of revolving disc A' works a pin *v'* attached to a lever, and working up and down through a curved slot in the main frame. By these means, an intermittent up and down motion is communicated to the lever *w'* (Fig. 396), and through the latter, by means of a pitman *x'*, and slotted adjusting arm *y'*, an intermittent vibratory motion is given to a toothed sector C', which is in gear with horizontal bevel pinion *z'*. The rotation of this pinion *z'* in either direction takes place at the close of the descent of the plungers P Q, and as they commence to move up again. On its arbor, it carries a spur wheel a^2, that gears with a pinion b^2, to rotate the plunger Q as required. The pinion b^2 (Fig. 397) turns loosely on a sleeve c^2, arranged to loosely surround the plunger Q, and having an internal key or feather that fits a longitudinal groove d^2 in the plunger, to admit of the latter sliding up and down through the sleeve, and yet to secure its rotation by the sleeve when the latter is revolved. The rotation of sleeve c^2 by pinion b^2 is effected by a clutch tension and friction device, consisting in part of half-clutches e^2 f^2, the former of which is fast to pinion b^2, while the latter is

404.





405.

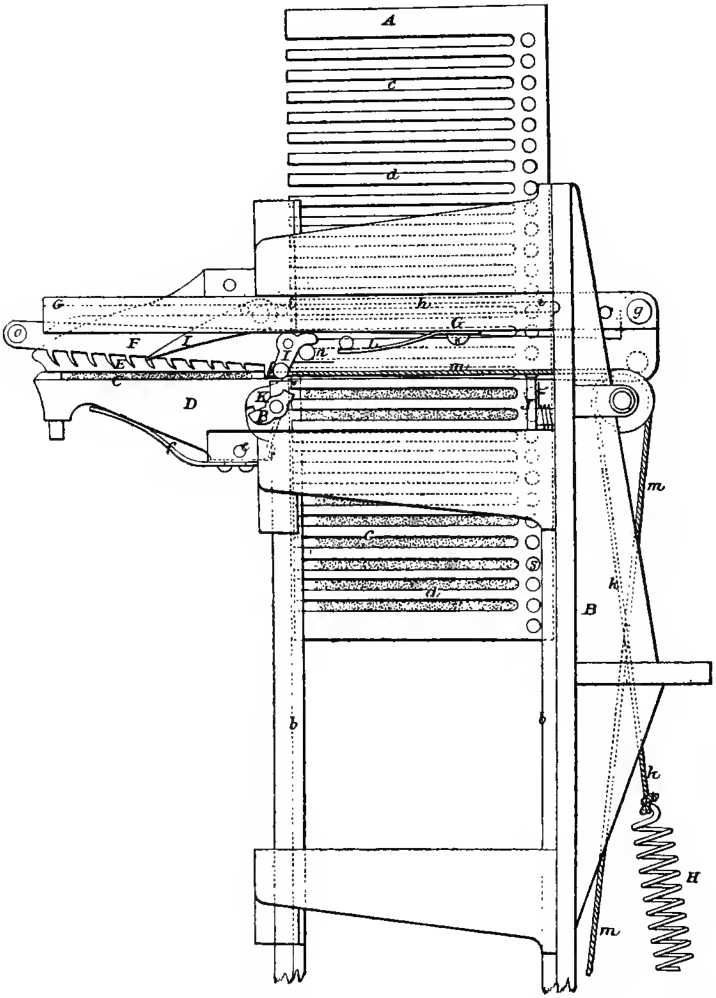
loose on the sleeve, and capable of up and down motion on it towards or from the upper half-clutch e^2, under control of a spring g^2, which presses at its lower end against an adjusting nut h^2 fitting a screw-thread on the sleeve, and presses at its upper end against a loose washer i^2, to bear the latter up against a leather or rubber washer k^2, which in its turn presses up against a washer or disc l^2, on the under side of the lower clutch f^2. By means of this spring tension and friction clutch, the plunger Q, when being revolved forwards to wrap the wire around the bristles and screw the bunch into the brush-back, is driven with an increased force by reason of the half-clutches e^2 and f^2 operating to compress the spring g^2, and to increase the friction of the washers i^2, k^2, l^2. The force is relaxed when the plunger Q is rotated to free itself from the inserted bunch, by reason of the reverse action of the pinion b^2, and slip of the clutch, allowing the spring g^2 to slightly relax and reduce the friction of the washers. This prevents the plunger Q, when rotated backwards, from unscrewing the bunch out of the brush-back. On the plunger Q, is a grooved tapering swell m^2, into the groove of which a spring guide n^2 attached to the rod r' of the outer plunger P enters, in the up stroke of plunger Q, to turn or adjust and ensure the proper relative position of the plunger with the oblique slot e' in the outer plunger, and with the wiring perforations m', preparatory to the descent of the plunger Q to perform its work.

The brush-back A automatically centres itself as regards bringing its holes a successively under the bunch-inserting devices, a conical centre D′, worked by the machine, bringing the hole in the back in precise position to receive the bunch of bristles. The centre D′ is cranked or crooked in its attachment to a vertical spindle o^2 (Fig. 402), which is made capable of a slight up and down motion at intervals, also of a vibratory motion around its axis. The action of the centerer D′ is as follows: Being swung to one side out of the way, it first slightly rises, and is then sprung forwards over or in line with the plungers P Q, then descends into the hole in the brush-back and centres the latter relatively to the plungers, after which it rises out of the hole, and is swung back out of the way to make room for the plungers to descend over the centered hole. The swinging motions of the centerer on its vertical spindle o^2 are effected at proper intervals by a cam p^2, working against a lever q^2 in combination with a spring arranged round the spindle o^2, the lever q^2 (which works on a centre s^2) being coupled by a connection t^2 with a crank u^2 loose on the spindle o^2, but in gear with the latter by a pin v^2 fast to the spindle and slot in the crank. This slot is made at its bottom or on its edge as at x^2, whereby, in the swinging of the crank u^2, and by the action of the spring, the centerer D′ is raised and lowered as required. A stop lever y^2, acting against a fixed guide z^2, and fast on the spindle o^2, limits and directs the movements of the centerer.

The apparatus for feeding and passing the wire to and through the perforations m' in the nut s and inner plunger Q are as follows:—E′ (Fig. 398) is a reel having the wire b wound upon it, and hung to revolve freely under the draft of the wire from it. F′ is the frame of the wiring apparatus (Fig. 403) hung to rock on trunnions a^3, projecting from a ring b^3 arranged to loosely surround the shaft. The front portion of the frame is forked at c^3, and rests on shoulders formed in the outer plunger P, being retained there by the action of a spring, except towards the completion of the down-stroke of the plungers P Q, or after they have moved a certain distance in common, and during a portion of their ascent, when the frame rests upon a fixed stop, e^3 (Fig. 396). The object of causing the wiring apparatus to rest by its frame on the plunger P, during the early portion of the descent of the latter in common with the inner plunger Q (which support also occurs during the completion of the up stroke of the outer plunger), is to ensure the entry of the wire b through the perforations m' in the nut s and inner plunger Q, and to avoid stoppage of the plungers when threading or passing the wires through the perforations. The wire b is taken from the reel E′ and passed through an oiler f^3 on the frame F′ (Fig. 403), and thence through straightening eyes or cups g^3, and through a feeding clamp h^3, and eyes or guides i^3, on a slide G′, which has a reciprocating motion along the frame F′, and is guided by slots r^3. From this slide G′, the wire b is passed through a clamp l^3 on the frame F′, through an anvil or cutting block m^3, and through a front eye or guide n^3, which is in line with the perforations m' in the nut s, where the fork c^3 of the frame F′ rests on the shoulders of the outer plunger P. The feed of the wire is established by the forward movement of the slide G′ by the clamp h^3 till the slide is arrested by a stop o^3, which determines the length of the wire to be cut off after its projection by the feed through the perforations m' in the nut s and inner plunger Q. A spring p^3 (Fig. 397) effects the forward or feeding stroke of the slide G′, and a cam q^3 on the shaft, its back movement; H′ is a cutting lever for severing the wire into successive pieces of the requisite length from the forward portion as it is projected through the nut s and outer plunger P; it is worked respectively by a cam r on the shaft C, and by a spring s. The clamp l^3 serves to hold on to the wire b after each cut, and during the back movement of the feeding clamp h^3, to keep up the supply. The clamps h^3 and l^3 alternately grip the wire, the former gripping when feeding, but relaxing when retiring, and the latter *vice versâ*.

More recently, an additional improvement has been made in the apparatus for feeding bristles to the machine. To provide for filling the comb with bristles, it is taken out of the machine, and there being duplicate combs, empty ones can be filled while the machine is at work, so that it can run without intermission. The novel filling arrangement shown in the accompanying figures enables one workman to serve several machines. Fig. 406 shows a side view of the comb-filler; and Fig. 407 is a plan of the same. The comb A to be filled is entered vertically from above, within grooved guides *b b* of a main frame B, secured to the side of a bench. The bristles C are entered transversely within the spaces *c c*, between the teeth *d* of the comb, and so as to overhang both sides of the latter in regular order, commencing with the space between the lower teeth, and repeating the filling operation, each tooth space, one above the other in succession, as the comb, controlled by pawls, drops down the grooved guides *b b* till it is wholly filled, when it is taken out from below for use in the machine, and an empty comb is inserted in the filler. Pivoted at *e* to the main frame in front, is a narrow lower jaw D, on and along which the bristles C are laid, so that they overhang both sides, being held in position by a fixed upper jaw E, which, with the lower jaw, grips them at about the middle. The introduction of the bristles between the jaws is effected by temporarily depressing the lower one, which is afterwards closed by a spring *f*.

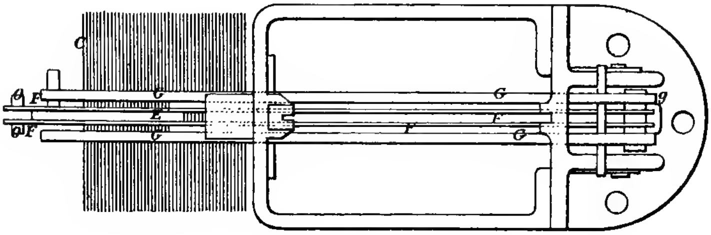
406.



The open edge of the comb A, when in place, lies immediately behind the jaws, and the bristles are drawn into, and more or less compressed within, each tooth space *c* in succession, by toothed feeding bars F F, pivoted at *g*, to a pair of outside horizontal slides G G, which are slotted at *h* to receive guide pins *i*, connected with the main frame. The toothed portions of the feeding bars F F lie over the bristles on the jaw D, and are held in a raised position, so as to be clear of them, by means of a spring *l*; and a forward traverse motion is given to the slides which carry the feeding bars, by means of a spring H, and cord or chain *k*.

To feed the bristles into a space *c* of the comb, power is applied by foot to a treadle below. This pulls upon duplicate cords *m*, which are connected with dogs I, pivoted on the feeding bars F F, and so arranged in relation to the slides G G and the stops *n*, that their first action is to draw down the toothed feeding bars F F into the bristles, and afterwards to draw the bars and slides backwards, by which the bars F F are made to distribute and pack, as required, the bristles within a tooth space *c* of the comb. The foot is then removed from the treadle, and the parts resume their normal position, to effect the filling of a succeeding tooth space, and so on till the comb is full.

407.



The comb A is retained in position and fed or allowed to drop as required, so as to bring each tooth space in succession into the receiving position for the bristles, by means of pawls J K, the former of which, catching in the holes *s* of the comb, simply serves to keep it from dropping too far while the latter is out of contact with the teeth of the comb, it being adjusted to enter successively within the tooth space *c*, to hold the comb at its precise required height. Towards the close of the back or feeding-stroke of the bars F F, pins on them strike levers, which, bearing against studs P of the pawl K, release the latter from the comb to provide for its next downward feed. When the feeding bars F F and slides G move forward again, a projection connected with them releases the pawl J to admit of the comb completing its drop; the pawl K being now released from the action of the lever, catches between a succeeding pair of teeth, for repetition of the crowding of another lot of bristles within the next tooth space of the comb, and so on till the filling is complete.

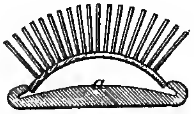
The Woodbury machine uses bristles, hair, tampico, or any other material equally well, and firmly secures the bunches in backs of wood, leather, indiarubber, bone, ivory, or other substances. It works 75 to 80 bunches per minute with the greatest ease, and fills an ordinary scrubbing-brush back in about the same time. Though extensively used in America, this machine has not been received with favour in England, an objection alleged against it being that the wire used for binding the bunch occupies so much of the hole as to prevent the bunch from fitting closely.

Round Brushes.—Round brushes for cleaning bottles, lamp-glasses, and other cylindrical vessels, are made by fastening the bristles, which project both ways, between two wires, which are then firmly twisted together.

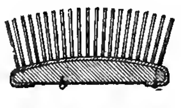
Steel Brushes.—For cleaning and removing sand from castings, very durable brushes are made by substituting for the bristles, a series of flat, well-tempered steel wires. They are an American manufacture, and are sold at 5½ to 18 dollars (say 23 to 75 shillings) per dozen, according to size.

Iron-wire Brushes.—Headed pins of ordinary iron wire are fixed in some elastic material, which is then attached to a thin sheet of metal, dished or bent so that the margin can be inserted in the undercut margin of a recess formed in the handle or back, as seen in Fig. 408. When the metal is bedded down upon the back *a*, the edges of the plate enter the recesses (Figs. 409 and 410), and it may then be secured by screws. If the plate be of steel or other metal having a degree of resilience, it may be sprung into place, and other fastening be dispensed with. The attachment of the elastic material to the plate is effected by sewing or riveting to the previously nicked or perforated plate, or by clamping over the edges of the plate, or by slitting them and turning up parts to be passed

408.

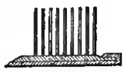


414.



411.

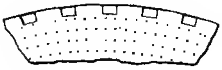
410.



through the elastic material and clamped down. Fig. 411 shows a margin which has been slitted; either needle and thread or rivets may be passed through. Fig. 412 is an example of clamping; in Fig. 413, the teeth are pointed for forcing through the material.

By another plan, the elastic material is fixed on a piece of wood by means of pins driven through the folded margin of the material and into the wood, or secured by stitches across the back, or by binding wire, &c., in a groove on the wood. The wood is then screwed to the handle, or cemented into a recess by shellac. Figs. 414 and 415 show the attachment by pins. In Fig. 414, the margin is so wide that it can be folded over the edge of the wood to the back; pins *c* are then driven through, or the opposite margins at *c c* are sewn together across the back. Fig. 416 shows an oval piece of wood fitted with a groove *d* on the edge; the edge of the material is folded over this, and embraced tightly by a coil of wire. In Fig. 417, the piece of wood is fitted into a recess in the handle or back *f*, which is of papier-maché, vulcanite, or of various moulded compositions. A hat-brush is shewn in Fig. 418: *i* is a piece of wood to which the material is secured; it is then fixed in a recess formed in the wooden back *k*, which is covered with plush, whose edges are folded underneath, hidden and secured by the back.

412.



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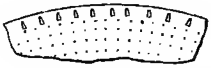

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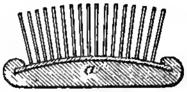

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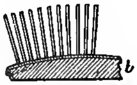
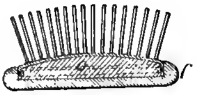
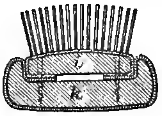


416.

417.



418.



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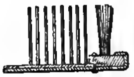
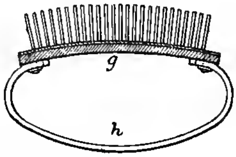


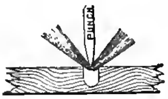
420.

Some brushes are made without wooden backs, the elastic pin-set material being stitched or riveted to a backing of leather *g* (Fig. 419), to which a leather strap *h* is attached, forming a handle under which the hand is held when in use. This kind of brush is useful for grooming horses, &c. It is also possible to have a margin of bristles around the metallic part of the brush; in those having recessed backs, the wire for drawing in the bristles is concealed; those having leather backs require the bristles to be wired in from the edge, as in Fig. 420, or from the back, as in Fig. 421. In the case of brushes with metal backs, such as cattle and horse brushes, the bristles are fixed in a strip of leather which is fastened to the metal back, and surrounds the wire pins forming the centre of the brush. Cylindrical brushes for brushing hair and other purposes are made by securing the pin-set material to the circumferences of the cylinders: preferably it is sewn to a strip of leather backing, and this is coiled spirally around the cylinders and cemented or tacked to them.

419.



422.



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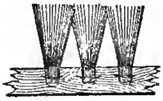


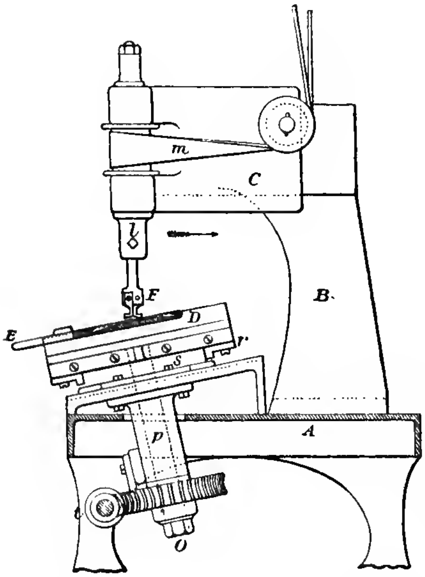
424.

425.

Bass Brooms.—Since the introduction of Piassaba (see Fibrous Substances), the manufacture of "bass brooms" has become an important branch of the brush-making industry. The rough "bass," as it is called, has to undergo a process of cutting, combing, steaming, "mixing," cleaning, and a final secret process, by which it is rendered more durable, in order to fit it for the brushmaker. The principal consumers of this material are J. and G. Horsey, of Mile End, who are the sole employers of machinery for making this class of brush. The backs or stocks are pierced partially through with holes, as by the Woodbury machine, before mentioned, and are automatically centered for the reception of the bunches. On one side of the machine, is a box filled with bass of the proper length, and at each revolution of the machine, a curious mechanism, called the "thief," darts into the midst of the bass, and abstracts just sufficient to form one bunch, which, being delivered to a travelling "carrier," is conveyed under the punch for fixing. Fig. 422 shows a section of the punch descending, and doubling up the bunch, at the same time forcing down a scrap of steel wire which, when down in place, is spread out, and holds the bunch in position, as shown in Fig. 423. Figs. 424 and 425 show a plan and sections of the wire, the bass being removed. The steel wire is run from an immense reel placed over each machine, whence it descends through a series of rollers, which deliver just so much at a time as will suffice to fix one bunch. Each machine, requiring the attendance of only one girl, can fix about 30,000 bunches per diem. Immediately the stock is filled, the broom passes through a set of combs, and between a series of knives, by which the surface of the bass is rendered flat and even. Finally, the backs are dressed smooth, and almost polished, by the action of a number of rotary and fixed knives.

Figs. 426 and 427, both partly in section, show respectively a side view and front view of one of the machines employed in recessing wooden backs. A is a framing, on which is fixed a standard B, one side of whose projecting head is planed and formed with "vee" slides, to receive a sliding carriage C. In bearings formed in bosses on this carriage, a cutter spindle *l* is fitted to revolve, receiving motion from a strap *m*. The carriage can be slid to and fro by means of a screw operated by a handle *n*, and working in a nut fixed to the carriage, as in the case of a lathe slide rest. A shaft *o* is fitted to revolve upon an inclined axis, in a bearing *p* fixed to the framing of the machine. On the upper end of this shaft, is formed a head *q*, which is planed and made with vee slides, and upon this head a table D is fitted to slide. Corresponding parts are seen in Fig. 428, which illustrates a modification in the machine. To the under side of the table, are secured two curved guide blocks *r r*, fitted to revolve around and in contact with an annular guide ring *s*, which is bolted to the table, but can be adjusted so as to be more or less eccentric with respect to the axis of the shaft *o*. If the ring *s* were fixed so as to be concentric with the shaft *o*, the table D would revolve with the shaft without sliding upon the head *q*, but when the ring is eccentric to the shaft, the table is made to slide to and fro on the head during each revolution. The table D is prepared to receive and hold in position the wooden back which is to be recessed. In the figure, the back marked E fits into a recess in the face of the table. A cutter F is fixed to the lower end of the spindle *l*. A revolving motion is imparted to the shaft *o*, by means of the worm and wheel G, the worm being fixed on a shaft *t*, driven by means of a strap. The back to be recessed is placed in position on the table, the carriage C having been slid away from the standard, so that the cutter would clear the work on completion of the back last operated upon. When the work is in position, the shaft *t* is started, and the work is thereby caused to revolve, and also to move to and fro in a direction across the axis of revolution. The carriage C is now moved in the direction indicated by the arrow, by turning the handle *n*, by which the cutter is brought into contact with the work. The movement of the carriage being continued, the cutter recesses the handle in all directions away from the centre, and, by the combined rotatory and rectilinear motions of the work, makes the recess of an oval form. The cutter is so formed that when the recessing is completed, which completion is determined by the further movement of the carriage being arrested by a stop, the margin of the oval recess is under-

426.



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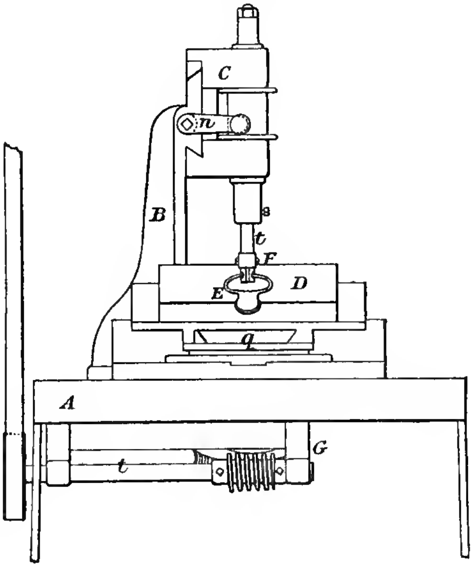


cut, as indicated in Fig. 408. For some purposes, the recess does not require to be under-cut, nor the bottom of the recess to be raised in the centre, for instance as in the case of Fig. 417. The action of the shaft o is then made vertical and not inclined.

428.

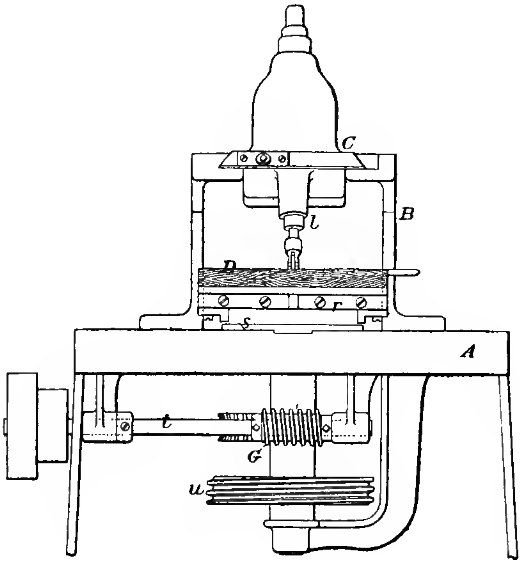
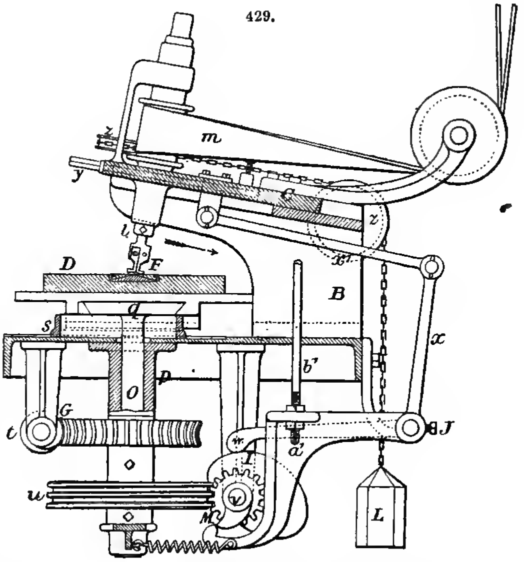


Fig. 429 is a side elevation, partly in section, of a modification of the foregoing machine when made self-acting to a greater extent. In this case, the table D revolves upon a vertical axis, but in other respects is arranged to act in the same manner as the table in Figs. 426, 427, and 428. The cutter spindle l revolves upon an axis which is inclined with respect to the axis of the shaft o, by which an effect corresponding to that of the first machine is obtained; it revolves in bearings in a carriage C, which is fitted to slide at right angles to the axis of revolution of the cutter spindle. A worm u, fixed on the shaft o, and gearing with a worm wheel fixed on a cross shaft v, imparts a comparatively slow revolving motion to the shaft, which revolves once during the recessing of a back or handle. Upon the shaft, is fixed a cam I, on which rests one end of a lever w, which is fixed upon a shaft J mounted in bearings. Upon the same shaft, is fixed a second lever x, the free end of which is connected by a link x′ with the carriage C. This connection is made capable of adjustment. In the figure, the link is jointed to a nut, in which works a screw y, mounted in the carriage in such a manner, that when the screw is turned, the carriage is moved in one direction or the other, while the nut remains stationary. The cam acts upon the lever w, to effect the sliding of the carriage C in the direction indicated by the arrow. A weight L, attached to a chain which passes over two carrier pulleys z z, tends to move the carriage forward in a contrary direction to that indicated, and thus keeps the end of the lever w pressed upon the cam. A second cam M acts upon a lever a′ mounted on the shaft J, and connected by a rod b′ with the strap guide bar of a counter shaft motion, from which the cutter spindle and the shaft t are driven. When a back to be recessed is fixed upon the table, and the machine is set in motion, the cam J slowly raises the end of the lever w, by which the carriage C and the cutter spindle are moved in the direction indicated, and the recessing is effected. When the recessing is completed, the cam permits the weight to move back the carriage C, and, during this backward movement, the cam M begins to depress the end of the lever a′, and thus to shift the strap which drives the counter shaft on to the loose pulley, so that by the time the backward movement of the carriage is completed the action of the machine is arrested.

429.



Brushes with Celluloid Backs.—In making brushes with backs of celluloid or other similar substances, the material is formed in moulds in two parts called half-shells. One of these is perforated with a series of holes for the tufts of bristles, whose inner ends are secured by being matted or ironed down upon the under side of the half-shell. A thin sheet of plastic material is now laid on, to further secure the bristles and keep them in position, this being covered with a wooden core extending into the handle of the brush, and strengthening it. This again is covered with the other unperforated half-shell, which forms the back of the brush, and the whole is then subjected to heat and pressure in a die, so as to mould the composition together, and close the holes about the tufts. In this way, a strong, cheap, and durable brush is obtained, in which there are no seams or joints to open during use, no cement to crumble and admit moisture, and no threads or wires to break off or rust out.

Brush-making is a trade which may be carried on upon almost any scale, according to the capital at command. A man may start alone with half a dozen tools and a five-pound note, or he may employ hundreds of hands, and any number of machines driven by steam. The manufacture is not confined to any particular place or country, but is spread promiscuously over every civilized land.

Imports and Exports.—The imports of brushes to or exports from the United Kingdom are so trifling as not to be specified in the trade returns. The imports of bristles for brush-making, in 1877, were, from Russia, 1,162,634 lb.; Holland, 209,457 lb.; China, 100,006 lb.; Germany, 960,614 lb.; United States, 73,045 lb.; Belgium, 63,557 lb.; France, 57,894 lb.; other countries, 26,253 lb. The exports for the same year were, to Belgium, 41,175 lb., value, 3219*l.*; other countries, 57,780 lb. value, 8649*l.*

BUTTONS. (FR., *Bouton*; GER., *Knopf.*)

Buttons may be said to mark the difference between ancient and modern styles of dress. The ancients, like the Easterns of to-day who have not put off old costumes for new, delighted in loose and flowing robes, rather flung around the body than deliberately put on; but from the time of the Roman toga downwards, there has been a gradual departure from the antiquated dress in the countries of the West, and the fate of loose robes was sealed by the invention of buttons about a century and a half ago. The first end to which buttons were applied was that of ornament, and consequently in their earliest forms they were splendid and costly; but men soon recognized their utility as a fastening for garments, which might thus be made less incommodious by reason of their fitting the person closely.

It would be difficult to enumerate all the substances which of late years have been made to contribute to the manufacture of buttons; but chief among them may be named gold, silver, copper, lead, iron, steel, brass, pewter, pearl, tortoiseshell, shell, ivory, bone, horn, hoof, hair, silk, Florentine (satin), linen, cotton, velvet, cloth, indiarubber, guttapercha, vulcanite, wood, amber, jet, glass, porcelain, enamel, clay, precious stones, leather, papier-maché, betel nut, vegetable ivory, or Corozo nut, and Manton's patent mineral earth as a substitute for the last named.

Metal Buttons.—These are made in two ways, either with a metallic shank for attachment to the garment, or perforated to admit the passage of the thread through the button itself. In the former case, they are usually manufactured by punching discs, out of sheet brass containing somewhat less zinc than ordinary brass, trimming the edges to remove the "bur," and planishing the faces under the action of a hammer to form the face of the button. This is embossed at the same moment that the maker's name is stamped on the back by means of *cameo* and *intaglio* dies. The shanks are formed of wire, which is run out by machine and cut off in sections of the proper length by a pair of shears, while a stud descends on the middle of the detached section, and forces it between the jaws of a vice, which give it the form of a staple or loop. It is then levelled by a blow from a small hammer, and dropped into a box. About a hundred of these shanks are taken out at a time and placed in position on the discs for which they are intended, being retained for the moment by a bent strip of flat iron. A scrap of solder is laid at the foot of each shank, and the whole set are then put on an iron plate, and heated in an oven till the solder melts. On cooling again, it fixes the shank, and forms a backing to the button. Each button is then turned separately in a lathe specially adapted, and afterwards gilt, electroplated, or tinned, as may be required. When the face only receives a plating, the buttons are known as "tops"; when the whole is thus treated, they are called "all-overs." Though the gilding is exceedingly thin, it will receive a polish with agate or bloodstone burnisher.

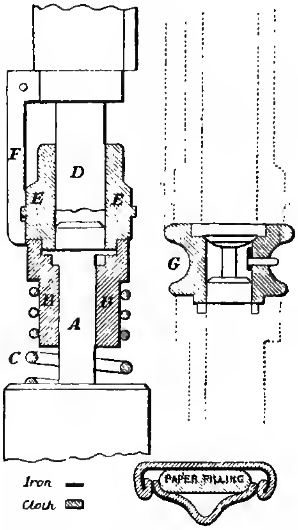
Metal buttons without shanks are turned out by stamping simply.

Cast buttons are produced by suspending a number of loops of wire—the shanks, with their ends expanded, in impressions in a mould, and pouring in the hot metal around them. When cold, the buttons are freed from sand, and chucked and turned in a lathe, when they are ready to receive polish or plating.

Livery buttons are now probably the only ones on which the die-sinker is employed, they being the last remaining trace of the ornamental application of buttons.

Covered Metal Buttons.—These consist of three essential parts—the metal framing, the textile covering, and the stuffing. The metal employed is exceedingly thin sheet iron, known as "taggers," made in plates measuring 14 in. by 10 in. The thickness generally used is No. 36 or 38, and the quality varies with the choice of the manufacturer. This is first scaled, the scales being removed by acid in order to preserve the tools, and then passed under a special punch. This punch is double, the outer portion cutting a circular blank of proper size, while an inner punch descends and forces the blank on to a die, so that its periphery is turned upwards, or so that the entire blank is rendered hemispherical in shape. These "shells" are next annealed in an ordinary furnace, and then conveyed to a horizontal revolving barrel, where they are tumbled with sawdust till thoroughly cleansed from all dust and grease. The under portion of the "shell," known as the "collet," is a somewhat smaller disc than the face, and is stamped out in an almost precisely similar manner, the inner part being punched out, leaving it with an annular shape. As the under side of the button is exposed, one face of the collet is japanned. A circular piece of the textile fabric to be used for covering the button is cut out by a die of the proper dimensions, and a pad or stuffing made of soft paper, silk, and thread (or sometimes of specially prepared paste-board covered with a bit of canvas) is punched into shape and fitted into the vacant space between the two metallic discs—face and collet. The discs, stuffing, and cover are united to make the finished button, by stamping them in a press with concave and convex dies, the shank of soft material, through which the needle is passed laterally, protruding through the aperture in the collet. The press used in finishing the button is shown in Fig. 430. A is a fixed mandrel, B a sleeve thereon supported by a spring C. On the upper mandrel D, is another sleeve E, sustained by a catch F. The lower face of the mandrel D is hollowed, and a projecting annular portion of the upper sleeve enters a corresponding portion of the lower one E. In using the machine, a shell is placed over the lower mandrel, and above it is laid the textile covering. The workman then causes the upper mandrel to descend, by which the covering is pressed down around the shell, and, by the return upward movement, both covering and shell are carried up inside the sleeve E. Then is inserted the annular piece G, provided with a cavity suitable for receiving the combined collet, tuft-piece or shank, and stuffing, the last being uppermost. The upper mandrel is again brought down, and the shell is thus forced into the collet with its accessories, the covering being at the same moment turned under. This particular form of button is called "iron-back," and is shown in its finished state in the figure. In another variety of the same class, known as "silk-back," the face consists of shell and cover, while the back is composed of four layers:—A concave circular piece of taggers iron somewhat smaller than the shell, a paste-board blank, a canvas blank, and outside of all a silk blank. These are put together in the manner already described, and then a nipple for attachment to the garment is made by a press.

430.



The oldest and largest button-making firm in the United States turn out about 65 millions of iron-backs per annum, consuming for the purpose about 500 to 700 boxes of taggers iron, each weighing 112 to 120 lb. The iron is of the very best quality, such as has only recently been produced in America. The various coverings—lasting, brocade, twist, &c., and the canvas for forming the shanks, are all imported from England, France, and Germany.

Another method of making covered buttons is as follows. The disc for the shell is left flat, and the back piece or collet consists of a smaller circular disc, with a round hole in the centre and having its edge cut into eight sharp points, which are so bent as to form nearly a right angle with the disc, but inclining slightly inwards. To complete the button, three pieces of paper and two pieces of cloth are required, and are arranged in the following way. On the cloth forming the outer covering, is laid a piece of paper of the same size, upon which is placed the iron disc forming the shell; this is overlaid by another piece of paper the same size as the shell, and this again by a small piece of paper to help form the shank; next comes a piece of coarse cloth, and finally the metallic collet. In putting on the back, the covering is gathered up over all the materials, and the points which are already inclined inwards are passed down into the covering, forming eight little hooks, which hold the button together in a neat and effectual manner. The paper stuffing forces the cloth to protrude through the hole in the collet, forming the shank for attaching the buttons.

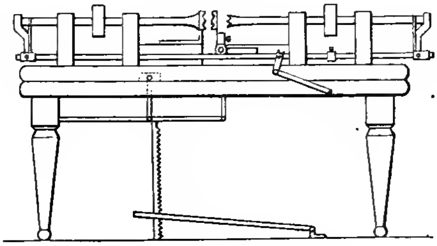
Pearl Buttons.—The manufacture of buttons from mother-of-pearl is an important branch of industry, and is distinguished by the fact that no elaborate machinery, and not more than a few shillings of capital, are required. The whole work is done by means of a lathe and skilled hand labour, consequently any efficient workman can carry on the manufacture alone, and as a consequence, this particular kind of button-making is carried on by a large number of persons, each engaged in a very small way. There are several varieties of pearl, all composed of the nacreous gum secreted by several species of mollusc. The finest and purest specimens are obtained from the white-edged Macassar shells, imported from the East Indian seas, and worth in this country about 140*l.* to 160*l.* a ton. The yellow-edged Manilla shells are similar; but the yellow tinge on the border reduces their value, and they are at the same time more brittle. This variety is principally used in Sheffield for delicate knife handles, and fetches 100*l.* to 120*l.* a ton. A smaller and less delicate variety is found in the Persian Gulf and Red Sea; they are known as Bombay and Alexandria shells. Their quality is very various, and prices range from 30*l.* to 70*l.* or 80*l.* a ton. The islands of the Pacific Ocean yield a so-called black shell, which, when polished, throws out a dark shade full of rainbow tints; portions also, when properly turned, give a white button, nearly as good as that from the best Malacca shells. The last and lowest variety, also from the Pacific, is the Panama shell, worth 20*l.* to 30*l.* a ton. The mother-of-pearl is cut out of the shell by a small cylindrical saw; the disc is turned in a lathe, and, if thick enough, split to make two. A "dove-tail" hole is drilled in each button to receive the shank, which is fixed by a slight blow with a hammer, thus expanding the lower part into the dove-tail so as to prevent its being easily withdrawn. The waste from pearl-cutting has been utilized for button-making, by grinding it to a fine powder, and mixing it with gum, to form a paste, which, on heating, may be pressed in moulds. The beauty and iridescent brilliancy of mother-of-pearl are owing to thin plates overlapping each other unevenly, and dispersing the light as they reflect it. Ornamental flutings and corrugations are formed in the lathe by means of an eccentric chuck and slide rest. (See Pearl and Coral.)

Porcelain Buttons.—The process of manufacturing porcelain buttons resembles that of making small ornamental articles of earthenware. The moistened clay is pressed into plaster of Paris moulds, carefully placed on boards to dry, and then taken to the "biscuit-oven," where it undergoes the first firing or baking. The baked clay is now called "biscuit," and is ready for the painter or printer. A great number are made uncoloured; but many also, both with holes and shanks, are partly or wholly painted, some with simple, others with complicated designs. The painting is effected either by hand or by transfer printing: in either case, the colours are "fixed" by the articles being baked in a muffle furnace or enamel kiln. In transfer printing, the design required is printed from copper plate, by means of a peculiarly prepared ink, on thin tissue paper, which is then placed, while the impression is still moist, upon the biscuit ware and allowed to dry, after which it is removed, the design having become transferred from the paper to the biscuit ware. The design is then burnt into the article in a muffle furnace. This baking effectually removes the oil used in preparing the colour, and leaves the button ready for the glazing process. Each muffle furnace is furnished with a little tramway, which traverses the interior of the furnace and projects forwards into the bakehouse. This tramway is provided with small, flat, movable iron platforms, on which the "frames" containing the buttons are carefully piled and then wheeled into the oven, around which a steady fire is kept constantly circulating. When the baking has been completed, the button is subjected, if required, to the glazing process, which is the same as that used for common porcelain, after which the shanks are added. (See Pottery.)

Glass Buttons are moulded by pinching the material, while in a half soft condition, in a pair of hot pinchers, which are furnished with a die if it is desired to impress a design on the buttons. (See Glass Manufacture.)

Shirt Buttons.—Common white shirt buttons are made in the following way. Finely powdered steatite is saturated with soluble glass, the mixture is dried and repulverized, and the powder thus obtained is pressed into moulds by suitable machinery. It is then fired or baked in furnaces, again dipped in soluble glass, and a second time submitted to the furnace. When cool, the buttons are polished by being put into a rotating barrel with water, then dried, and again polished by rotation in a similar barrel with soapstone powder.

431.



Turned Buttons.—Buttons made from ivory, bone, horn, woods, and such like substances, are turned in a button lathe (Fig. 431), and the holes, varying in number from two to four, are drilled, while the button is in the lathe, by means of long drills converging towards the button and forming all the holes at once. The cutter of the lathe is like a centre-bit, only both wings are cutters instead of one being a router. On the tool revolving, the centre pin transfixes the substance, and the wings circulating cut out a round disc, which is advanced towards the cutter by a sliding bar in the back poppet head. In the machine represented in the figure, the moving jaw of the clutch is forced against the blank by a spring, and drawn back again by a depression of the treadle. The bits are brought singly and alternately against the blank, being moved thereto by the bell-crank hand-lever. The woods chiefly employed are ebony, boxwood dyed black, and cocoa-wood. The so-called vegetable ivory or Corozo (Corosso, Corusco) nut consists of the hardened albumen of the interior of the nut, which is the fruit of a species of palm, *Phytelephas macrocarpa*, imported from the northern part of South America and from Central America. The nut grows in bunches as large as the double fist, but less than half of it is fit for use. It is milky white, lighter and softer than ivory, easily turned, and will take any shade of dye. Its value is about 25*l.* to 30*l.* per ton. (See Nuts.)

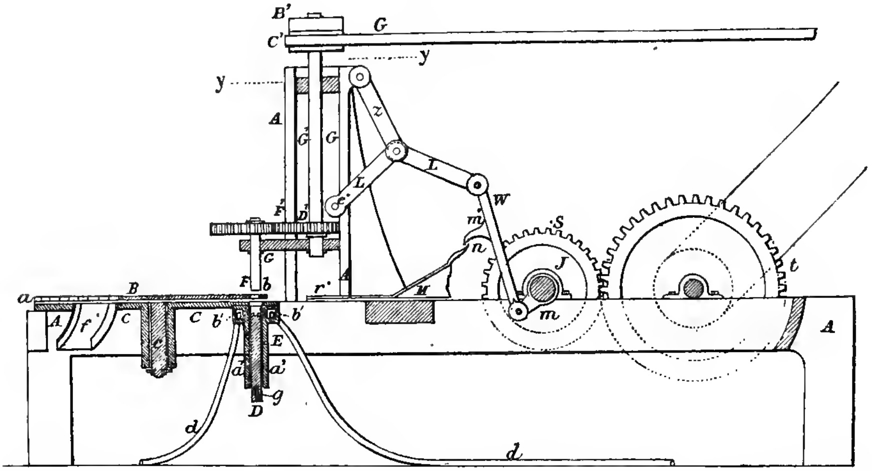
Button-moulds.—These are little turned wooden discs perforated in the centre, and exactly resembling miniature quoits in appearance. They form the shell over which a covering of cloth or other textile fabric may be sewn, so that the pattern can always resemble that of the garment on which the button is used. They are principally made in the south of France, where suitable wood is not expensive, and are imported into this country by millions. They are used almost exclusively on women's and children's attire.

Button Machinery.—During the last four or five years, several improvements have been effected in button making and ornamenting machinery, the principal of which will now be described.

An ingenious invention for polishing or finishing buttons made of horn, bone, wood, or Corozo nut, consists in subjecting them to frictional contact with prepared chalk, pulverized charcoal, or other fine cutting material, mixed with spirits of turpentine, naphtha, or such other liquid as, unlike water, will not "raise the grain" of the substance of which the buttons are made. They are by this means brought to a better finish in a few hours than was hitherto possible in several days. When it is designed to ornament the buttons by "lining" or marking them with sharply-defined annular lines, they are subjected to frictional contact under pressure of a die having an axial movement, by which, in addition to securing the requisite smooth surface, the colour of any dyes previously applied is rendered more vivid and bright, and the "lines" are made without the raggedness of contour resulting from the use of a cutting tool.

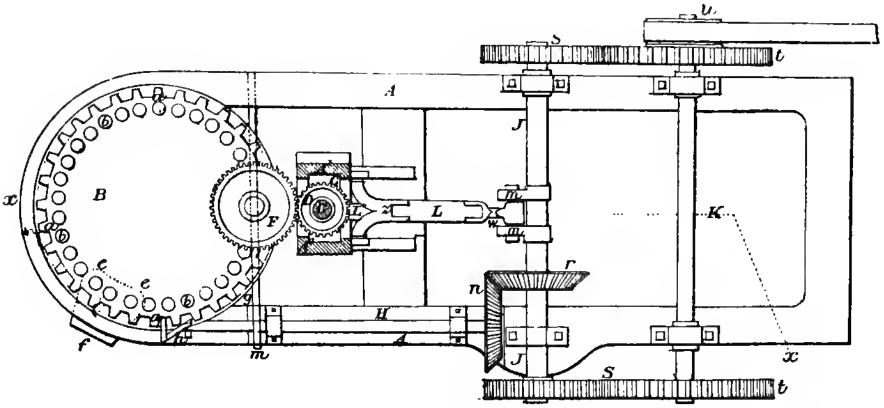
Fig. 432 shows a vertical section of the apparatus employed in polishing and "lining" buttons, on the line *x x*, Fig. 433, which is a horizontal section on the line *y y* of Fig. 432. In practice, the buttons are taken either as they come from the lathe, or, when coloured, as they come from the dye, and any desired number are mixed with about twice their volume (more or less) of prepared chalk, or other fine polishing substance; to the whole, is added a quantity of spirits of turpentine, or naphtha, or, failing these, alcohol or kerosene may be used, but with inferior results. The mass is then placed in a common tumbling box, which is made to revolve for several hours, varying according to circumstances, and continued until the requisite smoothness of surface has been obtained.

432.



The bed A is provided at its forward end with a flat circular disc or carrier plate B, furnished at its periphery with radial teeth *a*, and, concentric with its axis, with an annular series of holes *b*, these holes having a dimension and form corresponding with those of the articles to be polished, and extending quite through the carrier plate. The carrier plate itself is furnished with a downwardly projecting axial shaft *c*, which works in a bearing formed in the fixed plate C, which last closes the lower ends of the holes *b*, except as presently described. At the back of the plate C, is a vertical guide *a′*, in which works a lifter D. Upon the upper end of this lifter, and within the guide, rests the die E, while around the upper portion of the guide, is a steam chamber *b′*, furnished with steam pipes *d* connecting with a generator, and designed to heat the die E by circulating steam through the chamber. Arranged vertically, coincident with the lifter D and the die E, is a rotating die F, working in bearings provided in the lower part of the sliding head G, which moves in suitable guides A′ fixed upon the bed A. This head carries an upright shaft G′, upon the upper extremity of which are fast-and-loose pulleys C′ and B′, and which carries at its lower end a pinion D′, gearing into a spur wheel F′ on the rotating die F. The pulleys have a belt G* running to a shaft. The position of the two dies E F is such that, as the carrier plate B is intermittently rotated, the holes *b* will pass in succession immediately between the dies, to permit the upper or rotating die to pass through the holes, to act in conjunction with the lower die, which remains fixed except when lifted to discharge the finished articles. A slot is formed in the plate C, coincident with the adjacent portion of the series of holes *b*, and indicated in dotted line at *e* in Fig. 433; below it is an outlet chute *f*. The lower extremity of the lifter D is slotted, to allow a lever *g* to pass through it, one end of which lever is pivoted at one side of the frame A, while the other end is curved upward to rest upon a cam *m* on a shaft H extending along the opposite side of the frame. The shaft H has a spiral disc *h* at its forward end, which gives an intermittent rotary movement to the carrier plate, insuring the retention of each hole *b* in succession above the die E and below the die F for a certain definite time. The shaft H gears by bevel wheels *n r* with a bell-crank shaft J, driven by spur gears *s t* from a driving shaft K furnished with a pulley *u* for a driving belt. L is an elbow lever, whose extremity *e″* is pivoted to the lower part of the sliding head G, and whose free end connects by a pitman *w* with the crank *m* of the shaft J. To the bend of this elbow lever, is pivoted the bar *z*, whose upper end is pivoted to the fixed guides A′, in such manner that the bar and the part *e″* of the elbow lever form together a toggle joint, capable of giving a vertical movement to the head, from the rotation of the crank; the downward stroke of the latter continually increases in power as the toggle joint straightens. M is a bellows which, being actuated during the downward stroke of the crank *m*, by the striking of the stud *m″* of the elbow lever L upon the arm *n″* of the bellows, sends a puff of air through its nozzle *r″* to blow away any dust which may have accumulated upon or near the dies. The method of operation is as follows:—The buttons are placed singly in the holes *b*, and by the movement of the carrier plate are brought under the rotating die F. The movement of the carrier being suspended for a moment, the sliding head G is brought down with great force by the straightening of the toggle joint, the die F on the head G being meanwhile rapidly revolved by the action of the belt on the fast pulley C′. As a consequence, the button is subjected simultaneously to great pressure and to the frictional contact of the die F upon its upper or outer surface, the force of the die corresponding in contour to the surface of the button. It is thus effectually smoothed and burnished, the colours are brightened, and the lines are sharpened without crumbling. This operation concluded, the continued working of the machine lifts the die F, whereupon the cam *m* raises the lever *g*, while the lifter D forces up the lower die till its top is level with the upper surface of the plate C. Then the action of the cam *h* on the teeth *a* turns the carrier plate B, until the hole containing the button is brought over the slot *e*, whereupon the button falls into the chute *f*, away from the machine. The same movement of the machine also brings the next hole into proper

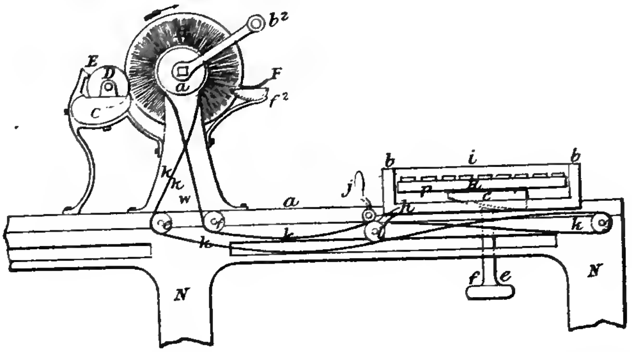
433.



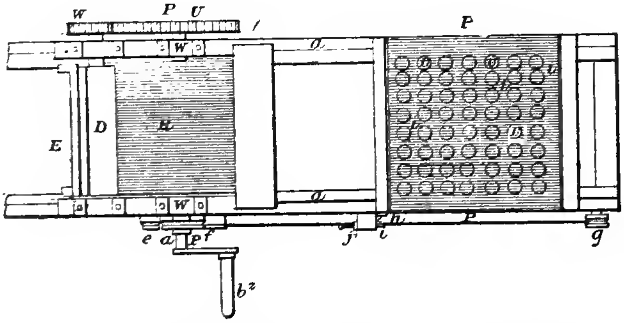
position with regard to the dies, so that the whole operation is continuous, and the work is performed with speed and economy.

Figs. 434 and 435 represent an apparatus used to give a coloured ornamentation to buttons. N is the supporting framework, furnished at top with two longitudinal guides *a*, upon which runs a carriage P, having an upright cleat *b* at each end. Between these cleats, is extended a series of tightly drawn parallel threads *i*, whose distance apart will correspond to the space desired between the colour markings on the button. In the bottom of the carriage P is a disc, flat on the top but spiral beneath, fitting into a seat in the carriage bottom in such a way that when turned by means of the thumb piece *e* on the shaft *f* it will be raised, and, constituting the cam *c*, will lift the board R placed upon it. This board is indented in its upper surface with numerous cavities *v*, which receive the buttons to be ornamented, and retain them with their upper surfaces projecting somewhat above the corresponding surface of the board. By turning the disc or cam *c*, the board is lifted till the buttons are brought up singly against the threads *i*. W is the shaft of the cylindrical brush R^*, and has a pulley a^* furnished at the outer end with a crank b^2. Upon the frame below, are two pulleys *e*, *f*; at the outer end of the carriage P is a pulley *g*, and at the inner end a horizontal arm *h* carrying a pulley i^*. An endless band *k* passes over these pulleys, and upon the extremity of the arm *h* is a cam lever *j'*, by which on occasion the band may be gripped against the pulley i^*, thereby attaching the carriage for the time being to a definite point of the band *k*. Under this condition, the rotation of the crank in the direction of the arrow causes the carriage to be drawn inward, passing underneath the brush, and at a speed bearing a proper proportion to that of the rotation of the brush. Behind the brush, is a trough C containing the liquid colouring matter to be applied to the buttons, and revolving in it is a feed roller D, working in contact with the brush and supplying it with colour, while E is a scraper arranged behind the feed roller, and regulating the thickness of the film of colour. The roller is rotated by gear wheels W U, or by a band running on pulleys. In front of the brush, parallel to and in contact with it, is a trough-shaped spattering bar F, below which, with its edge projecting a little farther back, is a secondary trough f^2. The effect of working is that the carriage is drawn back towards and under the brush simultaneously with the rotation of the brush, which latter is charged with liquid colour from the feed roller, and its bristles striking forcibly against the spattering bar, the colour spatters in fine

434.



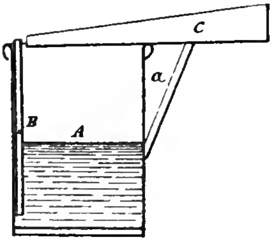
435.



drops upon the surface of the buttons not protected by the threads, dyeing that portion of them. By turning the board half round, the pattern may be made in checks, and various other devices may be produced by modifying the disposition of the threads. In order to change the position of the board or to remove it, it is only necessary to turn the cam c, which lowers it. The object of the secondary trough f^2 is to catch from the brush any large drops which might otherwise fall upon the carriage during its movement below, and thus spoil the work. By loosening the cam lever j' after the carriage has been brought to the rear of the frame, it may be run forward to its original position without the pulleys and band.

A simple method of mottling Corozo nut or vegetable ivory buttons consists in inserting in the pot containing the mottling liquid a vertical pipe or tube extending to very nearly the bottom, and from which a conical pipe is supported horizontally and at right angles to it. The nozzles of the pipes are brought close together, so that by blowing or forcing air into the horizontal one a spray of the mottling liquid will be caused to rise in the vertical one, and is thus directed on to the buttons. The simplest of the many ways in which these pipes may be arranged is seen in Fig. 436. A is the pot, to which the vertical pipe B is secured; C is the horizontal pipe held in place by the support *a*. Stripes, checks, or other patterns may be produced on the buttons by means of the frame D, Fig. 437, around which are arranged any desired number of pins or hooks *d*, whereon is secured netting of silk, twine, or wire *c*, or the threads may be stretched from pin to pin so as to form a variety of patterns. The frame with the pattern is placed over the buttons, and the mottling liquid is then blown over them in the form of spray. Devices may also be stamped in thin metallic or other sheets. The proposed compound for polishing vegetable ivory buttons is 4 pints ivory nut shavings, ½ pint prepared chalk, ½ pint terra Tripula (Tripoli), ½ pint terra Vienna, and ¼ pint pumice. This quantity will generally suffice for fifty gross of buttons. The buttons and compound are placed together in a vessel, and rotated or shaken till sufficient polish has been imparted. Any of the four last ingredients may be used separately, but always with the ivory nut shavings. They may be made into a liquid by the addition of water or spirits of wine, and may be used on the polishing lathe either wet or dry.

436.



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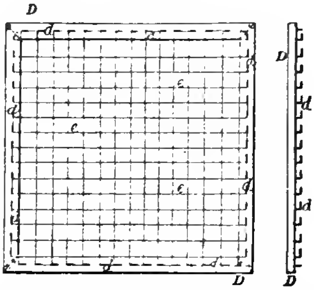
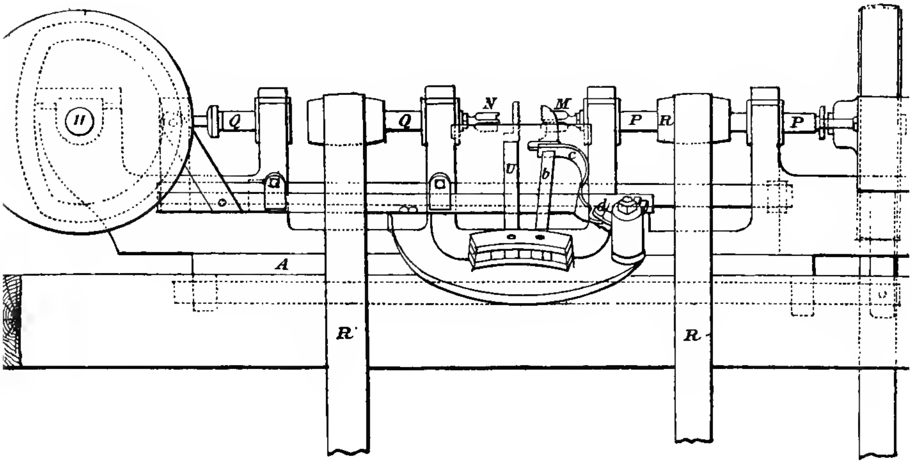


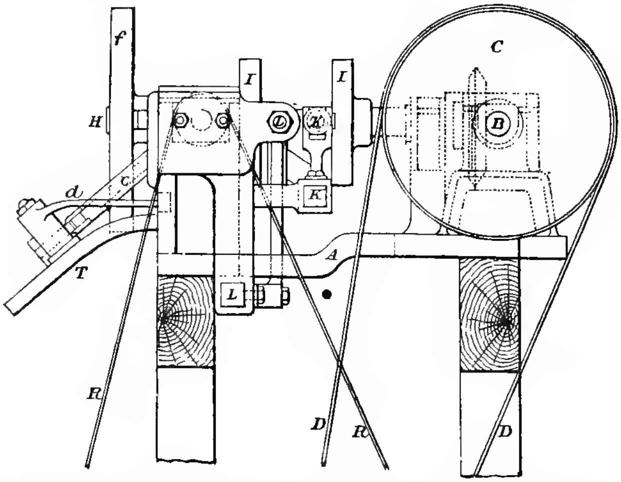
Figs. 438 and 439 show front and end views of a recent improved apparatus for manufacturing buttons, &c., from bone, vegetable ivory, and wood, its chief advantages being that skilled labour can be dispensed with, injury to the hands of the workmen prevented, and a greater quantity of the articles made in a given time than is possible with other machines in use. At the rear of the bed-plate A, is arranged a shaft B, on which is a pulley C for a band D, operated by an overhead or underneath motion. The shaft carries at one end a bevel pinion gearing into a corresponding wheel on a short shaft H at right angles to the shaft B. The shaft H has a couple of cams or eccentrics I upon it for actuating (through the intermediation of the sliding bars K L) the opening and closing of the revolving tools M N, by which the piece of rough material put in between them is cut and brought into the required shape, in accordance with the class of tool furnished to the tool spindles P Q. These last are driven by independent motions R, and thus revolve, the rotation for cutting purposes being in addition to the end-on motion from the cams and slide-bars. To the front of the bed-plate A, is attached a plate T, or it may be a skeleton frame, from which there projects towards the machine a rod U, at the end of which is fitted a jaw, for the piece of rough material to be put against by hand. Hinged to the plate or skeleton frame T, is a counter jaw *b*, by which the piece of material is held in by pressure of a spring *c*, while the tools approach and perform the cutting. This spring is attached to a lever bar *d*, and the pressure is removed by a backward travel of the spring and its bar through the action of a plate, on which is a roller running in the race of cam *f*, on the forward end of the short shaft H, the release of the waste piece and the shaped button being effected by the attendant before putting in a fresh rough piece. Sometimes a receiver is arranged between the fixed jaw and the movable one, so that the piece of rough material can be put in while the jaws are apart, thus preventing injury to the fingers. The receiver is composed of two wings or cup plates, which can be opened when the tools retire after completing the cutting, and allow the article and the waste to fall into a receptacle beneath, closing again for the reception of a fresh piece.

438.



The Figs. from 440 to 444, both inclusive, refer to a German improvement in presses and appliances for the manufacture of composition buttons in imitation of horn and vegetable ivory. It consists in providing the bed-plate A of an ordinary screw or lever press B, with a set of half-dies C, capable of being raised and lowered by a hand lever D, and sliding wedge plates formed

439.



of zigzag bars E E, which move in slots formed in a plate F, the upper part of which has chamfered or rounded-edged holes, in which the half-dies move. The "force" or head G of the press has upon its under side a corresponding number of half-dies H, these being formed by long pins or studs I, that they may pass through holes in a perforated plate J (Fig. 443), by which the composition forming the buttons is fed to the lower half-dies. The plate is capable of easy removal for each feed; it has a groove on each side-edge for a plain plate to be slid in to serve as a bottom, upon which the pieces of prepared composition rest when put into the holes in the perforated plate. The two plates act like a box; when charged it is put over the lower half-dies C, and the plain plate is then drawn out and the pieces of composition fall down on to the top of the lower dies; the force G is then lowered by rotating the handles L, and the pieces of composition become transformed into buttons of a shape and thickness corresponding to the distance between the half-dies when the pressure is on. The half-dies, top and bottom, may have any device or design upon them, and one of them may have a couple or more of pins projecting to form the holes for sewing purposes; or a short pin M may be upon, say, the upper half-die, by which the back of the button is formed, the pin M then making a hole of sufficient depth for the reception of a metal eyelet, shank, or loop, which can be inserted after the button is removed from the press. In fitting metal shanks to such composition buttons, the shank pins are arranged in holes formed in a plate N (Fig. 444), and with the loops exposed that they may readily be taken hold of by a pair of pliers. This plate has a recess under it, in which a gas or other burner is fitted, for heating the plate, and for imparting sufficient heat to the shanks, that their pins may enter the holes in the button backs when applied, the heat softening the composition and forming the attachment of one to the other. The ingredients forming the composition, after being mixed in suitable proportions and of the colour desired, are placed in a caldron enclosed in an outer vessel, the space between the two vessels being filled with sand, to maintain an uniform heat. The composition, when heated to the proper temperature, is stirred and rabbled into a stiff pasty consistency, and used as desired. This is removed from the caldron in suitable pieces and rolled in long strips, from which are cut smaller pieces, to fill the holes in the perforated plate. The rolling operation is done upon a hot plate, and the first-named perforated plate is heated partly by the hot plate and partly by the press, the half-dies in which are also heated, so that the composition, from the caldron to the finished button, is kept at about one temperature. The pressure is maintained upon each series or group of buttons for a few seconds, and when the "force" is lifted, the first-named perforated plate is removed, and made ready for the reception of fresh pieces of the composition. The lower half-dies are then lifted by the sliding wedge bars, to lift the made buttons above the level of the holed plate on the bed. A many-tined fork is then put in between the raised half-dies, and the buttons are lifted off the dies by the tines, the superfluous composition being removed and thrown back into the caldron to be rabbled along with the other. The rough edge of each button is then dressed by a plunger tool. Instead of making holes in the buttons by the pressure operation, a cone-shaped lump can be left upon the back of each, through which a hole can be made parallel with the back by a heated piercer needle, the socket of which rides in a kind of box. The socket can be pushed in a given distance, to force the heated needle

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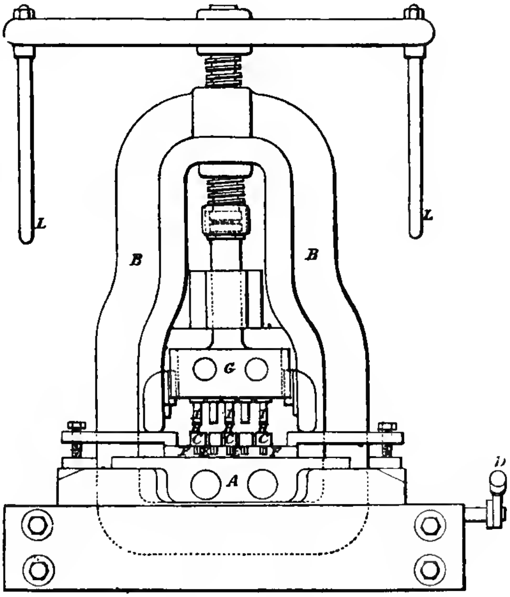
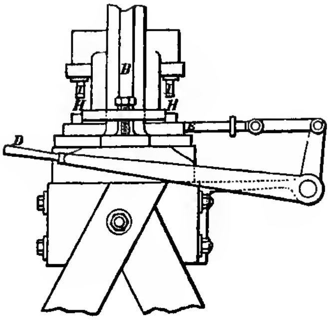


441.



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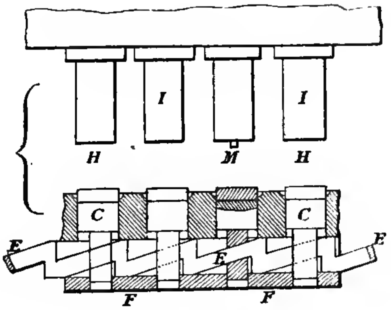

through the lump on a button put into a receiver or socket; the socket then recoils under the action of a spring, and the pierced button can then be removed.

The common practice in turning buttons, &c., is to employ a machine having two spindles mounted in line with each other, and revolving at a high speed, the cutting tools being fixed in the spindles, and the material to be operated upon being held between them by means of a "steady" and "grip," together forming a pair of tongs. The grip and cutting tools are worked by the operator by means of handles, and require a considerable amount of manual labour and skill in their manipulation. An improvement upon this plan consists in actuating the grip and tools by means of cams in connection with levers and rods in a self-acting manner, so as to open and close the grip, and push one or both tools backwards or forwards as required, enabling a girl to do a large amount of work without great labour or skill. Figs. 445, 446, show a side elevation and plan of the machine suitable for turning buttons of wood, vegetable ivory, and similar substances: *a* is the framing of the lathe; *b*, *b'* are spindles revolving in bearings on the framing; at their ends they carry the tools for turning the front and back of the button respectively; they are driven by straps taking on the pulleys *c*, *c'*; *d* is the "grip"; *e*, the "steady;" *k* is a cam mounted on a spindle, revolving in bearings, and caused to turn by means of a pinion *m*, the teeth of which gear with teeth formed on the circumference of the crank; the pinion *m* is mounted on a spindle, which is caused to rotate in its bearings by a strap taking on the pulley *n*. The crank is formed on the outside with a groove, in which works a roller *l*, mounted on a bar or connecting-rod *g*, which is guided at one end in the bracket *q*, and at the other end is attached to a spring *f* by means of a screw *r* and nuts, as shown, whereby the tension of the spring can be regulated. The spring *f*

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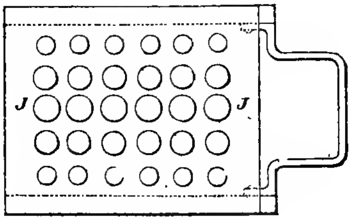

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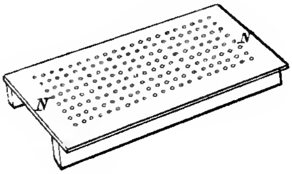

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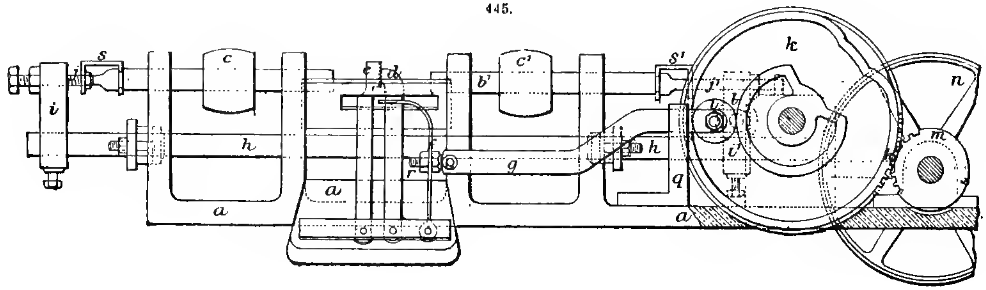

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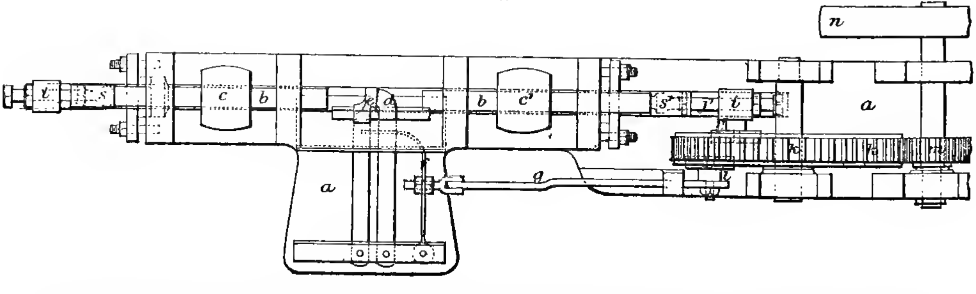
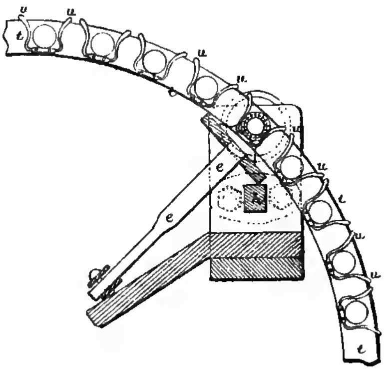


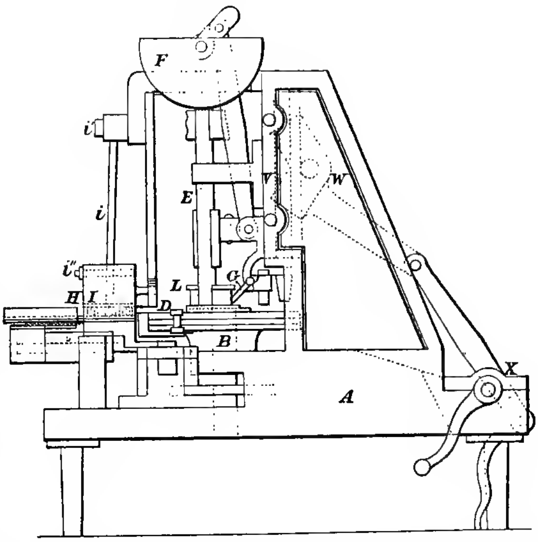
is, by preference, jointed below, and serves to push the grip d against the piece of material. The groove in the front side of the cam k is shaped so as to make the grip self-acting, allowing the piece of material operated upon to drop in the moment the operation is finished, when the operator places another piece in the grip. The back of the crank k is also formed with a groove, in which works a roller l' mounted on a stud in the bracket i', which, by means of a set screw, is fixed on a square bar h that is guided in the framing a, but by preference works through stuffing-boxes. The bar h has a similar bracket i at the other end. Through the brackets i, i', are passed the screws j, j', which abut against the ends of the spindles b, b' connected by the staples s, s', so that the spindles are made to partake of the movement of the bar, which is self-acting, and so timed and arranged by the shape of the back of the cam k that the tool on the end of the spindle b first cuts the face of the button, and then that on the end of the spindle b' cuts the back of the button. Thereupon the grip is opened, and the button falls out, a piece of new material is put in, and the operation continues. Fig. 447 shows a part of a self-feeding appliance which is suitable for small articles that are turned very quickly; t is a ring, which is made to revolve on four rollers placed equidistantly within it (not shown), formed with ratchet teeth all round, and actuated by a pawl. Motion is communicated by a lever and rod from a roller working in the outer groove of the cam k. The ring t is formed with holes in it; at each hole is a spring u for holding the piece of material; e is the steady. The pieces are fed in at leisure, and without the hand of the workman coming near the tools or grip.

447.



The next machine (Figs. 448 to 452) to be considered is an American invention, enabling all the operations of manufacturing covered metal buttons to be performed automatically. On a standard A, is a horizontal table, consisting of an under solid plate B, and turning in contact with it a plate C, having near its outer edge a series of holes c slightly larger than the button to be made. Above this second plate is a ring D, of the same size as the two circular plates, held stationary, but perforated with holes corresponding with those in the second plate. The bases of the holes in the plate C, being closed by the lower stationary plate, form a series of depressions in which the buttons are to be formed. The plate C is caused to revolve with an alternate motion by a suitable cam or ratchet wheel. At one side of the table and above it, in the line where the holes c revolve, is placed a vertical tube E, terminating above in a hopper F, where are placed the fillings for the buttons, stamped of the proper size. A brush is made to vibrate among the fillings over the mouth of the tube, the effect of which is to keep the tube full when once it has been filled, and to lay the fillings flat in position, so that they may fall down one after another. The base of the tube is closed, but a slot is arranged in one side, just large enough to allow of the exit of one filling at a time, and a reciprocating bar G, entering at the opposite side of the tube, pushes the fillings out in succession, so that they fall through the holes in the upper ring D into the holes c as the revolving plate C turns round. A little beyond the tube of fillings is a hopper H for the metal faces. These are placed in the hopper H, whose bottom is inclined towards the centre from each end. In the

448.



centre, is a slot-shaped depression h', running across the hopper in a direction towards the revolving plate which turns beside it. It is but little larger than the metal faces, and just deep enough to allow them to catch and rest in it. The hopper tilts backwards and forwards, making the faces slide over the depression h'. The machinery for causing the tilting is a cam-wheel P, operating in opposition to a spring (not shown), against a roller p on the end of a connection, with an arm fastened to the hopper, and projecting below the point at which it is pivoted, so as to tilt. In Fig. 451, one of the metal faces is seen in section, resting in the depression. In the hopper is a vibrating brush or pad I, swung by the arm i, pivoted at i', a pin passing through an elongated slot in i. The lower surface of the brush sweeps away any faces not lying in proper position. On the side of the depression h' towards the revolving plate, there is a slot in the side of the hopper H, through which the faces pass. After each tilting motion, the hopper pauses in a level position, owing to the shape of the cam wheel P which operates it, and the vibrating brush I being then also immediately over the depression, and the metal faces being lightly held in their position, they are pressed out of it by a reciprocating bar K through the slot k on the surface of the revolving plate, where they all lie with their turned edges downward. While the hopper is tilting, the slot in the side may be kept closed by a spring (not shown), which may also be arranged to open the slot when the hopper comes to a level position. The reciprocating bar K is shown actuated by a lever M pivoted at m, motion being given in one direction by the cam wheel P having projecting cams at proper points on its face, which bear upon a roller O, in the end of a connection with the lever M. Motion in the opposite direction is given to the lever by a spring N.

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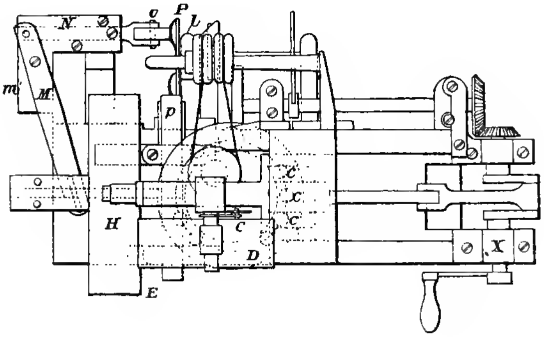

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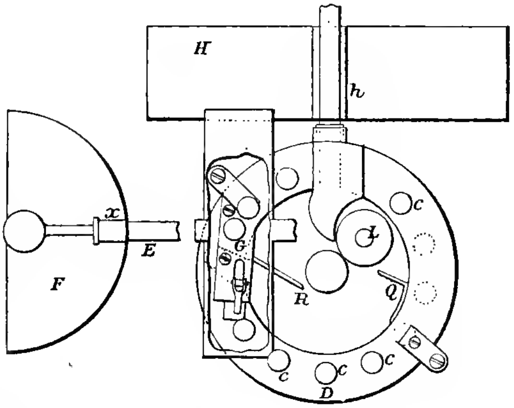
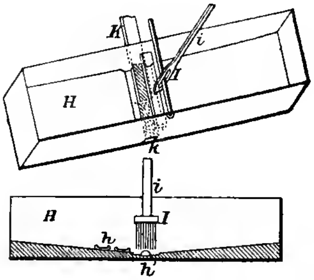
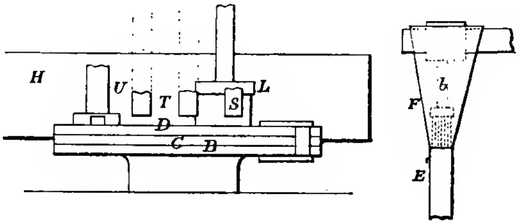


451.



452.



As the revolving plate turns, the metal faces are brought underneath a revolving brush L, standing above the plate and turning on a vertical shaft, arranged in a suitable bearing connected with the frame of the machine. The revolving motion of the brush L may be given by cords or belts from wheels *l*. The operation of the brush L is to sweep the metal faces into a guide Q on the surface of the revolving plate, which conducts them one by one to the holes in the upper surface of the plate, into which the paper fillings have already been put. By this means, into each of the holes is placed a paper filling, and immediately over it one of the metal faces with its edge turned down, so as to embrace its sides. In case the revolving brush brings the metal faces to the entrance of the guide, which conducts them to the depressions in the revolving plate, more rapidly than the guide delivers them, the surplus metal faces pass off by the side of the guide and are carried around by the plate to the opposite side of the machine, where they are guided off by the guide R, and may then be placed again in the hopper H. Each depression is next carried by the revolution of the plate under a punch S, which is arranged to descend into each as it comes beneath, and by a touch adjusts the metal face over the paper, so that the edges of the metal will enclose the paper filling. Immediately adjoining this punch is another punch T, by the descent of which, as successive depressions containing the fillings and faces fall beneath it, each metal face is firmly pressed down into the depression over the metal face, and its edges clenched around the paper filling. By the shape of the same punch, any desired configuration may be given to the button. Immediately adjoining this second punch is arranged a third punch U, having at its extremity one or more pointed instruments (not shown), which punch the necessary holes through each button. The punches should be arranged at the same distance apart as the holes *c*, and may be caused to descend and rise by being attached to frames sliding in ways V, and operated by a knuckle-joint W, moved by connections with the crank shaft X. The button, by the operation of the punch last mentioned, is finished except japanning; and after being carried a little farther by the revolving plate, is dropped through a hole in the under stationary plate into a receptacle beneath the machine, or it may be driven down through the hole in the plate B by a pin, operated by a sliding frame, the same as, or similar to, that which operates the punches. A compact arrangement for operating the several parts of the machine is shown in the figures; the vibrating brush, the reciprocating bar G for expelling the fillings from the bottom of the tube E, the punches and the pin, being all operated by the frame sliding in the ways V. The same cam wheel P also causes the tilting of the hopper H, and moves the reciprocating bar K. The machine is operated by a crank or by power applied to the crank shaft X, and motion may be given to the revolving plate or table, and to the cam wheel P, and from it to other parts of the machine, through pinion wheels connecting with the main crank shaft X. When it is desired to make buttons with two metal faces, an upper and lower one with a filling of paper or other material between them, the arrangement and combination is modified so as to introduce a second hopper for holding the under metal faces. Both metal faces have turned edges, as before described, and one is made slightly smaller than the other, so as to go within the edges of the other. The fillings are made of a proper size to go within the smallest of the metal faces.

Self-fastening Buttons.—Hitherto have been discussed only those kinds of buttons which, by means of holes pierced through them or by looped shanks attached to them, may be sewn on to garments with ordinary needles and thread. But an infinity of plans have been devised for making buttons which should be self-fastening, that is, possessing in themselves the means of attachment. One plan in very common use is to have a bent wire in the form of a figure ∞, but open at one end, which is inserted through the looped shank on the button, after the latter has been thrust through the material of the garment. By another method, two small bell cranks with long and short arm are mounted on the shank of the button, and provided with angles against which a spring presses, keeping the bell crank in position after the style of the spring in the back of a penknife. A direct pull outwards suffices to dislodge the button when necessary. Sometimes links are used with a metal washer. A description of all the improved forms of buttons introduced, even within the last few years, is quite inadmissible, on account of the space it would occupy; but it will be advantageous to refer to the principal half-dozen varieties, on account of both the ingenuity displayed and the principles involved.

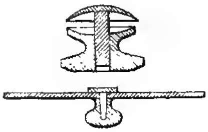
The form of a self-fastening button having a screw passing from the back of the material into the head of the button is shown in Fig. 453.

Hart's self-fastening button consists of a button with a shank formed of strips of metal or wire which will bend without breaking, and provided with a washer (Fig. 454). *a* shows a transverse section of the button fixed; *b c*, the two sides; *d*, the button with the washer; *e*, the washer; *f*, the metallic strip forming the shank. The shank should not be so long as to subtend the washer when turned down.

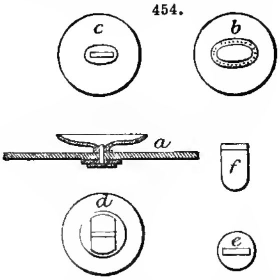
Fig. 455 (*a*, *b*, and *c*) represents a button with a movable head, so that the shank may be placed through the button-holes. The head is hollow, is partly filled with caoutchouc, is perforated on the under side, and has an internal groove or recess crossing the perforation at right angles. The shank terminates at one end in a disc, and at the other in a short transverse bar, so as to form a cross-head, as shown in *a*. To use the button, the cross-head D is passed through the button-hole in the fabric, and a caoutchouc washer is put on the shank B, to prevent it falling out when disconnected from the button head. The shank is then secured to the head, by passing the cross-head through the aperture E (*b*) and turning it one quarter round, when it is forced into the groove M, and retained by the pressure of the rubber R; *c* shows the complete button attached.

Barnum's button, an American invention, shown in Fig. 456, consists of a long shank A formed into a **T** at the end; and between the button and the cloth is a piece of rubber B through which the shank passes. A washer provided with a slot and a slight depression in it is placed at the back. The **T** is pushed through the slot and turned so as to fall into the depression, the spring of the rubber then draws the button firmly up to the washer, and holds all parts beyond the chance of slipping. The cloth is strengthened by the fastening, and the lap of the button-hole about the button is rendered better by reason of the space between the button and the fabric.

453.



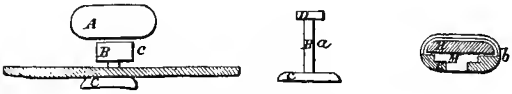
454.



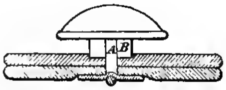
In Fig. 457 is seen an automatic fastening by means of a shank shaped into head, neck, and shoulder, passing through the fabric and fitting into a circular metallic socket in the knob of the button, the socket being so devised that on the shank being pressed in up to the shoulder the edge of the socket is forced to bend in and close round the neck of the shank and so prevent the latter being withdrawn: A shows the shank, with *a* the head, *b* the neck, and *c* the shoulder; B shows the head of the button, with the metallic socket *d* in the centre, and the orifice of the socket of equal diameter with the head *a* of the shank. On the shank being inserted in the socket, and pressed in till the shoulder is forced against the thin metallic circumference *e* of the orifice, the latter bends inwards and closes round the neck of the shank as shown in C.

According to another plan, the button consists of two parts, a head and a shank, held together by a spring of indiarubber or other material. The head piece is provided with a slot in the centre passing quite through the head, and a cross slot passing not quite through. The shank consists of a foot-plate, with an upright stem and cross-piece. When the button is to be attached, the cross-piece is put through the slot till it presses on the spring; it is then given a quarter-turn, and falls into the other slot where the spring holds it. By reversing the operation, it can be taken out.

455.



456.



Sometimes one or more spiral metallic springs are used to effect the same purpose.

To obviate the button-hole from cutting through the thread which fastens the button on, the button is sometimes made as shown in Fig. 458: *a a* is the base of contact of the button with the material; *b*, the annular surface to receive the button-hole; *c*, a flange to retain the button in the button-hole; *d*, a circular projection to prevent rubbing the thread. Holes are made through the bottom for fastening as usual. The button may be of any material, and either naked or covered.

An improved linen button consists of a metallic blank having two holes for sewing on to the dress, which is laid in a recessed die or bed having a corresponding recess for the linen disc; a sheet with an interior flange is then laid on the linen, and finally the back is put on the interior of the shell, and the whole is "closed up." The button is more durable than the ordinary form, and the cotton or thread, lying beneath the surface, is prevented from cutting in the wear.

A form of solid leather button designed to strengthen the shanks and prevent their getting loose and coming out, consists of a fixed metallic plate or collar on the underside of the button, which plate is provided with a slot or hole in the centre through which the bow is passed. In the act of fixing the plate or collar on the underside of the button, the button is provided with a recess round the shank, into which the collar is dropped and firmly held by the pressure employed in the construction of the button. A substitute for shanks is composed of metallic prongs of round wire, or cut from sheet metal, secured to the head of the button in the same way as the shank, and varying in number. If preferred, a metallic collar may be used in combination with the prongs and placed outside them. The latter are then put through the collar in the act of fastening the button on the material, and the prongs are turned down within the collar and firmly driven in, as shown in Fig. 459, A and B.

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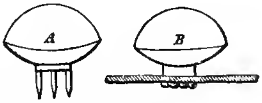
458.

459.



460.

A proposal for doing away with the stiffness in fastening buttons is to have a ball and socket joint, the end of the shank being spherical, and moving in a hemispherical hollow, giving it a certain amount of flexibility.

The last button that will be noticed is that shown in Fig. 460. It is formed as usual, except that the underside is made with a projecting neck, having a hole in the centre. On each side of the neck, is a slot in which slides a catch consisting of a slotted slide piece. The fastener is composed of a stem of metal with a flange or collet at the lower end, the other end being pointed or coned and shaped with a groove at a short distance from the end. The figure shows the underside of the button with the catch; *a*, the underside of the button; *b*, projecting neck; *c*, hole in the centre of neck; *c*, slotted catch sliding in the slots in the neck. The slot *c′* is enlarged at one end, *f* corresponding with the hole *c*. The diameter of the stem of the fastener allows it to pass freely, but without shake, through *c* and *f*.

Seat of the Industry.—The principal button factories are distributed, in about the following proportions, in and around the towns named:—London, 58; Birmingham, 161; Paris, 140; Brussels, 5; Vienna, metallic 15, porcelain 5, shirt 6, silk 11; Prague, several; Berlin, 49; Barmen, 29; Lüdenschied, 14; Elberfeld, 9; Hamburg, 5; Stuttgart, 6; Darmstadt, 3; Offenbach on Main, 3; Lubeck, 2; Breslau, 2; United States, 55, principally in New York (19) and Philadelphia (13). There are also several factories at Lyons, and one at Milan.

As regards the home manufacture, Birmingham turns out principally metallic buttons, and exports large quantities of linen shirt-buttons to France, though unable to compete with her in some other classes. It produces also some few glass buttons, and consumes about 15 to 20 tons of Corozo nut a week, for making vegetable ivory buttons. For pearl button-making, it uses about 2 tons weekly of the best shells, and perhaps 20 tons of the inferior sorts. France manufactures far more buttons than we do. She exports immense quantities of wooden button moulds to this country, and is known for bone, pearl, vegetable ivory, and glass varieties, the chief factories being concentrated in some three or four towns distant 40 to 60 miles north of Paris. A few years since, France enjoyed almost a monopoly for porcelain buttons; but since the destruction of Orleans by the Germans the trade has gone Rhinewards. Germany (including Austria) exports more buttons than France and England combined, supplying the markets of America, as well as those of northern, eastern, and southern Europe. She excels in cheap articles with a good outward appearance. Vienna is known for pearl buttons, eclipsing Birmingham in that branch, and several German towns have taken up the porcelain button-making, which does not seem to have made its way across the Atlantic as yet. Prague is now the great emporium for porcelain buttons. One works there possesses fourteen machines, costing only about 25*l.* each, which turn out individually an average of 1600 buttons a minute. The great bulk of the glass buttons, too, are made in Bohemia, where the cheapness of labour and raw material enables them to produce a good article at an absurdly low figure—about 11*d.* per 20,000, it is said.

Imports and Exports.—The values of the imports of all kinds of buttons, excepting metallic buttons, for the year 1878 were, from Holland, 405,210*l.*; France, 192,236*l.*; Germany, 32,309*l.*; other countries, 3551*l.* The value of all buttons (save metallic) exported from the United Kingdom to all countries, in 1878, was 7222*l.*

(See Bone; Celluloid; Glass; Ivory; Nuts; Pearl and Coral; Pottery.)

CAMPHOR. (Fr., *Camphre*; Ger., *Kampher*.)

The name "camphor" is technically applied to a great number and variety of gum-resins, all of vegetable origin, and possessing more or less similar general characteristics, coupled with minor distinctive peculiarities. Three kinds only are objects of commerce; they are derived from (1) *Laurus camphora* (*Cinnamomum camphora*, *Camphora officinarum*), the well-known camphor laurel of

China and Japan; (2) *Dryobalanops camphora* (or *aromatica*), a gigantic tree inhabiting the Malay Archipelago; and (3) *Blumea balsamifera*. The products are known respectively as Common camphor, Borneo camphor, and Blumea camphor. Each of these will be considered under a separate head; and, at the end of the article, will be added short descriptions of the less-known "camphors" of pharmacy.

Common or Laurel Camphor.—$C_{20} H_{16} O$. This is a colourless, transparent body, of tough, waxy, structure, having a specific gravity about equal to that of water, melting at 175° (347° F.), and boiling at 204° (400° F.). It volatilizes readily at ordinary temperatures, giving off the peculiar pungent aromatic odour which characterizes it. Recent researches prove it to be a phenol. It is very slightly soluble in water, to which it communicates its warm camphor taste; but in alcohol, ether, fixed and volatile oils, naphtha, aniline, &c., it dissolves with facility. On subjection to the action of oxidizing agents, it is transformed into camphoric acid, and, if the oxidation be continued, camphretic acid, $C_{10} H_{14} O_7$, will result.

The camphor laurel is a gigantic evergreen, bearing considerable resemblance to the common laurel, except in the matter of size, attaining, as it sometimes does, to a height of 50 ft. and a girth of 20 ft., with branches 8 or 9 ft. in circumference. The leaves are shining, and of a bright green colour, emitting a camphoraceous odour when bruised. The wood is white and fragrant, and is much used by the Chinese in carpentry, as it is proof against the attacks of insects. The chief habitat of the shrub is the island of Formosa, where it reaches the greatest size, and where most of the camphor of western commerce is produced. It also flourishes in China, the Chusan Archipelago, and Japan; the last-named country exporting considerable quantities of the drug. The shrub has now become naturalized in most of the tropical and warmer temperate countries of the world, as in Java, Brazil, Jamaica, and the West Indies generally, Cape of Good Hope, Mauritius, Madeira, and the Mediterranean region; and it has been proposed to introduce it into South Georgia and Florida. It forms a large and handsome tree in sheltered spots in Italy, as far north as the Lago Maggiore; it is commonly found in all the nurseries around Paris, and is not unknown in this country. The drug obtained from this laurel is prepared exclusively, or nearly so, for the markets of the West, and constitutes the only camphor of European and American commerce. As the native processes of collecting and preparing the substance vary in the different countries where the shrub is indigenous, it may be best treated geographically.

1. Formosa.—In the district of this island included under Chinese territory, the camphor laurel is not found; it is confined to the country of the aborigines, and its immediate borders. This circumstance is owing to the fact that the extraction of the camphor entails the destruction of the shrub; as this destruction has never been compensated by replanting, the forest has been gradually cleared away, the aborigines receding and the Chinese encroaching as the work of destruction has progressed. In consequence of the disturbed relations between the two races, thus induced on the border lands, the risk attending the camphor trade is very great, the distillers requiring to be always on their guard against attack; nevertheless, the industry maintains its ground. The method of preparing Formosan camphor is as follows:—The shrubs, as required, are selected for the abundance of their sap, many being too dry to repay the cost and labour of treatment. The best part of the wood is secured for timber; while the branches and refuse are taken, while freshly cut, and chopped up into little pieces for distillation. The stills, built up in sheds and moved as the Chinese advance into the interior, are of very rude construction; over eight or ten hearth fires, is placed a long wooden trough, often a hollowed tree, coated with clay and half filled with water. Boards pierced with holes are fitted on the trough, and above these are placed jars containing the chips; the latter are surmounted by inverted earthenware pots, and the joints are made airtight by means of hemp packing. When the fires are kindled, the generated steam passes up through the pierced boards and, saturating the chips, causes the sublimated camphor to settle in crystals on the inside of the pots, from which it is scraped off, and afterwards passed through a second process of distillation to remove some of the impurities. At the bottom of a copper still, is placed a bed of dry powdered earth from an old wall (selected, doubtless, for the sake of the lime it contains), and on this a layer of crude camphor; this is again covered with earth, and so on alternately till the vessel is full, the series terminating with a stratum of earth, and being finally covered with green mint. A second vessel, usually formed of straw smeared with clay on the outside, is inserted over the still and luted on. The apparatus is placed over a regulated fire, and the contents are heated for a considerable time. After cooling, the camphor is found to have sublimed, and attached itself to the upper vessel.

For transport from the interior, the camphor is packed in large vats or tubs, provided with escape holes at the bottom, and is stowed in carts of rude construction. Through these holes, exudes an oily or uncrystallizable liquid, known as "camphor-oil" (*q. v. post*). Almost all the camphor produced in Formosa is shipped from the free-trade port of Tamsui, at the northern extremity of the island. It is the characteristic export of the place, and one of the most interesting, forming the main supply of the European markets. It is the only commodity, either of export or import, for which the Transit Pass system is made use of. From Tamsui, the camphor is conveyed by native craft to Hong Kong, Shanghai, or Canton. Hitherto, owing to its being comparatively loosely packed, and containing a large percentage of water absorbed during its sublimation from the wood, the loss caused by evaporation during the journey between the two ports has been very large. The Customs allow for an estimated decrease of 5 per cent. (formerly 11 per cent. was the allowance); but the actual loss often amounts to 20 per cent. Lately, a hydraulic press has been established by one of the foreign firms trading at Tamsui, and the loss has thereby been reduced below the Customs' allowance. Chinese shippers have not yet learnt to appreciate the advantage gained; but it will be strange if they do not soon avail themselves of it. Until 1868, the Chinese Government enjoyed a monopoly of the Formosan camphor trade; but it was then thrown open, with very beneficial results. In 1870 and 1871, attempts were made to re-establish the monopoly, under cover of a tax of less than a ½*d.* per lb., in itself unimportant. With the removal of the objectional features of the impost, merchants have rested content, and things have gone smoothly since.

There is no doubt that the supply of camphor laurels in Formosa is being gradually exhausted, though a number sufficient to satisfy the needs of many years still remains. The seaboard has been stripped of its shrubs; but throughout the mountainous interior, the forests are still untouched. At Posia, a fertile plain among the hills in the middle of the island, Mr. Bullock's party, in 1873, found an abundance of camphor laurels; but the civilized aborigines inhabiting the spot are ignorant of their value. The prices ruling in Formosa, in 1872, gave a profit of 2 to 3 dollars (dollar = 4*s.* 1*d.*) a picul (133⅓ lb.) to the producer. For the western consumer, the Formosan camphor is reshipped, from the Chinese ports mentioned above, in square chests lined with lead-foil or tinned-iron, containing 1¼ to 1½ cwt. each. It consists of small dirty-greyish grains congregated together, their sp. gr. when pure being 0·98 to 0·99. It is always wet, as the merchants cause water to be poured into the cases before shipment, with a view, it is pretended, of lessening the loss by evaporation. The statistics of Formosan camphor production are as follow:—

1870. 17,239 cwt., value in place, 29,080*l.* Of this quantity, 12,368 cwt. were exported, viz.:—to China, 7890 cwt.; Japan, 2576; Bombay, 311; Strait Settlements, 1023; Germany, Holland, and France, 568. The bulk of that sent to Eastern markets was re-exported to the West, the portion which reached England being valued at 45,249*l.*, or an average of 3*l.* 16*s.* 6*d.* per cwt.
1871. 11,537 cwt., value in place, 15,048*l.*
1872. 17,500 „ „ ——
1873. 12,239 „ „ 23,633.
1874. 14,380 „ „ 25,666. Nearly all of this was sent to Hong Kong, and 3556 cwt. were ascertained to have been re-exported.
1875. 8,499 cwt., value in place, ——
1876. (About) 11,700 „ „ ——
1877. „ 17,500 „ „ 23,710*l.* Of which about 2700 cwt. went direct to non-Chinese ports.

The imports of Formosan camphor to this country are about six times as great as those from Japan.

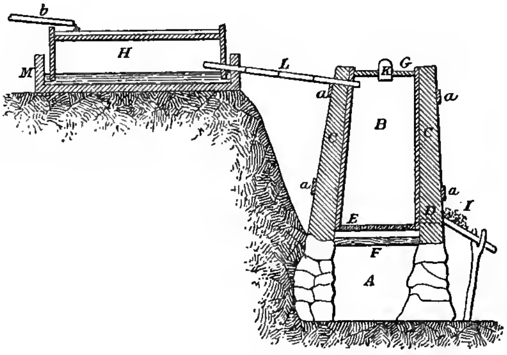
2. China.—An inconsiderable quantity of camphor is produced near Chinchew, in the province of Fokien, on the mainland of China. The method of preparation, which differs from that in vogue in Formosa, is as follows. The freshly gathered branches of the laurel are chopped into small pieces, and steeped for two or three days in water; they are then boiled in a suitable vessel, meanwhile being continually stirred about with a stick, until the grains begin to adhere to it in the form of a white jelly. The fluid is then poured off into glazed vessels, and is left at rest for some hours, when the camphor will be found in a concreted mass. The crude drug is then purified as in Formosa.

The shrub also flourishes in the Chusan Archipelago, growing to a large size if permitted; the natives, however, only use the wood, and do not extract the camphor as on the main.

3. Japan.—The camphor laurel is widely distributed throughout the three principal islands of Japan. It flourishes best in the southern portion of the empire, viz. in the province of Tosa, in Sikok; the mild, damp sea-air favours its growth here, and the principal preparation of the drug is carried on in this locality. The districts of Satsuma and Bungo also produce considerable quantities; the exports are chiefly from the ports of Osaka and Hiogo, and in much inferior proportions from Nagasaki.

The distillation of the camphor is carried on throughout the year; but the best results are obtained in winter. The workmen choose a space where the trees are abundant, and there build a temporary dwelling and a camphor still. When the patch is exhausted, the buildings are taken down and transported to another locality. The distilling process is very simple; but is much in advance of the methods practised in China and Formosa. A tree is chosen, and as soon as it is felled, the trunk, large roots, and boughs are cut up into small uniform chips, by means of a short-handled axe, and are drawn in barrows to the still. This is commonly placed on an incline, in the neighbourhood of a rivulet, which will furnish water for the wet distillation of the camphor. The most general arrangement of still and condenser, adopted in the Tosa district, is shown in Fig. 461. On a small circular stone wall A, serving to form a fire place, lies an iron plate F, 2½ in. thick. This is covered by a numerously perforated lid, luted tightly with clay, which at the same time forms the bottom E of the vessel B, which is 3 ft. 4 in. high, and 18 in. wide at the top. Near the bottom is a square opening D, which may be closed by a board. The whole is clothed with a thick coating of clay C, held fast by a binding of bamboo hoops *a*. The upper opening is closed by a clay luted cover G, having a hole in the centre, furnished with a cork K. Just under this cover, a hollow bamboo stem leaves the still, and passes to the condenser H. This consists of a four-sided box open beneath, divided into five intercommunicating compartments by means of four partitions, and turned with its open side into a vessel M containing water. This condenser is kept constantly cool by a stream of water, led over the top by means of the pipe *b*. The distillation is conducted in the following way:—After removing the cover G, the vessel B is filled with the chips of camphor wood, the cover is replaced, and well luted with clay; then through the opening K, a certain quantity of water is run in, which, after saturating the chips, will collect in the pan F. Gentle firing is now commenced, and is continued for twelve hours, so as to keep the water in F at a steady boil. The ascending steam, finding its way among the chips, carries all the camphor with it, and, on condensation in the cooler H, the camphor is deposited. After 24 hours, operations are suspended, the whole apparatus is cleaned out, and the camphor collected in H is removed into tubs. Here it is subjected to very gentle pressure to extract the oil, which amounts to 25 per cent. at least, and is quite limpid. In some districts, the raw camphor is submitted to a second, somewhat stronger, pressure, by which a greater proportion of the oil is forced through the joints of the casks. The two products are then ready for market. The camphor exported is never quite pure; it always needs to undergo a process of purification after arrival in Europe. The waste chips, after drying on the grating I, are used as fuel.

461.



Japanese camphor is distinguished from Formosan by being coarser grained, clearer, of pinker hue, and by subliming at a lower temperature. It is also known as "Dutch," or "tub" camphor, the latter name arising from its being imported to Europe in tubs covered with matting, each placed within a second tub, secured on the outside by hoops of twisted cane. No metal lining is used, and the camphor is thus drier than the Formosan. Each tub holds about 1 to 1¼ cwt. The selling price is nearly twice as high as the Formosan, and the imports to Europe are about as 1 to 6.

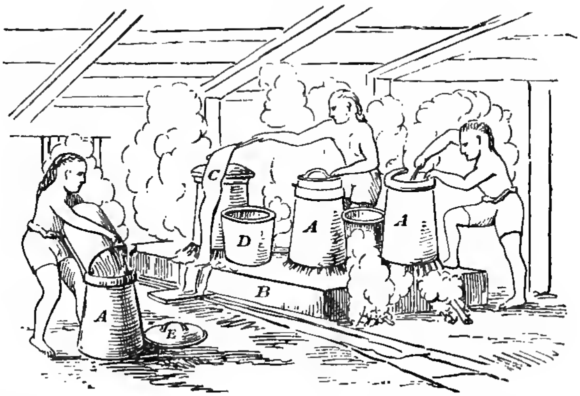
The amount of camphor exported from Japan, in 1870, was about 2360 cwt., principally to China (2171 cwt.); Straits Settlements (51 cwt.); and France and Germany (139 cwt.). Its value in the selling market was 14,498*l*., or about 6*l*. 2*s*. 10*d*. per cwt. In 1871, Hiogo and Osaka exported about 8450 cwt., and Nagasaki about 900 cwt. more: the total value was placed at about 25,000*l*. In 1872, the value of the export was stated at 30,576*l*. In 1876, Hiogo and Osaka exported about 10,000 cwt.

The imports of common camphor into the United Kingdom, in 1870, were:—Unrefined, 12,368 cwt.; refined, 2361 cwt.

Imitations of Common Camphor.—It is said that camphor has been prepared from the roots of the cinnamon shrub, and finds a ready sale in Ceylon and other parts of India; report also states that it has been obtained from several of the *Labiatæ*, notably in Spain. An imitation camphor is sometimes made in Japan; but it is readily distinguishable from the genuine article. An artificial chemical product, bearing a close outward resemblance to camphor, is obtained by passing hydrochloric acid gas through oil of turpentine surrounded by ice. Two compounds are produced: solid artificial camphor, $C_{20}H_{16}HCl$, white, transparent, lighter than water, and possessing a camphoraceous taste; and a liquid known as "terebine." This preparation has not been admitted into pharmacy, and is little more than a laboratory curiosity. It is easily recognised by the reaction with ammonia. If natural and artificial camphor be dissolved in alcohol, the former will not be precipitated permanently by ammonia, while the latter produces a flocculent precipitate, which is not dissolved in the supernatant liquid.

Refining Common Camphor.—The crude camphor consists of small crystalline grains of greyish-white or pinkish hue, cohering in irregular, friable masses; this, when dissolved in spirits of wine, leaves a sediment of 2 to 10 per cent. of impurities, composed chiefly of common salt, gypsum, sulphur, and vegetable matters. The latter are removed by careful distillation, in the presence of a little quicklime to absorb the oil, &c. Two earthen pots luted together, and having a small aperture provided for the escape of the air on the first application of the heat, answer the purpose roughly. In this way much camphor is refined by the natives of India. They buy it in the cases as it arrives from Chinese treaty ports, paying about 34 rupees (rupee = 2*s.*) a *Surat maund* of 42 lb. The process is illustrated in Fig. 462, and is conducted as follows:—About 1½ *maund* of camphor are mixed with 2½ *seers* (*seer* = 1¾ pint) of water, and placed in a copper still A, about 2½ ft. high. This quantity of camphor is made into a pyramid, and after it is piled into the vessel, an additional 2½ *seers* of camphor (? or water) are thrown in round the sides. A copper lid E is then put on, and, to make it perfectly tight, an iron bar is passed through it and the vessel by holes made for the purpose. The still is then lifted by handles, and set on an earthen *chula* B, below which fires are burning. The lid and edges of the still are smeared with wet clay, which is also piled up into a cone. In about fifteen minutes, steam comes through the hole where the bar goes, whereupon a cloth C attached to a bamboo is dipped into a receptacle D filled with water, and mopped over the clay cone on the still, so that the water keeps the upper portion cool. This is maintained for three hours, when the sides of the still are beaten with a stick. If this produces the sound of an empty vessel, it is known that the process of sublimation is complete; the still is then removed from the *chula*, and the lid is opened. The camphor is found in a thick crust lining the upper part of the sides of the still; it is divided into four pieces by a flat iron knife, and packed in boxes for sale to the dealers.

462.



The refining of camphor in Europe was long confined to Venice; but it is now carried on largely in England, Holland, Hamburg, and Paris, the product being much finer and purer than that obtained by the crude processes of the East. In England, the operation is performed as follows:—The impure camphor is broken up, mixed with 3 to 5 per cent. of highly slaked lime, and 1 to 2 per cent. of iron filings. These are well sifted, and introduced through a funnel into the necks of a series of *bomboloes*, flasks of thin flint glass, with flat bottoms and short necks, the name being of Venetian origin. These are placed in sand baths, which are heated by dishes of fusible metal, kept at the proper temperature by means of a furnace outside the room. The object of this is to avoid the necessity for bringing fire into the presence of the very inflammable vapour given off by the camphor. When filled and in place, the flasks are covered with sand to the neck, and rapidly heated to 120°–190° (248°–374° F.) for half an hour, to expel the water. The temperature is then gradually raised to about 204° (400° F.), and maintained at this point for about twenty-four hours. As the temperature increases, the camphor softens, and at last melts. When the mass has become fluid, the sand is removed from the upper part of the flask, and a paper stopper is put into the neck to partially close it. The heat is then carefully preserved at a point sufficient to sublime the camphor, but not to remelt it, so that it re-solidifies on the interior upper part of the flask as a semi-transparent cake, leaving all impurities behind. The temperature of the refining room is about 65° (150° F.), the air being very dry, and highly charged with camphor. To diminish the escape of camphor vapour during the process, each *bombolo* is covered with a glass shade; another use of this is to exclude the air, whose presence would make the sublimed camphor opaque instead of translucent. The whole process lasts about forty-eight hours; it requires the greatest attention and experience, on account of the inflammability of the substance, and the necessity for regulating the temperature very nicely, so that the sublimate may be deposited, not merely in loose crystals, but in compact cakes. When the sublimation is completed, the flasks are taken out, and cold water is sprinkled on them. This causes them to break, and the now pure camphor is removed from them in the form of large bowls or concave cakes, like gigantic quoits, about 10 or 12 in. in diameter, 3 in. thick, and weighing 9 to 12 lb. The *bomboloes* weigh about 1 lb. each, and measure about 12 in. across. Sometimes a little charcoal or sand is added to the lime, and, when sulphur is present, iron filings are a useful adjunct.

Following is an account of the Dutch method of purifying. To every pound of camphor, is added about 2 oz. of lime; the two are well mixed in a mortar or small mill, and about ¾ lb. of the mixture is put into each still. These consist of black glass flasks of round form and with long necks, a certain number being placed in a row on sand baths heated by a furnace beneath. They are buried some inches in the sand, and tightly stoppered with cotton or tow. Under each sand bath is a furnace and ashpit. To commence with, a gentle fire is made so as to liquefy the camphor. The steam rises into the neck, and would condense and fall back into the still in drops if it were not prevented. Each still is furnished with a conical hood or cap of tinned iron, which is covered with warm sand, and in which the vapour collects. In this way, all danger of breaking the still, by drops of camphor falling back, is avoided. When the camphor is fluid enough, and all the moisture has been eliminated from it, the sand is removed from the hood, or the latter is replaced by another, having a hole in the middle, to admit an iron implement for stirring up the mass in the still. As the camphor evaporates, it condenses again on the sides of the cap, and there forms a transparent mass. All outer air must be rigidly excluded. When the hoods have been exchanged, and the moment the sublimation begins, the fire is reduced. The temperature is maintained at the proper degree for a whole day. From time to time, the workman removes the cap and the cotton stopper, in order to stir up the stuff at the bottom of the still with an iron tool, and to keep the passage of the neck open, as the condensing camphor has a tendency to choke it up. Towards the end of the operation, the cap is altogether removed. The end is known to have arrived when the camphor collected on the sides begins to melt. The flasks are then taken from the sand-baths, cooled and broken, to extract the mass of camphor; this is then wrapped up in blue paper. Much camphor still remains in the fragments of the flasks, and as it would be too troublesome to scrape it off, the pieces are thrown into a very deep copper still, which is covered with a circular copper hood, and placed over a fire. The camphor collects as before around the hood, and is then easily removed. During the sublimation in the flasks, the temperature is maintained at 120° 248° F.) for half an hour, and is then raised to 190° (374° F.); at this point, the neck will be coated with moisture, which must be removed by inserting a sponge on a flexible stick. A temperature of 190° to 196° (374° to 385° F.) will melt all the camphor in three and a half hours. The residue is sublimed in a cast-iron vessel, and the little product obtained is thrown in with the next lot of raw camphor.

Uses.—The applications of common camphor are restricted almost solely to medicinal and antiseptic purposes.

Borneo Camphor; Malay Camphor; Borneole; Camphyl Alcohol; or **Kapur Barus.**—This is quite distinct from the camphor of western commerce. It is expressed by the formula $C_{20}\ H_{18}\ O_2$, or two additional equivalents of hydrogen. It fuses and boils at higher temperatures than common camphor, is harder and more brittle, of greater specific gravity (1·009), less volatile, and does not crystallize on the interior of a bottle when kept. Its crystals are coarse and resinous looking, about ¼ in. broad on the faces, and of different form from the ordinary drug. In the chief feature, viz. aroma, it closely resembles common camphor, but is less pungent.

It is the product of a magnificent forest tree, the *Dryobalanops camphora*, or *aromatica*, which often reaches a height of 90 or 100 ft. to the first branches, overtopping all its neighbours, and presenting a handsome head of dense foliage. The trunk often attains a girth of 17 to 18 ft. According to the natives of the Malay Archipelago, there are three kinds of this tree, named respectively *mailanguan*, *marbin tungan*, and *marbin targan*, from the outward colour of the bark, which is sometimes yellow, sometimes black, and often red. The bark is rough and grooved, and overgrown with moss. The leaves are dark-green, oblong-oval, and pointed; they smell of camphor, and are hard and tough. The exterior form of the fruit is very like the acorn; but it has around it five petals, placed somewhat apart, and the whole much resembles a lily. The tree flourishes to greatest perfection between the altitudes of 250 and 400 ft. above sea level; but is also found in dry (that is, not marshy) places near the sea coast, and rarely at an elevation of 1000 ft. Its chief habitat appears to be the extensive bush of the Batta country, on the west coast of Sumatra, north of Ayer Bangie; it is also found in the mountains of Santubong, Marang Sundu, and Sugony; in Labuan; in all the northern parts of Borneo, and it is said to be particularly abundant in the country of the Kyans, on the upper reaches of the Bintulu and Rejang rivers.

The camphor is secreted, in the form of coarse crystals, in the hollows and interstices of the body of the tree, especially in the knots, and swellings of the branches from the trunk; but it is not found in every tree, some observers remarking that only about one tree in a thousand appears in a condition favourable to the secretion of the gum. The natives have no means of estimating the quantity of camphor in a tree, and though they know that it increases with age, the latter is always an element of uncertainty with them. Trees in a state of decay often contain the most camphor. The drug is gathered at irregular intervals, according to the fancy of the Rajah on whose territory the trees are. About thirty men start into the forest; select a place where the trees are most numerous; and build rude huts, which sometimes form their dwelling for months together. They divide into two parties, one felling the trees, the other extracting the camphor. The tree is cut down just above its roots, divided transversely into several logs, and these again are split with wedges into small pieces, from the crevices of which the camphor, if there be any, is extracted. That which comes away readily in large, semi-transparent flakes is esteemed the prime sort or "head"; the smaller clean pieces are considered as "belly"; and the minute particles, chiefly scraped from the wood and often mixed with it, are called "foot." The last is separated from its impurities by steeping it and washing it in water, sometimes with the aid of soap. It is then passed through sieves or screens of different meshes, in order to make an assortment as far as regards the size of the grains; but much of the selection is also made by hand, and particular care is taken to distinguish the better kinds from that produced by the artificial concretion of the essential oil. The quantity of camphor yielded by a single tree probably averages about 10 lb. Its commercial name is *Kapur Barus*, the first word signifying camphor, and the second being the name of the Sumatran port whence this article is mostly shipped; it is sometimes called "bamboo camphor," from the fact of its being transported from the interior in hollow stems of that plant. It is in such great demand among the Malays and Chinese for embalming their dead, that it is only met with in Europe as cabinet specimens, the whole produce being consumed *in loco*. Thus the Chinese export to us their own Formosan product, while they import *Kapur Barus*, paying as much as 12*l.* 10*s.* a *catty* ($1\frac{1}{3}$ lb.) for the best quality.

The production of the drug is lessening yearly, and the profitable operations of 1753, when fully 1250 lb. were shipped from Padang, will probably never return. Trees are cut down at random without any being replanted, and this wilful and wasteful destruction will, it is feared, soon place the tree among the past species of the Archipelago. Propositions have been made to Government to have regular plantations formed in suitable localities (as is done with the teak tree in Java), notably in the district of Ayer Bangie, Ran, and Tapanolie Residence. The plants, four to six days old, may be transported in boxes half filled with wet sand, the contents being kept carefully wet and covered over with linen.

The tree yields several products besides the camphor. First may be cited the well-known camphor oil (*q. v. post*). The fruit, when fresh and well ripened, is eaten by the natives. The height of the tree prevents the fruit being gathered, but when it falls—in March, April, and May—the people go out to collect it. Prepared with sugar, it forms a very tasty preserve. It is said to be very unhealthy to remain near the tree during the flowering season, on account of the extraordinary hot exhalations given off by it. The wood of the tree is very tough and durable, and much valued by the natives for ship-building purposes. Its strong camphoraceous odour guards it against the attacks of the *kepang*, the destructive worm of those seas. It is adapted to making planks, beams, keels, stringers, and timbers, and has been proved invaluable for wharves and jetties. From its oiliness, it takes fastenings well, and iron is not liable to rust in it. Its weight is said to be about 70 lb. per cub. ft. At Johare, large steam saw-mills have been erected for the purpose of preparing the wood for export.

The following meagre statistics are all that can be found regarding this camphor:—The quantity imported into Canton, in 1872, was stated at 3159 lb., worth about 80*s.* a lb. In 1872–3, 2 cwt. were imported into Bombay, valued at 914*l.* The value of the production in

1873 was	£1043	1875 was	£3179 (about 5 cwt.)
1874 „	2578	1876 „	2337

Blumea, or Ngai Camphor.—A third variety of camphor is manufactured in China from the *Blumea balsamifera*, a tall herbaceous Composita called *Ngai* in Chinese, and abundantly distributed throughout tropical Eastern Asia. When in a crude state, the drug appears in dirty-white, crystalline grains, contaminated with vegetable remains; when pure, it takes the form of colourless crystals an inch long. It resembles the Bornese camphor in every particular, excepting in optical properties. Its value is about ten times that of Formosan camphor, and on this score it occupies an intermediate place between the two principal varieties of camphor. It is quite unknown in Europe; but in China it is much used, partly for medicine and partly for preparing the fine Chinese inks. The manufacture of this kind of camphor is carried on principally at Canton, the exports from which place are valued at 3000*l.* per annum.

A camphor-yielding plant which is closely allied to the preceding, if not identical with it, is the *Blumea grandis*, a native of the Tenasserim provinces, where it flourishes exceedingly, and grows to a height of 6 or 8 ft. Its leaves resemble those of the mullen, and, when bruised, emit a strong camphoraceous odour. Many years ago, the Tavoyers informed Mr. Mason that they were in the habit of making an impure camphor from the weed by a very simple process. Latterly, this has been improved upon by an Englishman, and the article has been brought into public notice. More than 100 lb. of it were refined and sent to Calcutta, and could not be distinguished from Chinese camphor. The plant is so abundant in the Provinces that they might supply half the world with camphor; wherever trees are cut down, this weed springs up.

Other Camphors.—Besides the three principal camphors of commerce, the following are more or less known in perfumery and pharmacy, viz.:—

Barosma Camphor.—The leaves of *Barosma betulina* yield on distillation about 1½ per cent. of a volatile oil, which solidifies on exposure to cold, and, after re-solution in alcohol, forms needle-like crystals, possessing a nearly pure peppermint odour.

Bergamot Camphor, or *Bergaptene*, is a product of the bergamot tree, a member of the *Citrus* genus, cultivated principally at Reggio, in Calabria. From the full-grown but still unripe fruit, gathered in November and December, an essential oil is expressed. For a period of some weeks after its extraction, the oil gradually deposits a mass of white greasy matter, which, when distilled with water, produces bergamot camphor.

Cinæbene Camphor is obtained from the essential oil of a variety of the wormseed, which grows especially about the Don and Volga, and in the Kirghiz deserts.

Cubebs Camphor, or *Hydrate of Cubebene*, is a deposit formed in cold weather from the oil of cubebs.

Neroli Camphor.—The fresh flowers of the bitter orange, when distilled with water in copper stills, yield an essential oil, most of which passes over on redistillation: the addition of an equal quantity of alcohol to the portion remaining in the still causes a little Neroli camphor to collect on the surface. By re-solution in boiling alcohol, it can be produced in a crystalline form.

Orris Camphor is the solid crystalline substance obtained by the distillation of orris root with water.

Patchouli Camphor.—The substance known in perfumery and pharmacy under this name is homologous with Borneo camphor. It is solid; fuses at about 54° (130° F.), and boils at 295° (563° F.); its specific gravity is 1·051 at 4° (40° F.); it is insoluble in water, but readily soluble in alcohol and ether; it crystallizes in hexagonal prisms; finally, it is a left-handed rotary substance, while Borneo camphor is right-handed.

Sassafras Camphor is yielded as a crystalline deposit, by cooling, in a freezing mixture, the volatile oil procured from the roots and bark of the sassafras shrub of America.

Thyme, Camphor of, or *Thymol*, is a crystalline product of the fractional distillation of essential oil of thyme.

Tobacco Camphor, or *Nicotiania*, is produced by distilling tobacco leaves with water.

Camphor Oils: *a.* Malayan.—During the collection of the camphor from the Malayan camphor tree, that is while the tree is being cut up, an oil drips from it in considerable quantities. Sometimes it is obtained also by tapping the living trees; but is not considered of sufficient value to warrant the destruction of the tree. The method of gathering this oil, as practised by the natives of Sumatra, is to make a transverse incision in the tree to a depth of some inches, the cut sloping downwards so as to form a cavity of the capacity of about a quart. In this, a lighted reed is placed for about ten minutes, and the hole is left for the night, when it becomes filled with the oil. This volatile oil, known as *Borneen*, holds in solution a resin, which, after a few days' exposure to the air, is left in a syrupy state. It is probably camphor in an undeveloped state, as the tree would yield camphor if left. It is seldom brought to market, probably because the price obtained is not a sufficient remuneration for the trouble of transport. Whenever it is offered at Barus, the usual price is a guilder (1s. 8*d.*) for an ordinary quart bottleful.

b. Formosan.—This is a yellowish brown, oily, or uncrystallizable camphor, which exudes from the cases of crude common camphor, to the extent of 3 or 4 per cent. It is very strong smelling, and holds in solution an abundance of common camphor, which it speedily deposits in crystals when exposed to a low temperature. Its symbol is $C_{20}H_{16}O$; its density is 0·910. By exposure to oxygen, or the action of nitric acid, it absorbs oxygen and becomes solid camphor. It is much used by the Chinese as an embrocation, especially in rheumatic diseases, and will probably soon be a valuable European import as a cheap substitute for *Lin. Camphoræ.* It is scarcely saleable on the spot, and is considered much inferior to the Malayan camphor oil, from which it is distinguished by an odour of sassafras. In Japan, the oil is expressed from the camphor, and is employed as a lighting material by the very poor people, who are content to burn it in open lamps, in spite of its powerful odour and heavy smoke. A recent native Japanese paper says that a resident at Osaka has built a large factory for preparing this oil,—not for making oil out of camphor, as *Nature* says—which has proved superior to kerosene, both in cheapness and illuminating power.

(See Drugs; Inks; Oils; Perfumes; Resinous Substances.) C. G. W. L.

CANDLES. (Fr., *Bougie;* Ger., *Kerze, Licht.*)

The use of wax candles as a source of artificial light dates from the middle ages, though, from the costliness of the material, it was probably confined, for a long period, to the dwellings of the wealthier classes. Until the introduction, in comparatively modern times, of tallow and vegetable fats, the substitute for wax candles in the houses of the poor, and still to be found in some country districts, was the ordinary rush-light, which is the simplest and most primitive form of candle known. The use of candles made from tallow and palm oil, and various compounds prepared from them, as well as from wax, paraffin, and other substances, has of late years largely increased, and the manufacture has assumed very considerable dimensions in some of the larger towns of Great Britain, and on the Continent.

A candle consists essentially of two parts: (1) the combustible material; and (2) a porous substance through the medium of which combustion takes place. The first portion of the candle, the combustible material, is composed of various fatty or hydrocarbonaceous matters; and the second portion, or the wick, the type of which is found in the rushes employed by our forefathers, is usually made of cotton. Before proceeding to describe the manufacture of candles, in itself a simple operation, the materials of which they are compounded, which are very varied and complex in their nature, must be fully dealt with.

The Combustible Materials Employed.—These are chiefly tallow and vegetable fats, and substances prepared therefrom by complicated chemical processes; also wax, spermaceti, paraffin, ozokerit, &c.

Tallow.—Tallow is simply beef or mutton fat, or a mixture of both, prepared by being heated in contact with water and under slight steam pressure until the membranous matters in which it is enveloped aggregate into lumps, and collect in a layer between the tallow and the water, when the steam is turned off. For candles which are to be moulded from tallow alone, mutton suet is employed, while the commoner or coarser tallow is kept for those which are to be dipped, and also for the preparation of stearic and other fatty-acids.

When melted tallow is allowed to cool very slowly, and without disturbance, it separates into two portions, one much harder, and the other much softer, than the original tallow; and if the temperature of the whole mass does not fall below 24°–27° (75°–80° F.), it will consist of hard, round nodules, suspended in a liquid oil. This process is technically called "seeding," and the idea of separating the solid from the liquid constituents of fats, by exposing them to pressure while in this condition, originated with the French chemist Chevreul, in 1823.

The researches of Chevreul and others demonstrated the following facts with reference to the composition of fatty bodies generally; and it is to a clear comprehension of these, and of the bearing of other scientific facts and phenomena upon them, that are due the various manufacturing processes which have resulted in the elegant and useful commercial products called "candles," the varieties of which range from the softest and cheapest English "cottage composite," to the alabaster-like stearic acid "*bougie*" of the continental salons.

It will be desirable, therefore, to consider the important fact, demonstrated by Chevreul, that all the ordinary neutral fats of commerce are, chemically speaking, "salts," in which the base is glycerine, and the acid is a mixture of various fatty-acids, which may be separated from each other, and prepared in a greater or less degree of purity. Hence

$$\text{Salt} = \text{Acid} + \text{Base}$$
$$\text{Neutral fat (e.g. tallow)} = \text{stearic and oleic acids} + \text{glycerine, } C_3H_5(OH)_3$$

The fatty-acids of commercial solid fats belong chiefly to the series known as the "Adipic," of which Formic acid, CH_2O_2, and Acetic acid, $C_2H_4O_2$, are the lowest terms. The two members of most frequent occurrence are Stearic acid, $C_{18}H_{36}O_2$, which is a large constituent of tallow, and Palmitic acid, $C_{16}H_{32}O_2$, which occurs in similarly large proportions in palm oil. Beeswax (to be referred to again presently) contains one of the highest known members of the series, Cerotic acid, $C_{27}H_{54}O_2$. The fatty-acid of the fluid constituents of most natural fats, and especially of the non-drying oils, is called Oleic acid, $C_{18}H_{34}O_2$, and belongs to another series, known as the "Acrylic." Each of the above-mentioned fatty-acids is capable of forming three salts with glycerine, the glycerides in natural fats being the third term in each series, tallow, for example, being a mixture of tri-stearine and tri-oleine. Chevreul's researches materially assisted in developing the theory of "Saponification"; but as this will be fully discussed in the article on "Soap," it need not be alluded to here, further than is necessary to explain the principles of the process by which stearic acid was at first entirely, and is still very largely, manufactured.

When neutral fats are boiled in open vessels, with a solution of a strong caustic alkali, as soda, or with lime mechanically suspended in water in a thin cream, the glycerine is replaced by the alkali, and a salt or soap is formed by the union of the fatty-acids with the alkali, thus:—

$$\text{Neutral fat} + \text{Alkali} = (\text{Fatty acids} + \text{Alkali}) \text{ i.e. "Soap"} + \text{Glycerine.}$$

When the "soap" is dissolved in water, and a strong mineral acid is added to the solution, the fatty-acid is liberated—

$$\text{Soap} + \text{Sulphuric acid} = \text{Fatty acids} + \text{Sulphate of soda (or lime).}$$

As neither saponification, nor the decomposition of a soap by a stronger acid, in order to liberate its fatty-acids, can take place except in the presence of water, the elements of water—H_2O—play a very prominent part in all reactions relating to neutral fats, and the preparation of soaps and fatty-acids from them.

It was soon discovered by Chevreul and his *collaborateurs* that the removal of glycerine from natural fats, i. e. their conversion into fatty-acids, enormously increased their hardness and illuminating power, so that candles made from the mixture of stearic and oleic acids, resulting from the removal of glycerine from tallow, by the process indicated above, were less greasy, and gave much more light, than candles made from the same tallow untreated, though they had not so nice a colour. The next step was the separation of the harder from the softer portions of the fatty-acids, and it was found that when this was effected by pressure, the oleic acid, in flowing away, carried with it in solution the whole of the colouring matter of the mass, leaving the crude stearic acid tolerably white. To make it absolutely so, little else was found necessary than repeated pressings at various temperatures, the series of operations, after the removal of the glycerine, being purely mechanical. In carrying out this on a manufacturing scale, the expensive alkalies soda and potash were soon replaced by lime, and the preparation of stearic acid by this process is now conducted as follows:—The tallow to be purified is placed in a large, slightly conical, wooden tun, which will be more particularly described hereafter. In this tun, the tallow is mixed with 16 per cent. of good slaked lime, made into a thin cream with water. After tightly closing the tun, steam is introduced from a pipe below, and the contents are boiled for four hours. During the boiling, the mixture is kept constantly agitated by means of a wooden shaft bearing three horizontal arms, worked by steam power. The action of lime upon the constituents of tallow has the effect of decomposing them, glycerine being set at liberty, while stearate, and oleate, of lime are formed. The formation of these salts, which, when mixed together, constitute an insoluble soap, greatly facilitates the subsequent separation of the solid and liquid constituents of the tallow. To ascertain when the operation is complete, a small portion of the boiling mixture is drawn out in a ladle, and cooled. When cold, the sample should appear perfectly smooth and solid, and should be very brittle, powdering finely in a mortar. When the operation is complete, the steam is shut off and the agitator is stopped, the whole contents standing until cool, and the fatty matters and lime form a solid mass at the bottom. They are then dug out and removed to another tun, similar in all respects to the last. Here they are treated with four parts of strong sulphuric acid for every three parts of lime previously added, and are then heated and agitated in the same manner as before. During the operation, the lime salts are decomposed by the acid, sulphate of lime falling to the bottom, and the soapy fat rising in a thick layer to the surface. Again, the whole is permitted to stand; when cool, the fat is skimmed off and placed in a third wooden vessel, where it is well washed with water and by steam blown into it. The washed fat is next heated to the melting-point, and run into dishes or troughs made of tin; these are placed in a room, the temperature of which is kept at from 20° to 30° (68° to 86° F.), and left for two or three days, or until the contents have assumed a granular or crystalline structure, when they are removed from the dishes, and cut into shreds by machinery. The shreds are then placed in canvas or woollen bags, or between large, square sheets of canvas, and are carefully deposited between the plates of a powerful hydraulic press. Pressure is exerted gently at first, and is gradually increased until the flow of the liquid oleic acid ceases. The press is then unlocked, and the hard, thin cakes of crude stearic acid are thrown into another wooden tun similar to the others. Here they are melted down by blowing in steam, which is continued for some hours. After settling, the fatty matters are drawn off into tin dishes, and placed aside to cool. The temperature of the room in which the cooling is conducted should be slightly higher than the previous one, or about 30° (86° F.). The dishes should remain here until the contents assume a crystalline structure, when they may be emptied. The blocks are then cut up into lumps, and ground to a mealy powder by means of a rasping machine, worked usually by steam. This powder is gathered into bags, made either of hair or of wool, or both, and is then submitted to a second pressure in another hydraulic press, differing from the former one by having a heating apparatus attached; the plates should also be heated before the press is used. The necessity for heat in this second pressure is due to the extreme difficulty experienced in eliminating the last portions of oily matter from the fat. When the full pressure is being exerted, the press is left for about fifteen minutes before being unlocked. The cakes thus obtained are cleaned with a knife, the parings being added to the next batch. They are again melted by steam, a little wax being sometimes added, in order to destroy the crystalline texture of the stearic acid, which renders it unfit for use in candle-making. This finishes the process, and the stearine is melted into blocks ready for use.

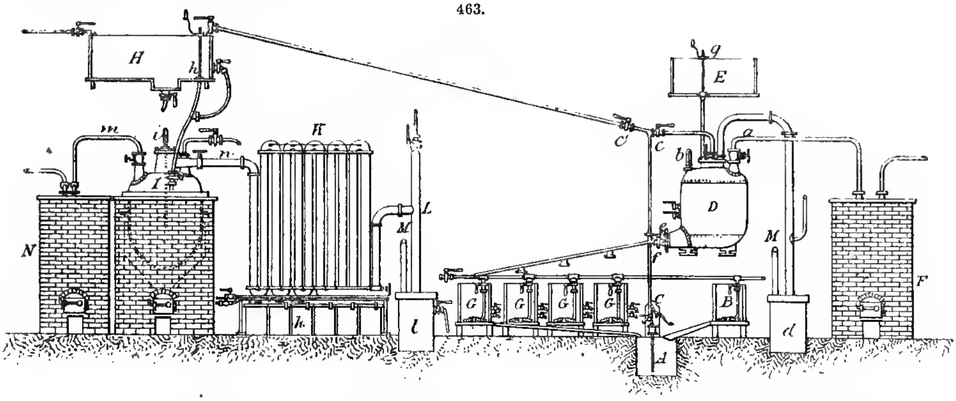
The tun in which the saponification of the tallow takes place is made of oak or cedar, and is tightly bound with iron hoops. Steam is introduced by means of a spiral copper tube, laid on the bottom, and perforated with numerous small holes. An upright wooden shaft, carrying wooden arms fitted with teeth, is fixed in the centre of the tun, and revolves during the process. The tuns are arranged in rows in a large room, two being required for the completion of each batch.

It will be observed that in this process a very large amount of lime—16 per cent. on the weight of tallow employed—is used. The disadvantage of this is that much sulphuric acid is necessary to decompose the lime soap, thereby injuring the colour of the resulting fatty-acids. It was soon found that if the saponification were conducted in closed vessels, under a steam pressure of 3 or 4 atmospheres, the amount of lime might be reduced to about 3 or 4 per cent. upon the tallow, thus reducing the cost, and improving the colour, of the product. This modification is still very largely worked, especially in America. Subsequently it was discovered that if sufficiently high temperature and pressure were employed, the lime might be dispensed with altogether, and that the resolution of the fat into fatty-acids and glycerine might be effected by steam alone. This process, known as the "Autoclave," has been largely worked, both in Europe and America; but in consequence of numerous accidents, arising from the explosion of improperly constructed vessels, it is usual to decompose tallow at a lower pressure, with the aid of 2 or 3 per cent. of lime, the subsequent operations of crystallization of the fatty-acids, hot and cold pressing, &c., remaining the same.

The next advance was the discovery that when neutral fats are exposed to a very high temperature, 300° (572° F.), or above, in presence of superheated steam, they are decomposed, and the fatty-acids are volatilized; and that when these vapours are condensed, the fatty-acids are almost white: that, in fact, fatty-acids may be distilled, almost unchanged, in an atmosphere of superheated steam. It was impossible, however, to conduct this process on a large scale, in consequence of the simultaneous production of aeroleine, a vapour resulting from the decomposition of glycerine, and possessing intensely irritating properties; but, in 1841, it was discovered that if neutral fats were treated first with concentrated sulphuric acid, and then boiled with water, they might be distilled without any such inconvenience, and the problem was thus solved by Dubrunfaut. In 1842 and 1843, Messrs. Jones and Wilson, under the name of Price and Co., took out two patents for the combined treatment of fatty bodies by sulphuric acid and water successively, and their subsequent distillation by the aid of superheated steam. From that time to the present, this process has been worked, in its various modifications, on a most extended scale, especially in England. It gives a much larger quantity of material, of good colour for candle-making, from a given weight of fat, than any other known process. The candles are not so hard, nor quite so white, as the continental *bougies* of stearic acid; but while tallow, treated by the saponification process, yields only about one-half its weight of candle material, tallow and palm oil, when distilled, give at least 75 per cent. of such material, of a slightly inferior quality.

The most perfected form of apparatus now used in the distillation process, as made by Merryweather and Sons, Long Acre, London, is shown in Fig. 463. The process is conducted as follows:—The fat is melted from the casks in which it is stored, by means of a steam jet inserted in the bunghole, and runs into the underground wooden tank A, where it is left for some hours to settle the condensed water out of it. Hence it is pumped, by means of the gun-metal lift and force-pump C, into a series of lead-lined collecting tanks B, fitted with steam coils, by which the material is boiled before being passed through the tap *c* to the vessel D. This latter, which is known as the "Acidifier," is made of stout copper, supported either on wrought-iron girders or on brickwork. It is fitted with a valved pipe *a*, for the admission of superheated steam; a copper pipe fitted with water shower pipe *d*, for condensing the vapours generated by the acidifying process; a thermometer *b*, for guidance as to temperature; and a gun-metal cover *e*, at the lower side, for cleaning out, and to which is affixed a tap *f*, for drawing off the acidified materials. On admission to D, the fats are heated for a certain time, by the introduction of superheated steam at a temperature of about 176°

463.



(350° F.), from the superheater F, constructed from the special design of Ed. Field. Sulphuric acid, in the proportion of from 3 to 6 lb. per cwt. of fat, is next supplied to the acidifier from the tank E by opening the plug *g*. When the acidification is complete, the material is left to stand for about six hours, and is then discharged into a series of lead-lined, open washing-vats G, provided with copper steam coils, and containing water and a little sulphuric acid. Here it is boiled with free steam for another two hours, and is left for about twenty-four hours to settle; it is then drawn off into the tank A, and pumped through the tap *a'* into a large, open, lead-lined tank H, placed at a sufficient elevation. This tank is fitted inside with a coil, which is charged with steam, to keep the contents in a liquid state. By means of the valve *h*, about 5 tons of the material is run into the still I, consisting of an iron body, and copper dome; it is fitted with a thermometer *i*, and the necessary taps of copper or gun-metal. The contents of the still are heated, by fire, to a temperature of about 116° (240° F.); superheated steam, at about 294° (560° F.), is then admitted by the pipe *m* from the superheater N, and the process of distillation commences. The temperature must be regulated according to the quality of the material operated upon. The vapours pass over by the pipe *n* to the refrigerator K, which consists of a series of vertical copper pipes, connected at top and bottom by gun-metal bends. These pipes are mounted on iron frames, over a set of six circular iron tanks *k*, into which they can be emptied. The tanks are furnished with pipes for the admission of steam, and with spiral copper cooling-coils, through which cold water may be passed. The "essence-tank" *l* is fitted with an improved shower-pipe L, which prevents any vapour passing away uncondensed. The pipe M conveys vapours to be burnt in the flue. The fatty-acids are collected in pails from the mouths or outlets of the copper coils, the greater part in a fit state for candle-making, without the necessity for putting them through hydraulic presses. That part which is not fit for candle-making, as it comes direct from the still, is pressed and redistilled. As the result of distilling tallow, it may be mentioned that out of every 100 lb. subjected to this process, 78 to 80 lb. of crude stearic acid is produced. Three-fourths of this, or about 60 lb., is ready for making stearine (i. e. stearic acid) candles without further treatment; the remaining fourth, about 20 lb., after being pressed and redistilled, yields about three-fourths of stearic acid and one-fourth of oleic acid. Thus the total proportion of the latter product is only 5 lb. Besides the stearic and oleic acids, there is a large quantity of a third product, called "pitch." If allowed to get cold, this is a hard, black substance; but provision is made for passing it at once to an iron vessel, where it is submitted to great heat, and yields a product similar to that obtained by the distillation process, and which is often used in the preparation of "composite" candles, though much inferior to the pressed and purified material. The pitch, after this operation, becomes a commercial article of many uses, and will in all probability soon be recognized as an efficient substitute for "black-japan," for coating iron, the latter article being worth from 20*s.* to 30*s.* a gallon. The approximate cost of the plant required for distilling tallow or palm oil according to the above process, exclusive of steam boiler, may be stated at from 1700*l.* to 3150*l.*, according to whether 1 ton or 3 tons are to be distilled at a time.

The following table shows the quantity and value of tallow and stearine imported to this country in the year 1878:—

(N.B. Stearine, chemically speaking, i.e. stearate of glycerine, is seldom or never made now, and the term "stearine" is somewhat loosely applied, commercially, to stearic or palmitic acids in various states of purity.)

	Cwt.	£
From Russia	73,646	158,480
„ France	14,810	42,760
„ United States	456,715	873,696
„ Uruguay	63,587	124,054
„ Argentine Republic	66,754	134,765
„ Australia	216,786	419,268
„ Other countries	28,905	61,156
	921,203	1,814,179

The total quantities and values for the four preceding years were as follows:—

1874.	1876.	1876.	1877.
cwt. 1,155,243	cwt. 967,396	cwt. 1,344,445	cwt. 1,224,239
£ 2,331,479	£ 2,045,863	£ 2,875,170	£ 2,568,479

Palm Oils.—Palm oil is now used in enormous quantities for the production of palmitic and stearic acids at Price's Candle Company's works, as well as by almost every candle manufacturer in Great Britain, about 25,000 tons being annually consumed. In many continental countries, a prohibitive duty prevents its employment. The process employed consists in acting upon the fat with sulphuric acid, and then submitting it to distillation. The plant and the *modus operandi* scarcely differ from those last described. The distilled mixture of stearic and palmitic acids is cut into shreds, by means of a revolving knife, and the shreds are wrapped in canvas or woollen cloths, spread in even layers between mats of cocoa-nut fibre, and submitted first to the cold press, and afterwards to the hot press, at a temperature of 29° to 32° (85° to 90° F.). The pressed cakes of fat are pared, and then melted again by steam, in large, wooden, iron-hound vessels, containing water and sulphuric acid. The whole is boiled for a time and is then allowed to stand, after which the acidulated water is drawn off. The melted fat is repeatedly washed with hot water, and then run into moulds; when cold, it is quite pure, and ready for manufacture into candles.

It will be observed that three processes for the decomposition of neutral fats have now been described—viz. (1) By saponification with a strong alkali, at a temperature but little above 100° (212° F.); (2) By the use of water, with or without a very small quantity of lime, at very great steam pressure, and a correspondingly high temperature; (3) By treatment with strong sulphuric acid and water in successive portions, and subsequent distillation at normal atmospheric pressure, but at a dangerously high temperature—above 300° (572° F.). It was reserved for a physician at the Danish Court, the late Dr. J. C. A. Bock, to demonstrate the important fact that, by properly conducting the operation, water alone might be made to decompose tallow into fatty-acids and glycerine, and that by the use of water and sulphuric acid combined, fatty-acids might be prepared from tallow in open lead-lined tanks furnished with steam coils,—without any of the complicated and dangerous apparatus required by the "autoclave" or the "distillation" processes, without any lime or other alkali, and with a much less expenditure of acid than was required by any other process. Unlike many inventors, he was able to carry out his ideas into actual practice, and in the International Exhibition held in London in 1862, were shown some beautifully white and hard stearic acid candles, which had been prepared by this process in the manufactory of O. F. Asp, Prindsessegade, Copenhagen. Since then, the process has been constantly at work in that factory; it has also been adopted in several other continental candle factories, and is now at work, among other places, in New Zealand. The simple character of the "plant" required renders it peculiarly valuable for distant countries. Considered from a theoretical point of view, it is, perhaps, the most ingenious and the most strictly scientific of all the methods for decomposing neutral fats.

Dr. Bock pointed out, that tallow is composed of exceedingly minute globules of fat, surrounded by membranous envelopes, composed, probably, of albumen; and that until these enveloping walls are destroyed, no reagent can act upon the fat within. In ordinary saponification, the albuminous envelopes are dissolved by the caustic alkali; in acidification, they are burnt and charred by the strong sulphuric acid, the quantity of which may be so adjusted as not to burn and discolour the tallow itself, which, after pouring out from the destroyed envelopes, is in a state to be readily decomposed by water at 100° (212° F.). Dr. Bock's process was described by him in an article in Dingler's 'Polytechnisches Journal,' for May, 1873, of which the following is a synopsis.

"By the lime saponification plan, the albumen contained in the fat is dissolved, lime-soap is formed, and the extraction of the glycerine is rendered possible. By acidification, the whole process is effected at once. Conducted properly, the fat, washed out with water, always remains as neutral fat, and, by the use of concentrated sulphuric acid, not a trace of glycerine is left. Acidification, rationally conducted, is only a preliminary operation, intended to break up, corrode, or carbonize, the albumeniferous matters. But the conduct of the operation was long based on the erroneous belief that a double acid, sulpho-stearic, was formed. With due care, only the envelopes of the cells are blackened, and these are soluble neither in fat nor in fatty-acids. The production of a real black solution is only an evidence that a certain part of the fat has been burnt, which should be avoided under all circumstances. There is no doubt that the operation has generally been carried to excess, in the matters of duration, height of temperature, or strength of acid. By proper acidification, the neutral fat is only unclothed, as it were, and freed from the cells, or at any rate, the latter are so ruptured, as to allow of the easy exit of the fat. This latter is then in a condition to be decomposed, an operation accomplished in much shorter time by the chemical equivalent of acid—4 to 4·5 per cent.—and the necessary water. After letting out the glycerine waters, the fatty-acids appear more or less black. They may now be distilled. Their melting-point varies from 49° to 57° (120° to 134° F.).

"The real value of Dr. Bock's method consists in dispensing with distillation. The object of this operation is the removal of the black colour, or rather of the black-coloured matters, by superheated steam. These black matters are the partially carbonized albumen cells, which swim about in the fatty-acids because the sp. gr. of the two bodies is about the same. This difficulty is overcome by oxidizing the mass, by which the sp. gr. of the cells is raised from 0·9 to 1·3. They are thus precipitated, and the fatty matters can be washed off. The subsequent cold and hot pressing are the same as with ordinary methods.

"From several years' experience at Messrs. Asp's works, the following results have been deduced. Tallow yields, by complete decomposition, 95 per cent. of fatty-acids, which lose 2 per cent. by oxidation and washing. The glycerine obtained equals 6⅔ per cent. from tallow at 23° B., and is quite free from all organic acids. The oleic acid resembles that produced by the lime saponification process; but it is much richer in solid acid. The stearic acid is also like that produced by the lime saponification method; but it is much harder, and its melting-point is 58°–60° (136°–140° F.). It equals 55–60 per cent. of the tallow employed.

"The plan is free from danger, as the steam is only used in open vessels. The plant is much cheaper, as nothing special is required. The labour also is much reduced, as the operation is completed in one vessel. It is as applicable to vegetable as to animal fats."

The process indicated above has now been for fourteen years in daily operation on a manufacturing scale in Copenhagen, and in the hands of the inventor and his son, has been greatly improved and simplified since its first introduction. At that time, there were five stages in the process, viz.:—(1) Acidification, to remove the membranous cellular tissue from the tallow; (2) Decomposition, by acidulated water, into dark fatty-acids and glycerine; (3) Oxidation, to increase the sp. gr. of the dark membranous matters, so that they might separate themselves from the fatty-acids; (4) Repeated washings with water; (5) Pressing, both cold and hot.

The greatest improvement is due to the discovery that the dark membranous matters may be oxidized while the fat is still neutral. The acidification, oxidation, and decomposition are all now conducted, in rapid succession, in one and the same wooden tank, after which, one or two washings in another tank render the fatty-acids fit for the press.

Another point of great practical importance, which has been developed in the working out of this process, is the increased hardness of the stearic acid produced by it, arising from the solidification of some of the oleic acid in the tallow, by the prolonged action of sulphuric acid upon it. This reaction has lately been pointed out as a novelty, by Bornemann and Kraut; but it was suspected twelve years ago, and soon afterwards was definitely proved, by the Messrs. Bock. They observed that the fatty-acids became harder and harder, so that cold pressure had no effect upon them; by the adoption of hot-pressing, they produced white stearic acid, and an exceedingly brown oil. This latter, when distilled, saved the cost of distillation, by its yield of solid matters. It is claimed, therefore, for the Bock process, that stearic acid can be made of better quality and in larger quantity from a given weight of tallow, than by any other process at present known.

Whichever of the four processes (lime-saponification, autoclave, distillation, or Bock's) is employed, a large proportion of oleic acid is unavoidably produced. The quantity of it, per ton of neutral fat, varies in inverse proportion to the hardness of the original fat, or of the material manufactured from that fat. For many years, it was difficult, at any rate in England, where soft soaps are much less used than on the Continent, to find a suitable outlet for this oleic acid: it could not be used as a lubricant, owing to its acid reaction upon metals; when saponified by the ordinary methods, it produced a very soft and very brown soap, slow of sale. It was discovered, however, that when saponified with soda-leys of very high specific gravity, a hard soap could be made from it, containing a very large percentage of fatty-acids, and good for ordinary cleansing purposes, but whose smell was considered objectionable. A few years ago, M. Radisson, of Lyons, taking advantage of a laboratory reaction of oleic acid which had long been known, developed a method of converting it into palmitic acid, and, by dint of great perseverance, worked out the details of the process on an industrial scale; it is now a commercial success, and has been patented in nearly all countries where candles are manufactured. Whether it is more economical to convert the oleic acid into soap or into palmitic acid, depends upon the relative cost of the two processes, and the current market value of the manufactured products.

The following information relative to this remarkable process, which is extremely interesting, from both scientific and technological points of view, was kindly supplied to the writer, by the patentee, M. St. Cyr Radisson, 37, Boulevard-Oddo, Marseilles.

In 1841, Warentrapp announced that when oleic acid was heated with a great excess of caustic potash, it was decomposed into palmitic acid, acetic acid, and hydrogen, the acids combining with the potash, the reaction being explained by the following formula:—

$$\overset{\text{Oleic acid.}}{C_{18}H_{34}O_2} \quad + \quad \overset{\text{Potash.}}{2\,KHO} \quad = \quad \overset{\text{Palmitate of Potash.}}{C_{16}H_{31}KO_2} \quad + \quad \overset{\text{Acetate of Potash.}}{C_2H_3KO_2} \quad + \quad \overset{\text{Hydrogen.}}{H_2}.$$

At M. Radisson's factory at Marseilles, this is practically realized, and about 3 tons of oleic acid are daily converted into palmitic acid, by this process.

The conversion is effected in cylindrical cast-iron vessels, with sheet-iron covers; they are about 12 ft. in diameter and 5 ft. high. A fireplace is built beneath them, sufficiently far off to avoid heating by radiation. About 1½ ton of oleic acid and 2½ tons of caustic potash leys at 43° B. are pumped into one of the vessels. The evolved steam passes off by a large manhole on the upper side; when the soap gets dry, this manhole is closed, and the disengaged gases are conveyed through pipes, first to a condensing tower, and thence to a gasometer. The temperature of the mass is slowly raised to 320° (608° F.). A mechanical agitator revolves in the mass, with the double purpose of ensuring equal distribution of heat, and of beating down the froth, which rises abundantly. Eventually the soap undergoes igneous fusion, and at 290° (554° F.), begins to give off hydrogen. When 320° (608° F.) is attained, the escaping gases have a peculiar smell, very readily recognized; at this point, it is necessary to suddenly stop the operation, since if the heat were continued longer, the materials would enter on the stage of "destructive distillation." In order to effect this stoppage, steam and water are introduced by a Giffard's injector, and at the same time, a door in the bottom of the cylinder is opened, by which the palmitate of potash falls into an open tank, where the soap and a quantity of water sufficient to melt it, are heated together by a steam-jet. After subsidence, the contents of the tank divide themselves into an upper layer of neutral palmitate of potash, and a lower layer of potash leys, usually about 18° B. The neutral palmitate is removed to another vessel, and decomposed with sulphuric acid; the last traces of sulphate of potash are removed by washing with water.

At this stage, the palmitic acid is of a clear chocolate hue, and when cooled, crystallizes in large tables; its solidification point varies between 50° and 53° (122° and 127° F.), according to the nature of the oleines employed. It can be distilled with great facility in the usual apparatus, and leaves only 3 per cent. of pitch. After distillation, the palmitic acid is extremely white, and burns with a very clear, smokeless flame. Moulded into candles, it compares very favourably with the best stearic acid; and when mixed with ordinary stearic acid, it "breaks the grain" of the latter (i. e. destroys its tendency to crystallize), and gives it a semi-transparency, very valuable in the eyes of a candle manufacturer.

Instead of decomposing the palmitate of potash by sulphuric acid, it may be boiled with milk of lime, under a pressure of three atmospheres, when the result will be a lime-soap, floating in caustic potash leys. So much water, however, is necessary for this reaction, that the resulting leys are only 6° B., and their concentration to 43° B. is so costly, that it is more economical to regenerate the sulphate of potash by Leblanc's process. The potash leys may be completely causticized in the cold at a sp. gr. of 20° B. with six hours' brisk agitation, thus economizing fuel. The carbonate of lime so obtained is pulverulent, and can be easily washed by "displacement" (i. e. running water through it to wash out the potash), in a layer 3 ft. thick. The caustic leys are rapidly concentrated to 43° B., and stored in tanks, where, on cooling, they deposit the small amounts of sulphate and carbonate of potash which they contain, and the vertical partitions of the tanks become covered with crystals of acetate of potash, arising from the preceding solidification. The perfectly clear leys are then employed in the transformation of fresh portions of oleic acid into palmitic acid. The crystals of acetate of potash are separated from the leys which hang about them, by a centrifugal machine, and are then taken to a distilling apparatus, where the acetic acid is displaced by sulphuric acid. The crude acetic acid, thus obtained, is purified by a second distillation, and becomes of commercial value. Its quantity should be 2·5 per cent. of the oil solidified.

Oleic acid, which is the product of the distillation of fatty bodies, contains small quantities of hydrocarbons analogous to natural petroleum. These distil over during the conversion of oleate of potash into palmitate, and are condensed in a tower, furnished with transverse partitions, extending alternately nearly across its diameter. A simple rectification makes them pure enough for illuminating oils, and the paraffin which remains in the heavy portions of the oil can be separated by crystallization in the cold. As a matter of purely scientific interest, it may be mentioned that caprylic alcohol, sebacic acid, caproic acid, and other rare substances, are formed, in very small quantities, simultaneously with the palmitic acid.

All fatty bodies, with the exception of mare's grease, and the fat of "suint," can thus be solidified by the action of caustic potash; but the ultimate products vary, and the palmitic acid is by no means always pure. Different percentages of palmitic acid are obtained in the final result, according to the nature of the fatty bodies employed. Thus, 100 lb. of oleic acid, resulting from tallows decomposed by lime, should yield 91 lb. of palmitic acid fit for candle-making, while 100 lb. oleic acid resulting from distillation processes, only yields 87 lb. of white palmitic acid.

The following figures give the cost, in francs per 100 kilos., of white palmitic acid produced from distilled oleic acid:—

General charges	5·80	Sulphuric acid	2·60
Labour	6·35	Wear and tear of plant	·95
Loss of alkalies	2·60	Distillation	3·50
Fuel for all operations	8·10		
Carbonate of lime	0·60		31·15
Caustic lime	0·65		

or a total of about 13*l.* a ton.

It is not necessary to describe here all the difficulties encountered in obtaining, by the Leblanc process, an economical transformation of sulphate of potash into caustic. It may, however, be mentioned that an evaporating pan, placed at the back of the furnace on a level with its bed, has been found most useful. It is fed by the mother-liquor of the sulphate of potash, which, by its evaporation, keeps up a supply of moisture around the small particles of potash, which are volatilized, or carried over mechanically by the furnace draught, and thus, by increasing their density, causes them to settle in the pan. This simple contrivance has so reduced the loss of potash as to render possible the application of the Leblanc process.

M. Radisson claims the following advantages, as accruing to the stearic acid manufacturer from the adoption of his process:—I. Utilization of the oleine, a troublesome by-product of variable value; 2. The floating capital necessary for the purchase of raw material is diminished by about 30 per cent., the production of stearine being increased by nearly the amount of oleine produced; 3. The manufacturer can use low-priced greases, whose value varies in inverse proportion to their richness in oleine; 4. The stearine produced by this process is little, if at all, inferior to that produced by any other process.

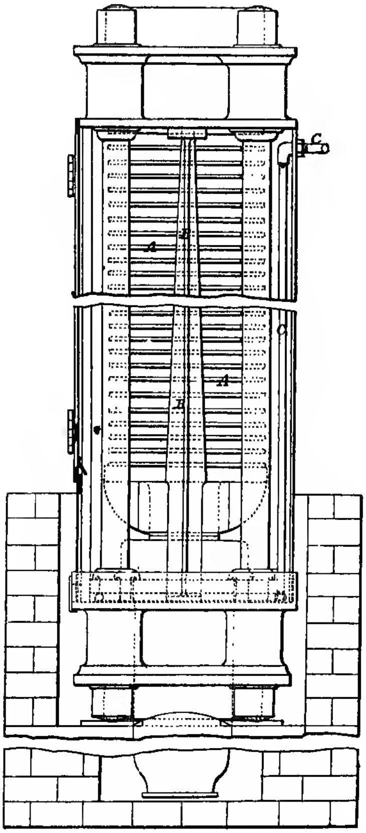
It may be noted as an interesting fact, that the oleic acid produced by Bock's process is more suitable for conversion into palmitic acid than that produced by either of the other methods. The two processes (Bock's and Radisson's) are worked conjointly with the most satisfactory results. The percentage of palmitic acid from Bock's oleic acid, is higher than that from any other.

Wax.—Beeswax is a product of no small importance for candle-making purposes. A trifling proportion only is made in England, but it is of far superior quality to the produce of other lands. A considerable quantity is imported annually from Corsica, and smaller amounts from India, Ceylon, North America, and Brazil. Beeswax is always of a brownish or yellowish colour, and has a peculiar smell resembling, and derived from, honey. It is purified and rendered white by being melted in hot water, or by steam, in a vessel either of tinned copper or of wood. It is allowed to settle, and the waxy superstratum is run off while fluid into a wooden trough, having a row of perforations in its bottom, by which it is distributed upon horizontal wooden cylinders, made to revolve with their lower portions surrounded by cold water. The ribbons or films made in this way are then exposed to the bleaching action of the atmosphere and sunlight, being frequently moistened and turned over during the process. It is necessary to guard against wind, which might scatter the shreds; for this purpose, large cloths are provided. The operation is continued until the wax becomes perfectly clean and white. It is usually conducted from April till September, the exigencies of the weather preventing it at other seasons. In France, it is customary to add a little cream of tartar or alum to the water in which the wax is melted, by which the long and tedious operation of bleaching is rendered unnecessary, or much shorter. Bleaching agents, such as chlorine, cannot be employed to bleach wax, since they render it unfit for making into candles. Purified in the above manner, beeswax is perfectly white, and has neither taste nor smell; it has a specific gravity of from 0·960 to 0·996; at a temperature of 30° (86° F.) it becomes soft, and melts at 68° (154° F.); at 0° (32° F.), it is hard and brittle.

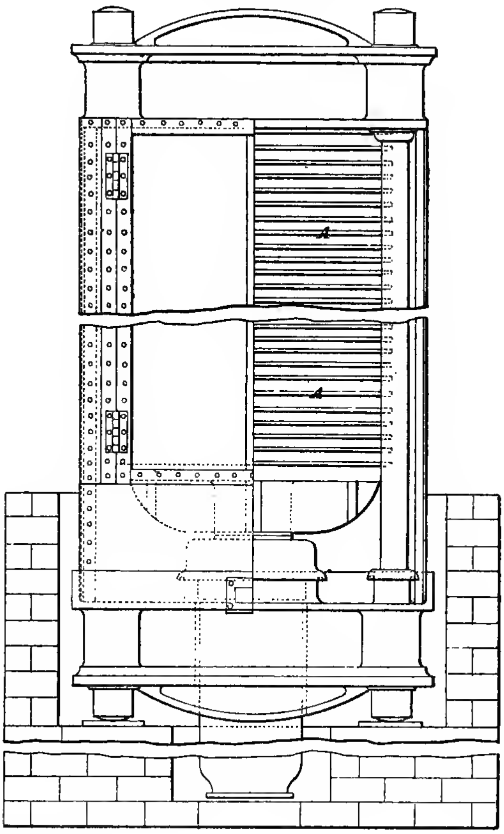
Other kinds of wax are also used, such as Chinese wax, derived from an insect, the *Coccus ceriferus;* Japan wax, of vegetable origin; Carnauba wax, from Rio de Janeiro, which is also a vegetable wax, remarkable and especially valuable on account of its high fusing-point; and several other varieties of vegetable wax, derived, like the last two, from palms. Besides these, may be named the greenish Myrica, or myrtle wax, obtained from the fruit of the *Myrica cerifera.* It is used in America for candle-making. Wax candles are superior to tallow candles, not merely on the score of hardness, elegance, and cleanliness, but also on account of the greater purity and brilliancy of their light.

Paraffin.—During the last twenty years, paraffin has come largely into use for candle-making. The crude solid product separated from the light and heavy oils by the mineral oil refiners, and known as "paraffin scales," is of somewhat variable composition. The impurities amount, on an average, to 20 per cent. of the weight, and consist of blue oil, greasy hydrocarbons of low fusing-point, solid refuse, and water. The oil manufacturers, having an eye to the quantity of solid product, often separate the scales from the oil, as early in the process of oil refining as possible, knowing that the subsequent distillation and the treatment with acid and alkali will reduce the weight of solids by decomposition. Hence the process of refining may vary according to circumstances. The method adopted by Messrs. Young and by Wm. Walls and Co., of Glasgow, is first to melt the scales in a large pan, by the introduction of steam through a perforated wrought-iron coil. The mechanical impurities and the bulk of the water subside; the supernatant liquid is decanted into another vessel, and mixed with a due proportion of coal oil or spirit, varying in gravity from 0·735 to 0·765. It is then caked, or allowed to fall on a revolving drum, kept cold by an internal flow of water; less oil or spirit—say $\frac{1}{4}$ of the weight of the scales—is required by the former plan, more by the latter. The cakes or pulp, as the case may be, are then placed between porous or absorbent materials, usually cocoa-nut matting lined with canvas. These are arranged in a hydraulic press, fitted with iron plates and wickerwork mats to keep the layers distinct, and are subjected to pressure. This operation is repeated till all the oil and greasy hydrocarbons are removed. When this is accomplished, the cakes, as removed from the press, should be almost transparent. Instead of employing clean coal oil or spirit at each operation, some manufacturers, with a view of economy, use the pure liquid for the last wash only. When this principle is adopted, the liquid pressed from the cakes at the last operation is used for those at the second stage, and from that stage again for those at the first stage. Thus the scales are subjected to three pressings, which, if done with care, should be sufficient to produce highly refined paraffin. It is obvious, however, that unless the scales have been properly treated by the oil refiners, before coming under the operations described, disappointment and failure will result. It is also clear that the refining will be more perfect by using pure spirit at each operation.

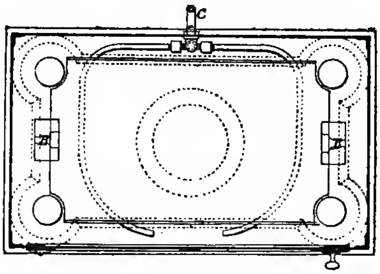
464.



465.



466.



The oldest form of hydraulic press was the vertical cold press, still used for the commoner kinds of fat. The newly introduced hot presses, on the other hand, are horizontal in shape, and altogether of superior construction. They are made by Needham and Kite, of Vauxhall; and by Galabrun Frères, of Paris. Figs. 464, 465, and 466 show respectively a front elevation, partly in section, side elevation, partly in section, and a plan, of a novel hot press specially adapted to the requirements of paraffin, sperm, and stearine refiners. It is made by James Clarkson and Co., Maryhill Engine Works, Glasgow, from the design of W. Walls, Esq., of that city, through whose kindness the following description and illustrations have been obtained. For convenience in working, and economy of labour, whether as a hot or as a cold press, it is unequalled. The plates A are notched at each end with a check of varying width, corresponding with the diameter of two vertically tapered bars B, placed at each end of the press and parallel with its supporting pillars. The object of this contrivance is to do away with the necessity for a balance weight, or other arrangement for bringing back the ram, plates, &c., when the press is opened. By this plan, on the ram being lowered by its own weight, each plate falls back into place, being stopped by the increasing size of the tapered bars; thus the plates are held in their places, equidistant from each other, and in a position to render the refilling of the press a matter of the greatest ease and simplicity. The bottom of the press is cast with a trough on it, which receives all the drippings from the plates, while the cylinder head, and the bottom collars on the pillars, are provided with projecting drooping rings; in this way, no oil can escape down the sides of the tapered bars or the pillars, but all must drop into the trough. The press is entirely encased in sheet iron, with hinged doors in front, for introducing and withdrawing the materials. A perforated steam pipe C is introduced at the top of the press, and is carried down the back inside; thence it passes on both hands around the bottom of the trough, for the purpose of keeping the drippings in a liquid state. An outlet pipe is attached to the front or back of the trough, and serves to conduct the oil to a tank.

The process of purification is simply mechanical; its efficacy, other things being equal, may be a subject of arithmetical calculation, the factors being the relative quantity of spirit or oil used at each wash, the amount of oil left in at each pressure, and the number of washes. There is, moreover, another matter which exercises an important bearing upon the results, viz. the temperature at which the cakes are cooled after each melting. In the act of cooling, crystallization takes place, and the slower this is performed the more perfect are the crystals. The result is that when a perfectly crystallized cake is subjected to pressure, it behaves like a sponge, yielding up the impurities to combination with the spirit. A quickly cooled cake, on the other hand, may be compared to a piece of putty or dough, and will not press to advantage, nor yield satisfactory results. The washes containing the impurities, along with paraffin in solution, are, as has been shown, either sent back in the process in bulk, or the naphtha may be distilled off, and the residue returned and treated *ab initio*. In all cases, the liquid which has been used for the washing at the first stage is the most heavily charged with low hydrocarbons, and must be subjected to distillation. The spirit is separated from this residue by steam heat, and may be used again; but the heavier portions require treatment with acid and alkali, as in the case of crude oils.

The cakes, which, by repeated washing and pressing, have been freed from colour, and from the greasy constituents which would spontaneously decompose and injure the wax, will, even after extreme pressure in hydraulic presses heated by steam, still contain a proportion of naphtha. To get rid of this, the cakes are put into a still or rectifier, an iron vessel furnished with a condensing apparatus. Amongst the melted paraffin, high pressure steam is introduced through a perforated pipe, and produces violent agitation. This is continued till the last trace of smell is removed, 12 to 70 hours being required to effect it, according to the specific weight of the oil or spirit used. The condenser is employed for the purpose of recovering the naphtha for future use.

The only operation now requiring explanation is the passing of the liquid wax through animal charcoal. Before this process can be applied with effect, every trace of suspended moisture must be removed; this is done by heating the liquid, as decanted from the rectifier, in a steam-jacketed pan. After the complete removal of the water, freshly burned animal charcoal, to the amount of 5 to 8 per cent., is added to the wax, stirred actively for half an hour, and left to settle. The clear liquid is then allowed to percolate through filters, which effectually remove the very fine particles of charcoal that refuse to subside. This liquid, which should now be as pure as water, is put into moulds to cool, when it will be ready for candle-making.

By the method above described, the very finest "wax" is now made by the Glasgow firms before mentioned. The only drawbacks to this interesting process are the risk of fire, created by the accumulation of inflammable vapour of naphtha, and the loss of volatile materials from the same cause. To obviate these drawbacks, other methods of refining paraffin have been devised and duly patented by their inventors; but no other process has proved effective in yielding a paraffin-wax of equal purity and beauty. The patent process adopted by Price's Candle Company, at Battersea, depends upon the fact that paraffins have different melting-points. Oil has a greater solvent power over the low paraffins, consequently when a properly crystallized cake is warmed to a degree below the fusing-point of its higher constituents, the lower grades melt, and carry away with them oil and other impurities, leaving the former comparatively pure and free from oil. The proportion of oil in these drainings is such that, when caked, they can be pressed without any addition of naphtha, and can thereafter be mixed with scales for draining again. This operation is performed in "cooking cupboards," closets about equal in size to an upright hydraulic press, fitted with shelves formed of double iron plates, each shelf being charged with steam. The hard, partially purified paraffin cakes, which remain on the shelves of the "cooking cupboard," are melted in a lead-lined vessel heated to 177° (350° F.), and into them is forced from 5 to 10 per cent. of sulphuric acid, sp. gr. 1·845. Sulphurous fumes are copiously given off, and must be conveyed away by suitable means. The agitation with steam is kept up for several hours, and by this treatment, all the more unstable hydrocarbons are destroyed, and settle down in the tank. The contents are allowed to stand for a time; the paraffin is drawn off, treated with weak soda-ley, then digested for a considerable period with animal charcoal, and passed through a filter, heated by a steam jacket to maintain the fluidity of the mass.

Several materials have been substituted for charcoal in the above process. In one instance, the addition of about 12 per cent. of powdered fuller's earth, at a temperature of 110° (230° F.) is recommended. The mixture is well agitated, then left to settle, and the clear paraffin is run off. The fuller's earth may be cleansed from paraffin by washing or agitation, and used again. By another process, invented by Smith and Field, silicates of magnesia, and of other bases, may be employed for the same purpose.

Pure paraffin is sometimes used alone for candle-making; but it is generally mixed with proportions of hard stearine, varying from 5 to 15 per cent. The refined paraffin causes the candle to burn with a flame of great power, while the high melting-point of the stearine renders it less liable to bend under the influence of a warm atmosphere, and to give off smoke during combustion.

Spermaceti.—The substance known as "spermaceti" is a valuable product for candle-making. The first operation needed to fit it for use is technically termed "bagging." The crude sperm oil, as brought in by the whalers, is placed in a reservoir, at the bottom of which are a number of pipes leading into long bags lined with linen, and temporarily closed at the bottom by tying cords round the mouths. The pressure exerted by the body of material in the reservoir forces a large proportion of the oil through the parts of the sacking, leaving behind the solid or "head-matter," as a dingy brown mass. This so-called crude or "bagged" sperm is deprived of a further quantity of oil by the application of pressure. It is put into hempen bags, which are deposited between the plates of a hydraulic press such as that shown above. The pressure applied is about 80 or 90 tons. When the oil ceases to flow, the sperm is taken out, melted by heat, and then drawn off into trays to granulate. The brittle crystallized blocks are ground to a coarse powder by means of revolving cylinders; the powder is collected in a bin beneath, and is filled into cloths, and subjected to a hydraulic pressure of about 200 tons. The oil expressed under this force contains a small amount of solid matters, and is therefore returned for re-bagging. The blocks, as turned out of the press, are melted down, and boiled for 2–3 hours with caustic soda ley of sp. gr. 1·109, in the proportion of 40 parts by measure of the former to 1½ of the latter. It is important to guard against an excess of alkali beyond that required for combination with the oil, as it would tend to saponify the spermaceti, and cause a waste of material. The mixture is kept at a low, equable temperature, till the oil is taken up, and is allowed to remain at a gentle simmer, while the soap that has been formed rises to the surface and is skimmed off. The heat is then raised to about 121° (250° F.), and the mass is treated with small successive doses of water, the additional scum being carefully taken off as it rises, till the whole is clear. It is then drawn off to crystallize in flat tin dishes, whereupon the cakes are again reduced to powder, placed in linen bags, and subjected to hot pressure in a very powerful hydraulic press heated by steam, after which the spermaceti will still contain a quantity of oil, or weak sperm, which no mere pressure will remove, and which must be extracted by saponification. The final operation consists in boiling down the sperm with strong alkaline ley at 112° (235° F.), removing the scum as before. When the latter ceases to appear, further purification is effected by introducing a little water, at intervals, while the heat is lowered. The supernatant spermaceti, now perfectly colourless and transparent, is cast into blocks and crystallized.

Spermaceti candles are valued for their beauty and illuminating power. They usually contain about 3 per cent. of wax or paraffin, to counteract the crystalline structure of the spermaceti, and are moulded in the ordinary way. The addition of a little gamboge makes the spermaceti resemble wax, the compound being known as "transparent wax."

Ozokerit.—From "ozokerit," or "earth wax," a kind of mineral paraffin, have long been fashioned crude miners' candles, in the districts where it is found; but the application of the substance to the manufacture of candles suited to civilized needs is confined in England to one firm, Messrs. Field, of Lambeth. The colour of the mineral varies from brown to greenish and yellow tints; its fracture is resinous. It contains 85·75 per cent. of carbon, and 15·15 per cent. of hydrogen, and appears to consist of a group of hard, solid hydrocarbons, whose melting-points range from 60° to 80° (140° to 176° F.). Dr. Letheby says that the illuminating power of ozokerit exceeds that of the best paraffins, and is therefore far beyond those of spermaceti, wax, and stearine. The following table shows the number of grains of the various substances enumerated required to give the light of 1000 grains of the best spermaceti candles :—

Ozokerit	754	Wax	1150
Paraffin	798—891	Various compounds	992–1189
Spermaceti	1000	Stearine	1200

The leading properties of ozokerit are:—(1) That it has a very high melting-point, and does not bend or soften in a warm atmosphere; (2) that it has a great illuminating power; (3) that it burns with a dry cup, and is not so liable to "gutter" as ordinary transparent candles; (4) that it is entirely free from smell, is not at all greasy to the touch, and has an appearance closely resembling the finest bleached beeswax.

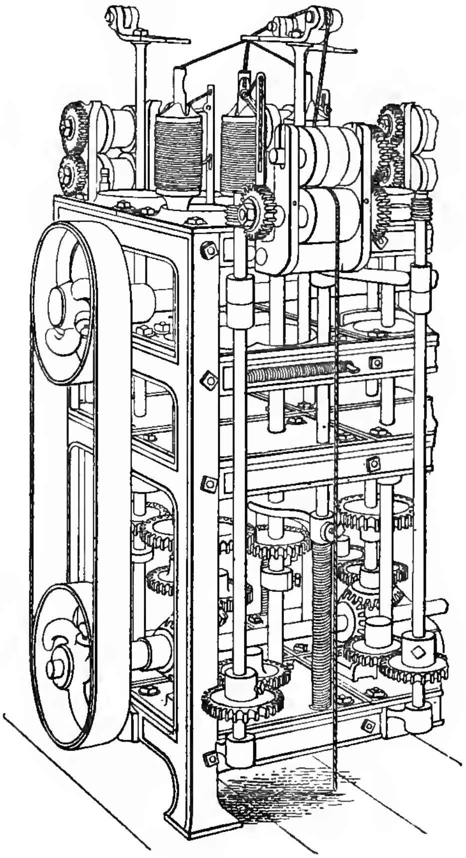
The refining of ozokerit for the purposes of candle-making is almost identical with the processes, already described, for refining palm oil and paraffin. The mineral is first carefully distilled; the product mixed with oil is submitted to powerful pressure, to remove the latter as much as possible, the extraction of the last traces requiring a treatment with sulphuric acid. The melted material is thoroughly washed, and repeatedly filtered through animal charcoal. When thus purified, the ozokerit resembles fine beeswax in colour, but is more translucent than wax, though less so than paraffin. The hardness and high melting-point of the candles made from this source give rise to a drawback, common to wax candles, viz. the smouldering of the wick on extinction. The immediate cause of this is the fact that the cup of the candle dries and solidifies as soon as the flame is blown out, so that there is no liquid matter left to extinguish the spark. This difficulty is now overcome by a special contrivance of the wick.

Wicks.—The next point for consideration is the wick, constituting the medium through which the combustion of the fatty or hydrocarbonaceous matter is performed. The chief essential qualities of a wick are good power of absorption, and a capacity for burning freely, evenly, and thoroughly, while producing the least possible proportion of ash. It must necessarily be quite free from inequalities of whatever kind, and should be made of perfectly sound fibres. The forms and kinds of wick differ widely with the quality and composition of the candle; the melting-points, and other characteristics of the hydrocarbonaceous bodies forming the candle, vary to such an extent that, in order to burn to the best advantage—or indeed, in some cases, to burn at all—each sort of candle needs to be accommodated with a special wick. One of the greatest secrets of candle-making is to have the wick perfectly suited to the peculiarities of the fatty matters employed; on this score, it is impossible here to do more than indicate the principles involved.

But little variety is to be remarked in the choice of material for making wicks. The original, and not yet obsolete, medium was the common soft rush, *Juncus conglomeratus*, to be found in most moist pastures, and by the sides of streams and ditches. They are in best condition in the height of summer, but may be gathered on to the autumn. As soon as cut, they are placed in water, otherwise they would dry and shrink, and the peel would not run. They are then stripped of half the peel, the object of which is to expose the pith sufficiently to enable it to conduct the molten fat, while enough of the rigid epidermis remains to afford it support. When duly peeled, they are laid out to bleach and take the dew for some nights, and are afterwards dried in the sun. These rushes are gathered in Lancashire, and abundantly in the Fen Country, and in Ireland. Candle-wicks are ordinarily made of fine cotton yarn; Turkish cotton rovings are said to be the best, but of the cotton employed for this purpose there is certainly a great deal more imported from the United States than from Asia Minor. The wicks of night-lights vary greatly in composition, according to the fancy of the manufacturer. Sometimes little sections of rush are used, as well as very fine cotton yarn; but the majority consist of "inkle," a fine flax yarn.

The manufacture of cotton and flax wicks is now performed almost exclusively by machinery, the threads of fibre being bound together either by twisting or by braiding. For dip candles, the wicks require to be bulky and of loose texture, in order that the melted tallow may rise freely. They are therefore made by twisting, and constitute the simplest form of wick after rushes. The cotton yarn chosen for the purpose must be "oozy" or furry, and the threads must be free from twist. This is placed ready balled in the cutting machine, a simple contrivance already repeatedly illustrated elsewhere. By it, the yarn is doubled in proper lengths around a rod; a knife then descends and severs the yarns, to which a twist is communicated, by means of a rolling apparatus worked by a treadle. The twist is secured by dipping the wicks at once in molten fat. Twisted wicks have a great drawback, inasmuch as they are only very partially consumed in the flame, and thus necessitate the troublesome operation of snuffing. The first attempt to remedy this evil was made by Price's Candle Company, on the occasion of the Queen's marriage. The candles were made self-snuffing, by means of plaiting the wick, and "gimping" strings of wire, or other fibrous material, into the plaits, with the object of bending the wick outwards, so that the end of it should reach the oxidizing part of the flame, and thus be destroyed. A simplification of this plan consisted in plaiting the wick with strands of unequal length, by which the same result was attained. In these cases, the wick was round.' At the present day, plaited wicks are made flat, by which means they acquire a natural inclination to bend. For all kinds of moulded candles, plaited, or in technical language, "braided," wicks are used, the old-fashioned twisted wick being reserved for "dips." An improved form of wick-plaiting machine is shown in Fig. 467; of a triple set, one apparatus only is seen. The contrivance is simple, but very ingenious. The strands of cotton yarn are carried on three revolving bobbins, whose gyrations are regulated by the beater beneath. The plaited wick is passed away in an endless rope over the wheels In principle, this is identical with ordinary braiding machines, but it differs from them in always having but three bobbins. Given proper materials, the success of a wick depends upon the manner in which it is plaited, and especially upon the relative tightness of the plaiting. Stearine candles require a moderately tightly braided wick; for paraffin, the braiding must be extra tight; for sperm and wax, on the other hand, it needs to be unusually loose. Few candle-makers plait their own wick, at least in any quantity; they prefer, in most instances, to entrust the work to cotton spinners who make it more or less a specialty. The leading firm in this business is Haynes and Co., of Hampstead Road, London, who will courteously afford every information.

467.

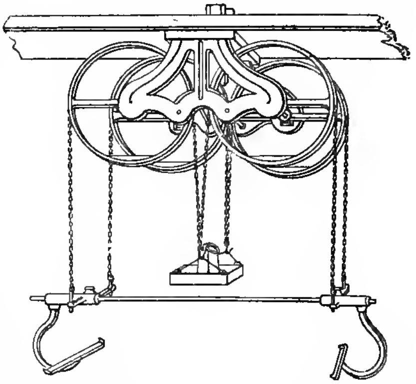


After being twisted or plaited, the wicks are bleached in the ordinary way, and thoroughly dried. Before being used by the candle-maker, they are dipped in a bath of pickling liquor, the effect of which is to retard combustion, and to help in causing the destruction of the ash. The pickle most commonly employed is a solution of about one pound of boracic acid in 75 pints of water; in this, the wicks are soaked for about three hours. When taken out, they are either wrung, or put into a centrifugal machine, to remove the first excess of water, and are then completely dried in a tinned-iron box, provided with a steam jacket. Various other pickles are recommended; the principal are —1, A solution of 5 to 8 grms. of boracic acid in 1 litre of water, to which 0·3 to 0·5 per cent. of sulphuric acid has been added; 2, a solution of phosphate of ammonia (used in some Austrian works); 3, a solution of sal-ammoniac at 2° to 3° Beaumé (proposed by Dr. Bolley); 4, a solution of 2 oz. borax, 1 oz. chloride of potassium, 1 oz. nitrate of potassium, and 1 oz. chloride of ammonium in 3 quarts water; 5, the wicks of the newly-introduced "snuffless dips" are plaited, and are then soaked in a solution of nitrate of bismuth.

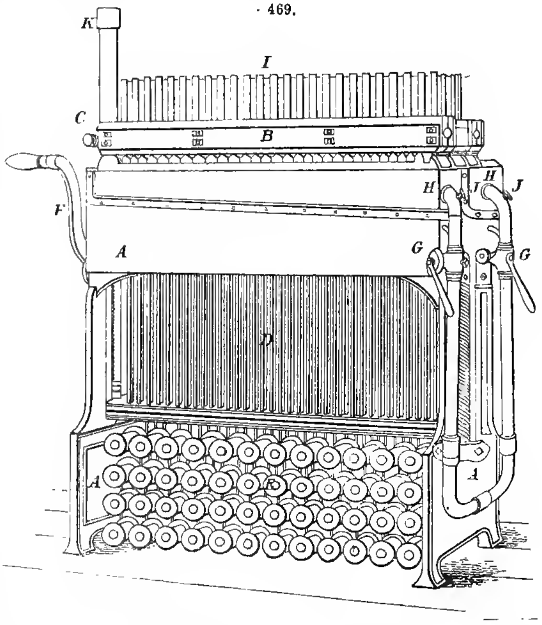
Candle Manufacture.—Having described the nature and preparation of the materials which, in one form or another, constitute the two component parts of every candle, the next consideration will be the manner in which their combination is effected. Two plans only are in vogue, each exceedingly simple; one is known as dipping, the other as moulding. The former is employed for common tallow candles, which are accordingly called "dips." The rods supporting the twisted wicks, as they come from the twisting and cutting machine, are transferred to a frame capable of being raised and lowered at will. This commonly takes the form of a beam, but a better arrangement is seen in Fig. 468. The frame, made of iron, and capable of revolving, is so suspended that a perfectly horizontal position is always maintained, even under undue pressure at either end; in this way, are secured a uniform length of candle and a plumpness at the top, which is difficult of attainment even by skilful workmen by the ordinary beam. Under the frame, are placed troughs containing melted tallow, into which the suspended wicks are repeatedly dipped. After each dipping, the adherent fat is allowed to cool sufficiently to retain a new coating on fresh immersion. The process is renewed until the candles have grown to the proper thickness; they are then left to cool and harden. Dip candles are still largely manufactured, and are much employed in mines and small factories, and by domestic servants, as well as in cottages; but within the last three or four years they have there been largely replaced by the small moulded "cottage composites," made from distilled fatty acids, with a self-consuming wick. These are, in fact, small and cheap composite candles, made in the same sizes as the old tallow "dips," and at nearly the same price.

They are very largely manufactured by several firms, among whom may be mentioned Christopher Thomas and Brothers, of the Broad Plain Soap and Candle Works, Bristol.

468.



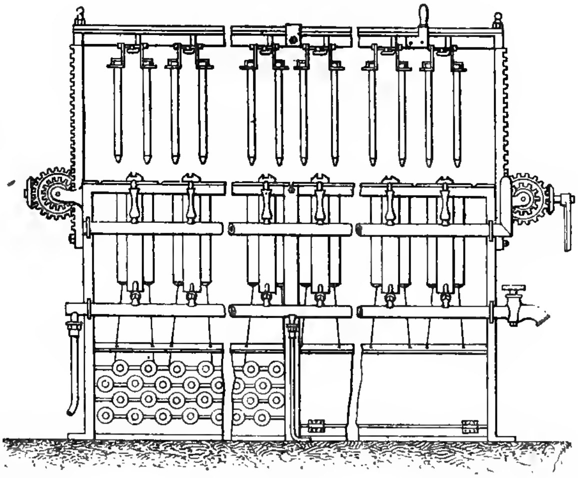
469.



By far the greater number of candles now manufactured are moulded, by which they acquire a much more finished appearance. The most simple form of moulding machine is that known as the "hand-frame," which is in use only among small manufacturers. The form commonly used is that made by Biertumpfel, of Albany Street, Regent's Park, and shown in Fig. 469; A, standards and water-box, with candle moulds partially enclosed; B, movable clamps, for holding the ejected candles; C, handle of eccentric wedge, for opening and closing the clamps; D, pistons, having the tips soldered at the top ends, which are fitted to the lower ends of the candle moulds; E, cotton bobbins, revolving on strong iron pins; F, crank handle, for raising the pistons, by the action of which the newly made candles are ejected into the clamps; G, handle of gun-metal gland cock, for emptying water-box (this cock is so arranged that it cannot leak or get out of order); H, overflow pipe, which prevents the box from being overcharged with water; I, newly made candles, held by clamps while the melted material is being poured in, so that the wick is centred in each mould; J, a clearing pin, to enable workmen to clear the bend of the overflow pipe if it should become choked; K, a pipe to admit hot or cold water to the water-box. The method of using the machine is as follows:—After having made the connection between the hot and cold water pipes and the machine at K, and having connected the outlet pipe with a drain, the machine is ready for cottoning. The pistons are raised by turning the crank handle F, until the tips are level with the butt ends of the tin candle moulds, where they can be held by the pawl catching in the pinion. A fine wire, doubled, and of sufficient length to go through the tip-mould and piston, is then inserted, and extended below the piston sufficiently to enable the operator to pass the candle wick end through the loop. This permits the cotton to be drawn up through the mould; it must then be secured in any convenient manner during the first filling. The crank F is returned, the melted material is poured in, and the operation is complete. When nearly cold, the butt ends of the candles are shaved off with a tin scoop or a wooden spud. The clamps B should be placed open over the machine; the crank handle F is then turned, and the candles are ejected into the open clamps. These are then closed by the handle C, so that each candle is held in its proper position. The crank handle F is then returned to allow all the pistons to recede into their places; the wicks are thus held in a central position by the candles I and the cotton bobbins E. The cotton should be slightly strained under the piston plate. The melted material is again poured into the moulds to form a second batch; when these are nearly set, the wicks are severed under the clamps, and the first batch is removed in the clamps. The temperature of the water in the machine is easily regulated, by shutting off or admitting hot or cold water, as required, at the T connection at K. The internal immersion pipes, situated inside the water-box and between the rows of moulds, are perforated. These machines occupy only about 3 ft. × 2 ft. of space, and are made to mould candles from 1 lb. each to 56 to the lb. It is also possible to make candles of two different diameters, or several different lengths, in the same machine. A polished appearance is given to the candles by alternately admitting hot and cold water into the water-box; the adjustment of the temperature is an operation needing special experience, the men's fingers forming usually their only thermometer.

Another form of moulding machine is shown in Fig. 470. It is manufactured by Galabrun Frères, of Paris, and is in general favour on the Continent; it is said to be capable of turning out 200 candles per half hour; but it is only suitable for stearic acid, or similarly hard material.

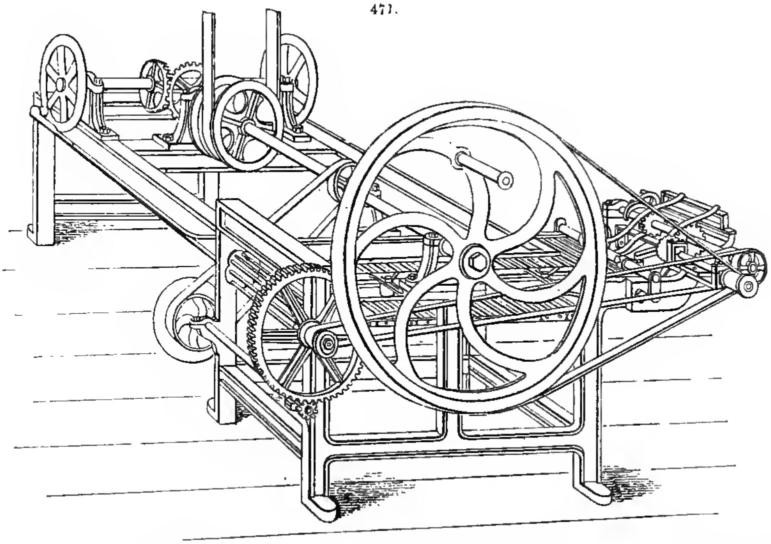
470.



When moulded and cold, the candles are taken to little tables, fitted with circular knives revolving at high speed. Here the butt ends are trimmed, and the length of the candles is adjusted to the weight. Some of the superior kinds of candle undergo a special polishing operation, performed by subjecting them to the friction of felt and other substances. In Fig. 471 is seen a trimming, washing, and polishing machine combined, as made by Galabrun Frères.

Modifications of Candle Manufacture. — *a.* Double wicks.—Some very thick candles, such as the so-called "police-lights," and others, used in ships' lanterns, &c., are made with double wicks. Ordinary frames cannot be used in this case. The wick is threaded on a kind of metallic skewer, which is thrust into the centre of the candle mould. When the candle has partially cooled, the skewer is withdrawn, and the wick is left behind. The space left vacant by the extraction of the skewer is filled up with candle material.

471.



b. Fancy patterns.—Instead of the plain cylindrical form, candles are sometimes made in a variety of fancy patterns—spiral or ropelike, with figures to indicate the hours, &c. These require special moulds.

c. Self-fitting ends.—Many candles are now moulded with conical bases, so as to fit any holder. For these, a little tin mould is fixed above the ordinary frame mould.

d. Coloured candles.—For colouring candles, vegetable dyes are almost solely used. In these extravagant days, candle-makers are often required to supply an article of a tint which will match some particular ceiling or wall paper, and no little ingenuity is required to ensure such tints being permanent.

As an illustration of the demands made by fashion, it may be mentioned that Price's Candle Company keep 300 varieties of candle always in stock, and are open to make 1000 different kinds (including size, colour, and material) in case of need.

Though electric lighting has emerged from embryotic obscurity into a palpable, fully-developed fact, much to the consternation of the gas companies, there is no reason to suspect that it will, within a proximate date, at all displace candles. With abundant evidence that the antiquated rushlight is still an article of domestic use—Messrs. Haynes supply between three and four tons annually, principally to the University towns,—there is safety in predicting a long life for paraffin, stearine, and composite candles, and even for the humble " dip."

Illuminating Value.—It is somewhat remarkable that the public, in judging of the value of a candle, are entirely guided by its mere appearance, and more particularly by its colour. The primary object of a candle is to give light. In estimating the value of any light-giving material, three factors have to be taken into account, viz.:—(1), the cost of the material; (2), the rate of its consumption; (3), the luminous intensity produced. In practice, a sperm candle burning at the rate of 120 gr. an hour, is taken as the standard light with which all others are compared. This is the explanation of the phrases "sixteen-candle gas," electric light of so many thousand "candle-power," and so on. Such a standard, however, is unsatisfactory at best, since very slight inequalities in the wick, or changes of its curve in the candle flame, materially affect the luminous intensity, without appreciably altering the amount of sperm consumed. Various other standards have been proposed, but none are thoroughly reliable. (See Photometry.)

The following tables are the result of experiments by Dr. Frankland, F.R.S., as to the luminous intensity, cost, &c., of various sources of light:—

I. Quantities of different substances required to produce the same amount of light.

Young's paraffin oil	1·00 gal. (about 8 lb.)	Wax candles	26·4 lb.
American rock oil ..	1·28 „	Stearic acid candles	27·6 „
Paraffin candles ..	18·6 lbs.	Composite „	29·5 „
Sperm „ ..	22·9 „	Tallow „	36·0 „

II. Cost of different sources of light equal to that of 20 sperm candles, each burning for 10 hours, at the rate of 120 gr. an hour.

	s.	*d.*		*s.*	*d.*
Wax	7	2½	Sperm oil	1	10
Spermaceti	6	8	American rock oil ..	0	6½
Paraffin	3	10	Paraffin oil	0	5
Tallow	2	8	Coal gas	0	4¼

Although it is impossible to avoid the inference from the above figures, that candles in any form are very expensive illuminating agents, compared either with coal gas, or paraffin oil (or any of its numerous modifications), nevertheless, the numerous advantages which they possess render it exceedingly unlikely that they will, to a greater extent than at present, be superseded by either of the two cheaper methods of illumination. Neither coal gas nor paraffin oil can be employed except at what are, for all practical purposes, stationary points; they cannot be carried about, while evolving light, from one place to another, and are altogether destitute of that element of portability, which renders the candle so valuable. Further, except in so far as a fire may result from actual contact between a candle flame and any inflammable substance, candles are absolutely safe illuminating agents, and persons burning them are not liable to the alarming explosions and fires which result from the careless use of gas, or of paraffin lamps.

Notwithstanding, therefore, the competition of gas and petroleum, and, it may be added, possibly of the electric light, there seems no reason for believing that the candle trade will do other than increase with the needs of the population, and will continue to repay every effort devoted to its improvement which is founded upon truly scientific and sound commercial principles.

Night-lights.—The making of night-lights is an important branch of candle manufacture. In 1877, Price's Candle Company, who enjoy almost a monopoly of the production of these useful articles, turned out 32 millions of them. There are two distinct kinds of night-light; the common form, so long known as Child's, from the inventor, whose son now manages this department of Price's Candle Company's factory, and the Company's new patent night-light. The former are made by running molten fatty matters into little wooden cases, which are the result of a series of operations. Balks of timber, free from knots, are the foundation of the manufacture; the best American pine is preferred, but it is now becoming scarce and dear, and the so-called "tulip-wood" has often to be substituted for it. The balks of timber are brought under a huge planing machine, which shaves off beautifully even slices, no thicker than stout paper. These are used as well for the boxes in which the night-lights are packed for transport as for the cases of the night-lights themselves. It is perhaps a little out of order, but at any rate it is convenient, here to complete the account of the manufacture of the packing boxes. The slices of wood are cut into rectangular form of the required size, and corresponding sheets of tough, but very thin, paper are pasted over them, by boys, at great speed. In this condition, they are pressed, to ensure adhesion, and are then taken to a machine for the purpose of having incisions made in them, where the edges are to be turned up to form the sides and ends. The cutters of this machine are so beautifully adjusted, that they completely sever the wood without so much as scratching the paper backing, which remains to form the hinges or angles. The same thin slices of wood are used in making the night-light cases. The slices, each of a size to form about a dozen cases, are coated with paper. This, like all the remaining processes in the manufacture of Child's night-light cases, is performed in a most dexterous manner by girls. The slices are placed on a table before a girl, who with one hand pastes a printed yellow label on the wood, while with the other hand she costs the paper label with gum, which gives it a glazed appearance, and at the same time renders it waterproof, the latter being an important consideration, as the light has to be burnt in a saucer of water. The double slices are immediately rolled to a given diameter, and are then carried on trays to a heated room to dry. After drying, each roll is subdivided into the proper number of cases, by means of a lathe, at the rate of 150 per minute. Next they are bottomed with cardboard, by means of a fitting stick, and an aperture is punctured in the centre for the introduction of the wick. This is provided with a tiny square tin-foil sustainer, which is secured to the case by means of a single drop of wax. The cases, thus prepared, are placed on trays to be filled. This operation is entrusted to boys, who manifest a skill and exactitude quite astonishing, and have proved themselves superior to any mechanism which has yet been tried for the purpose. The creamy fat is poured from a can with a narrow straight spout, sufficient being tipped at one operation into each case to exactly fill it and no more. When cool, the exterior of each case is scraped with a blunt knife to remove accidental splashes, and the lights are ready for packing in the boxes already alluded to.

The new patent night-lights differ from the foregoing, not only in being made from very much better materials, but also in the method of manufacture and mode of burning. Cases are dispensed with, and the fatty material, usually derived from palm oil, is moulded to the required shape by being run into a frame, which consists of a number of moulds or cups securely fitted to a bed of iron or wood. Into these, the melted material is poured and left to cool. When cold, the excess of fat is scraped off with a blunt tool, and the night-lights, ready punctured for the insertion of the wick, are lifted out by a screw. The wicks are introduced by boys. On each wick, cut to the proper length, is threaded a tiny square of tin-foil, which is to serve as a support for it during the latter stage of the combustion of the light; the wick is then thrust through the little disc of opaque white fat, and is secured by a cleat effected by a sharp blow on a miniature vertical anvil. The rapidity and precision with which the lads perform this operation is something to admire. The lights are now ready for burning, for which purpose they are placed without water in little glass cups. Night-lights are made of various sizes, calculated to burn for six, eight, or ten hours.

(See Glycerine; Oils; Ozokerit; Paraffin; Photometry; Soap; Spermaceti; Wax.)

W. L. C.

CANE. (Fr., *Canne;* Ger., *Rohr.*)

The term "cane" is properly restricted to the class of plants known as "rattans," included under two closely allied genera, *Calamus* and *Dæmonorops*, of which there are many species. They are generally classed among the palms; but they seem rather to form the connecting link between palms and grasses, uniting the habits of the former to the inflorescence of the latter. On the differences in their methods of growth, has been founded their classification into "ground rattans," and "climbing rattans," the latter being by far the more numerous and important. Nothing can be imagined more graceful or beautiful than a cane-bush. The plants often grow in extensive plots; but frequently also as single specimens, creeping to the tops of the highest forest trees, falling again in festoons, alternately trailing and climbing. They sometimes attain the enormous length of 500 ft., though more commonly 250 ft. is the limit, with a diameter somewhat less than half an inch. During growth, the plant is sheathed in a case of numerous and most beautiful leaves, which are stripped off when preparing the canes for market, leaving distinct rings to mark where the leaves have sprung from the stem. The stem, leaves, and tendrils are covered with terrible thorns. The fruit hangs in clusters of about fifty berries, each as large as a cherry, bright, cream-coloured, and edible. The stem contains much water, which may be extracted by cutting off a section and blowing through it. The roots and sprouts, when just above the ground, make a good vegetable. The plant requires a moist rich soil. It is very widely distributed throughout the Indian Archipelago, Malay Peninsula, China, India, Ceylon, Africa, and Australia, being specially abundant in all the moist tropics of the East, both continental and insular.

Over fifty varieties of *Calamus* have been identified; those principally entering into commerce are the following:—

C. rotang; stout.
rudentum; indigenous to the Moluccas.
verus; indigenous to Cochin China and the Moluccas.
draco; indigenous to Sumatra and the Moluccas; furnishes the "dragon's blood" of commerce (see Resinous Substances); this and the two preceding are varieties of *C. rotang.*
erectus; found at Silhet, in India.
Scipionum; most abundant in the Malay Peninsula; slender; supposed to yield the malacca cane brought from Siak.
Royleanus; grows the farthest north of any, being found at Dheyra Doon, in India, and plentifully in all the eastern forests of Kumara.
gracilis;
tenuis; } indigenous to Chittagong and Assam.
extensus;
australis; indigenous to the Louisiade Archipelago.
petræus; a variety of *C. rotang.*

Rattans, or rotans, are among the most abundant of the trees indigenous to the Straits Settlements; the many varieties are distinguished by the natives as follows:—

Sigga; knotted, used for chair bottoms.
Tiga segi; three-sided.
Kawat; used for rigging.
Tawar; grows on river banks, and drops in long tendrils armed with thorns, which will pull a man out of a boat.
Mannau; used for walking-canes.
Samamboo; also used for walking-sticks; dark coloured and glossy, with joints far apart; grows to many hundred feet in length.
Dhannan; very long and thick; perhaps the largest cane of the species.
Sinnee; long and delicate; colour, white; used by Malays for rigging and cables.
Ligor benar; true rattan.
Jomang; yields "dragon's blood."
Salak; produces edible fruit: *Calamus zallacca.*
Bumban; ground rattan: grows straight up; length, about 7 or 8 ft.; used for tying on thatch.
Saboot; used for cables and rigging.
Binni, or *Dinni;* has poisonous leaves.
Oodang; red rattan; used for blowpipes for native poisoned arrows.

In Borneo and Sumatra, rattans abound in all the old and dense jungles in damp situations, and form almost the principal vegetable production. The rattans of Borneo are esteemed finer than those of any other part of the world; they are exported to Singapore and Batavia in immense quantities from the Coti and Banjar rivers, on the southern and eastern parts of the island. They are collected and brought down these streams on rafts by the Dyaks, for very small remuneration. The principal supplies of Borneo are gathered at Banjarmassing (fine sort), Pontianak (common), Coti (small, fine), Sarawak (fine and coarse), Sambas (very long, mixed); the chief places of production in Sumatra are Jambi, and Pandagon on the west coast (glossy kind); Perak is the most important locality on the Malay Peninsula.

The Bugis traders of Borneo barter European and Chinese productions with the natives for the canes. These are then taken to Batavia, Somataya, Singapore, Penang, &c., and are there purchased by European merchants, and shipped to London and Liverpool. The majority of those produced at Coti and Banjarmassing go to Holland: those from Perak, to Penang, being re-shipped thence to London, and known as "Penang quality." All the rivers of Northern Borneo abound in canes, and 4000 tons might be cut every year without exhausting the supply. The inhabitants would contract to cut them for a trifle; but the cost of carriage to shipping ports and for freight would equal 50 or 70 per cent. on the first cost. By far the most valuable rattan, perhaps a distinct species, is brought from Banjarmassing, on the south coast of Borneo. It is worth 150 per cent. more than any of the others. Vast quantities of rattans are shipped from the Malay Archipelago to Europe, India, and China, probably amounting in all to four or five millions from British territory alone.

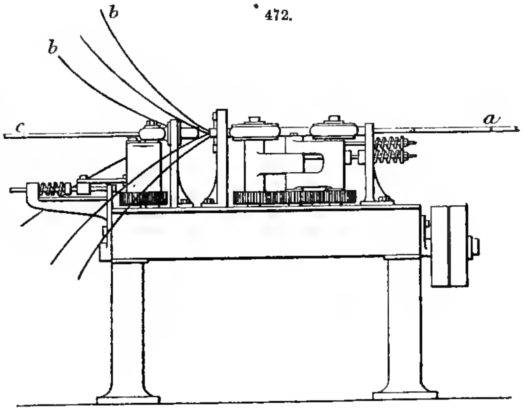
A few species are found in Madras territory; but in India they chiefly abound in the forests of Chittagong, Silhet, and Assam, whence they extend along the foot of the Himalayas as far north as Dheyra Doon. The East Indian rattans from Calcutta are very inferior, and usually glossy; those from the Eastern Archipelago are, except the Penang and Sumatra varieties, not glossy. Rattans of rather coarse kind are found in all parts of Formosa. A small trade is done in them to the Chinese coast, where their low price often affords them a market before the finer but dearer kinds from the Straits.

The most common "ground rattan" is the *Rhapis flabelliformis*, which grows all over China, but especially in Lin-kin and the southern districts. It attains a height of 30 ft. and upwards. Most of the fibre used by the Chinese is from the bark of this plant (see Fibrous Substances). Their great use among us is for walking-sticks, for which purpose they should be chosen tapered, heavy, well glazed, and with short joints, preferably those with roots attached, and always of sufficient length to cut up into a definite number of sticks, 38 to 42 in. long, without waste.

The mode of collecting rattans is as follows:—A native goes into the forest with his *parang*, or bill-hook, to cut as many as he can carry. Having cut a cane, he hacks a notch in the nearest tree; next he strips off a small portion of the outer bark of the cane, and inserts the peeled part in the notch in the tree. By simply pulling it through, he easily and rapidly divests it of its leaves and epidermis. When he has gathered and peeled about 300 or 400 canes, which are as many as he can carry in a green state, he sits down, doubles up each one, and ties them in bundles of 25 to 100. All that is necessary to fit them for the market is drying, a very easy matter in a tropical country. By this process, the canes assume the yellow colour with which we are familiar, some becoming glossy, others dull. On account of the small amount of labour entailed in their preparation, they can be sold very cheap. The natives usually sell them by tale (100); the Chinese merchants, by weight (the *picul*, or 133⅓ lb., containing nine to twelve bundles); in India and the United Kingdom, they are sold by tale, and are imported hither in bundles of 100, worth from 1*s*. 6*d*. to 3*s*.

On account of their lightness, flexibility, length, and strength, canes are applied to a great many purposes in the countries where they grow. One variety, *C. rudentum*, is used in enormous quantities for cables, cordage, and fishing-lines, after being split and twisted. The splitting is performed longitudinally; the canes are then soaked, and attached to a wheel. One person turns this, while a second binds the split cane together, adding others to the length from a quantity carried round his waist. From the cordage thus made, bridges, hundreds of feet in length, are constructed; over these, laden men, and even men on horseback, pass with ease. In China, houses and sheds are built of rattan, at a cost of about 5 dollars each. Much of the beautiful and elaborate basketwork of the Chinese and Japanese is from this source. Mats made from split cane are exported from China to all parts of the world. Very large quantities also are employed as thread, for sewing pieces of fabric together to form coverings for boats, carts, &c., as a substitute for tarpaulins; and for joining the leaves of palms, constituting the roofs and sides of dwellings. Another very wide application of thin threads of the cane is for the bottoms of rice-sieves. The well-known broad-brimmed Chinese hats are made of the same material plaited. The applications to which canes are put in this country are scarcely less important and varied. For all large baskets, such as are used in cotton mills, sugar refineries, and most factories, as well as for those employed on railways, and by gardeners, hucksters, coal-dealers, and washerwomen, canes have almost entirely replaced willow, buffalo hide, &c. They are unusually well adapted for making the baskets used in transporting carboys containing acids—forming an important branch of the basket-maker's trade—as the silica contained in the outer bark serves as a protection against the acid, which is sure to be spilled on them sooner or later. The manufacture of balloon cars, rustic and garden chairs, lattice-work, meat-safes, and brooms, also consumes a large quantity. Rough matting also is made of rattan, and is sold at 2*s*. to 2*s*. 6*d*. the square yard.

472.



In Fig. 472, is seen a machine which is used for splitting rattans. One of its chief advantages is, that it produces from the centre of each cane *a*, a perfectly round and even rod *c*, of considerable value for making ornamental window blinds, fancy baskets, chairs, &c.; whereas with the old-fashioned method of hand splitting, this core is sacrificed, in order to obtain the strips of outer surface. The cane is carried past the hollow cutter by revolving feed rollers, other rollers being placed beyond the cutter, for drawing out the central core. The cutter is so constructed that it divides the cane at one passage into any desired number of strips *b*, at the same time removing the central core *c*. The rate of feed is 150 ft. a minute; by simply changing the cutter, the cane can be cut into strips of any desired width. A great improvement consists in the feed rollers being arranged to work horizontally; the strips of cane as they leave the cutter are thus easily collected. The machine weighs about 7 cwt., requires only ¼ horse-power, makes 200 revolutions a minute, and costs about 55*l*. It is made by Messrs. Ransomes, of Chelsea, from the designs of Mr. John Fisher, of Mincing-lane and Singapore, who has secured patent rights for its application in the Straits Settlements, the headquarters of the export trade in canes.

For making the seats of chairs and similar work, an industry which consumes probably half the rattans imported into this country, the selected canes should be long, of bright pale-yellow colour, small size, and not liable to break. All such as are dark coloured and snap short on bending should be rejected. Four pounds of rough rattan are required to yield one pound of strips for cane work. A large quantity of cane is now used, as a cheap substitute for whalebone, in umbrella and parasol ribs; a set of cane ribs for the former costs only 2½*d.*; and for the latter, ½*d.* to 1*d.*; while whalebone amounts to 2*s.* 6*d.* or 3*s.* The siliceous exterior of the cane cannot be dyed; but the cores used for ribs, as described, may be stained any colour. They are usually dyed black by logwood and sulphate of iron. They range in size from that of a pin wire to the full dimensions of the cane. In saddlery and harness making, and in all kinds of wickerwork, rattans are now much employed. The helmets of the German army are made sword-proof by a lining of cane wickerwork. The lightness, strength, and cheapness of the material make it eminently fit for this purpose, and the idea is worthy of being copied in our own military and police forces.

The waste produced in peeling the canes by hand, as is still done in Belgium, is known as *crin végétal*, and is utilized as a fibre for filling mattresses, for making mats, for ties and bands used in agriculture, and as a substitute for hay and straw packing. Mattresses stuffed with this substance are in great favour on the Continent, and are much used in the hospitals of Antwerp and other large towns. They are always sweet and pleasant, and are sold wholesale at as little as 4*d.* to 8*d.* each.

Large as the consumption of cane now is, it was only in the early part of this century that importation first took place, and it is but very recently that canes have formed any considerable item in the commerce of the country. A very large trade is now carried on with Western Europe and the United States, the principal centres of export being Batavia, Sarawak, Singapore, Penang, and Calcutta. Statistics concerning the production, exports, and imports of canes are very scattered and disjointed. In 1870, we received more than 24½ million rattans from Singapore, and 8¼ millions from other places, besides about 6 million other canes and sticks, of the aggregate value of 83,841*l*. About 60,000 bundles of 100 each are annually imported into Liverpool alone. The estimated yearly consumption in Europe, the East, and America, is upwards of 25,000 tons. The export of cane matting from China to the United States alone is more than 10,000 rolls of 40 yards each per annum; but these figures probably include other canes besides rattans. From Java are exported about 80,000 to 90,000 *piculs*, of 12 bundles each, a year. About half of these are imported by the Dutch Trading Company, and the remainder by private merchants. In 1875, the exports from Java were about 79,000 cwt., principally to Holland, the Channel for orders, and America. The ruling price was 12 to 14 florins (of 1*s.* 8*d.* each) a *picul* (133⅓ lb.). The quantity exported from Java, in 1876, was about 73,000 cwt.; and the value of the rattans sent out of Borneo in the same year was 9854*l*. The Java exports, from 1st July, 1876, to end June, 1877, were 41,184 *piculs;* in the following twelve months they were reduced to 27,989 *piculs;* viz. to Holland, 13,839; Channel, 10,606; America, 2337; Denmark, 400; China, 259; Port Said for orders, 194; Cadiz for orders, 157; Lisbon, 130; Australia, 49; France, 18. This reduction was owing to the depression in prices in Europe and America, which ruled about as follows:—Padang, 13 fl. to 8 fl. a *picul;* Banjarmassing, 12 fl. to 10 fl.; fine long kinds, 14 fl. to 15 fl.

CARAMEL. (Fr. and Ger., *Caramel.*)

This substance is formed by the application of heat to sugar, or to various materials containing sugar, such as molasses, coffee, malt, &c. It is of a very dark-brown colour, and is quite tasteless; it dissolves rapidly in water, to which it imparts a fine sepia tint. If it be required in small quantities, and in a perfectly pure state, it may be obtained by dissolving burnt sugar in a small quantity of water, and precipitating with alcohol. On the commercial scale, it is most commonly prepared from brown "moist" sugar, which should contain as high a percentage as possible of saccharine matter. The sugar is placed in large circular shallow vessels, heated from beneath; when melted, the impurities which rise to the surface are skimmed off. The whole is left for a short time to cool, and is then reheated, the operation of removing the floating impurities being continued until they cease to rise. While still hot, the sugar is ladled into tin cones, measuring about 9 in. in diameter at the top and 1 in. at the bottom. These cones are open at the lower end, but wires are stretched across to prevent the exit of the semi-fluid mass. Through these apertures, the molasses contained in the sugar is allowed to escape into vessels placed below to receive it.

The sugar thus freed from all impurities is left to become hard, and is then once more heated in large copper vessels. It is kept gently simmering for some time; the heat is then suddenly raised, and the contents are allowed to boil rapidly for some minutes, during which time the conversion of the sugar into caramel is taking place, and the substance is acquiring its characteristic colour. When the operation is complete, the fire is suddenly withdrawn, and the contents are cooled as quickly as possible.

Another method of preparing caramel is by heating molasses. The latter, in quantity about 21 pints, is placed in a deep pan, and subjected to a strong heat; it is meanwhile continually stirred with a large wooden spatula, to prevent its burning on to the bottom of the pan. On heating, the molasses has a tendency to bubble up vigorously; to correct this, about 10 grm. of virgin wax are added. When heat has been applied sufficiently long, as indicated by the odour of the liquid, and by its slight adhesion to the spatula, the pan is quickly taken off the fire, and into it is gradually and cautiously poured about 8 pints of water, previously heated to 60° (140° F.) or 80° (176° F.), with constant agitation. At the conclusion of this operation, the caramel is passed at once through a hair sieve.

In France, sugar, which has been subjected sufficiently long to the temperature necessary to produce the desired tint, is dissolved in lime-water, and sold for colouring purposes.

The principal use of caramel is for communicating a brown colour to wines, spirits, vinegar, &c.; the greatest quantity is consumed in brandy making, for which it is invaluable, one gallon of good caramel being sufficient to brown 1000 to 1200 gallons of brandy. Porter also owes its dark colour to the presence of caramel.

CARBON. (Fr. *Carbone;* Ger., *Carbon.*) Symbol, C.; atomic weight, 12.

Abundant information as to the characters, occurrence, and combinations of this element are to be found in every handbook of chemistry. This article will be confined to a description of the artificial carbons employed in electric lighting.

The rods first used for the electric light were of wood charcoal, quenched in water or mercury; they burnt with brilliancy and regularity, but too rapidly. Next, the carbon which is deposited in gas-retorts was employed; its chief faults are found to be want of homogeneity and purity, causing variations in brilliancy; liability to split; and hardness, entailing considerable cost for cutting it into "pencils" of the required size. With the sudden impetus given to electric lighting, much ingenuity has been devoted to the production of a more suitable carbon for this purpose. In some instances this has been attempted by purifying gas-retort carbon. The first plan of this kind was as follows:—The retort carbon is fused with caustic potash or soda, and the carbon rods are digested in this bath at a red heat for fifteen minutes. In this way, the silica present is converted into a soluble silicate; the rods are then washed in boiling water, and are submitted for several hours to the action of chlorine at red heat, to change the earthy matters into volatile chlorides. These rods give a regular light, but the purification is costly and inefficient. From a number of experiments on retort carbons impregnated with different salts, it seems that potash and soda double the length of the voltaic arc, render it more silent, combine with the silica, and eliminate it from the carbons during the action of the current; they also augment the light in the proportion of 1·25 to 1. Lime, magnesia, and strontia increase the light as 1·40 is to 1; iron and antimony, as 1·60 or 1·70; boracic acid is said to lengthen the durability of the carbons by coating them with a vitreous layer, but it does not increase the light.

On the other hand, experiments have been made with a view to manufacturing a carbon from other sources. In one instance, it was endeavoured to imitate the process of formation of retort carbon with pure materials. Tars resulting from true distillation, therefore free from all non-volatile impurities, were decomposed in a tube of refractory earth in a furnace, and yielded plates of carbon which, when cut into "pencils," gave a light that was steadier, whiter, and 25 per cent. more powerful than that obtained with ordinary carbons. The hardness of the material, however, entailed great cost for cutting, and caused much waste. Another plan consisted in mixing two parts of pulverized retort carbon, two parts of pulverized wood charcoal or coke, and one part of tar; mixing the mass to a stiff paste, and subjecting it to great pressure. The moulded pieces were covered with a coating of syrup of sugar, placed beside each other in a vessel of retort carbon, and submitted to great heat for twenty or thirty hours. At an early date, a mixture of pulverized coke and sugar was proposed. To powdered coke, a small quantity of syrup was added, and the compound was pugged, moulded, and strongly pressed. Next it was heated moderately, thrust into a concentrated solution of sugar, and finally heated to whiteness. Curmer's carbon consists of lampblack, benzine, and oil of turpentine, calcined together, and moulded into cylinders of porous carbon, which is soaked with resins or saccharine matters, and again calcined. The objections to this are the high price of lampblack, and the difficulty of managing it. Peyret's carbon is prepared by soaking pieces of elder-tree pith, or other porous materials, in liquefied sugar, and decomposing the sugar by heat. By repeating this process, a dense carbon is obtained; it is then submitted to a current of carbon bisulphide vapour. In Archereau's carbon, the addition of magnesia makes the light steadier and increases its power. Carré adopts the following mixture:—Coke powder, 15 parts; calcined lampblack, 5 parts; and a syrup (composed of 30 parts cane sugar, and 12 parts gum), 7 to 8 parts. The whole is thoroughly triturated, and receives an addition of 1 to 3 parts of water to compensate for that lost by evaporation. The paste is pressed, and passed through a draw-plate. The carbons are next arranged in horizontal layers in a crucible, the lowest tier lying on a bed of coke dust, and the upper ones separated by paper to prevent adherence. Between the top and the cover of the crucible, is placed a stratum of coke dust; and upon the joint of the cover, is spread siliceous sand. In this position, the carbons are strongly heated, and are then placed for two or three hours in a concentrated boiling syrup of cane sugar or caramel, two or three intervals of cooling being admitted, in order that atmospheric pressure may force the syrup into all the pores of the carbons. These are then allowed to drain by opening a tap in the bottom of the vessel; after this, they are well washed with boiling water, to remove the sugar adhering to their surface. When dry, they are subjected to a second heating, and are passed through a repetition of the process till the requisite density is obtained. In many respects they resemble retort carbons, but are harder, more tenacious, and better conductors.

Upon the introduction of foreign substances into the carbon rods, a number of experiments have been made. The materials chosen have been phosphate of lime, borate of lime, silicate of lime, chloride of calcium, phosphate of magnesia, borate of magnesia, magnesia, silicate of alumina, and pure precipitated silica, with the following observed results:—

Phosphate of lime is completely decomposed, reduced calcium goes to the negative carbon, and in contact with the air it burns with a reddish flame. Lime and phosphoric acid are abundantly diffused in fumes. The light, as measured by a photometer, is double that produced by similar sized rods of retort carbon.

Borate and silicate of lime, and chloride of calcium are all decomposed; the boracic and silicic acids are volatilized, and escape electric action. The light does not equal that from phosphate of lime.

Magnesia salts are decomposed; the magnesium burns with a white flame, while the acids are vaporized. The light is less than from lime salts.

Silicate of alumina, and alumina, require a very strong current to effect their decomposition, and burn with a blue flame of small illuminating power.

Silica melts and volatilizes without undergoing decomposition.

M. Gaudoin has proposed two distinct methods of preparing carbon for electric rods. According to the first, he decomposes by heat, organic matters capable of yielding pure carbon after decomposition, e. g. pitches, fats, &c. The decomposition is effected in closed retorts, or in graphite crucibles, at bright red heat. In the bottoms of the latter, are provided a tube for the liberation of volatile matters, and a second tube for feeding purposes. The gaseous products of decomposition are led into a condensing chamber, for recovery and utilization. The more or less compact carbon remaining in the retort is finely pulverized, and with it are mixed certain proportions of lampblack, and of the carbides of hydrogen previously produced by the decomposition process. These, being quite free from iron, are much superior to commercial hydrocarbons. The draw-plate or moulding apparatus employed by Gaudoin differs from that commonly used, in the following important particulars. The carbon is made to issue horizontally, at a descending angle of about 50°, and is guided by tubes, and supported so that the mould can be emptied without interruption and the carbon does not break under its own weight. Gaudoin's second plan is to take dried wood, shaped in the form of the rod, and to carbonize it and soak it in carbonaceous liquids. The wood is then subjected to a slow distillation process, in order to drive off the volatile matters; it is then washed in acids or alkalies, to remove impurities; and is finally desiccated in a reducing atmosphere at very high temperature. The pores of the wood are closed by submitting it to the action of chloride of carbon and various hydrocarbons under heat. This process promises to afford carbons which will burn at a slow rate, and give a steady light.

The advantage derived from closing the pores of carbons has been further attested by the success of the Sawyer and Mann rods, which are prepared in the following manner:—The carbon rod is immersed in olive oil until it has become thoroughly saturated; while in this condition, it is included in a powerful electric current, the effect of which is to carbonize the oil in the pores and on the surface. Rods thus prepared are extremely hard, of steel grey colour on the surface, and give very constant light.

Bad carbons are undoubtedly rendered more uniform conductors by covering them with a coating of metal. A great increase of light is also secured by a slight coating of metallic bismuth, or by saturating with a solution of nitrate of bismuth. It has been proposed to attain the same end by incorporating powdered copper or iron with the carbon; also by inserting a wire core in the rod, and by winding a thin strip of metal around it.

Bibliography.—'The Electric Light,' Dr. Paget Higgs. (See Blacks; Gems; Graphite.)

CARBON BISULPHIDE, CARBONIC DISULPHIDE, SULPHOCARBONIC ACID, THIOCARBONIC ANHYDRIDE. (Fr., *Sulfure de carbone*, *Acide sulfocarbonique*; Ger., *Schwefelkohlenstoff.*) $CS_2 = 76$; relative weight, 38. Sp. gr. at 0° (32° F.), 1·0272; at 16° (60° F.), 1·272; sp. gr. of the vapour at 16° (60° F.) (theoretical), 2·6296; (observed), 2·6447; boiling point of the commercial article, 48° (about 118·4° F.), that of the pure substance 43° (109·4° F.).

Bisulphide of carbon is a colourless, heavy, very volatile liquid, possessing an acrid, pungent taste, high refractory powers, and a very powerful fœtid, alliaceous odour, due to the presence of impurities in the unrefined product, but only giving off an ether-like smell when pure. It has been considered insoluble in water; but this is not strictly true, as, by prolonged contact, water will dissolve it at ordinary temperatures, in the proportion of about $\frac{1}{1000}$ part of the weight of water. It may be mixed in almost all proportions with alcohol, ether, benzine, and the fixed and volatile oils; and it acts as a solvent of fats, oils, resins, indiarubber, sulphur, phosphorus, bromine, chlorine, iodine, camphor, &c. It cannot be solidified *in vacuo* except it be mixed with ether, and for its congelation, under ordinary conditions, a very low temperature is required; it may, however, easily be frozen by directing a very strong current of dry air upon the surface of the liquid. By the evaporation which ensues, so much heat is rendered latent that the mercury of a thermometer, placed in the vessel during the operation, will not have descended to 32° F. before a coating of the frozen substance will have been formed on the sides of the vessel. The temperature then falls rapidly to 0° F., while a white mammillated mass rises to the surface. When the whole mass has solidified, the temperature rises again to 10° F., where it continues until melting supervenes. The bisulphide will remain solid for some time, and, while in this state, possesses a peculiar aromatic odour. It is highly inflammable; its vapour when mixed with air takes fire, according to one authority, at about 149° (300° F.), exploding with great violence under some conditions; another authority asserts that, when mixed with hydrogen or carbonic oxide, it ignites below 216° (420° F.); it burns with a blue flame, giving rise to sulphurous and carbonic anhydrides. Further, it is deadly poisonous, inhalation of the vapour producing giddiness, vomiting, congestion, and finally coma. The pure liquid, exposed to sunlight for a considerable time, undergoes partial and gradual decomposition, turning yellow, and depositing an insoluble brown substance. Bisulphide of carbon is composed of 15·8 per cent. of carbon and 84·2 per cent. of sulphur, and is produced by passing the vapour of sulphur over charcoal kept at a red heat, or by distilling an intimate mixture of native metallic sulphides with charcoal or coke, the former being the only method employed commercially. Though not to be compared with sulphuric acid, for instance, as regards its importance among manufactures, it nevertheless takes a high place among chemical products, principally by reason of the fact that many substances formerly discarded as waste have, by its use, been made to render valuable returns.

Manufacture.—The arrangement of the furnaces employed in making bisulphide of carbon varies considerably. According to a very general plan, they consist of four fireclay cylinders, each about 5 ft. 10 in. high, and 20 in. internal diameter, with a ring about 6 in. from the bottom, supporting an earthenware tray full of holes, which forms a grating. Each cylinder is furnished with three holes in the cover, the first for the introduction of the sulphur, the second for the escape of the gaseous bisulphide, the third and largest for the introduction of the charcoal. The operation being conducted without intermission, three charges of charcoal per twenty-four hours are put into the cylinders, each of which is supplied at regular intervals of three minutes with charges of about 10½ oz. of coarsely pulverized charcoal, the four cylinders thus receiving, in the course of twenty-four hours, about 300 lb. of sulphur each, or a total of 1200 lb. The four cylinders are set perpendicularly in masonry, and heated by the flame of a single fire. A small porcelain tube about 2½ in. diameter passes through the cover of each cylinder, and also penetrates the false bottom, while it rises about 10 in. above the cover. A second opening in the cover admits the end of a bent tube, about 3½ in. diameter, by which the gases make their escape to the coolers. Finally, the third opening, 6 in. diameter, is intended for the reception of the leg of a funnel each time charcoal has to be supplied to the cylinders.

The cooling apparatus consists of about eighteen cylindrical vessels of sheet-iron or zinc, communicating with each other. Each of these is about 26½ in. diameter, bottomless, and with slotted sides, which plunge into a larger saucer containing water a little deeper than the openings, so as to form a water-lute, permitting the passage of condensed liquids while closing the exit against gases or vapours. The false bottom of these vessels has two openings, which receive the bent siphon tubes forming the connection between the jars themselves, and between them and the cylinders. The sides of these vessels rise about 4 in. higher than the false bottom, forming a saucer, which is filled with cold water to assist in the cooling. Each group of four vessels is supplied with a cylindrical cavity at a lower level, to admit of a receptacle being placed in position for siphoning off the liquid bisulphide as it accumulates. The gases escaping from the four cylinders circulate, by means of tubes, into the eighteen coolers, and from the last of these, are carried directly into the chimney of the works, or better, are first made to traverse "scrubbers" of pulverized lime in layers, for the purpose of retaining the hydrosulphuric acid gas, which would otherwise create a nuisance to the neighbourhood.

The mode of operation is as follows:—The four cylinders are filled with charcoal and properly closed; a fire is then made, and by it, the cylinders, and the charcoal contained in them, are rendered of a clear red heat. Then, but not before, the introduction of the sulphur commences, it having been previously wrapped up in little cartridges. Two cartridges, forming a charge, are introduced into the tube conducting to the false bottom of each cylinder; the upper end of the tube is then closed with a bung of clay enveloped in a covering of linen. The charges of sulphur are made every three minutes; at the end of seven or eight hours, the charcoal, partially consumed by the sulphur vapour, must be renewed. The introduction of sulphur is suspended, and each cylinder in turn is filled with charcoal, by means of an iron funnel placed in the opening. This is then closed, and the firing is commenced and continued for about one and three-quarter hours, to reach the temperature required. The charge of charcoal is thus renewed three times in twenty-four hours. The liquefied sulphide may be drawn off at any time without suspending operations; but advantage should be taken of each monthly stoppage to remove the sulphur which has formed in crystals in the first four coolers.

Sometimes the cylinders are made of the same material as glass-house pots. These are glazed inside, by a mixture composed of 20 parts soda and 12 parts boracic acid. They last about six months, with care.

At Swoszowice, in Galicia, the apparatus used for making bisulphide of carbon consists of perpendicular retorts walled into a furnace, provided at top with a cover pierced by two openings. Through one of the openings, a pipe, open at both ends, descends almost to the bottom of the retort, while the second opening communicates with a cooler. The retort, which is lined with fire-lumps, inside and out, is of cast iron, about 1½ in. thick, and of an elliptical form, measuring about 39 in. × 16 in. and about 6 ft. 6 in. high. Cast on the retort at the bottom, is an arm, provided with flanges, to which a tube is riveted, for the purpose of charging in the sulphur at the proper time, without any serious loss. A similar projection on the top of the retort is surmounted by another cast-iron tube, closed with a bung. From this, proceeds an inclined tube, for the passage of the vapours, fixed to an intermediate vessel of sheet iron, whose lower part, being supported by screw rods, may be removed and replaced at will. At the end of the inclined tube, is an opening, closed by a stopper, which may be made to intercept communication between the retort and a receiver. The cooler or condenser is composed of three intercommunicating cylindrical zinc vessels. The topmost carries an escape pipe. The condensed bisulphide is drawn off at pleasure by a tap. The three cylindrical vessels, as well as the tubes connecting them, are immersed in a water bath, capable of constantly receiving fresh supplies of water. The operations are conducted practically in the same way as with the apparatus previously described. The bisulphide formed always contains a certain quantity of sulphur, which has escaped the action of the carbon, and this sulphur, being less volatile than the bisulphide, condenses with a part of the solvent, and crystallizes in the receiver, which is specially intended to catch it, and from which it can be easily removed when the distillation is interrupted.

The charges of sulphur are introduced during ten hours, from morning till evening; the fire is fed during the night, in order to achieve the volatilization of the sulphur, and to leave the excess of charcoal bare towards the morning, when the communication with the cooler may be interrupted. The retort is now refilled with charcoal, the receiver is emptied of the sulphur which has collected, and is then replaced; and, when the temperature has again reached a bright red, the sulphur is added little by little at the lateral opening. The product of bisulphide, per twenty-four hours, will be about 5 cwt., from the conversion of 477 lb. sulphur (605 lb. total charged, of which 77 lb. recovered), and 90 lb. charcoal (out of a total of 242 lb. used).

A second retort at these works measured 7 ft. 4 in. deep, and was elliptical in form, the greater axis being 4 ft. 4 in. diameter, and the smaller 3 ft. 2 in. This made about 10 cwt. of bisulphide per twenty-four hours; but its great size was found inconvenient, as the heating was rendered uneven and spasmodic, causing considerable waste of sulphur. When using unrefined sulphur, the retorts need cleaning every two weeks; but with clean sulphur, they may safely run two months. This cleaning is a very troublesome operation, causing much loss of time and material, and exercising an injurious effect upon the workmen. The cast-iron retorts, when well built in, and thoroughly protected by fire-lumps, last about twenty-two weeks.

Sidot has proved that temperature has a most important bearing on the product of bisulphide of carbon. He experimented with 40 grms. sulphur and 10 grms. purified charcoal, at three different temperatures, with the following results:—

1. Dull red heat .. .. 5 gr. charcoal gave 17 gr. bisulphide.
2. Red heat .. .. 6·3 " " " 29 " "
3. Bright red . .. . 7·5 " " " 19 " "

The figures show the extent to which the charcoal is consumed in each operation. They show incontestably that a red heat is the one best suited, and that great care should be taken to avoid exceeding it, especially as there is danger of the bisulphide becoming divided up again at a high temperature, the carbon being redeposited, and the liberated sulphur distilling over with the bisulphide. With every precaution, there is a certain escape of sulphur in this way, giving the bisulphide the yellow colour peculiar to its crude state, and necessitating a process of purification, to be described farther on.

The very poisonous and inflammable characters of this substance render it one of the most dangerous chemical compounds, and necessitate the most rigid precautions in its manufacture, to prevent the least escape of the vapour. The inhalation of the vapour produces, on the workmen employed, symptoms of depression, weakness, and loss of memory, which is sometimes followed by coma. A solution of ferrous carbonate in carbonic acid water is found to be partially effectual in relieving these symptoms; but attention must be devoted to prevention rather than cure, as besides the evil effect produced by the vapour, its escape represents a direct monetary loss.

The crude bisulphide always contains a considerable proportion of sulphur—sometimes as much as 10 per cent.,—besides various hydrogen compounds, formed, during the preparation of the substance, by the action of nascent hydrogen on it, and producing the peculiar disagreeable odour which characterizes it. This crude bisulphide has then to undergo purification, to fit it for the market. At Swoszowice, recourse is had to simple distillation in a water bath, and condensing the distillate in an unusually long cooling worm; the product is a colourless bisulphide, but it always retains some sulphur, and loses but little of its bad smell. Numerous plans are adopted for securing more perfect rectification. According to one method, it is first washed several times with distilled water, and then transferred to a retort containing quicklime. After twenty-four hours' contact, the bisulphide is distilled off from the lime, and caught in a receiver, partially filled with copper turnings, previously roasted to remove all trace of fatty matter, and afterwards reduced by hydrogen. The lime remaining in the retort is strongly coloured by the impurities eliminated from the bisulphide, whose disagreeable smell will be found to have departed. Another way of performing the operation is to mix the bisulphide with Pb_2NO_3, and a small quantity of metallic lead; when the salt turns dark, the liquid is transferred to another vessel with a fresh quantity of lead salt, and so on till the salt remains nearly white after contact with the liquid. The latter is then placed in a retort, and distilled over. Friedburg recommends the following process. The crude bisulphide is first distilled, then poured into fuming nitric acid, agitated, and left for twenty-four hours. The bisulphide becomes saturated with peroxide of nitrogen, and this solution, which is brown, remains unaltered for weeks. The addition of cold water causes the bisulphide to separate as a rose or violet-coloured liquid, which is distilled at 50°–60° (122°–140° F.), again agitated with cold water, and, after another distillation, is perfectly pure. Other proposed means of purification are:— 1. Agitation with mercury. 2. Agitation with 5 per cent. sublimate, and distillation with 2 per cent. colourless fat. 3. Distillation with soda hydrate solution chlorine in water, and solution chloride lime. 4. Distillation with solution chloride lime. 5. Several distillations with pure oil, the oil extracting each time some of the impurities.

An improvement in the method of constructing the retorts and furnaces employed in the manufacture of bisulphide of carbon has been effected by S. H. Johnson. The object is to facilitate the replacement of the broken or burnt retorts, without the necessity of pulling down the furnace work, thus preventing the loss of heat usually sustained. This is attained, firstly, by employing a horizontal retort for the vaporization of the sulphur, in conjunction with a vertical one for heating the charcoal; and secondly, by forming the flues for heating the vertical retort in an iron cylinder, open at both ends, with its axis in the line of the axis of the retort. Inside this cylinder and concentric with it, a cylindrical lining of firebrick is constructed, leaving a space between it and the cylinder, filled with a suitable non-conducting material. At the sides and end of the furnace, are passages for conducting the products of combustion into the upper retort-chamber. Below this chamber, and between the flues, the horizontal retort is set. As this latter is not required to be very highly heated, the products of combustion do not come into contact with it, except at the end. It is set in a material which will not burn very hard, such as a mixture of fireclay and ashes, so that when burnt out or broken, it may readily be drawn out from the front, without disturbing the brickwork of the furnace. Its mouth is closed by an iron cover. The retort chamber is constructed within a cylinder of iron plating; the lining, which is exposed to the fire, is built up of firebrick, and between it and the iron cylinder is a backing of sand or ashes. The upper or vertical retort is set in this chamber, and communicates with the horizontal retort at its lower end. A joint is made between the two sections with fireclay, with which a little finely-ground glass may be mixed, to make it burn more soundly. The vertical retort is supported near its upper end by a number of radial firebricks, made for the purpose. On the side next the chimney, these bricks are set with narrow spaces between them, the spaces gradually increasing in size as the opposite side is approached. This is done with the object of rendering the draught uniform. The vertical retort is furnished with a cylindrical iron head, which communicates with an ordinary condenser; the cover is made air-tight by means of a luting of whiting or other material. The sulphur is melted in a cast-iron pot, and is drawn off from the bottom by a pipe leading into the horizontal retort. The pot is set in amongst the filling material, and becomes sufficiently hot for the purpose intended.

In the conduct of operations, the vertical retort is first charged with large pieces of wood charcoal, of the ordinary quality, made red hot. The retort is heated to a full red-heat, and the melted sulphur is allowed to flow into the lower retort, which is kept free from charcoal as much as possible. The sulphur vapour passes up among the red-hot charcoal, and forms bisulphide of carbon, which passes in a gaseous form to the coolers, and is there condensed. The cover is removed every few hours, the charcoal is poked down, and fresh red-hot charcoal is introduced. The lower cover is removed only at long intervals, to permit the clearing away of the accumulated charcoal ashes. When either retort breaks or becomes worn out, the furnace is allowed to cool, the upper retort is lifted out, and entirely removed if necessary, and the lower one is drawn out at the front, should it be required. The new retorts are introduced in the same way, and, for the purpose of making the joint between them, the cover is removed; thus, on taking out only a few bricks of the lining—which are so placed as to come out readily—and some of the backing, free access is given to the interior of the retort chamber. By these arrangements, the cost of the repairs is very materially reduced, and the loss of heat, and consequent consumption of fuel in the manufacture, is considerably lessened.

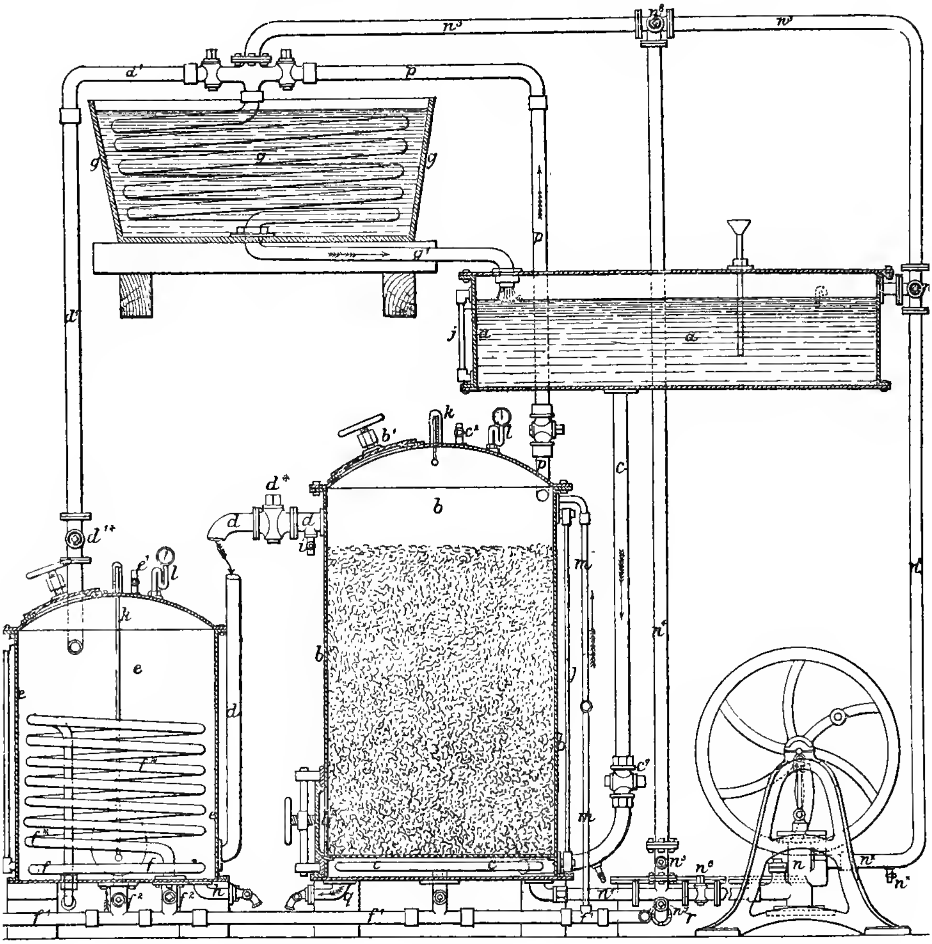
Uses.—The uses to which bisulphide of carbon is or may be applied are both numerous and important. The extreme degree of cold required to freeze it under ordinary conditions enables it to be used in thermometers for registering very low temperatures; and this property may be utilized for the production of ice, by directing a rapid current of air upon the liquid, which will then solidify the water as well as itself. The great actinism of its light has attracted the attention of photographers, and a special lamp has been invented for burning it in conjunction with deutoxide of nitrogen, to obtain a flame peculiarly applicable to photography. It is used for making chloride of carbon CCl_4, for purifying paraffin by Alcan's method, and for cleaning amorphous phosphorus. With perfectly pure bisulphide of carbon, the perfumes of the most delicate flowers have been separated, and even the odours of plants eaten by a cow have been recognized by treating her milk with it. For silver plating, a small quantity placed in the bath increases the brilliancy of the deposit. In the manufacture of yellow prussiate of potash, and of sulphocyanide of ammonium, it plays an important part. Its inflammable and explosive qualities are taken advantage of in making Phœnician fire, and a solution of phosphorus in bisulphide of carbon is employed for making matches, and for filling inflammatory rockets and shells. Its antiseptic properties admit of more than one useful application. Zöller has proved that, in an atmosphere containing a small quantity of bisulphide, animal and vegetable matters are effectually preserved against decomposition. A few drops will suffice, and, as it volatilizes at ordinary temperatures, no heat is required. Things may also be preserved for a very considerable time in closed vessels; upon opening them, the smell of bisulphide is very evident, but it soon evaporates. About 44 lb. of meat were perfectly preserved with 5 grms. of bisulphide for a period of four weeks, with the temperature never under 20° (68° F.), and often reaching 30°–33° (86° to 91° F.), and no unpleasant flavour was to be discovered. As a destroyer of insects in grain, its efficacy is unrivalled; not only does an exceedingly small quantity of it suffice to kill every living insect in the room where it is used, but it even destroys the germs of life contained in larvæ and eggs. In France, it has been used for years as a remedy against the *Phylloxera*, an insect that causes much destruction to the vines. It has been found that direct application of the preparation to the plants, while effective against the insects, causes the leaves to wither, though they remain on the branches. An ingenious remedy for this drawback is based upon the fact that, in treating oils with protochloride of sulphur in small proportions, they are transformed into a solid elastic condition resembling indiarubber, but transparent. If bisulphide of carbon be added at the same moment, it will be entrapped to the extent of 70 per cent., giving rise to a gelatinous substance having the appearance and consistence of quince jelly. This solid mass is difficult of ignition; it may be heated to 100° (212° F.) without giving a sign of fusion, and even at 160° (320° F.) forms only a black mass not easily inflammable. Though we have no vines in this country, we have other crops which are equally in need of some protection against the ravages of insects, and there is good reason to suppose that the potato disease and similar scourges may be combated as effectually as the phylloxera. Perhaps the greatest present demand for bisulphide of carbon is on account of its solvent powers. It is used by varnish makers; a solution of wax in CS_2 is employed for making wax paper, and a solution of indiarubber is used for a coating to maps. As a solvent of indiarubber, also, it is extensively used in the manufacture of vulcanized indiarubber; but Poincaré has found the structural lesions occasioned by the gradual action of the vapours of this compound on various animals so serious that, in his opinion, its use should be restricted to articles of real necessity. In extracting fat from bones, it is not much employed; and when used for removing grease from wool, the latter is left in a harsh and brittle condition, and of yellowish hue, due to the action of heat and bisulphide on the sulphurized constituents of the wool. The wool is not damaged by the bisulphide when applied in the cold; but the residual bisulphide adhering to the wool must be cleaned off by a current of hot air, steam, or hot water, which is certain to do the wool more or less injury. These considerations, as well as the cost of the bisulphide, render it incapable of competing with benzine for this purpose. In the extraction of oils from seeds, however, it is very extensively used, especially on the Continent. Colza and linseed principally are the seeds acted upon. They are first crushed to express some of the oil, and then dried by heating, before being subjected to the bisulphide treatment. Analyses show the residues to contain only 2 per cent. of oil, and 7 per cent. of water, whilst the residues from the ordinary pressure process gave 9 per cent. of oil, and 15 per cent. of water. The oil is also much improved in quality, the residue is still valuable for feeding cattle; and the workmen suffer no inconvenience. One works near Berlin, employing only six men, manufactures daily some 5600 lb. of oil good enough for lubricating machinery, using daily 15,400 lb. of bisulphide of carbon, of which about 60 lb. are lost. This loss of bisulphide, amounting to about 1 lb. for every 220 lb. of seed treated, is partly due to volatilization, and partly to its action on the metallic vessels. Copper vessels are rendered useless in a few years, iron less rapidly.

Even more important, from an economical point of view, are the services rendered by this substance in the recovery of valuable ingredients from what would otherwise be waste products. Thus, in the manufacture of fatty acids, brown compact deposits are produced; these, mixed with sawdust, and treated with bisulphide, yield up to 20 per cent. of the acids, which would in another case be lost. Again, the dirty mass of metal dust, grease, &c., from car and waggon axles, is first treated with warm dilute sulphuric acid, then with bisulphide, and then washed and dried, which isolates the grease in a saponified state. The cotton waste used in machinery is easily freed from grease, leaving both in a fit condition for re-use. The residues from beeswax manufacture, which formerly were only worth about 8*l.* per ton as manure, are now made to yield an excellent yellow wax by treatment with bisulphide. It is used for recovering oil from the refuse of cocoa manufacture. Bones treated with it at 40° (104° F.) yield 12 per cent. of grease, and are still fit for making animal charcoal. The cleanings of wool-cards, when acted upon by bisulphide, give about 30 per cent. of fatty substances, useful for the production of soap.

In Fig. 473, is seen a simple and inexpensive apparatus, in which bisulphide of carbon is used for dissolving out and extracting fatty matters from various waste substances; its construction and arrangement are such that the escape of the bisulphide is rendered practically impossible, and when the solvent has been separated, by distillation or otherwise, it can be used over again. The liquid bisulphide is placed in a strong closed tank, *a*, situated above and connecting with the vessel *b*, where the greasy substance to be operated upon is placed, and held at a short distance off the bottom, by a perforated false bottom, b^*. When the tank *a* is charged with bisulphide, and the close vessel *b* is filled with the greasy substance to be treated, the opening b' in the fixed cover must be secured, and it will only be necessary to open the tap c' on the pipe *c*, connecting the two vessels *a* and *b*, and the tap c^2 on the cover of *b* (for the escape of the atmospheric air), when this latter vessel will become filled with the liquid bisulphide. It is found desirable to leave the two bodies in contact for about twenty minutes, so as to ensure the perfect extraction of the grease. A further quantity of the bisulphide is then run from *a* into *b* under the false bottom. The greasy bisulphide is then discharged at the top through the pipe *d*, provided with a tap d^*, into another close vessel *e*, whose tap e' is first opened to allow the air to escape. When this vessel is nearly filled with the greasy bisulphide, the taps e' and d^* are closed, and the tap d'^* opened. Steam is then admitted from the steam pipe f', by opening the tap f^2, into the closed coil of pipe f^*, with which the interior of the vessel *e* is fitted. The heat of this steam will volatilize the bisulphide, and when this operation has been continued for a sufficient time, it may be desirable to finish the distilling by means of the coil of perforated pipe *f*, situated near the bottom of the vessel *e*, into which steam is admitted by the tap f^3, and allowed to bubble up through the greasy liquid. By this means, the whole of the volatile bisulphide is driven off from the fixed greasy matters, and the vapour, being conducted by the pipe d' to a condenser *g* above, is then reduced to a liquid state. It can then be run from the worm g' back again into the tank *a* for re-use. The greasy matters remaining at the bottom of the evaporating vessel *e* are then drawn off through a suitable pipe *h* for use. Taps, as at *i*, are for the purpose of drawing off and testing the liquid at various stages. All the vessels *a*, *b*, *e*, are provided with vertical glass gauges *j*, for the purpose of indicating the height of the liquid. Taps c^2 and e' allow of the escape of air, with which the vessels become filled during the operations, and which, if not liberated, would materially interfere with the efficient working of the apparatus. These several escape taps may be in connection with pipes, carried up through the building, for the purpose of leading away any noxious vapours. The vessels *b* and *e* are also provided with thermometers *k*, and pressure gauges *l*. In *b*, also, is a manhole b', through which it is charged, and another manhole b^2 at the lower part, through which the fibrous matters, when the grease has been extracted from them, are removed from the vessel. Similar manholes are likewise provided in e.

When the fibrous substances in b are freed from grease, the remaining bisulphide is driven off, by allowing steam from the steam pipe f' to be conducted by the branch steam-pipe m into the upper part of b, as shown. If sufficient pressure be used, the steam will force all the liquid bisulphide through the fibrous mass in the vessel, and up a vertical pipe n^4, the tap m^5 being opened for that purpose, and the two-way tap n^8 being turned so as to direct the liquid bisulphide by the horizontal pipe n^3 to the still g', or, if desired, to the tank a through the two-way tap n^9. By this mode of working, the steaming may be finished at one operation, with great economy of time and material. In some cases, however, it will be found convenient to use a pump n, which will draw the liquid through the pipe n^1 from the space below the perforated plate b^* (the tap n^6 being opened and the taps n^5, n^7, closed), and will force it up the pipe n^2 into the tank a above. The steam admitted to the upper part of the vessel b through the pipe m will percolate through the fibrous mass, and drive the liquid bisulphide into the space below the perforated plate b^*.

473.

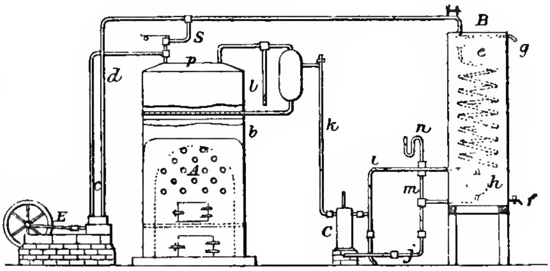


Before the fibrous substance is removed from the vessel b, an atmosphere of steam is driven through the mass from the perforated coil c. The bisulphide is volatilized by this means, and the vapour is conducted up the pipe p to the condensing vessel g, where it is reduced to a liquid state, and may then be run back again into the tank a. A small closed tank r is provided between the extractor b and the pump n, into which the bisulphide may be allowed to flow through the tap n^7, in case of accident to the extractor or pump. A draw-off tap n^* is provided at the bottom of the vertical pipe n^2, to empty it previous to taking the pump to pieces for inspection or repair. It will be seen that the pipe p communicates with the worm g' of the condenser, and that both it and the pipe *d'* are provided with a tap, for closing communication with the worm when required. The bisulphide may thus be used over and over again, and a large quantity of material be thoroughly cleansed from grease with very little waste of bisulphide, as none of the vessels are opened while there are any signs of the bisulphide being present. A running-off tap *q* is adapted to the bottom of the vessel *b*, for the purpose of letting out water or other liquid, used from time to time for cleansing the vessel. The tank *a* is provided with an overflow pipe, for withdrawing any excess of water resulting from the condensation of the steam used in vaporizing the bisulphide, and for blowing off the air which enters the apparatus during the operation of charging.

In the extraction of bitumen from schists, about 5 per cent. more product is obtained by treating with bisulphide of carbon than by the destructive distillation process, which, besides being very expensive, only yields about 8 per cent. altogether. For this purpose, the bisulphide is largely used in Galicia. In the same country, it is employed for extracting sulphur from a gypseous earth containing about 14½ per cent. of that mineral, with a loss of only about 1·66 per cent. of bisulphide. It is essential that the sulphur earth to be treated shall be perfectly dry, or the bisulphide cannot perform its duty.

The very low boiling point of bisulphide of carbon has caused engineers to turn their attention towards using it as a motive power. The Ellis bisulphide auxiliary for reducing the consumption of fuel for steam engines, is already well known in America at least. It can be fitted to all systems of steam engines, whether expanding or no, and requires no essential alteration in the construction; but lubrication must be effected with water, as grease would be dissolved. Our American cousins have gone yet another step in advance. Glycerine has no affinity for bisulphide of carbon, and is capable of mechanical evaporation in the presence of its vapour; it is a much better conductor of heat than water, and is capable of being heated to a certain degree with a less proportion of fuel, also of storing up caloric. When heated in a metal vessel, it becomes thin, and spreads over the surface, forming a protection and lubricator. The bisulphide is easily evaporated to a dense vapour, the latent heat absorbed for vaporization being about 280° F., that of steam about 1000° F., or a saving of 71 per cent. in the fuel. To utilize these substances in the creation of motive power, the apparatus shown in Fig. 474 has been constructed: A is a boiler; B, a condenser; C, a force-pump; D, a feeder; and E, the cylinder of an ordinary engine. To produce power, the boiler A is filled with glycerine, and heated to a temperature of 43°–260° (110°–500° F.); the valve *b* is opened, and a small quantity of bisulphide is run from D, through a perforated pipe *a*, into the boiler, and is thus brought into contact with the heated glycerine G, producing a pressure of vapour corresponding with the amount of bisulphide allowed to enter. The engine is now started by opening the inlet valve on the supply pipe *c*, and the vapour, after imparting its force in the cylinder, is discharged into the exhaust pipe *d*, which proceeds direct to the condenser B, when it passes through a series of worms, cooled by water flowing into the cistern *e* by the valve *f*, and out by the overflow *g*, and is thus condensed again into a liquid form, run down into the receiver *h*, and stored for future use. To regulate the flow of bisulphide so as to obtain a uniform quantity, the receiver *h* is connected by a double pipe *i j* with the force-pump C, and by the pipe *k* with the feeder D, so that the latter vessel, which holds a quantity of the material, is supplied as required, and regulates a steady flow by the valve *b*, independent of the action of the pump. To ascertain the contents of the feeder and receiver, two glass gauges are fixed at *l*, *m*. At *n* is a gauge for indicating the amount of vacuum produced by the condenser, and therefore useful to determine the necessary quantity of water by the inflowing valve *f*. The feeder D has a valve *p* and a pipe *o* at its upper part, direct to the top of the evaporator or boiler, so as to equalize the pressure and flow of the liquid bisulphide by the valve *b*, as before explained. To ensure against any loss of material through accidental excess of pressure, a safety valve is connected by a branch pipe *s* to the exhaust pipe *d*, the excess being then saved by passing direct to the condenser. The presence of air would partially prevent the condensation of the bisulphide, and cause a back pressure instead of a vacuum; therefore, before running in the bisulphide by the funnel *v*, or on starting for the first time, the air is exhausted as far as possible, by working the pump C by hand, closing the circuit by valves *b*, *p*, and opening *t*. During evaporation, the small portion of glycerine forced from the bulk proceeds with the vapour through all the pipes, &c., to the cylinder by which

474.



the power is utilized, and their gravity being nearly the same, the liquid bisulphide does not sink down or come in contact with the metal of the boiler, but is discharged as vapour from the surface of the bath of glycerine. This vapour may be utilized by any kind of engine, and may be led by the exhaust pipe direct to the condenser, for the purpose of extracting the latent and sensible heat, reconverting it for re-use.

Statistics and Cost of Manufacture, &c.—The principal seats of the manufacture of bisulphide of carbon in England are London (2), Ironbridge, and Manchester (1 each). Paris possesses 2 large works; Bordeaux, 1; and Marseilles, 3. There are several manufactories in Germany; and, in the Austrian dominious, 1 (in Galicia).

Though not exactly a newly established manufacture, it has only attained its present growth within recent times. It is constantly increasing, and will doubtless continue to do so, the more so as the valuable properties of the substance become generally known and appreciated. It is in the hands of a few who have made it a special study; there are probably not twenty manufactories of it in the whole world.

The capital required to carry on the manufacture is comparatively small, the great essential being skilful and careful management. The cost of production, as stated by Payen, is as follows:—

	£	*s.*	*d.*
Sulphur, 2200 lb.	8	6	8
Charcoal, 10 sacks (660 lb.)	1	13	4
Labour—4 men by day and 4 by night, with 2 to pound the sulphur	1	16	8
„ 4 children preparing the paper and 4 filling cartridges	0	10	0
Fuel—coke 110 bushels at 4*d.* per bushel	2	0	0
Cost of rectifying, cleaning, interruptions, and interest	1	13	4
	16	0	0
Deduct sulphur recovered, 330 lb.	1	5	0
Nett cost of about 15¾ cwt. of bisulphide of carbon	14	15	0
Sells at	16	5	0
Profit	£1	10	0

The differences between the theoretical and practical production are as follows:—

1. Charcoal: 1760 lb. of bisulphide obtained = about 278 lb. carbon; the 660 lb. of wood charcoal (excepting moisture and impurities) would represent a loss of 387 lb., or more than 50 per cent.

2. Sulphur: 1760 lb. of bisulphide = 1482 lb. sulphur + 330 lb. recovered = 1812 lb.; then the loss on 2200 lb. employed would be 388 lb., or 17½ per cent.

According to E. van Haecht, the cost of three days' working is:—

	£	*s.*	*d.*		£	*s.*	*d.*
Sulphur, 4189 lb.	12	7	0	Wood charcoal	1	18	0
Labour	2	0	0	Wear and tear	0	17	0
Coke	1	4	0		£18	6	0

The commercial value of the refined product, containing about ·001 to ·005 of impurities, principally an alliaceous oil, varies between about 20*l.* and 25*l.* a ton, according to the fluctuations in the prices current of sulphur. Greater purity than this is seldom required, but may be obtained at a rather higher price.

The quantity of bisulphide produced in the United Kingdom probably does not exceed about 1500 tons per annum. It is not imported, nor is it exported in any appreciable quantity. It is transported in drums of sheet iron, or small metallic canisters, of any desired size, which are closed by screw stoppers fitting with absolute exactness, so as to prevent any possibility of the vapour escaping. In this way, it may be sent any distance without danger. The chief consumers are indiarubber manufacturers and sulphur refiners, besides oil and fat refiners. The retail trade is very limited, and passes almost entirely through the hands of chemists and druggists.

(See Indiarubber Manufactures; Oils; Sulphur.)

CATGUT.

(Fr., *Corde de boyau*; Ger., *Katzendarm*, *Darmsaite*.)

The term "catgut" is applied to membranous substances prepared from animal intestines, generally those of sheep, more rarely those of horse, ass, and mule, but never those of the cat. Two methods of preparation are used, according to whether it is desired to produce twisted cord, or flat strips of membrane. In the former case, the first stage in the operation is the thorough cleansing of the intestines from the adherent feculent and fatty matters, after which the small ends are tied together, and placed over the edge of a tub, while their major portion is left for two days to soak in water, which is constantly changed. In this way, the peritoneal and mucous membranes are loosened. The bundle of intestines is then laid on a sloping board overhanging the tub, and their surface is scraped by a square steel edge, the external membrane being removed in breadths of about half the circumference of the intestine. This membrane, which the French call *filandre*, and which is employed for the cords of battledores and rackets, and also as a thread for sewing the ends of intestines together, cannot be removed by beginning at the large end. The scraped intestines are then steeped for one night in clean water, and next day are again scraped with a rounded edge; this process is called "curing." The large ends are now cut off, salted, and stored in covered tubs for sale to the sausage-makers. The small parts are again steeped for one night in fresh water, and next day are treated with an alkaline mixture, consisting of 4 oz. potash, 4 oz. carbonate potash, and 3 to 4 gall. water. After this, they are distributed to a number of women, each having two basins of the alkaline solution before her, and are drawn through a perforated brass thimble, pressed against the edge, for the purpose of rendering them smooth and equal. They are thus passed from one to the other of the two basins several times, and are then assorted according to their sizes.

In order to produce a cord—known as "whipcord"—from these intestines, they are sewn together by means of the *filandre* before mentioned, the joints being cut aslant to make them smoother and stronger. A number of these cords are then put into wooden frames, whose two uprights are furnished with a series of holes, containing pegs for securing the ends of the cords, and for passing the lengths round. The spinner attaches the end of one of the cords to the hook of a little whirling apparatus, similar to but smaller than the whirl of the rope-maker, which he causes to rotate rapidly by means of a handle. This puts a twist into the cord, and somewhat diminishes its length; the twist is retained by pegging the cord on to the frame. The others are then treated in this way, and when all are completed, the frames are piled up horizontally in a small close chamber lined with thin sheet lead, where they are subjected to the fumes of burning sulphur. This process is called "bleaching," but that is a misnomer, as the alkaline solution has already whitened the gut; the real object of the sulphuring is to prevent the putrefaction of any animal matter which may still be accidentally adhering. The cord may now be dyed black with common ink, or red with red ink, or green, taking the dye readily. The twist being completed, the cords are nicely smoothed, and then placed for an hour or so in a hot room—82°–93° (180°–200° F.)—which fixes and consolidates them. Lastly, they are cut off the frames and twisted into cords for sale.

The so-called "hatters' cords," for bowstrings, used in one of the stages of hat-making, are made of the longest and largest sheep guts, which, after being properly smoothed and cleaned with the alkaline solution, are twisted in lengths, 4, 6, 8, 10, or 12 together, according to the intended size of the cord, which is usually about 12 ft. long. This cord must be free from lumps and knots; when half dry, it is sulphured twice, and after each operation, is well stretched, twisted, and smoothed, and finally dried in a state of tension.

Clock-makers' cord must be very thin, strong, and durable, on which account it is made from very small intestines, or from larger ones slit up in the direction of their length, by a couple of razor blades fitted into a ball of wood, which serves as a guide. The wet gut, being drawn over the ball, is divided, and the two sections, if properly directed by the workman, fall into a basin beneath. This operation is one of considerable delicacy; but when well performed, the gut is divided, with great rapidity, into strips of perfect regularity. A number of these strips are twisted together, and treated as already described.

In France, a very strong cord is prepared from the intestines of the horse, ass, and mule. The gut, having been scraped, is divided into four equal parts, by skilfully drawing it over a fixed knob containing four sharp edges, or two semicircular blades arranged at right angles. Four, six, or eight of these strips are tied at the end with pack-thread, then twisted together, and polished with dog skin. The cord thus made is employed, as a substitute for leather belting, on light machinery.

The cords intended for the strings of musical instruments—violin, harp, guitar, &c.—require the greatest care in their preparation. The first scraping must be performed with great skill. A little alum is added to the alkaline solutions, which are made progressively stronger each day for four or five days till the membranes are well bleached and swollen. They are then passed several times through the thimble, spun, sulphured, polished by friction between horse-hair cords, and dried in the hot room. The best violin strings come from Naples and Milan, and are known as "Roman strings"; other Italian towns, where the industry is carried on, being Venice, Gubbio, Foligno, Bologna, Vicenza, Padua, Verona, and Bassano. Italy once enjoyed a monopoly of the manufacture, and, though strings are also made at Neu Kirsch, in Voigtland, in Bohemia, in the Tyrol, in Lyons, &c., the Italian strings still retain a superiority over all others. They are as clear and transparent as glass; but their chief distinctive features are combined elasticity and strength.

This is due to the leanness of the sheep, so that probably the Welsh, Highland, and South Down breeds of this country would give better strings than the Lincoln sheep. Emaciated carcases would also probably yield good strings.

About three-fourths of the whole quantity of catgut consumed in Europe is said to be derived from Italy. The best and largest bass-viol strings, and a very considerable proportion of the guitar strings, are made in Germany.

The manufacture of cord from the intestines of animals, for use in bows, and other weapons of war or the chase, has been practised from the earliest times; and its employment in musical instruments also dates from remote antiquity.

Until recently, no industry was more disgusting than that of gut-making, on account of the putrefactive odours generated by the steeping of the intestines; but the use of carbolic acid, and other deodorizers, in the liquors now prevents all smell, without in any way affecting the value of the product.

Silkworm-gut.—"Silkworm-gut," so-called, is the fine, strong fibre universally employed by anglers for attaching their hooks. It is obtained from silkworms, by taking them before they begin to spin, and very carefully pulling them asunder; the glutinous silk, contained in the *sericteria* or silk-glands, is then drawn into a single thread of variable length, from 1½ to 3 ft.; it is then gently dried. We annually import small quantities of it, chiefly from Italy. Hitherto, silkworms only have been employed for the purpose; but a plan has been set on foot to utilize the caterpillars which infest food plants. It is to be hoped that it will prove a practical success, as if the gut can be produced in long pieces, and at a moderate price, it will find numerous applications.

CELLULOID, PARKESINE, or XYLONITE. (Fr. and Ger., *Celluloïd.*)

"Celluloid" is decidedly the most convenient name for this product, as it is the one in general use. It consists virtually of vegetable fibre, treated with a mixture of nitric and sulphuric acids, and which, for want of a better term, may be called "pyroxyline," though it is not identical with that compound; this is dissolved in a suitable solvent, and afterwards dried. The product is a light yellowish-brown coloured body, which can be carved, planed, turned, sawn, stamped, or polished, and made either opaque or transparent. It may be made as hard as ivory, which it closely resembles, but is always elastic, and may be moulded into any form. It can be spread on textile fabrics, &c., and, by placing different-coloured layers alternately, and rolling them together while in a plastic condition, any desired marbled or granular effects may be produced. It is easily coloured any tint, and, as the colour permeates the whole mass, it is ineffaceable. It is plastic and malleable at 125° (257° F.), and decomposes suddenly, without taking fire, but with evolution of reddish fumes, at 140° (284° F.). It is non-explosive, and burns only when in direct contact with a flame. When pure, it is inodorous, and does not become electric by friction. An important property is that it can be united by means of its own solvent or cement; and no waste is entailed in its use, as all scraps can be worked up again.

The manufacture may be divided into two distinct stages: 1. The production of the so-called "pyroxyline"; 2. The treatment of this compound with solvents, in order to make it plastic, and give it other desired qualities. The first stage of the process suffers but little variation. A convenient quantity of cellulose or woody fibre, such as disintegrated cotton waste, paper, &c., is fed into an open vessel called a "converter," and treated with an acid mixture composed of 1 part of nitric acid, sp. gr. 1·420 and 4 to 5 parts of sulphuric acid, sp. gr. 1·845, mixed in a separate vessel, and kept as cool as possible. The acid mixture is pumped or forced up into the converter, while the fibrous substance, previously placed in a hopper over the converter, falls gradually into it by an opening in the top. The charging of the cotton into the converter occupies about ten minutes, and at the end of twenty to thirty minutes at most, it is chemically converted into the so-called pyroxyline, or nitro-cellulose. This, together with the excess of acids adhering, is then allowed to fall through an opening in the bottom of the converter, and is caught in a large box provided with a false bottom of perforated iron, or wire gauze, at about 6 in. above the real bottom. On this, the wet mass remains for an hour, to admit of the excess of acids draining away as far as possible; the still remaining impregnations of acid are then expressed by placing the pyroxyline in a cylinder with a perforated bottom, and subjecting it to hydraulic pressure. The result is a hard cylinder of pyroxyline, containing about 5 to 20 per cent. of the acid mixture, in which state it is stored for future use. When required, the cylinders of pyroxyline are torn into dust by special machinery, such as that employed for grinding paper pulp, and the disintegrated mass falls into a large tank, where it is well washed with water, to remove the last traces of acid. It is then again placed in the cylinders with perforated bottoms, and pressed to remove the water, leaving in only 5 to 20 per cent. The solid cylinders of soluble pyroxyline are again broken up in the disintegrating machine, preparatory for the treatment with solvents, which forms the second stage of the manufacture.

This is performed in a variety of ways, chiefly according to the ulterior applications for which the product is intended, and differing less in the apparatus employed than in the ingredients and proportions of the dissolving agents.

One of the first solvents employed on a large scale was wood naphtha, distilled with chloride of lime, in the proportion of 1 gallon of the naphtha to 2 to 6 lb. of fused chloride; the more of the latter used within these limits, the stronger will the solvent be. The first 3 quarts of the distillate are collected for use; the remainder is caught in a separate vessel so long as any spirit comes over, and is distilled again at the next operation with more fresh materials. The deposit remaining behind in the still is chloride of lime, dissolved in water, and contaminated with some tarry matter. It is run into an open iron vessel, heated by a fire beneath, to evaporate away the water, and fuse the chloride of lime ready for re-use.

The solvent thus prepared is applied to the pyroxyline, in such proportions as to make a pasty mass; but if used alone, the resulting celluloid would soon become hard and brittle. To avoid this, a certain quantity of oil is added to the mass, and kneaded up with it in the mixing machine. The proportion of oil will vary with the desired degree of toughness. To produce a consistency suitable for coating telegraph wires, or for spreading on textile fabrics, the proportion of oil may equal half the weight of the pyroxyline. If the oil used be first treated with chloride of sulphur, the compound is much more elastic. It is thus treated by mixing with 2 to 10 per cent. of liquid chloride of sulphur, according to the degree of elasticity required; but the chloride of sulphur should first be diluted with an equal bulk or more of mineral naphtha, or bisulphide of carbon, to prevent too violent action. The prepared oil is compounded with the dissolved pyroxyline, in various proportions, but seldom exceeds 20 per cent.

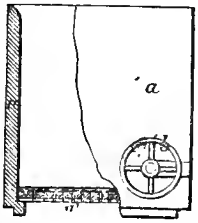
To increase the hardness and modify the colour of the product, sometimes a small portion of gum or resin, such as shellac or copal, is added, but seldom more than 5 per cent. The wood naphtha may be replaced by alcohol, and the chloride of lime by chloride of zinc, or manganese fused or dry. For economy sake, a small quantity of light spirits from coal may be mixed with the solvent, but it is not preferable. For the oil, may be substituted gum ballata, treated with chloride of sulphur—usually not more than 5 per cent. of the chloride. The combustibility of celluloid thus made may be corrected by the addition of chloride of zinc, or tungstate of soda. Ten per cent. of either effectually prevents burning; but usually much less will do, especially when pigments are used. The same end is attained by employing iodide of cadmium, oxalate of zinc or manganese, or gelatine dissolved in glacial acetic acid.

A practical difficulty attending the use of the above process is that the solvents employed are so volatile. Large masses of celluloid may be prepared better, quicker, and with less consumption of solvent by adopting nitro-benzol, aniline, or glacial acetic acid, and the celluloid may then be worked in the open air. The ordinary volatile solvents are improved by the addition of camphor.

When using nitro-benzol, the commercial article should be distilled off hydrochloric acid or chloride of lime, say 6 lb. of either to 1 gall. of nitro-benzol, which is thus rendered purer and sweeter. One hundred parts of pyroxyline are then moistened with ordinary solvent—preferably naphtha distilled off chloride of lime—and the excess of solvent is removed by hydraulic pressure. The other solvent is then added, in the proportion of 10–50 parts of prepared nitro-benzol or aniline, together with 10 to 50 parts of camphor, and 150 to 200 parts of oil, preferably cotton-seed or castor. This mixture is formed between rolls, heated by steam being admitted into them, till the whole forms a well-combined dough or paste, which will be more or less stiff, according to the quantity of solvent used. For a hard compound, the oil should be less than the pyroxyline; for a soft one, it should exceed the latter—say, 150–200 oil to 100 pyroxyline. In making celluloid with glacial acetic acid, 100 parts of pyroxyline are dissolved in 50 parts of the acid, for a stiff paste; or 100 to 300 or more parts, for a semi-fluid consistency.

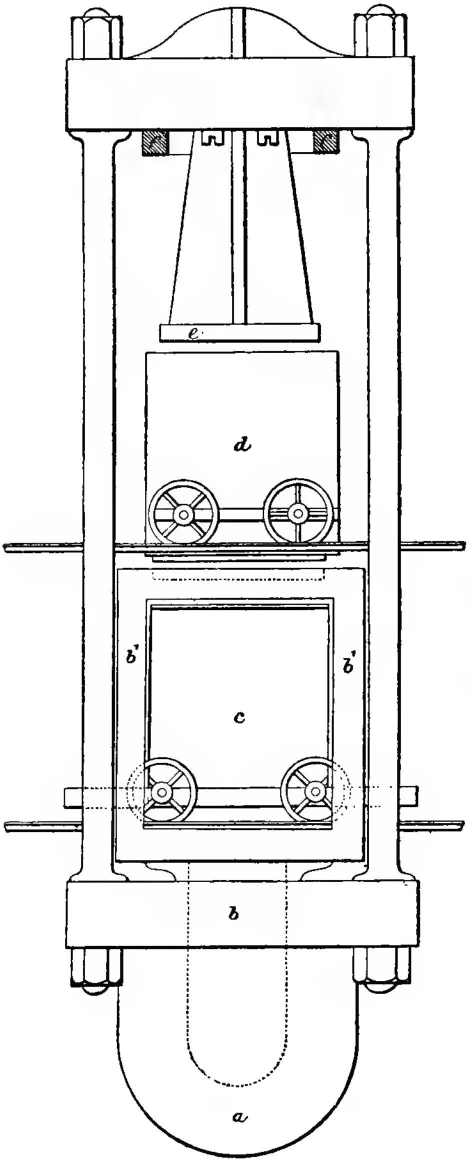
Usually the pyroxyline requires to be dried before dissolving it. The conduct of this operation on large quantities requires much care and time, and a very large space of drying room, so that great advantages, on the score of cost, ease, and safety, are to be derived from dissolving it in a moist state. For this purpose, the pyroxyline is prepared in the usual way, and when rendered soluble by the addition of hydrocarbon solvents, it is taken out of the acids and placed in a hydraulic machine, by which as much as possible of the acid is expressed. The cake of pyroxyline is then taken out of the press, opened out, put into a centrifugal washing machine, and washed with water until clean; then the rotation of the machine is continued, to throw out the surplus water. Or the pyroxyline, after conversion, may be placed in the centrifugal machine, and there deprived of the acids, and, without removal, be thoroughly washed, by admitting a copious supply of water, the operation occupying from a few minutes to an hour. When the pyroxyline does not contain more than 5 to 10 per cent. of water, it is dry enough for solution in naphtha, &c.

475.



Another improvement consists in mixing the pyroxyline and solvent, and combining the solution with oils and other matters, in a cylindrical vessel provided with a strainer or filter at the lower end, through which the materials are made to pass when sufficiently mixed and dissolved. Fig. 475 shows a side view, partly in section, of such a vessel. A strong cylindrical vessel *a* is mounted on wheels *b* suitable for running on a light tramway, and fitted with a metallic bottom *a′* perforated with small holes and covered with fine wire gauze. The moist pyroxyline is first mixed roughly with the solvent and other liquid with which it is compounded, and the whole is placed in *a*. When there, the materials are thoroughly mixed and beaten together, by means of a mechanical heater; this being completed, the mixing vessel is run into the press shown in side view in Fig. 476:—*a* is the cylinder of the press; *b*, the ram, on the head of which is a frame *b′*, and within it enters the receiving can *c*. When the ram rises, it receives the lower end of the mixing vessel *d* into a corresponding socket formed in it; thus the mixing vessel is lifted to the piston *e*, which comes down upon the material in the former, and forces the whole of its contents, with the exception of the impurities, to pass through the perforated bottom into the receiving can *c*; *f* is a projecting ring on the press head to prevent the ram rising too high.

476.



477.

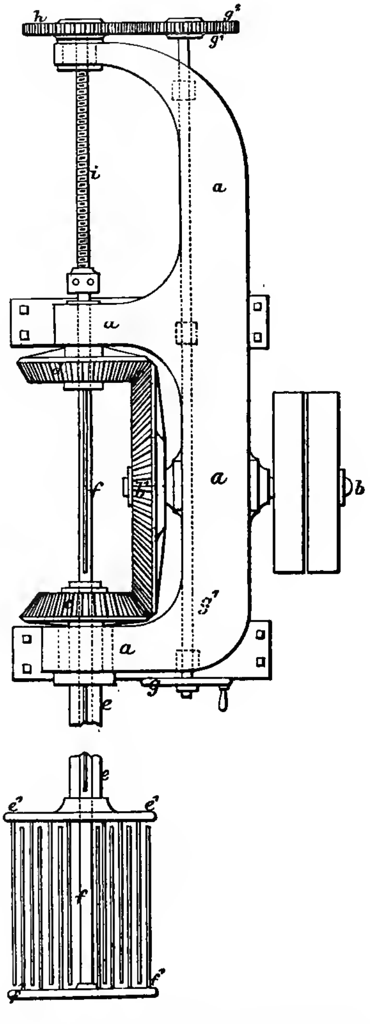
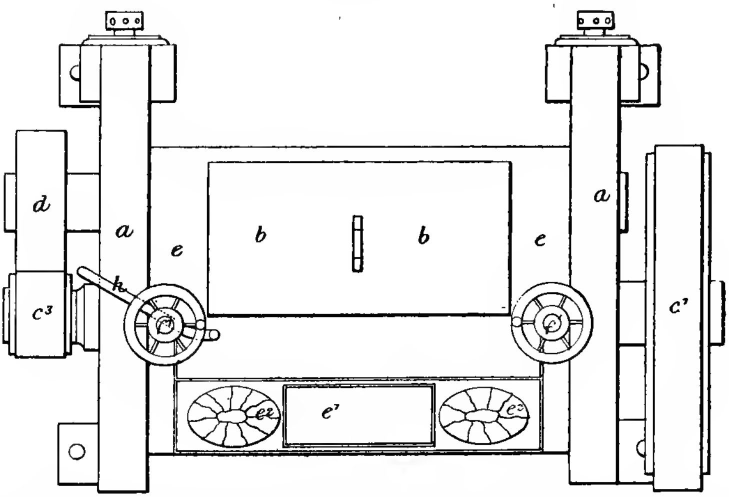


Fig. 477 is a side view of another mixing apparatus:—*a a* is the frame of the apparatus; on it is mounted the axis *b*, which receives motion from a driving strap; *b′* is a bevelled wheel, driving two bevelled pinions *c* and *d*, mounted on tubular axes, turning in bearings on the frame. Within the axis of the wheel *c*, is another tubular axis *e*, caused to revolve with it by means of a groove and feather, and able to slide up and down vertically, through the axis of the wheel *c*; *e′ e′* is a frame of beating bars fixed at the lower end of the axis *e*, and rotating with it; *f* is another axis passing in a similar way through the axis *e*, turning within it, and capable of sliding up and down within it; this axis passes down through the axis *c*, and carries, at its lower end, the frame of beating bars *f′ f′*, which bars pass between the bars of the other frame *e′* as they revolve in opposite directions. The axes *e* and *f* are raised and lowered, so as to lift them out of the mixing vessel, or lower them down into it, by means of the hand wheel *g* mounted on the axis *g′*; *g″* is a spur wheel at the upper end of the axis *g′*; it drives another wheel *h*, mounted on a hollow axis carried by the frame. This axis has a screw thread cut in it corresponding with the screw *i*, which works within it; the lower end of the screw embraces the head of the axis *f* so as to cause it to rise and fall with it, but at the same time allowing it to rotate freely. In a similar way, the axis *e* at its upper end is made to embrace a collar on the axis *f*, so that when the screw *i* rises or falls, the axes *e* and *f* with the beating frames upon them go with it. This machine is also very useful in mixing castor or other oil with chloride of sulphur, to produce a compound to be afterwards mixed with the preparation of pyroxyline.

According to another plan, the pyroxyline, having been dissolved and mixed with the other ingredients, is kneaded, and the excess of solvent and moisture is evaporated in an apparatus of the following description. The mixture is put into a box provided with an air-tight cover, and containing a pair of rollers, which receive a rotary motion by suitable gearing on the outside. The axles of the rollers enter the end of the box by air-tight joints; they are hollow, and are arranged to admit of the passage of steam or other fluid for heating the rollers. To this box or vessel there is a pipe attached, to convey off the vapour of the solvent. In order to induce the passage of vapour from the box, a fan or exhausting apparatus is applied, which keeps up a partial vacuum, not only in the box, but also in the reservoirs containing the solvent, and in other parts of the apparatus connected with it. The vapour passing off from the box is first conveyed into a chamber in which there is a perforated partition, whereon chloride of calcium is placed; through this the vapour rises, and any water is thus separated from the vapour of the solvent, which passes away from the cylinder to a condenser. The vapour of the solvent, on being condensed, passes into a reservoir.

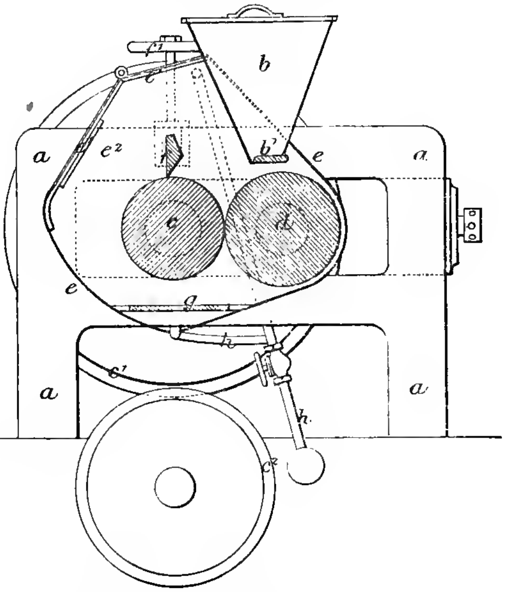
Fig. 478 is a plan, Fig. 479 a transverse section, and Fig. 480 a front view of the kneading apparatus:—*a* is the frame; on it is mounted a hopper *b*, into which the material is placed as it comes from the press; at the bottom of the hopper is a valve *b′*, which can be opened by hand when desired, to allow material to descend from the hopper to the rollers *c* and *d*, which are made hollow and heated with steam internally; the roller *c* is driven by the spur wheels *c′* and *c″*, the latter of which is fixed on a main driving shaft; *c‴* is a pinion at the further end of the roller *c*; it gears with a pinion *d′* of larger size on the end of the roller *d*, so that the rollers *c* and *d* are driven at different speeds, and have consequently a grinding action on the material passed between them; *e* is a casing surrounding the rollers; it is furnished with suitable doors, and is glazed at *e′ e′*, so

478.



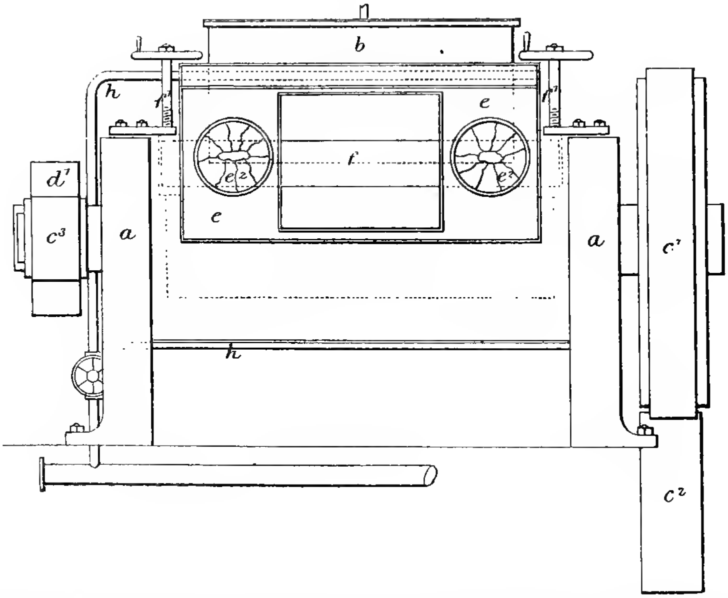
that the workman may readily see what is going on within; e'' e'' are apertures furnished with sleeves to allow the workman to introduce his arms within the casing *e* without causing any material escape of solvent vapour; *f f* is a collecting knife, set up to the surface of the roller *c* by the adjusting screws $f'f'$. The workman continually takes the material as it collects behind this knife, and passes it again between the rollers; he also collects the material from the table *g* beneath the rollers, and passes it repeatedly through the rollers, until it is thoroughly blended, and the solvent is sufficiently evaporated to bring it to the required consistence; *h* is a pipe leading from the top and bottom of the casing, to conduct away any solvent or vapour of solvent which escapes from the mixture, to a cylinder containing chloride of calcium, and thence to a condensing apparatus. A fan maintains a partial vacuum in the casing, drying cylinder, and condenser, and so draws the vapour through the apparatus. The chloride of calcium cylinder separates the vapour of water which results from the moisture in the pyroxyline, and the condenser retains the solvent and delivers it back into a suitable tank.

479.



Instead of evaporating the solvent used in making the celluloid, it may be removed by precipitating the pyroxyline by means of water, mineral naphtha, &c. There is thus obtained a semi-solid mass, containing a small quantity of the solvent, which is passed through grinding rolls or other disintegrating machinery, and then worked up as usual. The celluloid is placed in a vessel containing a revolving agitator or beater, together with water or mineral naphtha in the proportion of

480.



1 lb. of celluloid to 1 qrt. of liquid, and the agitator is set in motion. After a short time, the celluloid is let out in a curd-like form, and submitted to pressure (not excessive), to separate the liquid. It is convenient to place it in a vessel of cylindrical form, and about 12 in. in diameter, provided with a movable and perforated bottom, covered with several layers of wire gauze. This is filled with the curd-like celluloid, upon which a plunger is forced down, and a cheese-like block is produced. This is rolled down between rollers heated by steam, as already described, and any pigment, &c., is worked in by them at the same time, the mixture being passed through and through till perfected.

The solvent used is preferably mineral naphtha, as free from smell as possible. The solvent taken up by the liquid is recovered by distillation, if water has been used; but in the case of naphtha, the greater part will separate on standing, and may then be decanted off.

In order to make celluloid in imitation of pearl, fish-scales are mixed with the dissolved pyroxyline, and a pearly-lustrous material is thus produced. To form a thin veneer of artificial pearl, one part of this material is mixed with 100 parts of pyroxyline. The latter is first ground with a solvent and oil to a doughy consistency, the pearly compound is then added, the solvent is separated, and the celluloid is worked up in the ordinary way. But when the celluloid is required in a semi-fluid condition, the solvent must be increased instead of removed, and a much larger proportion of the pearly material will be needed. The best lustre produced is that made in France, from the scales of the whiting. In producing a coloured celluloid, preference should always be given to dyes—especially aniline—rather than pigments. The brightest and most delicate colours may be imparted.

To manufacture celluloid so as to resemble ivory, the following plan is adopted. The celluloid is made without any colouring matter, and is kept as clean and white as possible; when in a dough-like state, it is rolled into sheets $\frac{1}{16}$ in. thick. Meantime another celluloid is prepared, containing carbonate of strontia in the proportion of one part to about 200 parts of pyroxyline, and this also is rolled into sheets. These sheets are placed alternately one over another to produce any desired grain. A good plan is to lay a transparent and an opaque sheet one over the other, and roll them up together, then take the roll and twist it, pass it through heated rollers and roll it down into a slab, for cutting knife handles or whatever may be required.

In working white or light-coloured celluloids, or those in imitation of pearl or ivory, it is necessary that porcelain or glass vessels should be used in its manufacture as far as possible, and the rollers through which it is passed must be covered with platinum, as other metals are acted upon by the celluloid. A coating of platinum $\frac{1}{16}$ in. thick will be very durable.

For producing a white celluloid, without unduly increasing its specific gravity, the dissolved pyroxyline and other ingredients are mixed with white starch, either from wheat, rice, potatoes, &c., or with arrowroot, tapioca, or other amylaceous substance, or with wheat flour, or with cotton, ground and bleached.

To remove the solvent remaining in the celluloid, which imparts a slight odour to articles made of it, and renders them liable to shrink in course of time, such articles are seasoned while in a partially manufactured state, by soaking them in a liquid which will dissolve out the solvent without affecting the pyroxyline, such as bisulphide of carbon, chloride of lime, or benzol. The articles so soaked are afterwards placed in a vessel from which the air is exhausted, and the curing liquid is thus drawn out, condensed, and recovered.

The process employed for making billiard balls is as follows. To 100 parts of pyroxyline, dissolved, ground, and strained as usual, are added 300 to 500 parts of the usual solvent—alcohol 100 parts, naphtha 50 parts; 100 to 150 parts of arrowroot or starch; and 50 to 100 parts of the best zinc-white. The solid matters are added to the plastic solution of the pyroxyline, and the whole is placed in a closed rolling or grinding apparatus, the rollers being heated by steam as described, and the compound is ground up till most of the solvent is driven off. The latter is recovered by conveying it through pipes to a Liebig's condenser. The mass is now about as stiff as clay, and may be moulded or rolled, and placed in a warm place for seasoning. When well seasoned, the ball may be turned. When less specific gravity is required, it is best to employ as much amylaceous substances as possible, they being lighter than the zinc. Ground and bleached cotton fibre may be ground up with the plastic pyroxyline, in the proportion of 100 parts disintegrated cotton to 300 parts pyroxyline paste. When making coloured celluloid with amylaceous substances or cotton, the colours should be added at the same time, and ground up with the other ingredients.

Since the Paris Exhibition of 1868, where Parkes obtained a prize medal for his show of articles manufactured from celluloid, and where the substance was first named Parkesine, the Americans have made considerable advance in the manufacture. A modification worth mentioning consists in employing camphor as the solvent of the pyroxyline. The latter is first reduced to a fine pulp, by grinding it in water in a machine such as is used for grinding paper pulp, and to the pulp thus prepared, pulverized camphor gum is added, in the proportion of one part by weight of camphor to two parts pyroxyline when dry. At the same time, is added any desired material for colouring the celluloid, or modifying its specific gravity. The camphor is comminuted by grinding in water, trituration, or solution and precipitation. The camphorated mass is placed in a mould, and heated to a sufficient temperature to liquefy or vaporize the solvent, and is then subjected to heavy pressure. The temperature should never exceed 149° (300° F.), or the pulp in contact with the mould will become charred; sometimes 66° (150° F.) suffices. The mixture should remain in the mould under heat and pressure till the conversion of the pyroxyline is completed; it is then left to cool under pressure in the mould. When first taken out, it has the consistency of sole leather; but is easily softened by heat till the camphor has evaporated, when it grows as hard as horn.

For dental purposes, the transformation of the pyroxyline is effected by camphor, and without the use of fixed oils or fusible non-solvent gums, which are required to be combined with the material when ether, alcohol, &c., are used, and which would impair the strength, durability, purity, and firmness of texture essential in dental plates. Fifty parts at least by weight of camphor are added to one hundred parts of soluble pyroxyline; more camphor makes the compound more plastic. The plates formed are placed in a drying room heated to 65°–82° (150°–180° F.), the latter being the maximum, to drive off the camphor. A temperature above 93° (200° F.) will expand the material, and make it porous and brittle. It is said that this compound is lighter and stronger than dental vulcanite or indiarubber; its colour is the same as the natural gum, and is unchangeable; it has no unpleasant taste; it is absolutely non-injurious, and never shrinks or warps after setting.

The following process is adopted in practice to dissolve the pyroxyline in camphor, eliminate the solvent, and form a solid mass of celluloid at one operation. The prepared mixture of soluble pyroxyline and camphor is first dried, by compressing the moist, pulpy compound into convenient sized cakes, about ¼ in. to ½ in. thick, and arranging them in a pile with intermediate layers of paper, or other absorbent material, and subjecting the pile to pressure in a hydraulic press. By this means, the material is uniformly and sufficiently deprived of its moisture, while the compression of the material and exclusion of the air prevent all danger of ignition when exposed to the sun or the heated air of a drying room. The mixture of pyroxyline and camphor is subjected to pressure by means of a plunger in a heated cylinder provided with a discharge nozzle or pipe, the cylinder being of sufficient length to cause the conversion of the pyroxyline to take place while the material is being gradually forced through it, so that by replenishing it as it becomes partially empty, a gradual discharge of the celluloid is effected, in the form of a continuous bar or sheet as desired. The cylinder is unequally heated, in such a manner that the mixed material will first be compacted in the colder portion, before the solvent is melted and the process of transformation commences. The air is thus allowed to escape more freely, and is more completely expelled, while the conversion of the pyroxyline is effected in another and hotter portion of the cylinder, as the mass is forced through it. The upper or receiving end of the cylinder is cooled by being surrounded by a cold-water jacket; and the lower or discharging end is heated by a steam or hot-water jacket. The former is supplied by the escape pipe of the hydraulic engine. In the discharge end of the converting cylinder, is a central heating and distributing case, constructed with radial pins or projections, by which the material, before it escapes from the cylinder, is caused to pass through the annular space around the central core, and in contact with the heated surface of the cylinder, while the spurs or pins divide and mix the material, and at the same time serve to conduct the heat from the cylinder to the central core. The discharge pipe is passed through an equalizing warm-water vessel, which keeps it sufficiently warm to prevent the material in contact with the inner surface cooling faster than the central portion, as the unequal cooling, and consequent unequal consistency, of the different portions of the material would cause the central and softer portion to move faster than the outer and harder portion, thus destroying the homogeneity of the mass, and rendering the surface rough and broken.

The soluble pyroxyline is first comminuted in a wet condition, and the excess of water is pressed out. The camphor and colours, as required, are then thoroughly incorporated with it by the mixing rollers. The compound, thus prepared, is formed into cakes by means of a mould and follower, the bottom of the mould being made separate, and serving to transfer the formed cake to the pile. These cakes are preferably made about 12 in. square, and ¼ to ½ in. thick; it would be difficult to properly absorb the moisture from thicker cakes. These are laid up in a pile with layers of blotting-paper between them, and are then placed in a hydraulic press to remove the water as far as necessary. During this process, the compound is protected from the air, to prevent evaporation of the camphor, and to avoid the chance of ignition. The rapidity with which this drying is effected ensures great saving of time and space. The dried material is ready for conversion into celluloid, for which purpose, it is transferred, with the solvent, to the converting cylinder. The heat from the steam-jacket surrounding the lower portion of this cylinder brings about the conversion of the pyroxyline to a homogeneous mass of celluloid, which is then forced through a discharge nozzle, constructed according to the desired form of the product, e.g. in bars or sheets, or directly into a mould of the article to be manufactured.

The use of various solvents and combinations of solvent materials has been attempted or proposed; e.g. a mixture of camphor and oils in about the following proportions, viz.:—

Camphor, camphor oil, or liquid camphor	20	parts by weight.
Oil, such as castor or linseed, before or after boiling ..	40	,, ,,
Pyroxyline (soluble)	40	,, ,,

These will give a consistency suitable for covering telegraph wires, or for moulding or spreading. For material with greater or less flexibility, or greater or less fluidity, the proportion or character of the oil must be changed. In producing very hard or rigid material, it is preferable to use oils which will themselves harden by exposure to air, as those which have been boiled. Camphor may also be used in about equal proportions with hydrocarbons having a boiling-point at 104°–204° (220°–400° F.); or with alcohol or spirits of wine; or hydrocarbons in equal proportions with alcohol; or castor oil in equal proportions with alcohol; or a distillate of a mixture of camphor oil and hydrocarbons, or of camphor and bisulphide of carbon in conjunction with alcohol; or aldehyde, either alone or with alcohol. Either of these solvents may be employed with the other ingredients in about the following proportions, to produce a semi-fluid celluloid:—

Pyroxyline (soluble)	27	parts by weight.
Castor oil	27	,, ,,
Camphor	6	,, ,,
Either of the foregoing solvents	40	,, ,,

The consistency will depend chiefly on the proportions of the oil, as before.

The most recent and valuable improvements in the manufacture of celluloid, for all manner of purposes, will be found in two patents (Nos. 1865 and 1866) taken out, in May last, by Henry Parkes, a relative of the first European discoverer of the substance.

Uses.—It is only fair to premise that, in the following sketch of some of the applications of celluloid, no pretence is made to exhaust the list. It possesses such a combination of valuable properties that its sphere of usefulness must of necessity be enlarged, as the article becomes more generally known and appreciated, and as further steps are made in the direction of controlling its rather combustible tendencies under climatic changes. Nevertheless, it will be seen from the sequel that it has already attained a high degree of importance. It is superior to ivory on the score of durability, as it sustains hard blows without injury, and never loses its colour. One whole company in the United States employ it exclusively for organ and piano keys, and its consumption for that and similar purposes has assumed such proportions that ivory is much reduced in price in consequence. Billiard balls can be made from it at half the cost of ivory, while possessing equal elasticity and greater durability. It is extensively employed for making combs, brush backs (see Brushes), and various other toilet things wherein ivory has hitherto been used. For small-tooth combs, the cost is 25 per cent. less than ivory, and in large pieces, the difference is enormous. It effectually displaces ivory, too, in harness trimmings, foot-rules, chessmen, and handles of various kinds, especially knife and fork handles, for which purposes it is admirably adapted, as it neither cracks nor becomes discoloured by hot water. Indiarubber generally holds its own in competition with celluloid, on account of the relative prices; but the latter is much more durable, and is superior for pencil-cases, jewellery, &c., where gold mountings are used, as it does not tarnish the metal, whereas the sulphur in indiarubber tarnishes all gold under 18 carat. This freedom from sulphur, and the readiness with which it takes a natural flesh-tint, have caused celluloid to be used for dental blanks or gum, and other attachments of artificial teeth, in lieu of vulcanized indiarubber. It can be mottled to imitate the finest tortoiseshell, and its elasticity renders it less liable to fracture. In this form, it is much used for combs, card and cigar cases, match-boxes, pocket-books, napkin-rings, and all sorts of fancy articles. It can be made to resemble malachite and amber equally well, and is very suitable for the mouth-pieces of pipes, cigar-holders, flutes, flageolets, &c. For drum-heads, too, it is better than parchment, as it is not affected by moisture. It replaces porcelain in the manufacture of dolls' heads, which are practically unbreakable. Coral of all shades can be copied exactly, but dark or bright red, and not the rare and costly delicate pink shade, are mostly in demand. For optical goods, such as the frames of spectacles, eye and opera-glasses, it competes successfully with jet, tortoiseshell, &c.; and for photographic purposes, it is superior to ivory. It is used for shoe-tips instead of metal, and has the appearance of patent leather; it is also employed in in-soles. Many thimbles are made of it; and it is said to be the best material known for emery-wheels and knife-sharpeners. Within this last eighteen months or so, a new demand has arisen for the substance, as a substitute for linen or paper in shirt-fronts, cuffs, and collars. It looks like well-starched linen, is sufficiently light and flexible, does not wrinkle, is not affected by perspiration, and can be worn for months without injury. It soils less readily than linen, and, when dirty, is quickly cleaned with a little soap and water on a flannel. A more recent improvement consists in placing real linen between two sheets of celluloid. It has also been tried for neckties. For hatbands and hat sweat-bands, it is dearer than the articles in present use; but it is much superior, as it does not become rusty or greasy.

As yet the seats of manufacture are exceedingly few, principally owing to the fact that almost all the details of the manufacture are the subjects of patents, which are the property of only one or two individuals. All the celluloid produced in the United States, where the manufacture and application of the substance have received the greatest impulse, is turned out by one firm at Newark, in New Jersey. There is one works in France, at Staines, on the Seine, but beyond that there is none in Europe. A company instituted in England failed through constitutional defects, and a works started by a Hanover firm was abandoned because of the explosive nature of the material. If greater energy be not soon displayed in England, we shall probably become importers of the substance, first discovered and manufactured in our own country, by A. Parkes, so long ago as 1855. Though the invention is thus of no recent date, the manufacture has only been developed within the last few years.

The commercial price of the article in France is 8 francs per kilo. (about 2*s.* 10*d.* per lb.) for the raw product, and variable for coloured sorts. In America it sells at 2 dollars (8*s.* 4*d.*) per lb. for making umbrella handles, &c., while the same substance is charged at 4 to 5 dollars to jewellers, the price being adjusted according to the competition experienced from the various substitutes.

The American firm is concerned only with the manufacture of the raw material, which it supplies in blocks to the consumers, who have to prepare it according to their special needs. It is said to be exported largely to Cuba and South America.

Vulcanized Fibre.—Under the name of "Vulcanized Fibre," an American firm, whose works are at Wilmington, are producing a material much resembling celluloid in its origin and applications. It is prepared from a thick, spongy, reddish-brown paper, specially made for the purpose, which, when acted upon by certain chemicals, loses its original character, and is transformed into a homogeneous mass of almost metallic hardness. The material emerges from the process of manufacture in large flat sheets, which are made up into a long list of articles, principally for railway use, as fish-bolt washers, oil-box covers, "dust-guards," &c., &c. The company, it is said, sells nearly a quarter of a million track-bolt washers a month. An important application of the substance is for the manufacture of condense-pipes for steamers; exposure to the action of salt water, and alterations of temperature, do not seem to affect it in any way. From the scraps left in cutting large articles, carriage-washers are made. Roving-cans, used in cotton-mills, and formerly made of tin, are now made of this material. As yet, it has not been largely applied to making ornamental articles; but its finish makes it well suited to such purposes. It cannot be moulded, but may be sawn, cut, or turned; is capable of receiving various colours, and is used in both the polished and unpolished state.

(See Brushes; Buttons; Ivory; Nuts.)

CEMENTS. (Fr., *Ciment*; Ger., *Cement.*)

A cement is a substance, which, on being applied to the surfaces of two bodies, causes them to adhere strongly, when brought into contact. For the purposes of easy reference, a system of classification will be adopted in dealing with this subject, the subdivisions being Calcareous cements, Gelatinous cements, Glutinous cements, Resinous cementing compounds, and Non-resinous cementing compounds. These will be followed by a number of compositions often erroneously termed cements, but more properly designated Lutes.

Calcareous Cements.—Though comparatively few in number, these are by far the most important cements. Their ingredients are all obtained from the mineral kingdom, and their efficacy depends chiefly upon the treatment of the raw materials, and the proportions of their admixture. The principal varieties are the following:—

Mortar.—Mortar is composed of two essential ingredients, lime and sand, which are intimately mixed, in a fine state, by the agency of water. The sources of lime, in this country, are very abundant. It is obtained from the crystalline marbles of the Metamorphic system; from the coralline and shelly beds of the Silurian; from the cornstones of the Old Red Sandstone; from the coralline and shelly marbles of the Devonian; from the coralline, encrinal, shelly, and fresh-water beds of the Carboniferous; from the dolomites of the Permian; from the muschelkalks and gypsums of the Trias; from the oolites of the Jurassic; from the shelly bands of the Wealden; from the chalks of the Cretaceous; from the gypseous and nummulitic strata of the Tertiary; from the lacustrine marls of the Post-Tertiary. In composition, these rocks vary considerably, some being essentially carbonates, others sulphates, others again magnesian or dolomitic; further, these may be argillaceous, bituminous, ferruginous, or siliceous.

The limestones best suited for the manufacture of common mortar are carbonates which are free from silica, alumina, and iron. These, after being quarried, and broken into pieces of a convenient size, are calcined in kilns constructed in a variety of ways. The kiln should be placed as near as possible to the quarries whence the stone is extracted, so as to avoid carriage. The longer the stone has been exposed to the air, the less fuel will be consumed in driving off its inherent moisture, or "quarry water." Generally, ordinary pit coal is used in the calcination, one ton being necessary for every 4 or 5 tons of limestone; for some kinds of stone, however, slaty, or shaly coals, are better adapted than superior coal, not only from their being cheaper in price, but also because they burn the stone more slowly and equally, at the same time keeping it "open," and preventing its slagging and sintering. These impure coals may cause a greater amount of kiln-dust; but the lime will be more free from cores and slags. When properly burnt, that is to say, when not slagged or coated with a siliceous glaze, from too sudden ignition, the limestone will have lost its carbonic acid, and will have become converted into caustic or "quick" lime, protoxide of calcium. One hundred parts of raw limestone should yield fifty-six parts of quicklime.

The proper selection of the sand has as great an influence upon the mortar as has the character of the lime. The "sharper" and cleaner the sand, the better; the finest mortar is made with clean pit or river sand; the presence of earthy impurities will interfere with the chemical union of the lime and silica; sea sand is sure to be impregnated with salt, which will subsequently cause deliquescence or efflorescence.

Before mixing the lime and sand together, to form mortar, the former must be "slaked" with water. One volume of water is added to three volumes of lime, when the latter "falls down," with violent evolution of heat, into a powder, whose colour will resemble the tint of the limestone employed. The more rapidly and completely it falls, the better the lime; a lime that falls slowly and unequally will never be satisfactorily cohesive. When the lime is slaked, more water is applied, to convert it into a pulp or paste; this paste, thoroughly incorporated with an equivalent of sand, constitutes common mortar. The proportion of sand will vary with the richness or "fatness" of the lime, which latter is dependent upon the purity of the original carbonate of lime; for poor limes, 2 or 2½ parts of sand will suffice, while some fat limes will take 4 or 5 parts, and yield a superior mortar. The longer a lime remains slaked before being used, the stronger will be the mortar made with it. The admirable solidity of ancient buildings is entirely due to the fact that the slaked lime was covered with turf, and kept for a year, often even three years, before use. It is scarcely necessary to remark that mortar is distinguished from hydraulic cements, by its incapacity to set, or harden, under water.

Hydraulic limestones, or those which yield a lime capable of setting under water, are not so abundant as ordinary limestones. The blue Lias, stretching from Whitby, on the north-east, to Lyme Regis, in the south-west of England, is the chief source. Available beds, which have been ignorantly regarded as "bastard" limestones, and therefore neglected, occur among the Carboniferous limestones of Flintshire, Northumberland, Lanarkshire, East Fife, and the Lothians. These may always be distinguished, according to Dr. Page, by their tougher, earthier, and less crystalline texture, by not effervescing so violently under acids, and by weathering more slowly into a deeper brown surface. Some of the argillo-calcareous ironstones, known as "curl," and "cone in cone," and containing about 10 per cent. of iron, are used, as at Coalbrookdale, in the manufacture of hydraulic cements. The *Septaria*, or argillo-calcareous nodules, of the London clay and lower Lias, are well known for their strong and energetic hydraulic qualities. Recently, the beds of exceedingly pure gypsum, disclosed by the sub-Wealden borings, have been drawn upon by cement-makers.

There are some scores of hydraulic cements in the market; but their composition varies rather in method and proportion of admixture, than in the ingredients themselves. The essential components are lime, clay, and oxide of iron; the lime may vary from 50 to 80 per cent.; the clay, from 25 to 40; and the oxide of iron, from 3 to 14. In some cases, the limestone employed is naturally hydraulic; but more often, that quality is attained by an artificial admixture of the required materials.

The following are some of the best-known hydraulic cements:—

Parker's.—This cement is made from the nodules of indurated and slightly ferruginous marl, known as *Septaria*, belonging to the London clay, and found in the Isle of Sheppy, at Harwich, and on other parts of the south-eastern coast. These, as well as the argillo-calcareous nodules from the lower Lias, are naturally hydraulic limestones; when well selected and prepared, they furnish a quick-setting, strong, and durable cement. They are burnt with pit coal in conical kilns, in the same manner as other limestones, care being taken to avoid excessive heat, as, if the lumps undergo the slightest fusion, even on the surface, they will be unfit for cement-making. After proper roasting, the calx is ground to very fine powder, and immediately packed in barrels, to exclude air and moisture. For use, it is tempered with water, and applied at once; it soon hardens, and will not bear being softened down again with water.

Pew's.—Quicklime, 1 part; baked clay, 2 parts; powdered, mixed, and calcined; then, gypsum, fresh baked and in fine powder, 1 part, is added to powdered baked clay, 2 parts; mixed well, added to the former compound, and the whole thoroughly incorporated. It is very hard and durable.

Portland.—This cement, so largely manufactured on the Thames, the Tyne, and other rivers, consists of about 80 parts of chalk or rich lime, and 20 parts of fluviatile mud, or clay; the two ingredients are incorporated wet, then dried, calcined, and reduced to powder.

Roman.—Genuine Roman cement is manufactured from *pozzuolana*, a ferruginous volcanic ash from Vesuvius and other Italian volcanoes, and lime; or, from a combination of lime and a Tertiary volcanic earth, or kind of pumice, called *trass*, which occupies wide areas in the Eifel district of the Rhine. The only preparation required is grinding to an impalpable powder. The Roman cement made in this country is obtained from the *Septaria* of the London clay and the lower Lias, from the cement stone of the upper Lias, and from the shale beds of the Kimmeridge clay; it is also manufactured from several artificial admixtures of lime and ferruginous clay, calcined together. It must be kept in closed vessels, and is mixed with water for use.

For further information on the subject of Calcareous Cements, the reader is referred to Spons' 'Dictionary of Engineering,' and Supplement; to Reid's 'Cement'; and to Page's 'Economic Geology.'

Gelatinous Cements.—All animal tissues contain an adhesive substance, which anatomists call "histose." When the tissues are boiled in water, the histose is changed into a substance called "gelatine," which is dissolved by the water. It may afterwards be separated from the water by simple evaporation, when it forms a dry, hard substance, which has different names according to the source from which it has been manufactured. That obtained from cartilage is called "chondrine"; that from bones, hoofs, and hides, "glue"; that from the air-bladders and intestines of fishes, "isinglass"; and that from the less tenacious and adhesive constituents of parchment scraps, and some other animal membranes, "size." The process of manufacture, in all these cases, consists in boiling in water; the hot water causes the animal substances to change into gelatine, which it dissolves. (See Bones.) Of the products mentioned above, two only are employed as cements, viz. Glue, and Size.

Glue.—This useful article is made from fresh bones, freed from fat by previous boiling; from the refuse scraps produced in trimming skins for tanners; from the hoofs and horns of cattle; and from leather cuttings. The best glue is obtained from the "soundings" of sheep-skins and cattle-hides, known as "fleshings," and also, from their industrial application, as "glue-pieces." These are first placed in pits containing milk of lime, where they are allowed to soak for several days, or even three weeks; the milk of lime is changed every six or seven days, and the pieces are occasionally turned over. When sufficiently soaked, the pieces are taken out to drain and dry, for which purpose they are placed on hurdles, or in layers on a sloping pavement, and turned over three times daily. When dry and hard, they are ready to be sold to the glue-manufacturer, and are a better material for his purpose than the fresh skin-pieces. The first operation of the glue-maker is to soak the pieces in weak lime-water, and then to wash them in baskets under a stream of water. They are then drained, and exposed to the air, so as to enable the adhering lime to absorb carbonic acid from the atmosphere, and thus to lose its caustic properties, which would destroy part of the glue during the subsequent boiling operations. Glue which is to be used as gelatine, for culinary purposes, is derived from perfectly clean and fresh bones. For the manufacture of this material, beef-bones are preferred to all others, as they yield a perfectly transparent article, sold under the name of gelatine or isinglass. Calf-bones give a milky glue; hog-bones create a blackish foam in the solution; while the product from sheep-bones always retains the peculiar odour of the fat of these animals. The glue made from hoofs and bones is always brown and of common quality. Whatever the substance used, whether glue-pieces, bones, or horns, the process is essentially the same. The raw material is put into a flat copper boiler, provided with a perforated false bottom, at a little distance above the bottom, so as to prevent the solid material from touching the shell, where it would stick fast and be burned. The boiler is two-thirds filled with water, and heat is applied. In a few hours, after stirring repeatedly, the pulpy liquid is drawn off in successive portions, as soon as it is perceived that a sample taken out gelatinizes on cooling. Experience has taught that too long boiling injures the glue. The test for this cooled gelatinized material is that it must be fit to be cut into slices with a wire. Before drawing off the solution, the fire is let down, so as to stop the boiling, and allow the liquid to clarify by settling. The liquor is then drawn off into a deep boiler, where it settles for the second time, remaining hot for from five to six hours. The longer it stays in this vat, the better it will be clarified, and the higher will be its market price. Often a certain proportion of alum is added to it at this stage, to assist the separation of the impurities.

From the vats, the warm liquid is run into shallow, flat coolers, consisting of wooden boxes, about 14 ft. long, 12 in. wide, and 9 in. deep These are placed in a cold situation, so that the liquid may cool and gelatinize. This operation occupies from twelve to eighteen hours, according to the state of the weather; at the end of this period, the glue will be sufficiently firm to be taken out as an elastic cake. For this purpose, the wooden boxes are inverted on a moist table, and the mass of glue is then divided into a series of blocks, or "gobbets"; these blocks are next placed in a wooden frame, 12 in. by 7 in. by 6 in. deep, and provided with about a dozen slits, the whole much resembling a set of school-slate frames placed together. Each block is then cut horizontally into slices, by means of a brass wire stretched like a bow-saw on a frame, and inserted in the slits of the frame containing the block. The slices, thus cut, are laid out on sheets of galvanized iron wire netting, exposed on every side to the air, for the purpose of drying and hardening. This part of the manufacture is most exposed to the risks of possible failure, by reason of the influence exerted by the weather. A sudden heat will soften the glue, so that it will run through the nets; moist weather will prevent the drying, and, if it is warm at the same time, the glue may be so spoiled, and acquire such a bad odour, as to be fit only to be thrown away; a fog, or a thunderstorm may spoil the operation, and render all the previous trouble and expense totally useless. Glue which has once manifested a bad smell during the process of manufacture, even though dried afterwards to a perfectly odourless solid, will reveal its quality when dissolved at any subsequent period; nay, while still dry in the barrel, it will become disagreeably odorous on every moist day; and, what is worse, walls on which this glue has been used will give out the smell in damp weather. As a matter of course, such glue loses much of its commercial value. In the course of drying, the slice of glue shrinks until its size is only half of what it was when in a moist state; and it requires to be carefully watched and turned, to prevent uneven contraction, which would cause it to split. After being dried, the slices are taken into sheds, and washed with boiling water, for the purpose of removing any dirt or dust, which may have adhered to their surface in the course of drying. The glue is then packed ready for the market. The qualities commonly made are "town glue," worth about 6*d.* a lb.; "strong Russian dark," 9*d.*; "finest kid," 1*s.*

When glue-making is properly conducted, there should be no waste product. The large bones, after boiling, may be sold to the button manufacturer (see Bones, and Buttons); the small bones are valuable for making bone black (see Blacks), or for their fertilizing properties (see Manures); hoofs are useful for making combs; hair from the "fleshings" has many applications; the waste lime from the pits is an excellent manure.

A great improvement in the method of conducting the manufacture of glue is the application of superheated steam to the materials, by which a much larger proportion of glue is extracted, in a shorter time, and at less cost. Another improvement is the addition of Paris white (fine chalk) to the glue used by cabinet-makers. It has the following advantages:—1. It increases the adhesive qualities of the glue. 2. It makes the glue look whiter, and thus gives to a browner glue, the lighter appearance of a more expensive quality. 3. It is a pecuniary gain, since a substance costing only 1½*d.* or 2*d.* a lb. is added to one costing 1*s.* 3*d.* to 1*s.* 8*d.*; but it is not to be considered as a common adulteration: the buyer loses nothing, as the price is proportionally reduced, while the quality is improved. This is an American plan, and explains the milkiness of the glue made in the United States.

A novel feature in glue manufacture is the utilization of leather refuse for the purpose. Old leather, or leather refuse, is subjected to the action of 15 per cent. of a mixture of slaked lime and water, in closed vessels, at a temperature of 121° (250° F.). In this way, the leather is completely decomposed. Its principal constituents being tannic acid combined with gelatine, the tannic acid attacks the lime, forming tannate of lime, while the gelatine is set free, and is dissolved in the water. The high temperature required for the operation injures the glue, which is undoubtedly somewhat deteriorated by the previous action of the tannin on the leather from which it is derived. For these reasons, the glue obtained from leather is inferior in its adhesive qualities; but it may do very well for culinary purposes.

The Laplanders make an excellent glue from the skins of perches; and it is probable that eel-skins would serve the same end. The largest skins are chosen, and dried; they are then moistened with cold water, till they have become so soft that the scales can be separated; the latter are thrown away. Four or five of the skins are then put into a reindeer's bladder, or wrapped up in the soft bark of the birch tree, in such a manner as to exclude water. Thus covered, they are placed in a pot of boiling water, and kept at the bottom by means of a stone. After boiling for about an hour, they are uncovered, having, by that time, become soft or viscous. In this state, they are employed for joining the two pieces of the Lapp bows; if pressure be exerted till the glue is quite dry, the joint will never give way.

Good glue should be hard, and difficult to break with a hammer, though, when broken, it should yield suddenly to the force, and present a sharp vitreous fracture. It must be admitted, however, that some very fair glues, in thin pieces, will yield or bend a little, even when quite dry, before breaking. The colour, whether dark or light, should be bright, not too dark, and without any green tint. The substance should be transparent, and free from foreign particles, and should be capable of absorbing a considerable quantity of water, say, at least four to seven times its own weight. Generally speaking, the amount of water thus absorbed will serve as an indication of the quality of the glue, provided that the resultant mass is not too friable, and remains clear, or nearly so, and that when it has been melted and allowed to cool, the jelly it forms is tolerably clear and fresh, and not liable to rapid spontaneous putrefaction. From careful experiments made with dry glue, immersed for twenty-four hours in water, at 15° (60° F.), and thereby transformed into a jelly, it was found that the finest ordinary glue, or that made from white bones, will absorb twelve times its weight of water in twenty-four hours; that glue from dark bones will absorb nine times its weight of water; while the ordinary glue made from animal refuse will absorb but three to five times its own weight of water.

One of the best chemical tests of the quality of glue is to ascertain the proportion of pure gelatine in the mass. This may be done by means of a solution of binitrate of mercury, in water acidulated with nitric acid. The test should be compared with a solution containing a known amount of gelatine.

The usual chemical test to distinguish the presence of glue in any liquid is tannic acid, which forms, in a solution of any kind of gelatine, a copious leathery precipitate, of which the particles, however, cannot be made to adhere together like leather, the fibrous structure of the "histose," from which the gelatine is derived, being absent.

The imports of glue and glue clippings into the United Kingdom, in 1870, were 30,293 cwt., valued at 36,046*l.*; and the exports were 2439 cwt., valued at 4937*l.*

Liquid Glue.—(*a*) Ordinary glue, 5 lb., is dissolved in water, contained in a vessel which may be heated by means of a water bath, care being taken to stir from time to time. When all the glue is melted, 1 lb. of commercial nitric acid is gradually added in small doses. This addition creates an effervescence, and a disengagement of red nitrous fumes. When all the acid has been poured in, the vessel is withdrawn from the fire, and the contents are left to cool. This glue may be kept for a long time, even in uncorked vessels. It is used cold, by means of a brush. It may also be employed as a lute, by spreading it on strips of linen. (*b*) Ordinary glue, 100 oz., is dissolved in a water bath with 250 oz. vinegar; when the whole has become liquid, 250 oz. ordinary alcohol, and 10 oz. alum are added, the mass being kept over a fire for a quarter of an hour. It is very tenacious, and does not become putrid. When too thick, a little water may be added, and the mixture may be heated. It is very useful for cementing, in the cold, a variety of small objects, and is much employed by the makers of false pearls. (*c*) Four parts by weight of gelatine or ordinary glue are dissolved, in the cold, or better, at a gentle heat, in ten parts of commercial acetic acid. (*d*) Glue in fine pieces, 6 parts, macerated for some hours in water, 16 parts, adding hydrochloric acid, 1 part, and sulphate of zinc, 1½ part; the whole is then exposed, for ten to twelve hours, to a temperature of 80° or 90° (176°-194° F.); the mixture will keep unaltered for a long time.

Parchment Glue.—Parchment, 10 parts, is cut into small pieces, and boiled in 128 parts of water, until the liquid is reduced to 80 parts. The decoction is filtered through linen, and evaporated over a gentle fire, until it presents the desired consistence.

Size.—A recently introduced size which, for the paper-maker's purpose, is said to be 50 per cent. cheaper and much better than the ordinary size, is made in the following way:—In a copper pan heated by steam (waste steam will do) from 45 to 50 lb. of soda is dissolved in 200 to 240 lb. boiling water; while still boiling, 300 lb. powdered rosin is added, and thoroughly stirred in till it is entirely dissolved, an operation generally requiring three to four hours. This soda-rosin compound is dissolved in water, in the proportion of 1 lb. of the former to 30 to 40 lb. of the latter; it is then thoroughly incorporated with a glue solution, made by dissolving 100 lb. glue in 300 to 400 lb. water. The two solutions are then boiled together for about ten minutes, after which the mixture is run through a fine sieve or filter, and is then ready for use. The best proportions for mixing the vegetable and animal sizes are, for 1½ part of rosin, 1 part of glue; for some purposes, equal parts of each may be taken. The addition of starch, if required, can be made as usual.

Waterproof Glue.—In order to render glue insoluble in water, even hot water, it is only necessary, when dissolving the glue for use, to add a little bichromate potash to the water, and to expose the glued part to light. The proportion of bichromate will vary with circumstances; but for most purposes, about $\frac{1}{50}$ of the amount of glue used will suffice.

Glutinous Cements.—By glutinous cements, are understood those whose base is a substance containing a large proportion of gluten, such as the flour of wheat, rye, rice, &c. They are commonly known as "paste," of which the chief varieties are the following:—

Japanese Paste.—The Japanese make a very fine paste from rice flour. The flour is mixed with a little cold water, and into it is gradually poured boiling water, till the mass has attained the proper consistence; it is then boiled for one or two minutes. It is beautifully white and transparent, as well as very strong, and is consequently well adapted for fancy work requiring a colourless cement.

Ordinary Paste.—There are two distinct ways of making ordinary household paste:—(*a*) About a tablespoonful of wheat flour is mixed in a saucepan with say ½ pint of cold water, the latter being added gradually and thoroughly incorporated by continual stirring; the vessel is then put on the fire, and the contents are unceasingly stirred till they boil, great care being necessary to prevent their caking or burning on to the pot; (*b*) The water is first heated to boiling, and the flour is then added with constant stirring; to prevent the formation of lumps, the flour may be passed through a sieve, so as to ensure its more equable distribution; agitation is continued till the heat has rendered the mass of the desired consistence, and, after a few moments' further boiling, it is ready for use.

To preserve paste from the attacks of insects, and to arrest its decomposition, it is well to add a small quantity of some antiseptic material, e. g. a few drops of carbolic acid, or oil of cloves, or a little powdered corrosive sublimate, camphor, or colocynth. Thus treated, and placed in covered vessels, it will keep fresh for years. The addition of salt or brown sugar has a similar effect in a minor degree. Paste which has become hard or dry may be softened by beating up with a little hot water. With the object of considerably increasing the strength of paste, bookbinders, paper-hangers, and shoemakers usually add powdered rosin to the flour, in the proportion of $\frac{1}{6}$, or even $\frac{1}{4}$, of the weight of the latter; it is then known as "hard paste." Sometimes a teaspoonful of alum is introduced into each $1\frac{1}{2}$ pint of water, for the same purpose.

Starch Paste.—The best method of preparing starch paste is as follows. The starch is saturated with cold water in a mortar, to produce a thick paste free from clots; into this, is then poured a small stream of boiling water, till "starch" commences to form, which is recognized by the mixture becoming transparent; the remainder of the water is then added, the total requisite quantity being twelve to fifteen times the weight of dry starch used. Heating the mass is useless. The addition of a little alum to the water helps to preserve the paste.

Cementing Compounds.—The cements hitherto considered may be called simple, in contradistinction to the multifarious compounds which have now to be described. In the former, the adhesive virtue of one or more simple solid bodies is brought into play by the application of water, or heat, or both; into the latter, is introduced a great variety of substances, some possessing cementing qualities, others serving only as carriers of the preceding, or as driers. These compounds may be very conveniently divided into two classes, to be called respectively "resinous," and "non-resinous."

a. Resinous.—Under the term "resinous cementing compounds," will be included all those preparations which owe their cementing properties to the presence of a resin, gum-resin, or gum, such as common rosin, indiarubber, guttapercha, gum arabic, &c. Compounds of this class are numerous, the best known being the following:—

Bottle-corks, for.—The black bituminous cement used for bottle-corks consists of pitch, hardened by the addition of brickdust and rosin.

Chinese.—(*a*) For wood, glass, ivory, jewellery, and all fancy work:—finest pale-orange shellac, broken small, 4 oz.; strongest rectified spirit (58 O.P.), 3 oz.; digested together in a corked bottle in a warm place till dissolved, when the mass should have the consistence of treacle. This is one of the best cements for repairing glass, china, &c. It is so strong that pieces of wood cut obliquely across the grain and joined by it cannot be made to part at the juncture. Throughout the far East, it is used in joining bows, arrows, &c.; the fluid is smeared over the faces to be joined, a piece of very thin gauze is interposed, and the whole is pressed tightly together and thus left till the following day. Joints made with it will resist even the continual bending of a bow; it is invaluable for mending fishing rods, and similar articles. (*b*) Clean glass is reduced to a very fine powder, and passed through a silken sieve; the powder is ground with white of egg on a stone slab, powdered glass being added till the required consistence is attained. It forms a very firm cement for glass and porcelain, vessels repaired with it breaking in a new place rather than at the joint. (*c*) Shellac, 3 oz.; borax, 1 oz.; water, $\frac{3}{4}$ pint; the whole is boiled in a covered vessel till dissolved, then evaporated to the proper consistence. It dries slowly, but is cheap and useful. Druggists and oilmen often employ it instead of gum, for fixing paper labels to glass or tin, where exposed to damp.

Cutlers'.—For fixing blades of knives in their handles, the hank of the blade is heated and pressed into the hole in the handle, which has previously been filled with one of the following compositions:—(*a*) Rosin, 4 parts; beeswax, 1 part; and brickdust, or plaster of Paris, 1 part; (*b*) Rosin, 16 parts; hot whiting, 16 parts; and wax, 1 part; (*c*) Pitch, 4 parts; rosin, 4 parts; tallow, 2 parts; and brickdust, 2 parts.

Elastic.—Bisulphide of carbon, 4 oz.; indiarubber in fine shreds, 1 oz.; isinglass, 2 drachms; guttapercha, $\frac{1}{2}$ oz.; dissolve. Used for joining leather or indiarubber. The parts must be thinly coated with the solution, which is left for a few minutes to dry, and then heated to melting; the parts are placed in close contact, and the air-bubbles are well hammered out.

Electrical or Chemical Apparatus, for.—(*a*) A good cement for connecting the parts of chemical or electrical apparatus may be made by mixing 5 lb. rosin, 1 lb. wax, 1 lb. red ochre, and 2 oz. plaster of Paris, and melting the whole with moderate heat. (*b*) Black rosin, 7 lb.; red ochre, 1 lb.; plaster of Paris, $\frac{1}{2}$ lb., well dried, and added while warm; then heated to a little above 100° (212° F.), and agitated together, till all frothing ceases and the liquid runs smooth; the vessel is then removed from the fire, and the contents are stirred till sufficiently cool for use.

Grinders'.—(*a*) Pitch, 5 parts; wood ashes, 1 part; hard tallow, 1 part; melted together. (*b*) Black rosin, 4 lb.; beeswax, 1 lb.; melted; to these is added whiting, previously made red hot, and while still warm, 1 lb. These are used for fixing pieces of glass, &c., while grinding. (*c*) Shellac, melted, and applied to the pieces slightly warmed. Used for lenses and fine work.

Gum.—An aqueous solution of gum arabic and gum tragacanth gives a good cement which will keep for a long time.

Impervious.—An impervious cement for apparatus, corks, &c., may be made by rubbing up zinc white with copal varnish; this is applied and left to dry, then covered with the same material mixed thinner, and lastly with copal varnish alone.

Indianite.—(*a*) Finely-chopped indiarubber, 100 parts; rosin, 15 parts; shellac, 10 parts; dissolved in a sufficient quantity of bisulphide of carbon; (*b*) indiarubber, 15 grs.; chloroform, 2 oz.; mastic, ½ oz.; the first and second ingredients are mixed, and, when the rubber is dissolved, the mastic is added in powder, and the whole is left to macerate for a week. These cements are used for uniting pieces of indiarubber.

Indiarubber.—(*a*) Virgin or native indiarubber is cut with a wet knife into the thinnest possible slices, which are then divided by shears into threads as fine as small twine. A small quantity of the shreds (say $\frac{1}{10}$ of the capacity of the bottle) are then put into a wide-mouthed bottle, and the latter is three-fourths filled with benzine of good quality, and perfectly free from oil. The rubber almost immediately commences to swell, and in a few days, if often shaken, it will assume the consistence of honey. Should it be inclined to remain in undissolved lumps, more benzine must be added; thinness may be corrected by adding more indiarubber. A piece of solid rubber no larger than a walnut will make a pint of the cement. It dries in a few minutes, and, by using three coats in the usual manner, leather straps, patches, rubber soles, backs of books, &c., may be joined with great firmness. (*b*) Indiarubber, 8 grms; chloroform, 600 grms.; mastic resin, 150 grms.; the indiarubber is dissolved in the chloroform, the mastic is added, and the whole is left to macerate for eight days, that being the time necessary for the solution of the mastic. The cement is applied cold on a brush, and is used for joining glass. (*c*) Very finely-divided indiarubber is melted at a temperature of 200° (392° F.); as soon as fusion commences, one-fifteenth the quantity of tallow or wax is added, taking care to watch the heat and to stir without ceasing. When the mass is completely melted, lime, slaked and sifted, is added in small instalments, till it amounts to half the quantity of the indiarubber. The cement thus obtained is soft; if the proportion of lime be doubled, the cement will be harder, but still supple. When the compound has acquired a suitable consistence, the fire is withdrawn, and the preparation is finished. This forms a good cement for hermetically sealing vessels. It does not dry, and remains for a long time ductile and tenacious; but it may be made to harden, if necessary, by adding 1 part of red-lead to the quantities indicated above.

Ivory, or Mother-of-Pearl, for.—Isinglass, 1 part, and white glue, 2 parts; dissolved in water, 30 parts; the solution is filtered, and evaporated down to 6 parts; to this is added gum mastic, $\frac{1}{30}$ part, dissolved in alcohol, ½ part; and zinc white, 1 part. When required for use, it is warmed and shaken up.

Jewellers'.—(*a*) Gum mastic, five or six pieces as large as peas, is dissolved in as much spirits of wine as will suffice to render it liquid; in a separate vessel, is dissolved, in rum or other spirit, as much isinglass, previously softened in water and strained dry, as will fill a 2-oz. phial with very strong glue, adding a little gum galbanum or ammoniacum, which must be rubbed or ground till it is dissolved. The whole is then mixed, under the influence of sufficient heat. It is kept in a closely stoppered bottle, which is placed in hot water when the cement is to be withdrawn for use. It will effectually unite most substances, even glass to polished steel, and is principally used for joining broken pieces of china and glass. (*b*) The following is another mode of preparing the same ingredients:—Isinglass, 1 oz., in distilled water, 6 oz., boiled down together to 3 oz.; to this is added strong spirits of wine, 1½ oz.; the mixture is boiled for a minute or two, and strained; while still hot, it receives, first, milky emulsion of gum ammoniacum, ½ oz.; then, alcoholic solution of resin mastic, 5 drachms. (*c*) Shellac, melted and run into sticks as large as quills. Used for joining glass, earthenware, &c.; the edges are heated sufficiently to melt the cement, which is then applied, and the joint is made while the heat lasts. (*d*) Tears of gum mastic employed in the same way. (*e*) Shellac, 2 parts, Venice turpentine, 1 part; fused together and formed into sticks. Used as the preceding.

Labels, for.—Gelatine, 25 grammes; sugar-candy, 50 grammes; gum arabic, 12 grammes; water, 100 grammes. After having macerated the gelatine in water, overnight, it is mixed with the sugar and gum arabic in a porcelain vessel, and heated over a spirit lamp, with constant agitation. Ebullition must be continued till the mass becomes quite fluid. The labels are coated with the liquid, and left to dry; on moistening the coated surface, they will adhere strongly to glass and wood.

Lapidaries'.—(*a*) Rosin, 1 lb., is melted, and to it is added dry plaster of Paris, 4 oz. Makes a very strong cement for rough purposes. (*b*) Rosin, tempered with beeswax and a little tallow, and hardened with whiting and red ochre, or Spanish brown.

Leather, for.—(*a*) Guttapercha dissolved in bisulphide of carbon, to form a mass of treacly consistence. This forms a good cement for splicing leather. The parts to be joined must be thinned down; a small quantity of the cement is then poured on each end, and spread so as to thoroughly fill all the pores of the leather; the parts are warmed over a fire for a few moments, applied quickly, and hammered well together. To preserve this cement, it should be tightly corked in a bottle, and kept in a cool place. (*b*) Guttapercha, 1 lb.; indiarubber, 4 oz.; pitch, 2 oz.; shellac, 1 oz.; linseed oil, 2 oz.; melted together. It hardens by keeping, and needs remelting before application.

Leather and Metal, for.—A cement for joining leather and metal may be made by melting together equal parts of asphalt and guttapercha, and applying the mass hot under a press.

Marble, for.—The following curious composition is recommended for cementing pieces of marble, porcelain, or glass. About 100 snails are caught, and kept fasting for two months or less, taking care to clean them occasionally. They are then sprinkled with a little water to make them quit their shells, the excess of water being decanted as soon as they have come out. Thereupon is added a pinch of culinary salt, then the juice of four or five lemons, and a drop of vinegar, and the whole is beaten up together. The snails give off their mucus, which is collected, and intimately mixed, in a mortar, with 8 grammes of gum tragacanth, then 40 or 50 grammes of garlic juice, and 200 grammes of alcohol. The cement keeps quite opaque, and may be coloured to suit the materials to be joined. It is applied cold; but the joint must subsequently be exposed to the sun or a fire.

"Marine Glue."—(*a*) Finely shredded indiarubber, 1 part; coal-tar (or mineral) naphtha, 12 parts; digested in a covered vessel with heat and agitation; when the solution is complete, 20 parts of powdered shellac are added; the heating and stirring is continued till perfect liquefaction has taken place; the fused mass, while still hot, is poured out on slabs of polished metal or stone, so as to form thin sheets. For use, it is heated to its melting-point, 120° to 121° (248° to 250° F.), in an iron vessel, and applied, in a liquid state, with a brush. It is used by shipbuilders and others. (*b*) Indiarubber, 15 to 20 grains; chloroform, 2 fl. oz.; dissolved; powdered mastic, ½ oz., is added. The cement must be kept well corked, and in a cool place, to prevent loss by evaporation. (*c*) Finely divided indiarubber, 1 part, is dissolved in naphtha oil, or crude naphtha, 40 parts. The solution is not completed in less than ten or twelve days, and, in order to facilitate it, the mixture should be repeatedly agitated. To it, is then added gum lac, in the proportion of 2 parts by weight of lac to 1 part of solution. The compound is then placed in an iron vessel over a fire, and constantly thinned till it becomes homogeneous. It is then poured on a cold surface, such as a slab of marble or a flag-stone, and left till cool, when it is broken up and put by for use. The indiarubber is sometimes omitted, in which case, the proportions will be 1 part of naphtha and 2 parts of lac. When required for use, the cement is heated at a temperature not exceeding 100° to 110° (212° to 230° F.), in a thick vessel of copper or cast iron, and is brushed in thin and even layers on the surface to be joined; these are then brought into close contact, and strongly pressed. If the surfaces are so wide that the cement becomes cool before the operation is finished, it is well to pass a hot iron—say at about 60° (140° F.)—over it. It is valuable, not only for repairing broken wood, but also for cementing the moulds used in foundries, for caulking ships, for joining blocks of marble or granite, and for uniting wood and iron. It can be made as hard as desired, by increasing the proportion of lac. With the addition of bichloride of mercury dissolved in wood spirit, this cement might, with economy, replace the copper sheathing of ships. Wood, iron, plaster, and brick, to which it is applied, assume a varnished appearance; timber is rendered free from the attacks of insects and from liability to rot, and iron is preserved from rust.

Metal or Glass, and Wood, to join.—(*a*) Rosin is melted, and into it is stirred calcined plaster till the mass is reduced to a paste, to which is added boiled oil, in sufficient quantity to bring it to the consistence of honey. It is applied warm. (*b*) Into melted rosin, 180 parts, are stirred burnt umber, 30 parts; calcined plaster, 15 parts; boiled oil, 8 parts.

Metals and Glass, to join.—(*a*) Rosin, 4 to 5 parts; wax, 1 part; colcothar, 1 part; the whole melted together. A little powdered plaster is often added. (*b*) Copal varnish, 15 parts; drying oil, 5 parts; turpentine, 3 parts; essence of turpentine, 2 parts; strong glue, 5 parts; slaked lime, 10 parts; mixed. (*c*) Sandrach or galipot varnish, 15 parts; boiled linseed oil, 5 parts; turpentine, 2½ parts; essence turpentine, 2½ parts; marine glue, 5 parts; pearl white, 5 parts; dry carbonate of lead, 5 parts; mixed. (*d*) Copal or lac varnish, 15 parts; drying oil, 5 parts; indiarubber or guttapercha, 4 parts; coal oil, 7 parts; Roman cement, 5 parts; plaster, 5 parts. (*e*) Copal or rosin varnish, 15 parts; turpentine, 2½ parts; essence of turpentine, 2½ parts; fish isinglass, in powder, 2 parts; iron filings, 3 parts; ochre or rottenstone, 10 parts. These cements, especially the first, are much used for fixing metallic letters to glass, marble, or wood. The two following are particularly good for uniting brass and glass:—(*f*) Caustic soda, 1 part; rosin, 3 parts; plaster, 3 parts; water, 5 parts; the whole is boiled. This compound hardens at the end of half an hour;

the hardening may be retarded by replacing the plaster by zinc white, white lead, or slaked lime. (*g*) Fine litharge, 2 parts; white-lead, 1 part; copal, 1 part; boiled linseed oil, 3 parts; the whole is triturated together.

Metals, Wood, and Indiarubber, to join.—Shellac is soaked in ten times its amount of strong liquid ammonia; it takes about a month to completely dissolve. It has the effect of softening the surface of indiarubber before drying, and thus causes perfect adhesion. It is valuable for making steam-pipe connections with rubber washers.

Naturalists'.—Consists of mucilage of gum arabic, thickened with starch powder or farina, with the addition of a little lemon juice. Sometimes the mucilage is used alone. This cement is employed by naturalists, for mounting specimens; by artificial flower makers; by confectioners, to stick ornaments on their cakes, &c.

Plumbers'.—Black resin, 1 part; brickdust, 2 parts; melted together, with the occasional addition of a little pitch or tallow. It improves and grows harder each time it is melted. Used by plumbers and by seal engravers, for fixing pieces of metal while cutting, and for securing seals and tools in their handles.

Stone, for.—(*a*) Sulphur, 1 part; yellow wax, 1 part; rosin, 1 part; the sulphur and rosin are melted, and the wax is then added. It is necessary to heat the surfaces to be united; the cement is applied while still hot, and pressure is exerted till it is cold. (*b*) Powdered gum arabic, 2 parts; finely ground white-lead, 2 parts; pulverized sugar-candy, 1 part; the three substances are placed in a small bottle with a wide mouth, a little hot water is poured on them, and the whole is stirred by a stick into a homogeneous paste. The cement must be kept in a closed vessel, and a little water may be added if it becomes dry. Before use, it must be well stirred, to prevent the white-lead collecting at the bottom. It is employed for joining fragments of minerals, fossils, &c.

Stoneware, for.—Botany Bay (yellow) gum, 1 part; brickdust, 1 part; melted together. Employed for stoneware, earthenware, &c.

Turners'.—(*a*) Resin, ½ oz.; pitch, ½ oz.; beeswax, 1 oz.; melted together; fine brickdust is then added, in sufficient quantity to produce the desired consistence. (*b*) Rosin, 2 lb.; Burgundy pitch, 2 lb.; dried whiting, 2 lb.; yellow wax, 2 oz.; mixed and melted together. (*c*) Black rosin, ½ lb.; yellow wax, 1 oz.; melted together, and poured into a tin canister. When required for use, as much is chipped out as will cover the chuck to a thickness of $\frac{1}{16}$ in., and is spread over in small pieces, mixing with it one-eighth of its bulk of guttapercha in thin shreds; an iron, heated to dull redness, is then held over the chuck till the whole mixture is liquid; the work is chucked, and placed under a weight for half an hour, when it may be put into the lathe. (*d*) Rosin, 4 parts; pitch, 1 part; melted; to the mass, is added brickdust, till the desired consistence is attained.

Wood and Metal, Glass, or Stone, to join.—To a strong solution of glue, is added sifted earth, till the mixture has the consistence of varnish. The mass is applied, while still hot, to the surfaces to be united, and the latter are tightly compressed.

b. Non-resinous.—The group of "non-resinous cementing compounds" embraces all those whose composition does not permit them to be included in any of the preceding classes. With the exception of purely metallic cements, which have been already described as Solders (see Alloys), this concludes the list of cementing substances:—

Architectural.—Strong rice-water size is mixed with paper which has been pulped in boiling water; whiting is then added, in sufficient quantity to produce the desired consistence.

Beale's.—Chalk, 60 parts; lime, 20 parts; salt, 20 parts; Barnsey sand, 10 parts; iron filings or dust, 5 parts; blue or red clay, 5 parts; ground together, and calcined; patented as fireproof.

Bruyere's.—Clay, 3 parts; slaked lime, 1 part; mixed, and exposed for three hours to full red heat, then ground to powder. Hydraulic.

Building.—A mixture of clay or loam, broken pottery, flints, siliceous sand, or broken bottle-glass, and wood ashes; exposed to considerable heat in a furnace till it partially vitrifies; then ground to fine powder, sifted, and mixed with one-third its weight of finely powdered quicklime; afterwards packed closely in barrels, and preserved from air and moisture. For use, it is mixed up with water. Resembles Roman cement.

Caseine.—Instead of dissolving caseine in an alkaline carbonate, Dr. Wagner recommends the use of a cold saturated solution of borax, or an alkaline silicate, for the purpose. The boracic solution of caseine is a clear, viscous liquid, exceeding gum in adhesiveness, and applicable to many uses as a substitute for glue. The chief cement used in the island of Sumatra is made from the curd of buffalo milk, prepared in the following way. The milk is left to stand till all the butter has collected at the top. The latter is then removed, and the thick, sour mass left is termed the curd. This is squeezed into cakes and left to dry, by which it becomes as hard as flint. For use, some is scraped off, mixed with quicklime, and moistened with milk. It holds exceedingly well, even in a hot, damp climate, and is admirably adapted for mending porcelain vessels.

Chinese.—Bullocks' blood is mixed with one-fifth its weight of quicklime. It will scarcely keep longer than for seven or eight days, when the temperature is elevated. For use, it is thinned by the addition of a little water. It is employed by bookbinders and trunkmakers.

Curd.—(*a*) Skimmed milk is curdled by the addition of vinegar or rennet, and is then beaten to a paste with powdered quicklime. (*b*) Skimmed milk, ½ pint; vinegar, ½ piut; mixed with the whites of five eggs; the whole well beaten, and sufficient quicklime added to form a paste. These cements are used for mending glass and earthenware; they resist water, and a moderate degree of heat.

Earthenware, for.—Grated cheese, 2 parts; finely powdered quicklime, 1 part; white of egg, sufficient to form a paste when the whole is beaten up together.

Egg.—Consists of white of egg thickened with finely powdered quicklime. It does not withstand long exposure to moisture, except after subjection to heat. It is employed to mend china, glass, alabaster, marble, earthenware, &c.

Gad's.—Clay, well dried and powdered, 3 parts; oxide of iron, 1 part; mixed together, and made into a stiff paste with boiled oil. Used for work required to harden under water.

Glass Flux.—Red-lead, 3 parts; fine white sand, 2 parts; crystallized boracic acid, 3 parts; mixed and fused; levigated, and applied with thin mucilage of gum tragacanth. The edges to be united must be heated, so as partially to fuse the cement. It is used for mending broken china, &c.

Glass and Porcelain, to join.—Starch, 60 parts; finely pulverized chalk, 100 parts, are made into a mixture with equal parts of water and spirit, with the addition of 30 parts of Venice turpentine, taking care to agitate the mass with a stick, so as to ensure its homogeneity.

Glass, Wood and Metal, to join.—(*a*) Glue, melted with the least possible quantity of water, 4 parts; Venice turpentine, 1 part. It well resists moisture.

Glycerine.—A mixture of glycerine and powdered litharge. It hardens rapidly, and is useful for vessels containing volatile bodies; it is also an excellent cement for fixing iron on iron or stone, as well as for joining fragments of stone.

Hensler's.—Litharge, 3 parts; quicklime, 2 parts; white bole, 1 part; all finely powdered; then a quantity of linseed-oil varnish is added, sufficient to make a paste. This cement takes long to dry, but is very tenacious. It is used for china, glass, &c.

Iron Pots and Pans, for.—Sulphur, 2 parts; fine blacklead, 1 part; the sulphur to be held in an old iron pan over the fire till it begins to melt; the blacklead is then added, and the mass is well stirred till it has thoroughly melted and combined; then poured out on an iron plate or smooth stone, and, when cool, broken into small pieces. A sufficient quantity of this cement placed on a fracture in an iron vessel can be soldered with a soldering iron. If a hole exist, it should be first closed with a copper rivet, and the cement applied over it.

Labels, for.—(*a*) Corrosive sublimate, 125 parts; wheaten flour, 1000 parts; absinthe, 500 parts; tansy, 500 parts; water, 15,000 parts. This cement is useful for vessels which are kept in a damp place; the addition of the sublimate retards the destruction of the labels. (*b*) Starch, 100 parts; strong glue, 50 parts; turpentine, 50 parts; the whole boiled in water. This cement dries quickly.

Leather and Pasteboard, for.—Strong glue, 50 parts, is dissolved with a little turpentine in a sufficiency of water, over a gentle fire; to the mixture, is added a thick paste made with 100 parts of starch. It is applied cold, and dries rapidly.

Letter-fixing.—Copal varnish, 15 parts; drying oil, 5 parts; turpentine, 3 parts; oil of turpentine, 2 parts; liquefied glue, made with the least possible quantity of water, 5 parts; melted together in a water-bath; to this is added fresh-slaked lime, perfectly dry and finely powdered, 10 parts. This cement is used to affix metallic letters to shop-windows, &c.

Marble.—Plaster of Paris is soaked in a saturated solution of alum, and then baked in an oven, just as gypsum is baked to convert it into plaster of Paris; it is then ground to powder. For use, it is mixed up with water as wanted. It sets very hard, and will take a high polish. It is sometimes used for uniting glass and metal.

Marble, for.—Into a solution of chloride of zinc, sp. gr. 1·490 to 1·652, is introduced 3 per cent. of borax or sal-ammoniac; when this is dissolved, oxide of zinc, which has been subjected to a red heat, is added, till the mass attains the desired consistence. This cement becomes as hard as marble, and may be used for moulding.

Meerschaum, for.—(*a*) Garlic, crushed to form a sort of dough, is rubbed over the surfaces of the meerschaum to be united; the latter are then bound tightly together with fine wire, and boiled in milk for half an hour. (*b*) Quicklime is mixed to a thick cream with the white of an egg. These cements will also join fragments of glass or china.

Metals or Glass and Wood, to join.—Strong glue is boiled with water, and thickened with a sufficient quantity of sifted wood sawdust. It is employed hot.

Metallic.—For joining metallic surfaces where soldering is inconvenient, recourse may be had to a composition formed in the following way:—Pure and finely divided copper, such as that obtained by the reduction of sulphate of copper with zinc clippings, 20 to 36 parts, according to the degree of hardness desired in the cement, dissolved in a sufficient quantity of sulphuric acid to make a thick paste; with this is incorporated, by trituration in a mortar, mercury, 70 parts. The mass is soft, but hardens at the end of some hours. For use, it is heated to 100° (212° F.), and powdered in an iron mortar heated to 150° (302° F.); it then assumes the consistence of wax, and is harder in proportion as it contains more copper. It adheres strongly on drying.

Porcelain and Glass, for.—Fresh poor cheese forms a good cement when dissolved in carbonate of potash or soda, and the liquid is evaporated until the mass exhibits the proper consistence. On replacing the alkaline carbonate by silicate of potash, a still better cement is produced, which is very effective for repairing glass and china.

"Stick-all."—This is a solution of silicate of potash. Without the aid of any other substance, it will securely unite fragments of stone, marble, wood, &c., and forms a valuable cement for repairing statuary. It suffices to brush the surfaces with the solution, and to press them firmly together.

Stonemasons'.—Clean river sand, 20 lb.; litharge, 2 lb.; quicklime, 1 lb.; linseed oil, sufficient to form a thin paste. This cement is used for uniting fragments of stone; after a time, it becomes exceedingly hard and strong.

Universal.—Skimmed milk is curdled with rennet or vinegar, the whey is pressed out, and the curd is dried as quickly as possible by a gentle heat. When quite dry, it is ground in a coffee or pepper mill, and triturated in a mortar till it is reduced to a very fine powder. This powder is mixed with 10 per cent. of new dry quicklime, also in very fine powder, and, to every ounce of this mixture, is added 5 or 6 grains of powdered camphor. The whole is well triturated together, and kept in well-corked, wide-mouthed bottles. When required for use, it is made into a paste with a little water, and applied immediately. It is employed to join glass, earthenware, &c.

Water, unalterable in.—(*a*) Good grey clay, 4 parts; black oxide of manganese, 6 parts; limestone, reduced to powder by sprinkling it with water, 90 parts; mixed, calcined, and powdered. (*b*) Manganese iron ore, 15 parts; lime, 85 parts; calcined and powdered. Either of these cements requires to be mixed with a little sand for use; thrown into water, they harden rapidly. (*c*) Fine, clean sand, 1 cwt.; powdered quicklime, 28 lb., bone ash, 14 lb. Beaten up with water for use. (*d*) Quicklime, 5 parts; fresh cheese, 6 parts; water, 1 part. The lime is slaked by sprinkling with the water; thereupon it is passed through a sieve, and the fresh cheese is added. The latter is prepared by curdling milk with a little vinegar, and removing the whey. The cement thus formed is very strong; but it requires to be applied immediately, as it sets very quickly. (*e*) Fresh curd, as before, 1 part; quicklime, 1 part; Roman cement, 3 parts. Used for joining stone, metals, wood, &c. (*f*) A paste composed of hydraulic lime and soluble glass.

Lutes. (Fr., *Lut*; Ger., *Kitt.*)

A lute is a tenacious and ductile composition, becoming solid on drying, employed to secure the joints of vessels intended to be subjected to a corrosive influence, such as heat, water, steam, acids, gases, and to prevent the escape of liquid or volatile bodies. Lutes differ in their ingredients and modes of preparation according to the nature of the substance to be confined, and the degree of heat to be borne. The most useful are the following:—

Acid-proof.—(*a*) A solution of caoutchouc in twice its weight of raw linseed oil, heated, and mixed with an equal weight of pipeclay, yields a plastic mass which will long remain soft under cover, and never completely hardens, so that it may be easily removed at pleasure. It resists most acids and bears the heat at which sulphuric acid boils. (*b*) Melted caoutchouc alone will answer well for securing joints against chlorine, and some acid vapours. (*c*) A mixture of china-clay and boiled linseed oil, in the proportions needed to produce the right consistence. (*d*) Quicklime and linseed oil, mixed stiffly together, form a hard cement, resisting both heat and acids. (*e*) A stiffly mixed paste of pipe-clay and coal-tar. (*f*) A cement which, according to Dr. Wagner, is proof against even boiling acids, may be made by a composition of caoutchouc, tallow, lime, and red-lead. The caoutchouc must first be melted by a gentle heat, and then 6 to 8 per cent. by weight of tallow added to the mixture while it is kept well stirred; next, dry slaked lime is applied, until the fluid mass assumes a consistence similar to that of soft paste; lastly, 20 per cent. of red-lead is added, in order to make it harden and dry. (*g*) A concentrated solution of silicate of soda, formed into a paste with powdered glass. (*h*) Rosin, 1 part; sulphur, 1 part; brickdust, 2 parts; the whole is melted after careful mixing. This lute is proof against the attacks of nitric and hydrochloric acid vapours.

Algerian.—Wood-ashes, 2 parts; lime, 3 parts; sand, 1 part; mixed, passed through a sieve, moistened with water and oil, and beaten up with a wooden mallet till the compound has acquired the right consistence.

Almond paste.—(*a*) Ground almond cake, from which the oil has been expressed, is mixed up with an equal weight of whiting, and made into a stiff paste with water. It soon becomes very hard and tough. It is much employed for stills, retorts, &c., where the heat does not exceed about 160° (320° F.); it is capable of resisting the fumes of volatile oils, spirits, weak acids, &c., for some time. (*b*) Ground almond cake as before (or linseed cake) is added to starch paste and gum-water.

Aquariums, for.—(*a*) Plaster of Paris, 1 gill; litharge, 1 gill; fine white sand, 1 gill; finely powdered rosin, ⅓ gill: well mixed, bottled and corked till required; for use, it is mingled with boiled oil and driers till it is as thick as putty. It dries quickly. (*b*) Boiled linseed oil, litharge, and a mixture of red and white lead (the latter in excess), spread on a flannel, and placed on the joint. (*c*) Glue, 8 oz.; dissolved in Venice turpentine, 1 oz.; boiled together with constant agitation till the mixture is complete; the joints to be luted should be compressed for forty-eight hours, if necessary. (*d*) Gold-size, ½ gill; red-lead, 2 gills; litharge, 1½ gill; silver sand, sufficient to make the mass into a thick paste; sets in about two days.

Bottle-corks, for.—(*a*) A paste composed of commercial silicate of soda and pulverized kaolin, with or without chalk, is applied to the corks and left to dry. (*b*) Rosin, 1 lb.; tallow or suet, ¼ lb.; melted together; sufficient colouring matter is stirred in. (*c*) Rosin, 5 lb.; beeswax, 1 lb.; colouring, as last. (*d*) To 1 lb. of the last, is added finely powdered dry whiting, 3 oz.; powdered burnt ochre, 4 oz. (or red bole, sufficient to produce desired red tint). (*e*) To 1 lb. of *b*, or *c*, add ivory-black, sufficient to produce black colour. (*f*) Black pitch, 6 lb.; ivory-black, 1 lb.; whiting, 1 lb.; melted together; used in the same way as common sealing-wax on corks and bungs.

Brimstone.—Melted brimstone, either alone or mixed with rosin and brickdust. It is cheap and useful.

Cap.—(*a*) Rosin, 5 lb.; beeswax, 1 lb.; dried Venetian red, 1 lb.; melted together. (*b*) Red-lead and white-lead, equal weights; preferable to white-lead alone, and may be depended on for any temperature up to 100° (212° F.). These lutes are used for chemical and electrical purposes, e. g. connections of glass tubes, necks of balloons, &c., in metal mountings.

Chemical.—(*a*) Yellow wax, 4 parts; common turpentine, 2 parts; well-dried Venetian red, 1 part; melted together. Used as a temporary lute for the ends and joints of tubes which are not exposed to much heat, as is alkalimetry, &c. (*b*) Slaked lime is beaten up with white of egg; strips of linen are soaked in the mixture, and applied immediately, as it dries very rapidly. (*c*) Pulverized chalk, ½ part; rye flour, 1 part; white of egg, a sufficiency; the whole is formed into an almost liquid mass, which is brushed over strips of linen, and the latter are applied to the joint; an additional strip of linen is laid over them, and pressed with a hot iron, which dries the compound.

Coppersmiths'.—Bullock's blood thickened with finely powdered quicklime. Must be applied promptly, as it sets rapidly. Used under the edges and rivets of copper boilers, &c.; it is cheap and durable, and suited for many other purposes.

Crucibles, for.—A mixture of powdered clay and brickdust, made up with water, or a solution of borax. Used to join crucibles which are exposed to a strong heat. When mixed up with borax solution, the lute becomes a compact vitreous mass in the fire.

Dihl's.—A mixture of boiled linseed oil, litharge, and powdered china-clay. The whole is made into a paste, and applied with a trowel. The surfaces of the joint must previously be thoroughly cleaned and dried, or the lute will not answer; it is useful in damp places.

Engineers'.—(*a*) Ground white-lead is mixed with as much red-lead as will give the mass the consistence of putty. (*b*) White-lead and red-lead in equal weights, and boiled linseed oil, sufficient to produce the proper consistence. These compounds are applied by smearing them on a washer of hemp, yarn, &c., placed between metallic joints which are to be screwed up. They also answer well for luting the joints between stones, e. g. in cisterns, &c., and dry as hard as stone.

Fat.—(*a*) Clay is dried, powdered, sifted, placed in an iron mortar, and incorporated with drying oil, added gradually, the whole being well beaten up till the mass assumes the consistence of a fine paste. It should be preserved under a coating of oil, to prevent it drying up. It resists the action of corrosive gases, but inconveniently softens by exposure to heat. (*b*) Plaster of Paris mixed with water, milk, or weak glue. Stands a dull red heat.

Fireproof.—(*a*) Fine river sand, 20 parts; litharge, 2 parts; quicklime, 1 part; linseed oil, sufficient to form a thin paste. Acquires a stony hardness. (*b*) Good clay, 2 parts; sharp washed sand, 8 parts; horse-dung, 1 part; mixed thoroughly, and tempered like mortar. (*c*) Linseed, or almond meal, mixed to a paste with milk, lime-water, or starch-paste. Resists a temperature of 260° (500° F.). (*d*) Clay is puddled with water, and to it is added the greatest possible quantity of sand, which has been passed through a hair sieve; the whole is worked up in the hands, and applied in coats more or less thick on vessels needing protection from the direct action of the fire.

Fireproof and Waterproof.—(*a*) Thoroughly dried and pulverized clay, 4 or 5 parts; fine iron-filings, free from oxide, 2 parts; peroxide of manganese, 1 part; sea-salt, ½ part; borax, ½ part; well mingled, and rendered as hard as possible, then reduced to a thick paste with the necessary quantity of water, and perfectly incorporated. It must be applied immediately, and, after application, should be subjected to heat, gradually increasing almost to whiteness. (*b*) Sifted peroxide of manganese, 1 part; pulverized zinc-white, 1 part; commercial soluble glass, sufficient to form a thin paste. To be used immediately. These lutes become very hard, and present a complete resistance to red heat and boiling water.

Glass, for.—(*a*) As a coating for glass vessels, to protect them from injury during exposure to fire, pipe-clay and horse-dung are made into a paste with water. This composition is applied by spreading it on paper; it is used by pipe-makers, and will stand the extreme heat of their furnaces for twenty-four hours without damage. (*b*) Shredded tow, or plumbago, is substituted for the horse-dung.

Iron.—A lute which is much used for closing the joints of iron pipes, and for similar purposes, is composed of the turnings or borings of cast iron, which must be clean and free from rust, mingled with varying proportions of sal-ammoniac, flowers of sulphur, &c. For use, the mixture is stirred up with just enough water to thoroughly moisten it; and it is rammed or caulked into the joints with ordinary caulking tools, after which the joint is bolted together as tightly as possible. When the iron borings are very coarse, they are pounded down in an iron mortar, and the dust is sifted off before use. The various proportions employed are:—(*a*) Iron borings, 5 lb.; sal ammoniac, in powder, 2 oz.; flowers of sulphur, 1 oz.; water, sufficient to mix; (*b*) Iron borings, 12 lb.; sal-ammoniac, 2 oz.; sulphur, 1 oz.; water, as in (*a*). (*c*) Iron borings, 7 to 8 lb.; sal-ammoniac, 2 oz.; water, as before. (*d*) Iron borings, 4 lb.; good pipe-clay, 2 lb.; powdered potsherds, 1 lb., made into a paste with salt and water. The formula (*a*) is that most commonly used for ordinary purposes; but formerly much more sulphur and sal-ammoniac were employed. The strongest lute, perhaps, is (*c*); but when the work is required to dry rapidly, as in the case of steam joints wanted in a hurry, the quantity of sal-ammoniac must be slightly increased, and a very little sulphur must be added. This addition causes quicker setting, but reduces the strength. The power of these lutes is dependent upon the oxidation and consequent expansion of the mass, therefore the less foreign matters they contain, the better. They should be made up only as they are required, as they spoil rapidly; when containing much sulphur, they may become quite hot in a few hours, and combustion has been known to take place in them when left together in quantity for a night. The formula (*d*) produces a lute that becomes very hard when allowed to dry slowly; it is very suitable for repairing cracks in iron boilers, tanks, &c. (*e*) Finely sifted iron filings, 60 parts; finely powdered sal-ammoniac, 2 parts; flowers of sulphur, 1 part. This powder is made into a paste with water, and immediately applied; it soon sets as hard as the iron it is intended to lute.

Laboratory.—This lute is composed of equal parts of pitch, rosin, and thoroughly dried plaster of Paris. It is used for the masonry of chlorine chambers, sulphuric acid works, &c., and as a lining for casks containing chloride of lime.

Mahogany, for.—(*a*) Beeswax, 4 oz., melted, and to it is added Indian red, 1 oz., and yellow ochre, sufficient to produce the required tint. (*b*) Shellac, melted and coloured as (*a*). These compounds are used by cabinet-makers for filling up holes and cracks in mahogany furniture.

Maissiat's.—Indiarubber melted, either with or without about 15 per cent. of either beeswax or tallow; quicklime in fine powder is gradually added; and the heat is continued, until change of odour shows that combination has taken place, and until a proper consistence is attained. It is used as a waterproof and airproof covering for casks.

Marble, for.—Gum-lac is coloured to imitate the marble on which it is used; sometimes the gum is mixed with marble dust passed through a silken sieve. It is used for stopping up holes, cracks, and leakages in marble vessels.

Mohr's.—Equal parts of pulverized brick and litharge are made into a paste with linseed oil. After application, a little fine sand is dusted over the lute, and it is dried in an oven.

Oxychloride.—Zinc-white is mixed with an equal volume of fine sand, and to it is added a slightly greater weight of a solution of ferrous chloride of zinc of 1·26 sp. gr. The whole is ground in a mortar, and the paste is applied to corks, after pressing them a little within the neck of the bottle.

Plasters.—(*a*) Plaster of Paris, baked and ground, acquires great hardness and solidity when left for twenty-four hours, in contact with a solution of alum, and when, after drying in the air, it is submitted to a second baking. (*b*) Still better results are obtained by employing an aqueous solution containing $\frac{1}{20}$ of borate and $\frac{1}{20}$ of cream of tartar; the plaster, baked and in fragments, is plunged into this solution until it is saturated; then it is calcined, and pulverized. (*c*) A mixture of silicate of potash, 100 parts; carbonate of potash, 27 parts; and water, 500 parts, may also be used.

Putty for Windows.—(*a*) A mixture of boiled linseed oil, and whiting; (*b*) the whiting is sometimes replaced by white-lead. (*c*) Linseed oil, 1 part; fine sifted sand, 10 parts; finely powdered litharge, 1 part; Spanish-white, 2 parts; the linseed oil is boiled in an iron vessel, and the sand and litharge are added in small portions at a time. After some minutes' ebullition, the fire is withdrawn, and the mass is ground in a mill, with the gradual introduction of the Spanish-white. This lute will hold in wood, iron, and stone. Broken panes may be removed by passing the point of a hot iron over the joint.

Red-lead.—White-lead rubbed up with oil, 2 parts; red-lead, 1 part; it is used for the joints of gas piping, steam engines, and of pumps.

Serbat.—Sulphate of lead, calcined and ground, 72 parts; peroxide of manganese, 24 parts; linseed oil, 13 parts; intimately mixed. This lute is soft, and will remain in that state indefinitely. For use, it only needs to be rubbed up between the hands. It may be advantageously employed in boilers, steam engines, &c.; it sets perfectly, and does not soften under the influence of heat, but, on the contrary, becomes very hard, especially if care be taken to pass a hot iron over the joints. A sudden leak may be stopped immediately, by applying some of this lute under a hot iron. It is preferable to red-lead.

Steam Boilers and Pipes, for.—(*a*) Dried and powdered clay, 6 lb.; iron filings, 1 lb.; made into a paste with boiled linseed oil; used for stopping cracks and leaks in boilers, stoves, &c. (*b*) Litharge, in fine powder, 2 parts; very fine sand, 1 part; lime that has been allowed to slake spontaneously in a damp place, 1 part; mixed, and kept from the air; made into a paste with boiled oil, and used to mend cracks, and secure steam joints. (*c*) Good linseed-oil varnish ground with equal weights of white-lead, oxide of manganese, and pipe-clay. (*d*) Dry, powdered clay, 1 part; clean, sifted iron filings, 2 parts; acetic acid, sufficient to make a paste. (*e*) Dry, powdered clay, 8 to 10 parts; iron filings, free from rust, 4 parts; peroxide of manganese, 2 parts; sea-salt, 1 part; borax, 1 part; water, sufficient to make a paste. (*f*) Sulphate of baryta, 1 part; clay, 2 parts; made up with solutions of silicate of potash, and borax; it resists a very high temperature. (*g*) Finely powdered graphite, 6 parts; chalk, or slaked lime, 3 parts; sulphate of baryta, 8 parts; boiled linseed oil, 7 parts; the solid substances are mixed dry, then ground, and made into a paste with the oil. (*h*) Iron filings, free from rust, 50 parts; flowers of sulphur, 2 parts; pulverized hydrochlorate of ammonia, 1 part; these substances are mixed with water or urine, so as to make a solid and homogeneous paste, which is used in the joints of steam boilers. The lute swells, becomes very solid, and perfectly closes the joints. (*i*) Iron filings, 4 parts; loam, 2 parts; powdered sandstone, 1 part; made into a paste with salt water; becomes very hard on setting. (*j*) A thick paste, composed of silicate of soda and iron filings; the latter substance may be replaced by a mixture, in equal parts, of powdered oxide of zinc and peroxide of manganese. (*k*) Sand, 84 parts; Portland stone, 166 parts; litharge, 18 parts; pulverized glass, 0·90 parts: red-lead, 0·45 parts; sub-oxide of lead, 0·90 parts; the whole rubbed up with oil.

Vulcanized Indiarubber.—For the joints of small vessels, such as tubes, especially those of glass or earthenware, vulcanized indiarubber tubing, slipped over the joint and tied on both sides, will last for a long time. Flat rings or washers of the same substance are also good for still heads, &c., where the parts can be screwed up tightly.

Water-gutters, for.—Tar, 1 part; tallow, 1 part; fine brickdust, 1 part; the latter is warmed over a very gentle fire; the tallow is added, then the brickdust, and the whole is thoroughly mixed. It must be applied while hot.

Wood, Cracks in, for.—(*a*) Slaked lime, 1 part; rye meal, 2 parts; made into a paste with a sufficient quantity of linseed oil; (*b*) Glue, 1 part, dissolved in water, 16 parts; when almost cold, sawdust and prepared chalk are stirred in to the required consistence; (*c*) Oil varnish, thickened with a mixture of equal parts white-lead, red-lead, litharge, and chalk.

Wooden Vessels, for.—A mixture of lime, clay, and oxide of iron, separately calcined, and reduced to fine powder, then intimately mixed, kept in a close vessel, and made up with the requisite quantity of water when wanted.

Zinc.—A solution of chloride of zinc at 50° to 60° Beaumé, and powdered chloride of zinc, when mixed, combine to form the insoluble oxychloride of zinc which solidifies into a hard, white mass.

(See Alloys; Asphalt; Bones; Pigments; Resinous Substances; Varnishes; Wax.)

CHICORY, or SUCCORY. (FR., *Chicorée*; GER., *Cichorie*, *Wegwart.*)

The chicory of commerce is a product of the *Chicorium intybus*, a plant of the dandelion family, closely related to the common endive. In its wild state, it is indigenous to Great Britain, occurring most frequently in dry, chalky soils, and commonly by the roadsides. It is also cultivated in this country to a small extent; there are about 300 acres of land under chicory in Yorkshire, and about 50 acres in Northamptonshire. On the Continent, its cultivation is much more general, and very large quantities are grown in Germany, France, Holland, and Belgium. With us, the plant is grown almost exclusively for its root; abroad, the leaves also are utilized as salad, and for cattle-feeding. The leaves, too, on being treated like woad (see Dye-stuffs), yield a dye, which is extracted in some districts. Attempts have been made to introduce this useful vegetable into the United States, in Illinois, Long Island, California, and especially Wisconsin; but the results have been universally unfavourable to its cultivation being followed, in spite of the heavy import duty on chicory brought into America.

Cultivation.—The chicory plant thrives best upon a dry, deep, rich, loamy soil, with a clay subsoil; heavy clay, sand, and wet lands are unsuited to it. The seed, 4–7 lb. to the acre, is sown in drills, 10–15 in. apart. The time chosen is late March for a forage crop, May for a root crop. Such plants as run to seed must be pulled up, or they would spoil the market value of the bulk. When well up, the young plants are singled out like turnips, to distances of 6–9 in. in the rows, and need thorough cleansing from weeds. Abundant manure is required, as the crop exhausts the soil very much. The harvest commences in September, and may last all through the winter. Each root must be forked up singly, otherwise portions will be left in the soil, and will reappear in the following year. When gathered, the roots measure 1–3 ft. long and 2–4 in. thick, and should weigh about 3 lb. each. The yield is variously stated at 4–12 tons of the green root an acre; the value of the green root is 20*s.*–50*s.* a ton, and the cost of cultivation varies from 3*l.* 15*s.* to 4*l.* 10*s.* an acre. The roots grown in England are said to be more woody than the Continental produce, and attempted heavy cropping is stated to impair the value of the root for grinding.

Preparation.—In order to prepare the roots for market, they are washed, sliced up into small pieces in a turnip-cutter or similar machine, kiln-dried, and then roasted in iron cylinders, which are kept revolving after the manner of coffee roasters. In England, about 2 lb. of lard are added to every hundredweight of chicory while roasting; in France, butter is used. This imparts a lustre and colour resembling coffee. After roasting, the roots are spread out in boxes to cool, and when cold, are carefully picked over and ground fine in a mill. The ground chicory is bolted through sieves, and sorted into different sizes, the coarser powder being reground. The loss in drying amounts to 75–80 per cent. of the weight of green root, and that in roasting equals 25–30 per cent. of the weight of dried root.

The following analysis of ground chicory is from an American source:—

Moisture	9·09	Dextrine (starch gum)	6·12
Mineral salt	4·20	Saccharine matter	11·36
Extractive substances soluble in water	41·29	Caramel	2·10
Resinous (gummy) extracts soluble in alcohol	5·22	Cellulose (fibre)	19·10
		Carbon	1·18
		Empyreumatic oils	0·04

Chicory is intensely bitter, possesses heating and debilitating qualities, and is wholly destitute of any active principle in the least analogous to those of coffee, tea, and other dietetic drinks. Dr. Hassall states that it acts both as an aperient and as a diuretic; where any disease of the kidneys exists, it aggravates such tendency, and in some instances leads to disease of those organs. A celebrated Viennese oculist has described a form of blindness which he considers to be due to a continual use of chicory.

Uses—The only use to which chicory is applied in this country is for the adulteration of coffee, its old medicinal application having quite disappeared. In some parts of the Continent, notably Belgium, an infusion of chicory alone is largely used as a beverage. Destitute as it is of any valuable principle, it is difficult to account for the persistency with which chicory has been retained as an adulterant of coffee, now for more than a century, to the exclusion of almost every other mode of sophistication. The mixture of chicory with coffee is even legalized to the extent of 2 oz. of the former with 16 oz. of the latter, larger proportions only being considered as adulteration. Chicory is itself largely adulterated, the following substances being most frequently used for the purpose:—Peas, damaged corn, &c., roasted, ground, and coloured with Venetian red; parsnips, turnips, acorns, oak bark, baked bread, coffee husks, and many other substances. The most certain way to avoid the adulteration of coffee is to buy it in berry, always remembering, however, that patents (!) have been obtained for compressing a mixture of ground coffee and chicory into the form of coffee berries. A simple way of detecting the presence of chicory in ground coffee is to sprinkle a little of the suspected substance on the surface of clear, cold water in a glass; the coffee will float, while the chicory will sink. The two should be separately removed for examination under the microscope, when the difference of structure at once becomes apparent.

Mercantile and Statistical Information.—The import duties on chicory, imposed on the 2nd of May, 1872, are 13*s.* 3*d.* a cwt. on raw or kiln-dried, and 2*d.* a lb. on roasted or ground. The quantities imported, in 1878, were:—(1) Raw, or kiln-dried, 120,628 cwt., value, 76,586*l.*; of this quantity, 95,351 cwt. were entered for home consumption; the supplies were drawn chiefly from Belgium (106,171 cwt.), Holland (9699 cwt.), and Germany (4301 cwt.). (2) Roasted or ground, 238,902 lb., value, 3202*l.*; of this quantity, 47,050 lb. were entered for home consumption; the supplies were drawn chiefly from Belgium (171,383 lb.), Austria (46,216 lb.), Holland (10,021 lb.), Channel Islands (6335 lb.) A comparison of the imports for the years 1874 to 1878, inclusive, of raw or kiln-dried chicory gives the following figures:—

	Cwt.		Cwt.
1874	122,707	1877	109,207
1875	105,135	1878	120,628
1876	116,055		

The quantities exported in 1878 were:—

		£
(*a*) Raw or kiln-dried—To all countries	694 cwt.,	value 622
(*b*) Roasted or ground „ „	270,790 lb.	„ 2968
(*c*) Roasted or ground in bond—To United States ..	818,447 „	„ 8153
„ „ „ „ British South Africa	480,672 „	„ 5454
„ „ „ „ Australia	342,466 „	„ 3884
„ „ „ „ Other countries ..	114,407 „	„ 1262
	1,755,992	£18,753

The cultivation and preparation of chicory is assuming large proportions in the Australian Colonies. The consumption in England, as compared with that of coffee, is 30–40 per cent.

Bibliography.—'Our Farm Crops,' John Wilson; 'Food and its Adulterations,' A. H. Hassall; 'Coffee and Chicory,' P. L. Simmonds.

(See Beverages—Coffee.)

CHLORAL. (Fr., *Chloral;* Ger., *Chloral.*) Formula C_2HCl_3O.

Chloral is a peculiar, oily liquid discovered by Liebig, in 1832; he obtained it by the action of chlorine upon alcohol. It is colourless, greasy to the touch, and possesses a pungent, ethereal odour. At 18°, it has a specific gravity of 1·502; at 94·4°, it boils, and distils over unaltered. It is soluble in water, alcohol, and ether. When dissolved in a small quantity of water, it forms a semi-solid, crystalline mass of chloral hydrate, which dissolves readily in a larger quantity of water.

The preparation of chloral from alcohol is as follows:—A quantity of absolute alcohol is placed in a glass-stoppered retort, and dry chlorine gas is passed through it. The alcohol should be cold at first, but afterwards heated gently, until, when raised to the boiling-point, the chlorine gas comes through unaltered. The whole is then permitted to cool, when a solid, crystalline mass of chloral hydrate is formed. This mass is gently heated until it fuses, and is then shaken up with three times its volume of concentrated sulphuric acid. On the application of a gentle heat, a layer of impure chloral rises to the surface; it is removed, boiled for some time, and distilled with an equal volume of sulphuric acid; it is finally mixed with quick-lime, and redistilled, in order to remove traces of hydrochloric acid; the operation is finished when the surface of the lime becomes dry. The chlorine should be introduced into the retort by means of a bent tube inserted in the tubulure. Another tube, which should be of considerable length, is connected with the stem of the retort, in order to carry away the fumes of hydrochloric acid, and to permit the volatilized alcohol and chloral to recondense and flow back into the vessel.

The hydrate, $C_2HCl_3O \cdot H_2O$, is the more important compound, since it has lately received several applications in medicine. The following description of its preparation in quantity is given by Squire:—

Dry chlorine gas is passed for several days, through absolute alcohol, sp. gr. 0·795, until it becomes a thick, viscid liquid of sp. gr. 1·57. At the beginning of the operation, the alcohol is well cooled, to prevent inflammation and explosion; but towards the end of the operation, the alcohol is heated nearly to the boiling-point. The resulting liquid, which, after a day or two, becomes a solid mass of crude chloral hydrate, is agitated with four times its bulk of concentrated sulphuric acid, and the anhydrous chloral, which floats on the surface, is separated and purified by fractional distillation. The purified anhydrous chloral is placed in a still, mixed with 11 per cent. of water, and distilled over chalk, to remove any hydrochloric acid that may be present; the resulting solid distillate is then fused, and poured out into shallow vessels to cast into cakes. To obtain the hydrate in the purest form, it may be dissolved several times in pure bisulphide of carbon, and recrystallized.

Hydrate of chloral is a white, solid, crystalline substance having a pungent, agreeable odour. When dissolved in water, and treated with caustic potash, it decomposes, forming chloroform and formiate of potash. When injected into the blood, it combines with the alkali present therein, and the same decomposition occurs, chloroform being liberated in the system. It is, therefore, a powerful narcotic, and is much used as a sedative and soporific. In Dr. Richardson's reports on the physiological action of this substance, presented to the British Association in 1869, 1870, and 1871, he states that 90 grains will produce a deep sleep, and that 140 grains is a really dangerous dose. The ordinary dose, taken internally, is from 10 to 60 grains. Its habitual use is much to be condemned, since, when taken constantly, it exerts a most injurious influence upon the system, very similar to the effects produced by the habitual consumption of opium. The use of chloral and hydrate of chloral as anæsthetics was made the subject of a patent by Dr. Liebreich, of Berlin, in 1869.

CHLORINE. (Fr., *Chlorine;* Ger., *Chlor.*) Symbol, Cl; combining weight, 35·5.

This important element was discovered, in 1774, by Scheele, a Swedish chemist. Its elementary character was first established by Sir Humphry Davy, in 1810. At ordinary temperatures, chlorine is a gas, having a yellowish-green colour (Gr. χλωρός, green), and an extremely pungent, irritating odour. It does not support respiration, unless abundantly diluted with air. Under a pressure of four atmospheres, at 15°, chlorine condenses to a mobile, yellow liquid, having a density of 1·33. It has never yet been solidified. In the ordinary gaseous condition, it is two and a half times heavier than atmospheric air. Water dissolves twice its volume of chlorine gas, at ordinary temperatures, and a still larger proportion if the temperature is lowered; at 0°, a hydrate may be obtained in crystals. The aqueous solution possesses the colour, odour, and other general characteristics of the gas. Chlorine is a powerful bleaching agent, and is largely used for this purpose in the form of bleaching powder, or chloride of lime; it is also very effective as a disinfectant.

Chlorine is found widely distributed in nature, in the form of common salt, or chloride of sodium. This salt exists in enormous quantities in sea water, and in inland deposits, when it is termed "rock-salt." It also exists abundantly in combination with potassium, calcium, magnesium, and other metals. It may be obtained either by the action of sulphuric acid upon a mixture of common salt and peroxide of manganese, or of strong hydrochloric acid upon the peroxide alone. The former method is preferable when the gas is required in small quantity; the proportions used are four parts of common salt, three parts of the peroxide of manganese, and seven parts of concentrated sulphuric acid previously diluted with an equal volume of water. These are intimately mixed, and the mixture is placed in a flask and heated gently. Owing to its extreme solubility, the gas cannot be collected under water; it is best collected by downward displacement.

In the method employed in alkali works for the generation of chlorine gas on a large scale, for the manufacture of bleaching powder, hydrochloric acid, having a specific gravity of 1·15, is gently heated with the powdered peroxide, chlorine gas, chloride of manganese, and water being formed. The details of the manufacture of chlorine, on a commercial scale, by this method have been set forth in the article on Bleaching Powder, to which the reader is referred.

CHLOROMETRY. (Fr., *Chlorométrie;* Ger., *Chlorbestimmung.*)

Chlorometry signifies the methods by which the amount of free or available chlorine gas, contained in bleaching powder, and other disinfecting and bleaching agents, is determined. Commercial bleaching powder consists of a mixture, in variable proportions, of hydrochlorite, chloride, and hydrate of lime; it is valued and sold in this country by the percentage of available chlorine. This percentage is usually determined by a process known as Penot's method, first proposed by Gay Lussac. It depends upon the fact that arsenious acid in solution is oxidized, by free chlorine, into arsenic acid, the end of the reaction being determined by iodide of potassium and starch paste.

The arsenious acid is employed in the form of an alkaline arsenite, and is prepared in the following manner:—Dissolve 4·95 grm. of the purest sublimed arsenious anhydride, free from sulphide, in about 250 cc. of distilled water in a flask, with about 25 grm. of the purest crystallized carbonate of soda, free from sulphide, hyposulphite, or sulphite. The acid should be finely powdered, and the liquid needs boiling and shaking for some time, in order to complete the solution. When the arsenic is entirely dissolved, the solution is allowed to cool, and diluted carefully to 1 litre.

The solution used to determine the end of the reaction is prepared by boiling 1 part of clean starch with 150 or 200 parts of water, adding a small quantity of iodide of potassium, and allowing the mixture to cool. Slips of ordinary filtering paper are moistened with this solution, as required, and used while still moist, when it is far more sensitive than the dried paper recommended by Penot. The operation of testing is then performed as follows:—

The sample of bleaching powder is well mixed; 3·55 grm. are weighed out, put into a small mortar, a little water is added, and the mixture rubbed to a smooth cream. More water is then stirred in with the pestle, allowed to settle for a few moments, then poured off into a 250 cc. flask; the sediment is again rubbed with water, poured off, and so on, repeatedly, until the whole of the powder has been conveyed into the flask without the loss of a particle, and the mortar and pestle have been washed clean. The flask is then filled to the containing mark with water, well shaken, and 25 cc. of the turbid liquid is taken out with a pipe, and transferred to a beaker with a little distilled water. The arsenious solution is then run in from a burette, until a drop of the mixture, taken out upon a glass rod and brought in contact with the moist starch-paper, gives no blue coloration. Towards the end of the operation, the arsenious acid must be introduced drop by drop very cautiously, until the colour is just discharged.

The following table shows a comparison of the English and French chlorometric degrees. The French degrees indicate how many litres, at 0° and 760 mm., are yielded by 1 kilo. of bleaching powder; while the English degrees, which are also used in Germany, Russia, and America, show the percentage of "active" chlorine:—

French Degrees.	English Degrees.	French Degrees.	English Degrees.	French Degrees.	English Degrees.	French Degrees.	English Degrees.
63	20·02	80	25·42	97	30·83	113	35·91
64	20·34	81	25·74	98	31·14	114	36·22
65	20·65	82	26·06	99	31·46	115	36·54
66	20·97	83	26·37	100	31·78	116	36·86
67	21·29	84	26·69	101	32·09	117	37·18
68	21·61	85	27·01	102	32·41	118	37·50
69	21·93	86	27·33	103	32·73	119	37·81
70	22·24	87	27·65	104	33·05	120	38·13
71	22·56	88	27·96	105	33·36	121	38·45
72	22·88	89	28·28	106	33·68	122	38·77
73	23·20	90	28·60	107	34·00	123	39·08
74	23·51	91	28·92	108	34·32	124	39·40
75	23·83	92	29·23	109	34·64	125	39·72
76	24·15	93	29·55	110	34·95	126	40·04
77	24·47	94	29·87	111	35·27	127	40·36
78	24·79	95	30·19	112	35·59	128	40·67
79	25·10	96	30·51				

CLAYS. (FR., *Glaise;* GER., *Thon.*)

Clays may be defined as hydrous silicates of alumina, mingled with more or less mineral impurities, and coloured by metallic oxides and organic matters. Usually they are soft, sectile, and plastic, emitting, when breathed upon, a peculiar odour, known as "argillaceous." They chiefly occur as superficial deposits in river valleys, estuaries, dried lake beds, or in glacial drifts. Some of those found in the Tertiary formation are sufficiently plastic for use; but the beds of the older formations, except a few in the Carboniferous, Lias, and Oolite, are found to have acquired a slaty texture. There are several distinct varieties of clay, each possessing characteristics which fit it for a particular purpose.

Brick-clay.—Clays fitted for the manufacture of ordinary bricks, tiles, drain pipes, &c., are widely diffused; but the most important and extensive beds are those of the glacial or immediately post-glacial period. These clays are usually of fine texture, and coloured red, blue, grey, or yellow, according to the character of the formation whence they are derived, the colour being always due to the presence of foreign matters. Estuary silts, the Tertiary system, and the outcrops of the argillaceous beds of older systems also yield considerable quantities of brick-clay. It consists of a coarse and irregular admixture of silicate of alumina—pure clay—with sand, iron, lime, alkalies, and a few accidental impurities. Analyses of four varieties of good brick-clay from Dunfermline, Durham, Tullarone, and Portobello, reveal the following proportions of the principal ingredients:—Silica and sand: 64·14, 61·09, 66·16, 53·95; alumina: 13·54, 19·91, 16·08, 25·55; oxide of iron, 7·57, 6·75, 8·38, 8·06; lime, 1·90, 3·36, 1·88, 0·68; potash and soda: 1·54, 2·83, 1·83, 1·54. The clay must be free from large stones; but a considerable quantity of sand is not objectionable, some clays containing so much as to bring the total percentage of silica up to nearly 90. An excess of iron, lime, or alkalies is liable to make the clay run into a glass during the process of baking. Before manufacture into bricks, &c., the clay undergoes a "tempering," or exposure to the weather, especially to frost, which much improves it. It is then carefully ground, and mixed with water, after which it is left to dry.

China-clay.—This substance is also known as Kaolin, porcelain clay, and Cornish clay. It arises from the natural decomposition of felspar in soft disintegrating granite, gneiss, and porphyry; the rocks which are rich in soda-felspar yielding it most abundantly. The main supplies of this country are derived from Cornwall and Devon; in continental Europe, beds of good quality exist in France, Bavaria, Saxony, Prussia, Bohemia, Bornholm island, and Hungary; in China, it is very plentiful; and in the United States, it occurs in many localities.

The approximate composition of china-clay may be stated as silica, 47·2; alumina, 39·1; water, 13·7 per cent. Often a little iron, lime, and potash or soda are left in the prepared article, by the imperfection of the cleansing process. The most important characters are colour, plasticity, and a capacity for hardening under the influence of heat.

The china-clay industry of Cornwall and Devon has been admirably described by J. H. Collins, F.G.S., in a paper recently read before the Society of Arts.

Occurrence.—The natural clay rock is almost always covered with a thick layer of stones, sand, or impure and discoloured clay, known as "overburden." This capping often much resembles glacial drift; but it never contains any scratched or glaciated stones, or travelled blocks. It varies in thickness from 3 ft. to 40 ft., and must, of course, be removed before the clay can be wrought. The clay rock, being a decomposed granite, consists of china-clay, irregular crystals of quartz, and flakes of mica, with sometimes a little schorl and undecomposed felspar.

Extraction and Preparation.—The following descriptions apply, with more or less accuracy, to a majority of the larger works of the present day, turning out from 2500 to 8000 tons of clay each yearly. Two somewhat different methods are employed, according to the situation of the "bed" of clay, in relation to the surface contour of the immediate neighbourhood. The most general case is that in which the clay has to be raised from a veritable pit, the bottom of which is lower than the ground on all sides. The exact situation of the clay is first determined by systematic "pitting," to a depth of several fathoms, or occasionally by boring. A shaft is then sunk either in the clay itself, or, preferably in the granite close to the clay. From the bottom of this shaft, a level is driven out under that part of the clay which it is intended to work first, and a "rise" is put up to the surface, which should, by this time, be partially cleared of its overburden. A common depth for such a shaft will be from ten to twelve fathoms. As soon as the rise is completed to surface, a "button-hole" launder is placed in it, and the remainder of the rise is again filled up with clay. In the meantime, a column of pumps has been placed in the shaft, with an engine to work them, unless water-power is obtainable.

For water, many works are almost entirely dependent upon that met with in sinking the shaft and in driving levels; but, of course, this may be, and is, eked out by catching the rain-water in reservoirs, and by making use of such small streams as may happen to be available. A small constant supply is sufficient even for a large work, as it is used over and over again. The operation is begun by digging a small pit in the clay, around the upper end of the button-hole launder, and running a stream of water over the exposed clay, or "stope," which is broken up with picks. A very large quantity of sand is constantly disturbed, and as constantly shovelled out of the way, while the water, holding the clay and finer impurities in suspension, runs down the launder, along the level, and into the bottom of the shaft, from whence it is pumped up by the engine or water-wheel.

As the excavation becomes larger and deeper, more overburden is removed, and the upper portions of the launder are taken away, until at last the stopes reach the level, when the launder is, of course, no longer required. At first, the sand is thrown out by one or two "throws," but very soon it becomes necessary to put in an inclined road, for pulling up the sand in waggons; these are worked by a horse-whim, or by winding gear attached to the engine or water-wheel. As there are from three to eight tons of sand to each ton of clay, its removal, in the cheapest possible manner, is a matter of great importance. Any veins or lodes of stone, or discoloured portions of clay, are raised from the "bottoms" in the same way as the sand. The stream of water, holding in suspension clay, fine sand, and mica, is, in well-arranged works, lifted at once high enough to allow of all subsequent operations being carried out by the aid of gravity. The stream is first led into one or two long channels, the sides of which are built of rough stone. In these channels, called "drags," the current suffers a partial check, and the fine sand and rougher particles of mica are deposited. From these drags, the stream passes on into other channels much resembling them, but of greater number, so as to divide the stream still further. This second series of channels, known as "micas," are often built of wood, but sometimes of stone. They differ in no essential respect from the drags, but are more carefully constructed and better looked after, and, as the stream is greatly divided and very gentle, the fine mica is deposited in them. The micas are often about 11 in. wide, ten or a dozen in number, and 100 ft. or more long. Provision is made, by underground channels and plug holes, for the periodical cleansing of the drags and micas. This may have to be done twice a day, but generally only once. The deposit in the drags is worthless at present, and is always thrown away; but that from the micas is often saved, and sold as inferior or "mica" clay. The refined stream of clay then passes on to the "pits," which are circular, 30 to 40 ft. diameter and 7 to 10 ft. deep. These pits are built of rough masonry, and have an outlet at the bottom, opposite the point at which the stream of clay-water is admitted. This outlet is stopped by a gate or "hatch," or by a plug, and is kept closed until the pit is full of clay. In each outlet, however, is fixed an upright launder some 4 in. square, provided with "pin-holes" and wooden pins set close together. As the stream of clay enters on one side, it is constantly depositing its burden, and the water is as constantly drawn off nearly or quite clear from the pin-holes, the pins being put higher and higher as the clay rises in the pit. The effluent water is conducted directly to small storage reservoirs, and thence over the clay stopes, whence it does its work over again. When the stream of clay-water enters the pits, it contains from 1½ to 3 per cent. of clay; and what is called a good washing stream will carry about one ton of clay an hour. When the pit is full, the "hatch" is drawn, and the clay is "landed" into the tank. The upper portion is sufficiently fluid to run in of itself; but that near the bottom has to be helped out by men using "shivers" of wood or iron, which resemble large hoes; they are assisted by a small stream of water. The tanks are commonly, but not always, rectangular, built of stone, and paved with stone at bottom, often 60 ft. by 30 by 6, or larger. Once in the tank, the clay is left to settle, until it has the consistency of cream cheese, the water being drawn off from time to time; it is then ready to be trammed into the "dry."

The dry is a large building erected in immediate proximity to the tanks. It is always composed of two parts, the dry proper and the "linhay." The floor or "pan" of the dry is composed of fire-clay tiles 18 in. square, 5 or 6 in. thick at the fire end, and gradually thinning off to 2 or 2½ in. at the stack end. The flues are built of fire-brick about 14 in. wide, 2 ft. deep at the fire end, and 9 in. deep at the stack end. Each flue should be supplied with a damper. The furnaces are built in and arched over with best fire-brick; the fire-bars run longitudinally, and are about 6 ft. long. The grate surface is about 2 ft. 6 in. wide in front, and 4 ft. 6 in. to 6 ft. at back, according as each furnace supplies three or four flues. The clay, brought in from the tanks in tram-waggons holding about half a ton, is tipped on to the tiles, and spread in a layer from 9 in. thick at the fire end to 6 in. thick at the stack end. The fire end is loaded and cleared every day; the other end perhaps twice or thrice a week, according to the length of the dry, thickness of tiles, perfection of draught, &c. An average size for a first-class dry is perhaps 15 ft. wide and 120 ft. long; but some have been constructed considerably larger than this. The pan of the dry should be 6 or 8 ft. above the linhay whenever possible, so as to afford storage space for the dry clay, without expending labour in piling. The tiles should be as porous as possible, for very much more water passes through the tiles and into the flues than is driven upwards in the state of steam. The temperature should never be allowed to rise so high that the workmen cannot walk on the tiles, otherwise the clay may become baked and damaged.

In cases where there are no means of artificial drying, as at some old-fashioned works, the thick clay is at once transferred from the original settling pit to shallow depressions in the ground, called "pans." Ten or twelve of these, each holding from 40 to 50 tons, should be provided for each settling pit; they measure from 20 to 40 ft. square, and 2 ft. deep, and are enclosed by granite walls, the interstices of which are rendered impervious by plugging with moss. The clay, filling two-thirds of their depth, is here left exposed to the sun and wind, by which it is partially deprived of its moisture. In order to complete its desiccation, the clay is removed from the pans, after three or four months' exposure. A number of parallel incisions are made lengthwise in the clay, by means of a knife attached to a long handle; the strips are next divided transversely, by men with spades, who throw the blocks on to a board, upon which they are borne by women and children to the sandy drying yard, where, in fine summer weather, they soon become dry. They are then collected, and piled away in sheds, under a number of thatched gates or "reeders," or are placed in some sheltered position, where air can circulate around them without their becoming wet from rain. When required, the blocks are scraped by women armed with hoes, before being despatched from the works. The transport is often effected in small casks, holding about half a ton. A few years since, a machine for drying china-clay was invented by a mechanical engineer, named Leopoldo Henrion, of Sampierdacena, near Genoa. It is said that, by its use, the operation can be effected in a few hours, at a relatively small cost.

Collins was first led to adopt his arrangement in consequence of the formation of the ground; but he is inclined to recommend it in most cases if practicable. Very large quantities of stone are required in the dry pits, tanks, &c. Very often this is got, in part or entirely, in the process of excavating the pits, &c.; but if it cannot be so obtained, a very serious expense will be incurred, in some instances amounting to several thousand pounds. The total cost of the works may even be doubled from this cause, if stone has to be fetched from a distance of several miles. Two modes of building with rough stone are adopted; they are known as "lime building," and "dry stone walling." The first needs no special remark, but the second is very ingenious and very effectual. The wall is built up double, with a batter of about ¾ in., or 1 in. to the foot. Moss is placed between the joints of the wall, and the space between is filled in with sharp sand, the refuse of that or some other clay works. A small stream of water is then made to flow over the sand, which is well beaten in with rammers, or by treading with the feet. This process is continued, a foot at a time, till the wall reaches the required height, when it is either paved with rough stones set on edge, or turfed. A wall properly built, in the manner just described, is quite impervious to moisture, and will stand for fifty years or more. It is, where the proper kind of sand is abundant, much cheaper than lime walling, and is always preferred for the walls of pits and tanks.

Where the bed of clay is situated on a hill-side, with plenty of space below, a tunnel is driven in from the hill-side or from the valley to the required depth, and a rise is put up as before. This rise is then divided off into two parts. In the smaller, a button-hole launder is placed as before, and packed around with clay; but the larger is left open. A stream of water, obtained by pumping or otherwise, is made to run over the stope, and down the button-hole launder. It then flows along a launder placed in the bottom of the level, until it makes its exit in the valley. It may then be purified, settled, and dried exactly as already described—the works being laid out at a lower level than the adit; or, if the clear water is wanted to flow over the stope, or it is, for any reason, necessary to place the pits and tanks at a higher level than the stopes, the water is pumped up after partial or complete purification. The main difference in this mode of working is that, instead of pulling the sand and rubbish up over an incline, it may be tipped down the pass into waggons, run out through the level, and tipped over the hill-sides. In cases where water is abundant, it may even be washed out at night, thus saving the expense of tramming. Of course, when the workings have reached their full depth, the rise and the launder are dispensed with, and the adit level communicates directly with the " bottoms." By this mode of working, a considerable economy may be effected, especially when it is not necessary to pump the clay water for settling or repeating.

Uses.—The first use to which china-clay was applied was the manufacture of porcelain, and this is still popularly believed to be its sole application. This, however, is by no means the case, probably little more than one-third of the clay now produced is so employed. Large quantities are used by bleachers, for filling up the pores of calicoes as a dressing, and still larger quantities by paper-makers, to give "body" and weight to the paper, especially to printing papers. The manufactures of alum, sulphate of alumina, and ultramarine, consume very large quantities annually. Small quantities are taken by photographers, manufacturing chemists, and colour-makers, for a great variety of purposes; and, if reports are to be believed, it has been devoted to the adulteration of flour and of artificial manures. Should low prices be maintained, its use will, no doubt, be still more largely extended, in directions as yet unsuspected. The use of china-clay in the sizing of calicoes and other goods appears to have a very objectionable feature, apart from the question of fraud, inasmuch as the dust created, and the materials used to make the clay adhere to the warps, are productive of serious illness in the weavers. For further information on this subject, the reader may refer to the 'Journal of the Society of Arts,' vol. xx., pp. 625, 690.

Cost of Production.—Where the conditions of production vary so greatly, there must necessarily be great differences of cost; but, after having been at some pains to determine the cost under average conditions, Collins thinks the following figures and statements may be relied upon. A work capable of producing say 4000 tons of clay yearly will cost from 2500*l.* to 5000*l.* To get the clay in the linhay ready for the market, will cost about 9*s.* a ton, of which about 2*s.* 6*d.* must be expended in fuel for pumping and drying, 1*s.* in removing overburden, 1*s.* in removing sand, and 1*s.* for management and office expenses, leaving 3*s.* 6*d.* as the net labour cost of washing and drying a ton of clay. To the 9*s.* net cost of clay, must be added an average of 3*s.* for royalties, 4*s.* for transit and placing on board ship, and 1*s.* for agencies, commission, bad debts, and sundries, making the average actual cost amount to 17*s.* Some favourably situated works can no doubt save two or even three shillings on this account; in others, the cost may amount to 20*s.* or even 22*s.* As to the selling price, this varies much more widely than the cost of production, ranging from 14*s.* to 35*s.* *f.o.b.* Clays sold at the lower rates are unremunerative.

Nature and Utilization of Waste Products.—Besides the clay proper, there are certain waste or pseudo-waste products, produced in very large quantities. These are as follows:—

Fine mica.—This is deposited in the " micas "; a few years since, it was thrown away or rather washed away, as is still the case in many works. Sometimes, however, it is collected, dried in the manner of clay proper, and sold to the makers of soft paper, paste-board, inferior pottery, &c., at a low price.

Coarse mica.—This is invariably washed away or thrown away, there being at present no demand for it. It, however, contains a very beautiful material, which might be applied to many ornamental purposes.

Sand.—This consists of broken quartz crystals, mostly white or pale brownish; when washed clean, it is the finest building sand known, as the angles are all sharp. Mixed with one-eighth of Portland cement, it forms a concrete as hard as stone.

Discoloured clay.—This has to be dug out from among the good white clay in many places. It has been successfully used in the manufacture of white bricks, for building purposes. In some instances, a quantity of the sand already mentioned is mixed with the refuse clay, and produces an excellent fire-brick. The same material is used in the manufacture of the tiles used as a floor for drying the clay. The manufacture of bricks and tiles from this debris is a growth, it is believed, of the last twelve years.

Overburden.—The upper part of this consists of soil, or " meat earth "; this is usually removed and carefully preserved. Underneath is a hard, often stony or sandy layer, which, in districts where tin is worked, often contains enough tin to pay for washing. With this stony or sandy layer, is usually a considerable thickness of discoloured clay suitable for brick-making.

Branches.—These are stony veins which run through the clay stopes in various directions. Sometimes they are quite worthless; but, in a few instances, they are veritable tin lodes, and contain enough tin to pay for stamping and dressing. Thus at Carclaze, near St. Austell, each 1000 tons of clay yields something like one ton of oxide of tin, and formerly the proportion was much greater. The proportions of these waste materials as compared with the fine clay procured are thus stated:—

For every one ton of fine clay there is removed—from 3 to 7 tons of sand, average about 3½ tons; from 2 to 5 cwt. of coarse mica, average 3 cwt.; from 1 to 3 cwt. of fine mica, average 2 cwt.; from 0 to 1 cwt. of stones, average ¼ cwt.

A cubic fathom of clay rock, of average quality, will yield about 2½ tons of fine clay; and about half a fathom of overburden must be removed to get it.

Suggested Improvements in Preparing.—Collins thinks that there is still much room for improvement in the preparation of china-clay, but that such must be a growth of time and circumstances. At the present time, about one ton of water has to be driven off from each ton of clay in the dry, and this uses at least 2 cwt. of coals on an average, and costs from 8*d.* to 10*d.* in labour. In a few modern drys, a small economy in fuel has been effected by lengthening the kiln; but in none has it been brought so low as 1½ cwt. to the ton of clay. Mr. Stocker, in 1862, suggested the use of filter beds, and also devised a centrifugal dryer; but neither of these contrivances has come into use, and the first would seem quite inapplicable, on account of the extreme fineness of the particles of clay, and the impermeability of even a thin layer of that substance. Some economy might perhaps result from the use of hydraulic filters of calico, such as are used in the potteries for drying the slip; but it is very doubtful if any saving would be effected, as the labour would be about the same, and, against the 2*s.* a ton for fuel, would have to be placed the wear and tear of the calico. In washing the clay from the stope, some benefit might accrue from the use of a jet of water under a pressure of from 50 to 100 lb. per square inch, as in the so-called hydraulic mining. This could only be applied to stopes of even quality, where very little picking out of inferior portions was required; but it would supersede the services of the "breakers" on the stope, and greatly lessen the labour of the washers. It is but rarely that a natural head of water is obtainable equal to the required pressure; but where machinery is used for pumping, the additional cost of pumping, say 250 gallons a minute to a height of 150 ft. in a standpipe, would be very slight, as the extra power required is little more than that of one horse.

Statistics.—From statistics obtained from many sources, it is evident that the production has very largely increased from 1809 to 1874—2919 tons against 226,309. In 1810, Trethosa (one of the largest works) produced 300 tons per annum, and employed thirteen persons, viz. eight in removing burden and raising (breaking) clay (at per fathom), three washing, two attending ponds and packing. In 1874, one of the largest works near St. Austell produced 9000 tons, employing about thirty men. Many works produced 6000 tons, employing twenty men. The quantity sent annually from Cornwall must average at least 150,000 tons. It goes not only to Staffordshire, but also largely to France, Belgium, and other foreign countries. The extensive clay works recently opened in several departments of northern France have done much to curtail the export of Cornish clay to that country; and the large deposits of the island of Bornholm have lately been worked upon to supply the needs of Denmark, Sweden, and Germany; while similar utilization of native clays has been carried out in America. Nevertheless, the growth of home industries which depend in a measure upon this article will, doubtless, counteract the influence of decreasing exports.

ARTIFICIAL CHINA-CLAY.—The principal supplies of china-clay are obtained, as has been described, through the agency of natural decomposing influences in granitic rocks. In one instance, however, at Betleek, County Fermanagh, it is procured by calcining the red orthoclase granite of the district. The felspar is whitened by the process, and the iron becomes separated in a metallic state, and is removed by magnets.

Fire-clay.—The fire-clays are so named from their great fire-resisting properties. Unlike most of the other clays, which occur chiefly in surface beds, fire-clay is derived exclusively from the coal-measures, where it commonly forms the floor or "under-clay" of coal seams, varying in thickness from 1 to 4 ft. Fire-clays are abundant in Great Britain, the principal works being situate in the counties of Stafford, Worcester, Northumberland, Durham, Lanark, and Mid-Lothian. The essential qualities of a fire-clay are a uniform texture, a somewhat greasy feel, and the presence of only very small proportions of lime, iron, alkaline earths, or other impurities that would cause it to yield to intense heat. Nevertheless, considerable variety of composition is manifested by fire-clays, taken even from different parts of the same seam. Samples taken from Newcastle, Glasgow, Dowlais, Cool Island, Stannington, and Howth, showed the following maximum and minimum percentages of the principal ingredients:—Silica, 67·96 to 43·00; alumina, 40·9 to 21·18; oxide of iron, 8·4 to 1·19; water, 15·1 to 3·14. The celebrated Stourbridge clay contains:—Silica, 60 to 66; alumina, 25 to 31; oxide of iron, 2 to 6 per cent. Most fire-clays exhibit impressions and carbonized remains of plants.

Extraction and Preparation.—The beds are worked by the same shafts and levels as the coal seams, except where their outcropping admits of open quarrying, which is rarely the case. After extraction, the clay is first exposed in spoil heaps, over the greatest available area, for from three to eighteen months, according to the season. The action of frost is very serviceable in disintegrating the tough lumps. In dry weather, frequent watering is necessary; in wet weather, three months' exposure may suffice to render it "mellow," or "ripe," as it is called when it falls to powder. It is next ground in "edge-runner" mills, and carried on endless bands to the "riddles," whose mesh varies according to the destined application of the clay—4 to 6 for fire-bricks, 6 to 10 for fine cement clay, and 12 to 14 for glass-house pot-clay. The pieces that will not pass through the riddle are carried back on an endless band, to be reground. After being riddled, the clay is "tempered," or brought to the proper degree of plasticity, by the addition of water, and is then thoroughly stirred and kneaded in a "pug-mill," to fit it for moulding.

Uses.—Fire-clay is applied principally to the manufacture of a variety of articles which are required to withstand great and long continued heat, such as bricks and "lumps," for furnaces, fire-grates, ovens, retorts, flues, and the linings of fireproof safes, also smelting pots, crucibles, &c. For sewage pipes, it is quite equal to any other material employed, and, perhaps, superior on the score of durability.

Statistics.—According to Hunt's Mineral Statistics for 1878, the total production of fire-clay in the United Kingdom exceeded two and a quarter million tons; of this quantity, Durham and Northumberland yielded over 350,000 tons, and Scotland nearly as much; Staffordshire, 180,000; Yorkshire, 100,000; Lancashire, 60,000; Denbighshire, 23,000; Cumberland, 23,000; Shropshire, 17,000; Leicestershire, 15,000; Glamorganshire, 15,000.

Meerschaum.—This mineral is a hydrous silicate of magnesia, occurring in veins, or in uniform nodules, whose size varies from that of a nut to a cubic foot or more, in the serpentinous rocks of many countries, but chiefly at Kilchik, Eski-Shehr, and Broussa, in Asia Minor, in the island of Negropont, and at Baldissero, in Piedmont. In 1872, the discovery of a bank of excellent quality was announced from Southern California. Its approximate composition is—Silica, 60; magnesia, 28; water, 12 per cent.; it seems to arise from the decomposition and waste of the carbonate in older rocks.

Extraction and Preparation.—The deposits at Eski-Shehr are worked by pits and galleries at a depth of 4 to 5 fathoms. When freshly exhumed, the mineral is covered with red, oily earth, and is so soft as to be easily cut by a knife. After being scraped, to remove this coating, it is dried in the sun for five or six days, or in a hot chamber for eight or ten days, again scraped, and then polished with wax. It is then sorted into ten different grades, and is carefully packed with wool in boxes for export.

Uses and Statistics.—The common kinds are used in the manufacture of porcelain, and the fine qualities are consumed by the tobacco-pipe makers. The annual export from Asia Minor is said to reach 8000 to 10,000 boxes, representing a money value of about 100,000*l.*, principally to Vienna and German towns.

ARTIFICIAL MEERSCHAUM.—A cheap artificial imitation of meerschaum is made from gypsum, hardened, treated with stearic acid or paraffin, polished, and coloured by a solution of gamboge and "dragon's blood." Meerschaum pipes are said to be now manufactured in France from potatoes. The latter are peeled, and placed in a mixture of 8 parts sulphuric acid and 100 parts water, for 36 hours, whereby they become black. They are next dried by blotting-paper, and submitted to pressure, becoming thereby a material which can be easily carved. The counterfeit is said to be excellent.

Pipe-clay.—This is another variety of fine, plastic clay, so named from its application to the manufacture of tobacco-pipes. It is found in the counties of Cornwall, Devon, and Dorset, whence some few thousand tons are annually exported to France, Belgium, Holland, &c., besides that for home consumption. The composition of pipe-clay resembles that of china-clay, except that there is a preponderance of silica; it may be approximately stated as silica, 54; alumina, 32; water, 12; oxide of iron, lime, and magnesia, traces. The analysis of a light and a dark coloured sample from Dorset gave respectively:—Silica, 65·49, 72·23; alumina, 21·28, 23·25; oxide of iron, 1·26, 2·54; alkaline earths, 7·25, 1·78; sulphate of lime, 4·72, trace.

Pottery-clay.—The distribution of clays suited for the manufacture of earthenware or pottery is very wide, and their origin is very various. They always occur in more or less superficial beds, with but a slight thickness of earthy or gravelly covering, consisting of fine laminated silts of the Glacial period, or old estuary deposits, as well as river-valley accumulations, and re-formations from the waste and wash of the Boulder-clay. Their composition varies exceedingly; e. g.:—Silica, 44 to 58; alumina, 24 to 38; oxide of iron, 1 to 7; water, 10 to 15 per cent.; with traces of magnesia and lime. The coarser qualities approach brick-clay; the finer, china-clay. The requisite properties are plasticity, colour, and the absence of proportions of iron or alkalies which might be prejudicial to the burning process. They are worked by shallow pits, and are "ripened," ground, and washed, as the other clays.

(See **Alum**; **Alumina**; **Cotton Manufactures**; **Crucibles**; **Paper**; **Pottery.**)

COAL-TAR PRODUCTS.

In the distillation of coal for the production of illuminating gas, there passes over with the gases into the condensers, a variety of solid and liquid substances, the former being dissolved or suspended in the latter, and the whole forming a thick or unctuous mixture. When the mass is allowed to settle, it separates into two distinct layers: generally, the upper portion consists of water, holding in solution ammonia and ammoniacal salts, with more or less of the soluble constituents of the oily portion of the distillate; the lower portion is a mixture principally of oily hydrocarbons, and forms the article known as "coal-tar" or "gas-tar."

The mean average yield per ton of coal carbonized for gas in the various London gasworks, in 1878, is stated as follows:—Coke, 34·12 bush.; breeze, 3·17 bush.; tar, 10·40 gall.; ammoniacal liquor, 29·44 gall.; gas, 10,183 ft.

The composition of tar varies with the description of coal submitted to distillation, and with the degree of heat employed; though, probably, the degree of refrigeration to which the gas itself is submitted, after leaving the hydraulic main, has more to do with enriching the tar than all the other conditions combined. The specific gravity of tar ranges from 0·95 to 1·25; that of samples containing much naphthalene will fluctuate between 1·10 and 1·25: and such tars, being heavier than the "ammonia liquor," will sink in the tanks; the density of tars obtained from Scotch cannel coal approximates that of water, being sometimes a little above it, at others a little below—in such tars the naphthalene is replaced by paraffin.

London tar is always heavier than country tar; high heat increases the quantity of naphthalene. The larger gas companies generally dispose of their tar by contract; and, though there are most important differences in the quality and quantity of the distillate from tars of various origin; and produced under varying conditions of temperature, the distiller is unable to exercise any control over the character of the tar supplied to him. The tar is freed from the ammonia liquor, as far as is practicable, by allowing it to settle. It is then removed from the gasworks, in tanks fitted to railway trucks, or waggons, or in iron barges. On arrival at the works, the tar is pumped into large tanks of masonry or iron, sunk into the ground. Here it is left to settle for some days, to enable the watery portion to separate out. When the tar is very thick, the separation of the watery portion is facilitated by means of heat; through coils of copper or iron pipe placed in the tanks, steam or hot water is passed, until the tar is rendered fairly fluid. Over-heating should be avoided, as it might drive off the more valuable constituents of the tar. Too much care cannot be taken to free the tar from water, especially if the tar happen to be very thick, as is always the case in cold weather. The presence of water causes the tar to froth when being distilled, so that it boils over through the worms; it may even lift the still head, when contact with the fires will produce disastrous results. Tars which approximate the sp. gr. of water are not easily dehydrated; their distillation is best conducted on the Scotch or French systems. The inflammability of the tar products necessitates every precaution against fire. The tanks in which the liquids are collected are placed as far as possible from the furnaces, and are kept securely covered. As fires occur most frequently at the stills, it is best to isolate them from the general plant altogether; and, since it is impossible to extinguish burning tar, it is a good plan to supply each still with an outlet, at or near the bottom, communicating with an empty boiler or still, so as to run off the tar from the burning matter as quickly as possible. By taking this precaution, the opening of the outlet relieves the pressure due to frothing, and renders an accident from this cause much less liable to occur. There are three methods of treating tar—English, Scotch, and French; it will be necessary only to give those points of difference which render one method better suited than another in particular cases.

To avoid confusion, it may be well to point out that the treatment of tars varies according to their qualities and sources; unless otherwise stated, the remarks in this article apply to *English* tars, ordinarily obtained from London and country gasworks. London tar weighs 11 to 12¼ lb. a gall.; country tar, about 10½ lb. The tars known as "Midlands" are the most sought after by distillers; having been distilled at a lower temperature than the London tars, they are richer in benzol. When the heating is very low, the benzol may be replaced by eupion. London tar is principally obtained from Newcastle cannel or bituminous coals. Scotch cannel yields 15½ gall. of tar and 32 gall. liquor a ton; caking coal yields about half as much. The nature of the tar from the same coal will vary according to whether the retorts used are of clay or of iron; clay retorts are more strongly heated, which circumstance is said to diminish the benzol and increase the naphthalene. This may explain why country tars are preferred to London tar.

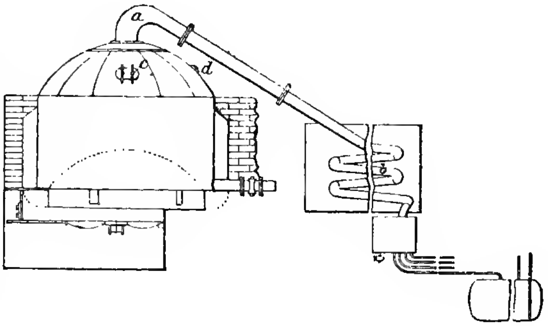
The form and capacity of still used in the "fractionizing," or fractional distillation, of coal-tar vary, principally, according to the extent of the works. The smallest capacity considered economical is 500 gall.; in large factories, stills holding from 1200 to 2500 gall., and even 4000 to 7000 gall. are used. A great advantage with the larger size is that it enables a manufacturer to dispense with much stowage space in the form of tanks, and consequently saves a great deal of labour; on the other hand, an accident is of much more serious consequence, and the charge cannot be run over without involving nightwork. For small works, those stills are preferred which admit of working off a charge in ten or twelve hours. The largest stills are convenient for dealing with special descriptions of tar, and in special modes of distilling. The most convenient size is 2500 gall., which, on the English system, is run over in about thirty-six hours.

In arranging the plant for a tar distillery, the great object is to enable the tar to be worked up as rapidly as possible, and with the smallest amount of labour. In the winter months, increased supplies frequently involve the erection of a few extra stills. The varying consistence of the tar may necessitate modifications in the method of distilling, so that it is almost impossible to prescribe any general rules in erecting the plant for this business. A few extra stills should always be put up ready for use.

There is no doubt that eventually most large gas companies will utilize their own tar; in such cases, it would be easy to determine what plant should be erected, because, as a rule, the coal used is the same, and the conditions of heating are likely to be kept uniform. The manufacturer who purchases his tar from several gasworks has to put up with a variable product.

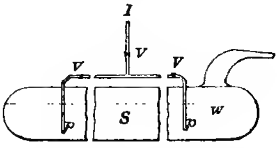
The English stills are constructed of ½-in. boiler plates riveted together; the portions which are likely to be more strongly heated are made thicker. If the distillation is to be carried to coking, cast iron should be used, as it does not burn out so rapidly, and needs no joints. To prevent burning, the bottom of the still rests upon brickwork, except in the coking process. The form of still chiefly used in England is that shown in Fig. 481. The "head" consists of a bent cast-iron pipe *a*, communicating with a series of iron pipes *b* arranged in a tank as a condenser. At the top of the still is a manhole *c*, and an inlet *d* for the tar; in some cases, the same inlet is used for injecting superheated steam, either for distilling purposes, or for driving out the pitch after the charge is finished. Around the neck of the still is a channel for collecting the portions which condense in the head; these are added to the distillates, as their falling back into the still may cause frothing, which is dangerous. Near the bottom of the still is a pipe for removing the residue. The stills are heated by separate furnaces, and are arranged under a light shed, so as to protect the workmen from the weather. They are sometimes enclosed in brickwork, as shown, with the view of preventing loss of heat. The heating flues should not reach above the space occupied by the contents of the still at the end of the operation.

481.



For a tar which is rich in light hydrocarbons, such as that yielded by Scotch cannel coal, and by the better kinds of lignite, another kind of still is required, as the application of fire-heat would be accompanied by danger. The method adopted with these tars is to distil them by steam-heat, in order to remove their more volatile constituents, until the residue in the retorts is reduced to a thick mass, known as "boiled tar." This is then withdrawn into tanks, or is pumped into other stills, in which the distillation is carried on in the usual way. These tars, being richer in benzol and anthracene oils, are much sought after by distillers, though the separation of water from them is more troublesome. The process, which is known as the "Scotch method," is conducted in the following manner:—The "green," or raw, tar is pumped from the settling tanks into stills—S, Fig. 482—having a capacity of 4000 to 5000 or more gallons, and made of ¾-in. boiler plate. A perforated steam-coil lies at the bottom of the still, or steam is admitted through branches *p*, with valves V, from an inlet pipe I. The stills should not be more than ¾ filled, say to W, as plenty of room must be allowed. The distillation is carried on until the distillate acquires a sp. gr. of 0·930; the residue in the retort, known as "“boiled tar," is then run out, through a hole near the bottom, into tanks, or is pumped into other stills at once, for further distillation over a naked fire. This process commends itself for several reasons; the most important are that the rapid recovery of the volatile constituents of the tar allows a large quantity to be worked up expeditiously, and that the naphtha obtained is more free from smell, and will keep better on exposure to the light. When the lighter portions are drawn over, the residue is stowed away for working up in slack time. Much of the so-called

482.



Scotch "solvent naphtha," now met with in commerce, behaves under acids so differently from English naphthas that it is questionable how far it can be used as a substitute for them. A great merit of the best Scotch naphthas is the absence of naphthalene from the "solvent" fraction.

The crude or "once run" naphtha obtained by this process is again distilled with steam, and the products are collected at different temperatures, as required. A residue, amounting to about 7 per cent. of the "once run" naphtha, is left in the still; it has a thick, tarry consistence, and is run in with the creosote oils, or sold to rosin-grease makers at 50*s.*–65*s.* a ton. In distilling with steam, a large quantity of water passes over with the product; as this continues during the whole operation, the distillate is received in a "separatory" apparatus, so as to allow the water to escape. This consists of a magnified "Florentine receiver," in the form of a rectangular iron tank. The "boiled tar" is distilled in vertical or horizontal stills, heated directly by a furnace. The heating should be very gradual, as this tar contains considerable quantities of water. About 1000 gall. yield 200 gall. of rough naphtha, which should give about 120 gall. of naphtha suitable for burning, &c., and about 320 gall. of creosote oils. The residual pitch will amount to 35–55 per cent., according to the temperatures at which the distillation has been conducted.

Ernest Smith says that in distilling Scotch cannel tar by the Scotch system, a little light oil, sp. gr. 0·850, first passes over, after which a rise takes place, and the whole of the light naphtha marks 0·890. The sp. gr. of the second naphtha is 0·910; to collect this, the receivers are changed, when the distillate rises to 0·930. The crude light naphtha from the best tars yields 10 per cent. at 120° (248° F.), with a sp. gr. of 0·880. He states that paraffin appears more copiously in tars obtained from cannel coal at a low heat, and that generally the anthracene, before purification, contains a larger quantity of paraffin. This certainly will help to account for the great differences in Scotch solvent, and explains the discordant figures given by various authors.

A continuous process of distilling has been lately introduced: by running the tar over molten lead the more volatile part is driven off, and the residue is received in retorts for further treatment.

The "French system" of distillation differs mainly in drawing off the aqueous portion of the tar at a much lower temperature. It is frequently effected in jacketed stills, or by means of circulating steam pipes. The same method is obviously applicable for drawing over the lighter oils, or for carrying on the distillation so as to separate the constituents of the tar at one operation. "Liquid pitch," or "thick tar," contains a little of what corresponds to the second light oils of the English method, and all the heavy oils; "fat pitch" is deprived of all the light oils, and partially of the heavy oils; "dry pitch" is obtained by heating until liquids are given off. The condenser usually employed consists of a series of 4-in. flanged iron pipes, joined together by cast-iron elbow-pieces, and arranged in a water-tank in zigzags or ovals. The joints are best made with sheet lead; where cemented joints are required, slaked lime worked up with a little tar makes a lute, which, after hardening, stands for a long time. For convenience in cleaning the condensing tubes, they are joined by tee-pieces, and the ends which project through the tank are closed by iron plugs or caps. The length of worm required is a matter of some importance: the liquids which come over at the first stage of the operation should be well cooled, whilst the heavier oils, if cooled too much, would choke up the tubes. The cooling must be so regulated that the distillate shall flow freely away to the receivers. About 160 sq. ft. of condensing surface is sufficient for a still working off 2000 gall. of ordinary tar per twenty-four hours. If the product solidify on cooling, or if much naphthalene come over with the creosote oils, it may be necessary to stop the cooling altogether, or even to heat the water in the worm-tank by injecting steam. It is not easy to define precise regulations, and, in operating upon a new sample of tar, it is by far the best plan to watch the distillate itself; for not only is it a matter of great importance to know how to adjust the condenser, but the proper time for changing the receivers must be ascertained, especially if the preliminary distillation is used for partial fractionizing.

In treating ordinary English tar, the distillation is thus conducted:—The firing is generally got up as the filling progresses. It is important to raise the heat very cautiously, and to watch for the commencement of the distillate going over; this can be done by feeling the condensing tube, and, as soon as it becomes warm, the fire should be checked, the object being to distil very gradually at first, and to make tolerably certain that all the watery portion has come over. If frothing occur, the still head may be cooled with water, unless the still be of cast iron. The water present in the tar makes the distillate come over more copiously. The first distillate consists of water charged with ammonia ("ammoniacal liquor"), and the more volatile hydrocarbons. As soon as the water has stopped, the receiver is changed, and the heating is slightly increased. The product which now passes over is called "first light oils," and amounts to 8–10 per cent. of the quantity of tar originally taken. During this time, the temperature gradually rises, from the fact that the tar parts from its more volatile portion, and what remains has a much higher boiling-point. In the earlier part of the process, the refrigeration must be as perfect as possible; but as the receivers are changed for the heavier and less volatile portions of the distillate, it is not so essential to keep them very cool. This is not entirely a matter of economy of water: a little heat facilitates the flow of the condensed liquids, and hastens the distillation.

In the English and Scotch systems, the receivers are changed for collecting what is known as "second light oils," and there is no doubt as to the advantage of this, especially where large quantities of tar are treated; by the French method, no fraction is obtained corresponding to this.

The distillation is carried on until a few drops of the distillate will sink in water; but it is better to stop the collection of second light oils at an earlier stage, for the distillation of some tars, as those yielding paraffin, can be carried on at a very high temperature without yielding a product heavier than water. It is better to use a thermometer, and to change the receiver as soon as the temperature is sufficiently high. With ordinary English tar, the first and second light oils are collected until the distillate sinks in water, when the receivers are changed for the "heavy oils," "creosote oils," or "creosote." As the product now contains much naphthalene, which may choke the condenser, the latter must be kept warm; diminishing the flow of cold water will secure this under ordinary circumstances, but it may be necessary to heat the condensing worm, if large quantities of naphthalene are present.

After a time, the distillate changes again, and has a green colour; this is known as "anthracene," or "green oils," and is collected in a separate receiver. Towards the end, the distillate becomes black, and the receivers are finally changed for what are termed "last runnings." The residue contained in the retort constitutes pitch, which, while still liquid, is drawn off (or blown out by superheated steam) into a closed tank, to cool down to about 204° (400° F.), before being placed in its ultimate receptacles. The reason for this is that its temperature is so high that it would readily ignite, if immediately exposed to the air.

Neglecting the ammonia, which has been already treated of at p. 232, the products of the fractional distillation of coal-tar are:—

1. "First light oils," with water and ammonia, passing over at .. .. 100° (212° F.).
2. "Second light oils," or "once run" (or crude) naphtha, passing over at 149° (300° F.).
3. "Heavy oils," or "creosote oils," or "creosote" „ „ 171° (340° F.).
4. "Green oils," or "anthracene" „ „ 204° (400° F.).
5. "Black oils" „ „ 425° (800° F.).
6. Pitch, left as a residue.

The temperatures given are approximately those at which the receivers are changed.

On the French system, the fractions are collected at slightly different temperatures.

The next consideration will be the products derived from each of the above-mentioned groups, omitting all theoretical or purely scientific elements, as well as compounds of no immediate importance.

Once-run (or Crude) Naphtha.—This liquid is almost colourless when freshly drawn over, but rapidly acquires a brownish tinge, by oxidation, on exposure to the air and light. It is rather curious that those constituents of coal-tar which are so readily affected by light appear to have escaped the attention of the scientific photographer. A test for the purity of rectified naphtha is its non-changeability in colour on exposure to light; and the treatment to which it is subjected is for the purpose of removing those principles which render it liable so to change. If the receiver has been changed after the water has passed over, the crude naphtha will be considerably less rich in those principles which boil at or under 100° (212° F.), and the watery vapour will have carried over much of those having a boiling-point above that of water. This is more perceptible with those tars which are lighter than water, for the vapour, in passing through the tar, mechanically carries over a little of all the principles contained in it, and which of themselves would not go over except at a higher temperature. If the receiver has not been changed, the crude naphtha will contain the first and second light oils. In the case of tars containing much creosote, it is more economical and convenient to split the crude naphtha into first and second light oils at the first operation. Many manufacturers of benzol, solvent naphtha, and aniline products, purchase crude naphtha from the tar distillers; and as this product varies in composition and value, the manufacturer should know what he is actually purchasing. Its value chiefly depends upon how much it contains of benzol, toluol, xylol, and cymol, which come over at different temperatures, and upon their sp. gr. It is submitted to a rectification or second distillation, with or without the oily portion which separates out of the ammoniacal liquor. The latter is best treated separately, as it consists mostly of benzol and toluol, and is consequently a convenient source of high-class benzols. The object of the second distillation is to separate the more volatile benzol and toluol, and to clear the solvent naphtha of a great portion of the heavy oils. It is pumped into a still, heated by steam or hot water, and covered with felt and cement, to prevent the heat escaping and raising the temperature of the room. The process is governed by the temperature indicated by a thermometer immersed in the vapour. This operation is carried on with extra care; the vapours are led away to an efficient condenser at some distance from the building, and the liquor is received in covered tanks sunk in the ground. As a rule, the crude naphtha is only fractionized once; but it may be split up into different products, according to the requirements of the manufacturer. To produce high-class benzol, the receivers may be changed as soon as the temperature rises to 100°–104° (212°–220° F.). The usual plan is to allow the distillate to flow into a closed vessel supplied with two or more cocks, and containing either a hydrometer or some excisemen's beads, so as to guide the distiller in changing the receivers. Scarcely two distillers fractionize naphtha in exactly the same way; everything depends upon what it is wished to extract, without rendering the residue unsaleable. Some collect the distillate until the temp. rises to 115°–121° (240°–250° F.); others go so far as 132°–138° (270°–280° F.); and others, again, make only one change of the receivers, collecting, at 121°–132° (250°–270° F.), all that comes over until the temp. rises to 149°–160° (300°–320° F.). The capacity of the stills must depend on the number and extent of the fractionizings. A disadvantage is experienced from splitting the distillates into too many products; but this is removed by collecting the products of the first distillation, in such a way that two fractionizings will be sufficient for the second distillation of each of the first products. In the rectification of the crude naphtha, whatever comes over at the lowest temperature should be added to the second product obtained in the first distillation, and thus the products should be treated throughout.

To avoid repetition, it may be stated here that the treatments of all the products are pretty much the same. Dilute acids are used to separate the bases, and alkaline solutions are employed to remove the acids, the process being called "washing." In particular cases, steaming is used to facilitate it, when special appliances are necessary to avoid evaporation.

The following synoptical arrangement will give a clear idea of the primary products obtained by ordinary fractionizing on the English system:—

1st, or Preliminary Distillation. Stills charged with gas-tar, yield:—	2nd. Distillation or Rectification. Stills charged with products from gas-tar, yield:—
A. 1st Product, containing:— *1st Light Oils.* Water charged with ammonia, &c. Benzol } going over with the Toluol, &c. } vapour of water. } A′.	A′. Obtained from A by standing to separate. Ammonia liquor. Benzol. Residue added to B.
B. 2nd Product, containing:— *2nd Light Oils.* Benzol } small quantities. Toluol } Xylol } principal Cymol } constituents } B′. Heavy oils, &c., small quantities.	B′. Obtained from B. Benzol, 40 per cent. to 60 per cent. Toluol. Solvent naphtha, with small quantities of light and heavy oils. Residue added to C.
C. 3rd Product, containing:— *Creosote, or Heavy Oils.* Carbolic acid Cresylic acid } C′. Naphthalene, &c.	C′. Obtained from C. Crude creosote:— Separated by pressure, &c., into Carbolic acid. Cresylic acid. Naphthalene.
D. 4th Product, containing:— *Green Oils.* Anthracene, &c. D′.	D′. Obtained from D by heat and pressure. Crude anthracene. Residues added to crude creosote, or redistilled.
E. 5th Product, containing:— Dead oil, or Last runnings F. 6th Product. } E′. Pitch.	E′. Obtained from E and F. Soft pitch contains the dead oils. Hard pitch is deprived of a great deal of these oils.

When the tar is distilled so as to yield a hard pitch, by removing as much as possible of the anthracene oils, it is converted into softer kinds by addition of the creosote oils.

This list gives only the principal constituents of each product; by repeated fractionizings, their proximate constituents may be isolated, according to the purity required for the commercial article. The tar distiller rarely has to carry his operations so far as to obtain more than the approximate separation of the series contained in the second column. As the preliminary treatment of most of these is almost identical, it will suffice to give one general description.

Washing.—Formerly, the crude naphtha and light oils, freed from their watery portions, were pumped into large, lead-lined, wooden vats, and agitated by perforated rotating fans, for some hours, with sulphuric acid and caustic soda solutions, each washing being followed by a good agitation with water. The acid and other liquids must enter in a fine spray. Now, it is the general practice to re-run the crude naphtha before washing, as many impurities are thus removed, and a saving of material is effected. Sulphuric is preferable to other acids, because it more easily carbonizes the impurities, and causes them to separate out as a soft resinous mass, in addition to which, it forms, with the bases, salts which can be removed by washing. About 3 per cent. by measure of acid (c. o. v.) is gradually diffused through the liquids, and the whole is well agitated; on standing, the impurities collect on the bottom; the naphtha is drawn off into another tank, to be agitated for five or six hours with 6 per cent. of acid. After settling, it is again drawn off, and agitated with repeated fresh supplies of water, until all the acid is removed. The water is drawn off, and the naphtha is then agitated with 10 per cent. of a solution of caustic soda, sp. gr. 1·03. Sometimes milk of lime is added; but its use requires extra care. After standing for some time, the naphtha is treated with water as before, or is pumped into a still, and drawn over by superheated steam. Three washings with acid are given, the last being sometimes with a mixture of sulphuric and weak nitric. The acid sludge has been largely used for making superphosphate.

After the separation of the water by standing, the naphtha should be colourless, i. e. "water white," and remain nearly so on exposure to light; this is the best test of thorough washing. For "second light oils," caustic solutions are first used, as the chief matters to be removed are carbolic and other acids. As these vary in different naphthas, a preliminary test is made, to ascertain how much caustic solution is required (see Carbolic Acid, p. 44). After removing the soda-salt formed, by washing with water, the whole is left to settle; the liquid is drawn off and treated with acids, as above, or is first submitted to distillation.

Various ways of carrying out these rectifications are adopted by different manufacturers; some have only ideal advantages, whilst others are more useful. As a rule, it is found that by pushing the distillation too far, in the preliminary treatment of the tar, little or nothing is gained. The object is to minimize the washing, which means saving acid and alkali, as well as labour. A saving of acid and alkali is effected by not allowing the heavy oils to go over with the second light oils, and, for the production of solvent naphtha, this is an important consideration. It is necessary to guard against loss from evaporization, caused by the heat generated on mixing the naphtha with acid or alkali. The products, either crude or rectified, are redistilled for new products.

The stills used for fractionizing the crude naphtha are known as Coupier's and Clark's. The vapours are condensed in a leaden worm, and the liquids are received in a closed box with glass sides, containing some coloured "specific gravity beads"; at the bottom, are several cocks communicating with separate tanks for the reception of the fractionized products. The still is covered with felt and cement. It converts the crude products into second-class benzols, toluols, and solvent naphtha, the residues being drawn off into the creosote tanks. The condensation must be thorough, to prevent escape of the vapour, which, from these portions of the distillate, is very inflammable. In the first fractionizing by Coupier's still, the proximate principles are only comparatively isolated, though more so than is usual with the English products; but by submitting the products to a second or third rectification, it is possible to separate the principles very completely. Thus Coupier's distillates have justly earned an enviable reputation. His still is used principally on the Continent. Clark's still, like the one previously mentioned, is, in many respects, similar to the Coffey still (see Ammonia). It may be used in a variety of ways; the same results may be attained as by Coupier's still, but with the advantage that the liquid is broken up into several products at one operation.

Few manufacturers adopt these methods, unless for some special purpose. The most economical way of working is to take advantage of the preliminary distillation for the first fractionizings, and, in re-running the crude naphtha, to follow a similar plan. This entails a greater outlay in tanks for stowage, which may be economically replaced by puncheons, provided they can be kept from leaking, and from allowing the lighter products to penetrate the wood.

Solvent naphtha, or, as it is more frequently called, "solvent," is much used in the manufacture of indiarubber waterproof goods, as it readily dissolves or softens indiarubber. It is also a solvent of resins, oils, &c., and, at one time, was largely used in the manufacture of varnishes, paints, and cements; but for such purposes it is now almost entirely replaced by the lighter kinds of petroleum. It is often adulterated with petroleum or shale oils. Good solvent naphtha, from English tar, has a sp. gr. of about 0·870 at 15° (60° F.), and should commence to boil at about 118° (245° F.), although it frequently requires 121° to 127° (250° to 260° F.) before any appreciable distillate goes over. Between its boiling-point and 142° (288° F.), about 70 or 80 per cent. of its bulk should pass into the receiver, and the sp. gr. of this fraction should be a trifle less than that of the original sample. The distillate collected between 142° and 160° (288° and 320° F.) should be a little heavier than the sample, and should correspond to 15 or 20 per cent. of the original bulk. The residues, when containing naphthalene, are often as high as sp. gr. 0·950, and solidify in cold weather; otherwise the sp. gr. of the residues and fractions will not vary much from that of the solvent itself. When petroleum or shale oils are present, either as adulterants, or when the naphtha is derived from the tar of cannel coals, the sp. gr. will be 0·845. Scotch solvent goes over at lower temperatures than the English product, and is of lighter sp. gr. If much distil at or below

118° (245° F.), petroleum oils are probably present; this can be ascertained by the sp. gr. of the fractionized product. Scotch solvent gives 95 per cent. distillate at 160° (320° F.).

The vapours of solvent naphtha have a peculiar intoxicating power over those unaccustomed to its use; a person thus affected rapidly recovers when taken into the open air. The effect is indicated by giddiness and hilarity, which is not followed by depression on recovery. It is rare for the same individual to suffer more than one or two attacks. The ventilation of the buildings where it is evaporated is generally well arranged. Formerly, they were lighted, when necessary, by gas jets fixed outside the windows; now, a good supply of air is admitted, and dilutes the vapour so rapidly as to remove all chance of explosion. (See Indiarubber Manufactures.)

Benzol, or Benzene. C_6H_6.—This liquid was discovered by Faraday in 1825, and was named by him "bicarburet of hydrogen." In 1834, Mitscherlich obtained it by distilling benzoic acid with hydrate of lime. It may also be procured by passing benzoic acid through a red-hot tube. A mixture of one part of benzoic acid and three parts of slaked lime yields, by distillation, benzol in a pure state, and calcic carbonate. The mixture should be gently and gradually heated; the benzol, which goes over with a little water, is separated from the latter, and distilled over a solution of caustic potash. Benzol is one of the most important principles of gas-tar; it exists largely in the petroleums known as Rangoon tars, and in some of the petroleums of Europe, the Caspian, &c. When pure, it is a colourless mobile fluid, boiling at 81° (178° F.), and solidifying at 3° (37° F.) into a colourless crystalline mass. Its sp. gr. at 0° (32° F.) is 0·899, and at 20° (68° F.), 0·878. It has a peculiar aromatic smell, is very inflammable, and burns with a smoky flame. It is slightly soluble in water; but dissolves freely in alcohol, ether, carbon bisulphide, and the liquids obtained by distillation from gas-tar. It is also miscible with the petroleums. It dissolves iodine, sulphur, phosphorus, fats, oils, resins, guttapercha, and indiarubber. It may be used in varnishes and in paints, as a substitute for turpentine; but its price is too high for this at present. It removes grease spots from cloth, silk, &c. Its volatility renders it a convenient source of illumination. The "Benzol" or "atmospheric" light is obtained by passing a current of air or hydrogen through benzol. The saturated air is distributed in the same way as coal-gas, and burns freely. The conditions which operate against this method of illuminating are condensation in cold weather, and the difficulty of saturating the air at low temperatures.

The fact that benzol solidifies when cooled to a low temperature supplies a method for its purification on a large scale. The solidified mass is submitted to pressure, by which the benzol is freed from its liquid impurities; by redistillation alone, this would be almost impossible. Benzols which become solid at −1° (30° F.), are prepared for special purposes.

In commerce, it is rarely met with in such a state of purity; but is sold as 90 per cent., 40 per cent., &c., which means that when the sample is distilled, 90 per cent., 40 per cent., &c., passes over at or below 100° (212° F.): 90 per cent. is the highest commercial rectification, and in preparing pure benzol it is better to work upon this basis. Pure benzol is obtained from the commercial article by repeating the process for the production of the latter, and expressing the congealed mass.

It is of great importance when purchasing benzol, toluol, naphtha, &c., first to have an understanding with the seller, as to the conditions of performing the distillation:—

1. The quantity to be placed in the retort for distilling.
2. The capacity of the retort.
3. Whether the bulb of the thermometer is to be immersed in the liquid or in the vapour.
4. The rate, whether in drops or in a stream, at which the distillate shall pass over.
5. The method of applying the heat.
6. When the distillation shall be considered complete.

Corrections for barometric pressure may sometimes be necessary, and, in all cases, the distillate should be measured at the same temperature as the liquid, the loss due to imperfect refrigeration and condensation being considered as a part of the distillate. The residue, if measured off immediately the distillation is ended, will be warm; if left in the retort to cool, the few drops collected in the receiver after the distillation is ended must be regarded as part of the residue. This may easily give rise to a difference of 2 or 3 per cent.

Manufacture and Rectification.—Several forms of apparatus for separating benzol from once-run naphtha have been already mentioned. The essential feature in all of them consists in receiving the vapours in a condenser kept at such a temperature that only those liquids can pass over which are vaporizable at that degree, those vapours which are condensed at this same degree being returned to the still. By using a series of condensers, the liquid may be fractionized to any extent at one operation. This portion of the factory is kept cool, and is placed as far as possible from boilers and furnaces, on account of the volatility of benzol and the inflammability of its vapour. The distillation is effected by steam or heated water, as it is then easier to regulate the temperature; direct heat colours a portion of the liquid. The vapours are collected in another boiler, placed on end, provided with a thermometer, and jacketed so that it can be kept at any required temperature by steam or water; those vapours which are condensable at that temperature are here arrested, whilst the others pass on to a properly cooled receiver, whence they are delivered into a vessel provided with two or more taps, communicating with stowage tanks. When the temperature of the intermediate condenser is so high as to keep the benzol in a state of vapour, the product will be richer. When it is desired to collect the distillate at different temperatures, the jacketed boiler is heated to, say, 82° (180° F.), so as to allow the benzol to pass over; as the temperature is raised, the cock leading to the benzol tank is closed, and another cock is opened, so as to collect the second distillate; thus any number of products may be drawn over from the same still of crude naphtha.

The crude benzol is washed by thorough agitation with strong sulphuric acid in well-closed, lead-lined vats; on the large scale, the agitation is performed by steam power; the acid is then drawn off, and the benzol is well washed with water. These operations are repeated according to the degree of purity required, or until the acid drawn off is nearly colourless; the final washing is with lime water, or a weak alkaline solution. When well washed, the benzol will suffer no change of colour on addition of sulphuric acid. The sulphuric acid may be used afterwards for the treatment of crude naphtha. The benzol is then carefully distilled. To avoid the loss due to heating, the sulphuric acid is added slowly and at long intervals. The treatment with acid and alkali, and final washing with water, are best carried out in separate vessels; by arranging them one above another, the liquids are easily decanted, and the sludge can be caught in receptacles placed beneath. Lime is cheaper than soda; but it forms, with many of the tar acids, less soluble compounds, which are thus less easily removed by washing. The alkali waste from this and similar operations is now frequently burnt for reconversion.

The amount of benzol contained in a sample of tar will, under ordinary circumstances, depend upon the amount of refrigeration to which the gas is submitted. The reader's attention is called to Lake's patent method of obtaining benzol from gas (No. 488, 1869); if the figures therein given can be sustained in practice, an enormous amount of benzol and toluol can by this method be recovered from coal-tar. Coal-tar naphtha boiling at 130° (266° F.) is worth about 1*s.* 9*d.* a gall., whilst petroleum boiling at 149° (300° F.) is worth about 9*d.* a gall.; 60 per cent. benzol is worth 3*s.* a gall. If it is possible to recover, say, 12 per cent. of the liquid used in washing the gas, there should be 2½ to 5 gall. of a product worth from 3*s.* to 4*s.* a gall. from every 10,000 cub. ft. of gas, so that it would be more economical to carburet the gas with such liquids if necessary. This fact is important to gas manufacturers, and not without interest to gas consumers. If the sole object in distilling coal were to use the gas as fuel, there could be no advantage in this process. It appears quite possible that, by selecting the coal and arranging the heats, the tar may be enriched in benzol, with only a slight sacrifice in the quantity of gas produced. The production of liquid hydrocarbons from coal, as a source of profit, does not seem to have occurred to gas companies. The comparative poverty of the highly bituminous coals in benzol and anthracene places many distillers of English tar at a disadvantage in the manufacture of these two products.

Toluol, Toluene, or Methyl Benzol. C_6H_5,CH_3.—Toluol was discovered by Pelletier and Walther in rosin-oil, and was called by them "Retinnaphtha." The name "toluol" was given to the liquid by Deville, who obtained it by the distillation of Tolu-balsam. It exists in wood-tar; but its commercial source is coal-tar. It is met with in commerce as "rectified toluol," "commercial toluol," "rosaniline benzol," &c. Its highest degree of rectification would be exhibited by the fluid obtained in preparing benzol by refrigeration; but commercially it is procured from the distillate of naphtha which comes over between 107° and 121° (225° and 250° F.); some samples contain a distillate going over at higher temperatures. It is a colourless, limpid, oily liquid, which does not solidify when cooled to any ordinary temperature. In odour, solvent properties, and miscibility with other hydrocarbons, it resembles benzol. By oxidation, it becomes benzoic acid. Its sp. gr. is 0·88 at 0° (32° F.), and 0·87 at 24° (75° F.); it boils at 110° (230° F.). The value of commercial samples is found in the same way as benzol. It is best stored in galvanized iron drums, or glass carboys, as benzol.

Xylol, Xylene, or Di-methyl Benzols. $C_6H_4\left\{\begin{matrix}CH_3\\CH_3\end{matrix}\right.$.—When purified coal-tar naphtha is submitted to fractional distillation, a liquid boiling at 139° to 140° (282° to 284° F.) is obtained. This was at first regarded as a pure compound; but recent researches have shown it to be a mixture of two di-methyl benzols, which, having nearly the same boiling-point, cannot be separated by distillation. They are known as "methyl-toluol" and "iso-xylol"; the latter forms the principal ingredient of the solvent naphtha used by indiarubber manufacturers. Commercial xylol contains a little toluol, as it is the product of the higher distillation after the commercial toluols have been drawn over, and consequently forms the bulk of the second light oils. It is prepared by Beilstein and Wahlfoss by treating the naphtha distillate which comes over at 141° (286° F.) with fuming sulphuric acid, after repeated treatment with acid and alkali, as in preparing benzol, naphtha, &c.; this dissolves the xylol, which is subsequently extracted by dry distillation.

Creosote.—The portion of the distillate which is collected as creosote oils is generally sold as "creosote," without any further treatment. It is a thick, black liquid, containing principally carbolic acid and naphthalene. Its consistency varies with the proportion of the latter; creosote from London tar is particularly rich in it, and, in cold weather, frequently solidifies. The principal use to which creosote is applied is the preservation of timber. Its value for this purpose depends, according to Dr. Letheby, upon the following points:—It should have a density of 1·045–1·055; it should not deposit any crystalline matter at 4°-5° (40° F.); it should not yield less than 5 per cent. of crude carbolic acid to a solution of caustic potash at 1·070 (14° Tw.); and it should furnish 90 per cent. of liquid oil when distilled at 315° (600° F.). Some contracts issued in 1867, by the Dutch Government, stipulated that the creosote should be clear, and not yield more than 40 per cent. of naphthalene when cooled to 0° (32° F.), and kept at that temperature for twenty-four hours. It should dry up with little loss, and should harden by oxidation when imbibed by porous substances. This fraction is also worked on for carbolic acid.

The creasote of the druggists is a totally different product, derived from the distillation of wood.

Creosote oils accumulate in a works in excess of requirements; they may be utilized as fuel, in accordance with the patented plan of Edward Dorsett (No. 176, 1868). Crude creosote is worth 2*l.* to 2*l.* 5*s.* a ton.

Naphthalene. $C_{10}H_8$.—This substance was discovered by Garden, in 1820, in coal-tar. It is formed by the destructive distillation of many organic bodies, especially when their vapours are passed through tubes heated to redness. It is found in wood-tar, and also in Rangoon petroleum; it has been produced synthetically by passing the vapour of phenyl-butene dibromide through a red-hot tube. Its commercial source is coal-tar. It exists most abundantly in tars from bituminous coals; in lignite and boghead tars, and also the better classes of cannel tar, it is replaced by paraffin.

In the distillation of tar for the production of crude naphtha, the process is arrested when a few drops of the distillate solidify on collection on a cool surface. The substance then left in the stills contains much naphthalene and phenol. Until anthracene received commercial importance, this residue was distilled for creosote oils only. The presence of naphthalene in naphtha is shown by the high sp. gr. of the residues at 160° (320° F.); on evaporating these slowly in a water bath till the bulk is reduced one-half, and cooling, naphthalene is obtained; when pressed so as to separate the adhering liquid, it will be found tolerably pure. It is sold in rolls, which are obtained by casting the melted article in moulds; in this form, it is supplied for carburetting gas, by the method known as the albo-carbon. The further purification of naphthalene is effected in the following way. The material is first melted, in closed vessels, with a solution of caustic soda, and well agitated. Whilst boiling, the watery vapour carries away a considerable quantity of naphthalene, which should be collected; as the vapours cool, it is deposited almost pure. The caustic solution and naphthalene are separated by cooling and compression; after being well washed with boiling water, the latter is treated in a similar way with water acidulated with sulphuric acid. These operations are repeated according to the degree of purity required. It is then distilled in cast-iron retorts over a naked fire, at a temperature not much exceeding 205° (401° F.). The residue will contain much naphthalene; but at higher temperatures, it is contaminated with other products. The distillation is carried to dryness, and the last product is added to the crude naphthalene for re-treatment.

Naphthalene crystallizes easily from saturated solutions, or by sublimation, in large silvery white plates or scales. It melts at 79° (174° F.) into a perfectly clear liquid, and, on cooling, solidifies into a crystalline mass. It boils at 216° (421° F.); its sp. gr. is 1·15. It is slightly volatile at ordinary temperatures. It burns with a smoky flame, being rich in carbon. It has been proposed to carburet illuminating gas with it, as already remarked. It is insoluble in water, alkaline solutions, and weak acids; but is acted on by the stronger oxidizing acids. Alcohol, ether, wood naphtha, and the liquids obtained from coal-tar, dissolve it readily. With picric acid dissolved in warm alcohol, it forms a yellow solution which, on cooling, deposits beautiful yellow needles of picrate of naphthalene. This reaction is very characteristic.

As naphthalene easily distils with the vapour of water, it may be purified by heating with water, on a water bath, or by passing a current of steam into the melted mass; it condenses in beautiful pure scales on the sides of the receiver, which may be made of lead, and simply inverted over the other vessel. Pure naphthalene has been used medicinally: for the production of colouring matters, it is not necessary to carry its purification so far. The following plan is adopted by Calvert and Co. for producing it in a chemically pure state:—The material is treated with rectified sulphuric acid, and heated in an iron pot; it is well stirred, and then allowed to cool and settle, when it separates into two layers, one of naphthalene at the top, and a dark, tarry mass beneath. The upper portion is boiled by steam in an earthenware vessel, with frequent changes of water, until it is perfectly free from acid, adding a little weak soda to render it perfectly neutral. The naphthalene is then placed in a jacketed still, and distilled by steam-heat. The distillate is collected in a large receiver, and constitutes an exceedingly pure article.

The production of red, scarlet, yellow, and violet colouring matters from naphthalene has given it some importance, still its production considerably exceeds its demand. The heavier oils being less important, manufacturers make the creosote oils contain as much naphthalene as possible. Only a few naphthalene colours have received much application; generally they lack brightness, freshness, and permanence. Still there is a wide field for attention to naphthalene as a source of colours; its price is considerably below that of any of the other products used for this purpose, and it is more than probable that an increased demand for it would tend to lessen rather than enhance its cost; it is easily purified, and its compounds are readily obtained of the necessary purity.

The general treatment of naphthalene and its derivatives for the production of colouring matters consists in direct oxidation into nitro-compounds, from which, by reducing agents, &c., as with aniline, derived compounds are obtained:—

Nitro-naphthalenes.—Four nitrated naphthalenes are known: the mono-nitro is obtained by boiling powdered naphthalene, or its solution in acetic acid, with ordinary nitric acid, for half an hour; concentrated nitric acid yields two modifications of di-nitro; fuming nitric acid boiled with the (*a*) modification converts it into tri-nitro, of which there are three modifications; two modifications of tetra-nitro are obtained by the continual boiling in nitric acid of the two previous corresponding bodies.

Naphthylamine or Amido-naphthalene. $C_{10}H_7.NH_2$.—Two parts nitro-naphthalene and three of iron turnings are mixed, and acetic acid is added to cover the mixture, which should be heated so as to fuse the naphthalene. When the reduction is ended, the mass is distilled, water and acetic acid first come over, the receivers are changed, lime or soda is added to the residue, and the distillation is carried to dryness. The oily liquid which comes over solidifies, and is purified by dissolving in sulphuric acid and precipitating with ammonia, or, after adding soda in excess to the sulphate, distilling with steam. It crystallizes in colourless needles, melting at 50° (122° F.); it boils at 300° (572° F.); its hydrochloride heated with aniline to 280° (536° F.) for thirty-six hours gives naphthyl-phenylamine or phenyl-amido-naphthalene.

Amido-azo-naphthalene, $N_2\left\{\begin{matrix}C_{10}H_7\\C_{10}H_6\end{matrix}\right..NH_2$, is produced by adding potassium nitrite to a solution of amido-naphthalene hydrochloride. It crystallizes in orange needles, with a beetle-green lustre; its salts, which are decomposed by water, have an intense violet colour. It dyes silk a fine orange, turning purple when dipped into hydrochloric acid, and becoming again yellow when washed with water.

Sulpho-acids of Naphthalene.—When naphthalene is heated with concentrated sulphuric acid, three sulpho-acids are formed, viz.:—monosulpho-naphthalic acid, of which there are two modifications (α and β), and bisulpho-naphthalic acid. By heating 5 parts naphthalene and 4 parts acid for some time in a salt-water bath, the mixture will contain principally the α modification of the mono-acid; but if the heat is carried to 116°–118° (240°–245° F.), it will yield the β modification. The acids are first freed from the unaltered naphthalene, by pouring the boiling mixture into a large quantity of water: the naphthalene separates out on cooling; the excess of sulphuric acid is removed by boiling with a little chalk, filtered to remove the sulphate of lime; the filtrate yields crystals of sulpho-naphthalic acid on concentration; the acids are separated by conversion into lime salts, the latter being difficultly soluble, whilst the former remains in the mother-liquor. The disulpho-acid is obtained by heating for several hours 1 part naphthalene and 5 acid. The removal of the sulphuric acid can be effected by oxide of lead, the sulphate of lead being insoluble, whilst the sulpho-naphthalic salts are separated by their differences of solubility in water and alcohol. The free acids are obtained by decomposing the lead solutions by sulphuretted hydrogen.

These acids form the starting-point in the production of several compounds which have been worked upon more or less for tinctorial products. The conversion of these acids into naphthalic alcohol, or naphthol, is thus accomplished:—Sulpho-naphthalic acid is neutralized with potash, after separation of the unaltered naphthalene; the salt thus obtained is fused with caustic potash or soda; by the addition of dilute acids to the aqueous solutions, the naphthol is precipitated in a crystalline form, of which there are two modifications, corresponding with the sulpho-acids.

Naphthalene Chlorides.—Naphthalene melts and absorbs chlorine when the latter is passed over it; the dichloride, which is first formed, is a heavy pale-yellow oil; by repeated distillation, and the action of alcoholic potash, it is resolved into hydrochloric acid and mono-chloro-naphthalene. The continued action of chlorine converts the dichloride into tetra-chloride.

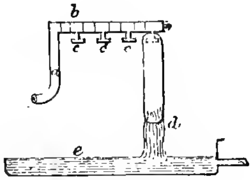
Naphthalene Dichlorhydrate, $C_{10}H_8\left\{\begin{matrix}Cl_2\\(CH)_2\end{matrix}\right.$, is obtained by dissolving naphthalene in concentrated hypochlorous acid. Naphthalene, treated in the cold with a mixture of hydrochloric acid and chlorate of potash, is transformed into naphthalene dichloride, and di-chloro-naphthaquinone.

Phthalic Anhydride. $C_8H_4O_3$.—This is produced by the action of nitric acid on dichloride of naphthalene. When the dichloride of naphthalene is treated with boiling nitric acid, it dissolves slowly, with evolution of nitrous acid. The solution deposits crystals on cooling. These crystals are purified by recrystallization from boiling water: the mother-liquor contains oxalic acid. Pure phthalic acid crystallizes in white nacreous laminæ, arranged in rounded groups. It is sparingly soluble in cold water, but dissolves easily in alcohol and ether. By distillation, it is converted into phthalic anhydride.

Anthracene, or Paranaphthalene. $C_{14}H_{10}$.—This substance is the last product of commercial importance obtained in the distillation of tar. It commences to go over at about 171° (340° F.), and as the temperature is raised, it is contaminated more or less with the heavier oils; this constitutes the "Green oils." In its crude state, it contains naphthalene, phenanthrene, creosote, &c., from which it is separated, in the first instance, by straining, and finally, when it is well drained, by submitting it to pressure. It is then in the form of flat, irregular pieces, about 1½ in. thick, with a slight greenish colour; exposed to the air, it changes colour, passing to a dirty-brown. The percentage of anthracene in this crude product is about 30. A great difficulty in its purification arises from its being nearly insoluble in ordinary solvents. It may be freed from the greater part of the liquid oils by means of a filter press. The same end is attained by pumping it up into bags, suspended over a shallow tank; when well drained, air is pumped through, and forces out a further quantity of the adhering oily liquids. On a small scale, these oils are driven off by centrifugals.

In the treatment of green oils for recovery of anthracene, the following method is usually followed on the large scale, though slight modifications may be made according to the plant employed, and the degree of purification required. The oils are completely cooled; this facilitates the separation of the anthracene, and reduces the solvent action of its associated oils, so that they present the appearance of a soft buttery mass, in which are scattered, more or less, grains of anthracene, which may even give the mass a granular aspect. They are pumped into a series of pipes *a*, *b* (Fig. 483), furnished with T pieces opening at the bottom, and to which are attached strong canvas or flax bags *d*, to receive and filter the oils. These bags are 3 ft. or 4 ft. long, and are stitched with packthreads, which can be drawn out, so as to open them lengthwise for the removal of their contents. The pipes are 4 in. diameter; the T pieces may be 8 or 10 in. apart; at the end of each, is a collar *c*, for attaching the bags. A shallow tank *e* receives the liquid filtering from the bags, and returns it to the stills or the store tanks. At first, a large quantity of liquid comes away; after a short time, the bags are well distended by the oils being forced into them. As the solids accumulate, the liquids cannot so freely escape; they are then allowed to drain for some hours, after which they are removed to a powerful hydraulic press, which squeezes out a further quantity of the liquid oils. Since the adhering oils, when heated, readily dissolve the anthracene, cold pressure must be first used, to remove the liquids; hot pressure may be employed to complete the operation.

483.



The whole treatment of crude anthracene is open to very great improvement. Crude anthracene submitted to the same process of refining will have a higher percentage in summer than in winter, because of its diminished solubility in the adhering oils. It is further purified by being very finely powdered, and agitated with about 25 per cent. of high boiling naphtha, or "solvent," (petroleum is sometimes used instead), submitted to straining, pressing, &c., as before. The washing increases its percentage value from 20–25 to 30–35. The washing process is repeated two or three times, in closed iron cylinders fitted with mechanical agitators. The principal aim is to obtain the anthracene as finely divided as possible, and to bring every portion well into contact with the naphtha. For the final washing, the anthracene is sublimed, so as to obtain it in as fine a powder as possible.

Anthracene from Pitch.—It has been proposed by Fenner and Versmann (1871), and Lucas (1872, No. 747), to obtain it by distilling pitch to coking. Whether this can be made a profitable operation must depend upon the quantities obtained; some coals yield considerably greater quantities of anthracene than others. Kopp says that the soft pitch from the gas used in Turin contains as much as 4 or 6 per cent., which is three or four times the amount present in tar. It has been suggested to distil soft coal-tar pitch with superheated steam, for the production of anthracene, and this plan has been tried on a working scale with varying success; but the process does not appear to be carried out to any great extent, though it is one which commands attention. In distilling pitch to coking, certain disadvantages are said to arise. Anthracene is drawn over between 171° and 371° (340° and 700° F.), and the stills are emptied whilst the residue is still liquid. If the distillation be carried to coking, the distillate will contain much chrysene and pyrene, from which it is best freed by a second distillation. It is well to maintain a partial vacuum in the still by exhausting the vapours. A current of superheated steam blown through the still does not appear to act so well as exhaustion, though probably it is more convenient in most cases. Large quantities of anthracene are now obtained thus; the main precautions are to keep the stills supplied with melted pitch to one constant level, and, as the heavy vapours do not rise, to bring down the still head as near as possible to the surface of the pitch, and to surround the condensing pipes with boiling water; the vapours are assisted over by suction or blowing. In most cases, the pitch is run into the stills direct from the tar stills. The plan adopted on the Continent is to coke the pitch in ovens or retorts of clay; on opening them, the coke which is formed is burnt off. The preliminary washings, &c., are the same as before; but a little more care is necessary. The liquids which are collected from the crude anthracene are frequently added to the creosote oils; but as they are always saturated with anthracene, some method should be adopted for its recovery.

The principles associated with crude anthracene are phenantrene, $C_{14}H_{10}$; chrysene, $C_{18}H_{12}$; pyrene, $C_{16}H_{10}$. No colouring matters are at present made from these substances, although they yield compounds which may eventually become sources of profit in this direction. When the oils recovered from the crude anthracene are distilled, there remains in the retort, after the anthracene has been drawn over, a soft tarry residue containing much chrysene and pyrene; this may be mixed with the creosote oils, or, if burnt in suitable chambers, may be a source of a black pigment for which the "last runnings" are frequently employed. These residues are frequently, and with greater advantage, added to the pitch, for making softer kinds.

It may be worth while to point out, that tars differ widely as regards their richness in anthracene; as a rule, those which yield much benzol will be the best, and probably this fact may be usefully applied by gas companies who are interested in working up their own refuse. There are many natural bitumens in which benzol and anthracene exist; and it is not improbable that an examination of petroleum residues may lead to some important additions to the list of dyeing products. The amount of anthracene contained in a sample of the crude article is of great importance, since it is always sold by analysis. Its point of fusion will approximately indicate the amount of the oily impurities; these may be absorbed by pressing between blotting-paper in a hot-press. The anthracene may be washed with cold alcohol, which will further free it from naphthalene and other oily matters. The melting-point of the product will give a very fair idea of its purity; that of pure anthracene is about 210° (410° F.). The only method practically used for valuing samples of anthracene is Luck's anthraquinone test. A wide-mouthed flask of sufficient capacity has a wide glass tube 3 ft. long fitted into it with a cork; the upper end of the tube is open, and carries a funnel furnished with a stop-cock, which regulates the flow of chromic acid solution. The whole is supported on a stand over a Bunsen's burner, and protected with wire gauze. One gramme of anthracene is dissolved, by boiling with 45 c. c. glacial acetic acid, in the flask; 10 grm. chromic acid, free from lead, in 5 c. c. glacial acetic acid and 5 c. c. water, is added gently by the funnel, so as not to disturb the steady boiling, which is continued until a distinct and permanent greenish-yellow colour appears, or until a drop of the liquid produces a reddish spot on a piece of silver foil. It is then cooled, and gradually diluted with 150 c. c. water; the anthraquinone is precipitated, collected, and washed with water on a filter, then with hot dilute potash lye, again with water, dried at 100° (212° F.), and weighed on the filter, which is afterwards weighed and deducted. The operation lasts four to six hours. To the net weight is added ·01 grm., as, by Luck's experiments, this quantity is taken up by the acetic acid and water used. The unoxidized impurities are thoroughly removed, by adding drop by drop, until the red colour does not vanish, a solution of permanganate potash to the residue on the filter; after washing it off into a beaker, oxalic and sulphuric acids are added, to remove the excess of permanganate; the whole is thrown into the same filter, washed to remove the acid, &c., then with dilute boiling soda lye and water, finally dried at 100° (212° F.) as before. Sand and other fixed impurities are determined by incineration.

Purification of Anthracene.—For final purification, anthracene is submitted to distillation, and the product coming over between 332° and 349° (630° and 660° F.) is collected. The distillate will contain a little anthracene before it reaches these temperatures; but as the object is to obtain the article free from impurities, it is better to collect the distillate between temperatures which will allow the maximum quantity to come over. In the distillation of anthracene, there is always formed a large quantity of tarry matter, resulting from the decomposition of a portion of the anthracene, so that as little heat as possible should be used. The best way of conducting this operation is to place the partially purified anthracene in an iron ⌓ retort, set in brickwork, and heated by a furnace immediately underneath; as soon as the contents boil, a current of deoxidized air or steam is blown through; this carries the anthracene into a closed chamber, where it condenses. Preference is given to steam: air carries the sublimate over dry, but is liable to oxidize it. The sublimate is dissolved in recently-drawn naphtha, boiling at 121°–149° (250°–300° F.); the naphtha is saturated at the boiling-point, and, on cooling, deposits the anthracene in crystals, which are drained, strongly pressed, dissolved in alcohol, and recrystallized. They still possess a slight yellow colour, which it seems is not entirely removed by redissolving and crystallizing; but may be removed by washing with ether, or carbon bisulphide, or by carefully crystallizing from benzol with exposure to light. The pure crystals possess a fine blue fluorescence. Pure anthracene solidifies at 210°–215° (410°–420° F.); boils at 360° (680° F.); and evaporates slightly at its point of fusion; its vapours have a disagreeable odour, and are irritating if inhaled. Alcohol and ether dissolve it sparingly; benzol, readily, especially when heated; in water, it is insoluble. It has been obtained synthetically; and although the methods for obtaining it in this way are, at present, of scientific rather than of practical importance, still the high price of the pure article, and the demand for its derived colouring matters, are sufficient inducements for research in this direction. The present price of the crude article containing 60 per cent. anthracene is about 150*l*. a ton; the value of the pure article would be about 15*l.* a lb. Improvements in the manufacture of this substance may be directed towards the prevention of loss in subliming or distilling; it might be well to try the effect of the superheated vapours of benzol or naphtha injected into the retorts, instead of steam, for the anthracene might be much more economically sublimed, even if a little loss of an expensive solvent were incurred. A difficulty would be met with in the condensing; but it does not appear insurmountable.

Instead of the naphtha process, the article is sometimes purified at once by distillation with lime and caustic potash. There is a difference of opinion as to the merits of this process, as the coking which takes place with steam, even at high pressure, entails a great loss in working. Experience generally is in favour of the distillation with potash, and it is not improbable that, when this process has been unsuccessful, there has been a want of proper precaution in heating the retorts, for as a rule, bodies volatilizing at very high temperatures require much more care, and whilst superheated steam may admit of easier adjustment, it is probable that extra care with the potash process would be compensated for in the yield.

ANTHRAQUINONE, or OXYANTHRACENE. $C_{14}H_8O_2$.—By acting upon anthracene with oxidizing agents, anthraquinone is produced. Bromine, nitric acid, and chromic acid, have been employed for the purpose. It is obtained by the action of chromic acid, set free by adding strong sulphuric acid to a solution of bichromate of potash; the anthracene is dissolved in boiling acetic acid, or more generally in ordinary oil of vitriol free from nitric acid, and diluted with twice its bulk of water, in lead-lined vats. The bichromate is gradually added to the solution, when the heat produced is sufficient to bring about the complete reaction. When acetic acid is used, some method must be adopted for its recovery. The anthraquinone is precipitated by the addition of water, and well washed; it separates in the form of light, silky, almost colourless needles, which are dried in thin layers on trays, ready for subliming; the retorts used are similar to those for subliming crude anthracene.

On the large scale, thoroughly purified anthracene is converted into anthraquinone, by placing it with a little water in large lead-lined wooden vats, adding bichromate potash, or chromic acid, boiling, and adding sulphuric, acetic, or nitric acid. The boiling is continued for several hours, or even a day or more, by injected steam, which gives the requisite agitation. It is then allowed to settle, and the clear liquid is siphoned off; the precipitate is well washed for some days with boiling water, and after settling and cooling, the water is again drawn off, and received in other tanks for further subsidence for several days. The washed anthraquinone is dried in a filter press, and is then a yellowish-white, silky, crystalline powder. The solution of the chromium salts is reconverted into bichromate, or used in making chrome-alum.

The methods which have been proposed for converting anthracene into anthraquinone are:—

(1) Anthracene, 1 part; bichromate of potash, 2½ parts; concentrated acetic acid, 10–15 parts; heated in a clay or glass vessel at 100°–120° (212°–248° F.), till nearly all the bichromate is dissolved, and the liquid has acquired a deep-green colour.

(2) Acetic acid is replaced by sulphuric acid diluted with 1–2 parts water.

(3) Anthracene, 1 part; glacial acetic acid, 10 parts; heated to 100° (212° F.); nitric acid (sp. gr. 1·3) is added in small portions at a time till the violent reaction ceases; the acetic acid is partly recovered by distillation. The objection to nitric acid is the alleged formation of nitro-compounds, which is said not only to impede the purification of the product, but involve a loss, from the conversion of the anthracene into compounds incapable of yielding alizarine.

(4) The method proposed by F. Baeyer, to heat anthracene with 5 parts manganese to 200° (392° F.), answers very well on a small scale, and yields the sublimed anthraquinone at one operation.

The crude anthraquinone thus obtained is washed with water, dried, heated with sulphuric acid to 120° (248° F.), and the carbonized matter is removed by washing and filtering. The anthraquinone is thus raised to 93–96 per cent., and is purified by sublimation in iron retorts fixed over a naked fire, the sublimate being blown over into the subliming chambers by superheated steam. Much of the substance is decomposed and leaves a fine hard coke, the loss being about 30 per cent. This coke is, according to Bolley and Kopp, rich in chromium oxides; it may therefore be possible that the loss is due to imperfect washing of the anthraquinone: on the small scale, it sublimes without leaving any residue, which may be attributed to the more easily controlled heating, and may suggest its being sublimed on a large scale by supplying it continuously to the retorts. The sublimate has a fine, silky, crystalline texture, a light-yellow colour, and contains streaks of reddish, crystalline matter. It is dried on canvas in heated rooms, and mixed by sifting, when it is ready for conversion into bromo-, chloro-, and nitro- compounds.

Dibromanthraquinone, $C_{14}H_6B_2(O_2)$, is formed by the direct action of bromine on anthraquinone at 160° (320° F.); it is more conveniently made from tetra-brom-anthracene, one part of which is heated with two parts chromate potash, and 5 to 6 parts colourless nitric acid, sp. gr. 1·4, in a large flask, as the action is very violent at first, and the liquid frequently froths; the action is complete as soon as bromine vapours cease to escape. It is mixed with water, and the pale-yellow mass is collected on a filter, washed, and recrystallized from benzol. The oxidation succeeds as well with glacial acetic and chromic acids. Dibromanthraquinone crystallizes in light yellow needles, and sublimes unaltered in the same form.

Sulpho-compounds.—Anthraquinone heated with sulphuric acid and mercuric nitrate, and the product treated with soda or potash, produces disulpho-anthraquinonic acid.

Anthraquinone, and sulphuric acid (sp. gr. 1·848), in the proportions of 1 to 3 parts by weight, are heated in a glass or porcelain retort at 260° (500° F.) till the former is completely converted, as shown by its complete solution in water. The mixture is then left to cool, and diluted with water, and the excess of sulphuric acid is removed by the cautious addition of carbonate lime; the sulphate is removed by filtration, and the filtrate is treated with carbonate soda or potash, to remove any traces of lime; the evaporation of clear solution leaves the sulpho-acids of anthraquinone combined with the alkali.

It has been found that there is no need to convert the anthracene first into anthraquinone; the same results are attained by converting anthracene into sulpho-anthracenic acids, and then oxidizing into sulpho-anthraquinonic acids. Anthracene, and sulphuric acid (sp. gr. 1·848), in the proportion of 1 to 4 parts by weight, are heated for about three hours at 100° (212° F.), and the heat is then raised to 149° (300° F.), and maintained till an entirely soluble product is obtained. This is diluted with about three times its weight of water, and to the solution is added, for every 1 lb. anthracene employed, 2–3 lb. manganic dioxide, so that on boiling, the oxidation may be complete. The free sulphuric acid and oxide manganese are removed by milk of lime, which is added till the reaction is alkaline; carbonate soda or potash, added to the filtrate, removes the lime, and yields the alkaline salt in solution. Peroxide lead, chromic acid, nitric acid, or other acids capable of effecting the desired oxidation, may be employed. It is necessary, however, if the oxidant be soluble, to remove its excess before carrying out the second part of the process: nitric acid may be driven off by evaporation; chromic acid, and peroxide lead, may be acted on by a current of sulphuretted hydrogen, or sulphurous acid. According to another plan, anthracene, 1 part, and sulphuric acid, 4–6 parts, are boiled for some time, diluted with water, and neutralized with carbonate lime or baryta, or caustic alkali; the resulting sulphates of lime or baryta are removed by filtration, and the clear solution is heated at 180°–200° (356°–392° F.)

To convert anthracene into chloro-anthracene, and afterwards into sulpho-anthraquinonic acid, the anthracene in fine powder is spread out, in contact with chlorine, on leaden trays, for about twenty-four hours; this crude dichlor-anthracene may be used at once, or after purification by crystallizing from benzol. One part of it is mixed with 4–5 parts fuming sulphuric acid, and excess of binoxide manganese, and the whole is heated at 112°–149° (234°–300° F.) till it will dissolve in boiling water. The product is diluted with three or four times its bulk of water, and well boiled with excess of binoxide manganese, till the diluted solution does not appear fluorescent; it is then poured off, and milk of lime is added until the solution is alkaline; the whole is well boiled and filtered, and the residue on the filter is well washed. The filtrate is concentrated, and carbonate potash or soda is added until all the lime is precipitated.

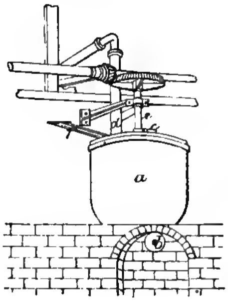
Nitro-compounds.—Meister, Lucius and Brüning's method of oxidizing anthracene into anthraquinone by nitric acid, with formation of nitro-anthraquinones, is objected to as causing a serious loss; the fact, however, of this patent (1872, No. 2649) being extensively worked in England contradicts the existence of any great obstacle, even if a loss can be established; and it is not improbable that the loss (if any) has been due to impurities and their subsequent elimination, or intermediate reaction due to their presence; probably the use of nitric acid in such quantities as to produce only mono-nitro-anthraquinone may explain why nitric acid has not been an advantageous oxidizer. Highly purified anthracene, melting at 207°–210° (405°–410° F.), is heated for some time with a mixture of bichromate potash and dilute nitric acid; the product is boiled for three hours with six parts by weight of fuming nitric acid (sp. gr. 1·50); this yields a yellow solution; from this, after boiling, and addition of water, is formed a yellowish precipitate, which consists principally of dinitro-anthraquinone. The acid liquor is filtered off, and may be used in the oxidation of a further quantity of anthracene.

NITRO-BENZOLS; NITRO-TOLUOLS; NITRO-XYLOLS.—Benzol, toluol, and xylol dissolve in nitric acid, with evolution of heat; on the addition of water, the nitro-compounds are obtained, as heavy oily liquids.

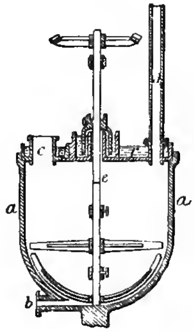
By boiling benzol with strong nitric acid, or with a mixture of strong sulphuric and nitric acids, dinitro-benzol is formed. Toluol forms two isomerides with nitric acid, which are separated by distillation: 1·4 nitro-toluol melts at 54° (129° F.), and boils at 237° (459° F.); 1·2 nitro-toluol does not solidify in a freezing mixture, and boils at 223° (433° F.). Dinitro-toluol exists in two forms: the first is produced by acting on 1·4 or 1·2 nitro-toluol, with hot concentrated nitric acid, and crystallizes from alcohol in long, colourless, brittle needles, melting at 71° (160° F.); the second is obtained from 1·3 nitro-toluol, with concentrated nitric acid, and forms long, yellow needles, melting at 60° (140° F.). Xylol, or iso-xylol forms similar compounds: nitro-isoxylol is a pale-yellow liquid, boiling at 239° (462° F.); the dinitro compound crystallizes from alcohol in long, brilliant prisms, melting at 93° (199° F.); the trinitro forms colourless crystals, melting at 177° (351° F.). Before nitrating toluol and xylol, it is important to wash out all traces of the heavy oils, in the same way as from naphtha and benzol (q. v.), otherwise explosive compounds may be formed.

Nitro-benzol was first made on the large scale by Collas, at Paris, and was sold under the name of "Essence of Mirbane." It is generally prepared by the action of two parts fuming nitric acid and one part concentrated sulphuric acid; the benzol is placed in the still, and the acids are gradually added, with agitation; the nitric acid must be applied slowly, until red fumes appear. The end of the reaction is indicated by the liquid becoming colourless, or nearly so, and separating into two distinct strata, on the addition of water.

484.



485.



Figs. 484 and 485 represent one of a series of apparatus described by Perkins (Cantor Lectures) as being used for its manufacture in this country: *a*, cast-iron pot standing on brickwork; *b*, outlet for finished product; *c*, inlet for raw materials; *d*, an iron pipe to carry away nitrous fumes, connected with a condenser for collecting the benzol which is evaporated; *e*, spindles of stirrers, worked by toothed gearing, and entering the pot through a water-lute supplied with nitro-benzol; the pots are cooled by water flowing over them, as at *f*. The use of the sulphuric acid is to take up the water which is formed, thus keeping the nitric acid undilute, and preventing action on the pot. When *b* is opened, a mixture of acids first runs out; then the nitro-benzol, which is washed and distilled, if necessary. Washing may be effected in closed cast-iron tanks, supplied with exhausters, for drawing off the nitrous fumes, and, at the bottom, with a perforated serpentine coil for conveying lime water, or water, in the form of fine spray. The final washing is made with water, but the presence of a little lime is not detrimental. Distillation should be performed by steam.

Nitro-benzol has generally a brown colour, but when quite pure, is a pale-yellow, strongly-refractive liquid, boiling at 220° (428° F.); it has a burning sweet taste, and a smell resembling that of oil of bitter almonds and cinnamon; its specific gravity is about 1·200.

Nitrate of soda is sometimes used instead of nitric acid; in this case, the sulphuric acid added must be sufficient to convert the soda into the acid sulphate. The advantage is the comparative inexpensive production of concentrated nitric acid. The same apparatus is applicable.

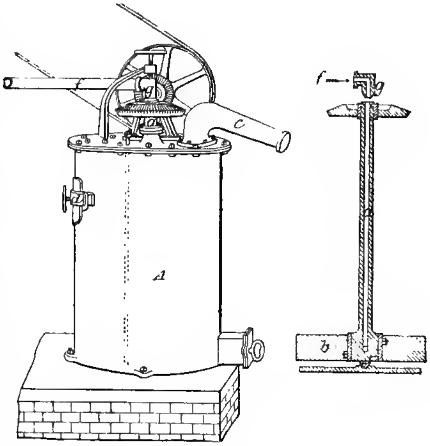
When properly made, the yield of nitro-benzol should be 130–135 per cent. on the benzol employed. Three kinds are met with in commerce:—"Light," boiling between 204° and 210° (400° and 410° F.), constituting the "essence of mirbane," and used for scenting common soaps, and in low-class perfumery; "heavy," boiling between 210° and 220° (410° and 428° F.), possessing a fatty smell and rather dark colour, used chiefly for the preparation of aniline reds; "very heavy," boiling between 221° and 235° (430° and 455° F.), with disagreeable smell, and chiefly used for colours requiring high-boiling anilines. The essence of mirbane is sold as artificial oil of bitter almonds.

Aniline. $C_6H_5.NH_2$.—This substance was discovered in 1826, by Unverdorben, who obtained it from indigo, hence its name, *anil*, being the Portuguese for indigo. It exists in the heavier tar-oils; but its extraction from them is a matter of scientific curiosity rather than of commercial importance, and its quantity is too small to compete with nitro-benzol. By the action of reducing agents, nitro-benzol is converted into "aniline," or "amido-benzol." The process generally used for the commercial production of aniline, is, with slight modifications, that known as Béchamp's. In a capacious retort are mixed 1 part by weight of nitro-benzol, 1·2 part of iron-filings, and acetic acid (1·068 sp. gr.) equal in volume to the nitro-benzol. A reaction immediately commences, with active effervescence, accompanied by a rise of temperature. To prevent the passing over of the acetic acid, it is well to cool the retort. Whatever may have passed over should be returned, and, after a little time, the distillation may be begun. The product will consist of aniline, acetate of aniline, and acetaniline, the last appearing towards the end of the operation. A little milk of lime, or potash, added before distilling, will greatly prevent the passing over of the two last. By using acetate of protoxide of iron, the action has been rendered less energetic, and more controllable. The yield of aniline will be 60–65 per cent. on the nitro-benzol used.

The main points in the commercial production of aniline are practically the same; but scarcely two manufacturers adopt the same details. The superiority of many of the aniline colours depends upon the quality of the aniline employed, which is generally subjected to one or more rectifications. This is performed by distilling, and collecting the distillates separately, the portion richest in benzol-aniline being collected between 182° and 199° (360° and 390° F.). It is difficult, by fractionizing, to free aniline from toluidine, consequently high-class benzols should be used for low-boiling anilines.

Some manufacturers reduce the nitro-benzol to crude aniline in separate vessels, and distil in special retorts; this is not necessary, and the two operations are usually performed in the same vessel. A great advantage in this consists in obtaining the aniline at one operation; the unaltered benzol is collected, and returned to the still, until the reduction is complete, when direct heat may be applied, and the aniline may be drawn over sufficiently pure without further rectification by distilling, unless for the very finest class anilines. In this case, a little lime is thrown into the still before drawing over the aniline. Much depends upon the extent of the operations: a method which would be far from economical on a small scale, may be the only one practicable on an extensive scale. On a small scale, it is better to work with nitro-benzol suited to the special description of aniline required, and to work it off in one still, as shown in Fig. 486. A cylindrical still A is fitted into masonry, with a furnace so constructed as to avoid direct action of the fire. Through the cover, which is bolted on, passes the spindle *a* of the agitator *b*, which rotates during the whole time that the conversion is going on; a bent tube or still head *c*, fitted to the cover, conveys the vapour to a properly cooled condenser. Before the cover is bolted on, it is usual to put into the still the required quantity of iron-turnings, otherwise a suitable opening *d* must be left, especially for continuous working, to avoid removing the cover every time the still is filled. A small opening *e*, provided with a stop-cock, and communicating with the nitro-benzol reservoir, enables this liquid to be delivered as required, at or near the bottom of the vessel, so as to avoid its evaporation before coming into contact with the iron-turnings. A quantity of acetic acid is poured over the turnings, either all at once, or gradually. It is sometimes replaced by hydrochloric acid, whose more energetic action requires it to be added more cautiously. The heat generated will drive some unaltered nitro-benzol into the condenser; this should be poured back again. The agitator should be worked gently, and at intervals, as required. As the nitro-benzol is added, the heat increases, and when no further augmentation of heat is perceived, the reaction may be considered almost complete; this, however, will depend upon the way in which the operation has been conducted. The main precaution is the prevention of volatilization, until the whole of the nitro-benzol is reduced; in order to secure this more effectually, it is better to add the liquids alternately at intervals, and to keep them well cooled and agitated.

486.



When the liquids which pass into the condenser remain clear on the addition of hydrochloric acid, it may be assumed that all the nitro-benzol is reduced; and the distillation may be commenced, by lighting the fire under the still. The spindle *a* is hollow, so as to admit the steam from the pipe *f g* for distilling. A little care will remove most of the difficulties of the process; and, by giving a little extra time for working off the charge, a product can be obtained, which, by one rectification, will yield an aniline of sufficient purity for almost any purpose. The aniline can be freed from the mass by occasionally stirring with the agitator.

Crude aniline is generally fractionized by the colour manufacturer, who is often in a position to supply himself with anilines which he could purchase only at a highly enhanced cost.

Aniline is a limpid liquid, with strong refracting power, colourless when pure, but generally of a pale-sherry colour, which rapidly turns brown on exposure to air and light; it possesses an agreeable, aromatic, vinous odour; it burns slowly and with a smoky flame, at ordinary temperatures, but with great violence when strongly heated; its sp. gr. is 1·02 at 16° (61° F.); it boils at 182° (360° F.); it forms well-defined salts with acids, which furnishes a means of separating it from any unaltered benzol; it is very poisonous; its sulphate has been used medicinally.

Commercial anilines are of variable character, and consist principally of aniline, para-toluidine, meta-toluidine, xylidines, and cumidines. Light aniline oils distil generally at about 162° (360° F.), the heavy oils, above this point; the term "aniline-tailings" is applied to the heaviest oils, of high boiling-points. Tables have been drawn up, showing the proportion of heavy and light aniline oils for different shades of colour; but they are scarcely reliable. Reimann says that the best oil for "fuchsine" is that yielding 61 per cent. of distillate between 185° and 190° (365° and 374° F.), and 28·5 per cent. between 190° and 205° (374° and 401° F.); Girard and De Laire state that the most suitable oils are those containing about equal quantities of true aniline and toluidine, and yielding 10 per cent. between 182° and 185° (360° and 365° F.), 40 per cent. between 185° and 195° (365° and 383° F.), and 10 per cent. between 195° and 200° (383° and 392° F.); Kopp says the best "fuchsine" oils are those which almost wholly pass over between 185° and 210° (365° and 410° F.); while Hofmann found that various specimens of the oils actually in use on the large scale boiled between 182° and 220° (360° and 428° F.).

These anilines, or "aniline oils," as they are called, serve for the industrial production of the "aniline colours," or "toluidine colours," of which the principal are—1. Red: rosaniline or megenta, toluidine, xylidine, &c.; 2. Blue: phenyl-rosanilines, diphenylamine, toluidine, aldehyde, &c.; 3. Violet: rosaniline, mauve, phenyl, ethyl, methyl, &c.; 4. Green: iodine, aniline, leucaniline, chrysotoluidine, aldehyde, toluidine, methyl-aniline, &c.; 5. Yellow, and orange: leucaniline, phenylamine, &c.; 6. Brown: chrysotoluidine, &c.; 7. Blacks: aniline, toluidine, &c.; 8. Greys.

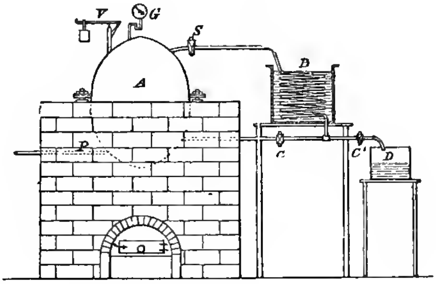
Aniline readily combines with the iodides and bromides of alcohol radicals; it comports itself in this reaction like an "amine," and, for this reason, was formerly called "phenyl-amine." The names of these aniline products are made up of a prefix from the name of the alcohol employed and the terminal "aniline."

Methyl-aniline. $C_6H_5N\left\{\begin{matrix}H\\CH_3\end{matrix}\right.$.—When aniline is mixed with methyl-iodide, a violent reaction sets in, accompanied by copious effervescence, so that on mixing it is best to agitate the vessel, to facilitate the escape of the vapours; on cooling, the mass solidifies into crystals of methyl-aniline hydriodide. It is also produced, together with dimethylamine, by treating aniline hydrochloride with methyl-alcohol under great pressure in a "cohobator." The base (methylanile) is obtained free, by adding caustic potash, and distilling. It is a colourless liquid, resembling aniline, and boiling at 193° (378° F.); it gives a blue coloration with bleaching powder; and forms salts having a striking resemblance to aniline. The amido derivative of dimethyl-aniline, or dimethyl-phenylene-diamine, is converted into a blue colouring matter, by Caro (1877, No. 3751), by adding a solution of ferric chloride to the acidified and diluted solution, and passing a current of sulphuretted hydrogen, until the colour is produced.

Ethyl-aniline. $C_6H_5N\left\{\begin{matrix}H\\C_2H_5\end{matrix}\right.$.—When anhydrous aniline and bromide of ethyl are mixed together, and slightly heated in a flask, so as to allow the bromide of ethyl which evaporates to fall back again into the aniline, the mixture soon boils, and, on cooling, becomes a crystalline mass. If this product is mixed with a solution of caustic potash, and distilled, there will be obtained a clear colourless liquid, readily turning brown on exposure to the air, and boiling at 204° (400° F.). It does not yield a violet colour with alkaline hypochlorites. Its salts are readily soluble, and with difficulty crystallizable.

Di-ethyl-aniline. $C_6H_5N(C_2H_5)_2$.—This is obtained by acting on mono-ethyl-aniline with bromide or iodide of ethyl in excess. At ordinary temperatures, the bromhydrate of di-ethyl-aniline requires four or five days to separate out; it boils at 157° (315° F.).

487.

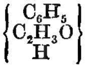


A simple cohobator is shown in Fig. 487; it consists mainly of a digester A, made of copper, for high pressures, and connected with a worm B, where all vapours given off are condensed, and, by opening the cock C and closing C′, are returned to the digester: by closing C and opening C′, they can be collected in D. G is a pressure gauge, and V, a safety valve. The cock S is opened for relieving pressure, or for distillation. The two parts of A, which are nearly spherical, are firmly bolted together. A steam pipe P admits steam, when necessary, to carry off any of the products. When the whole of the materials cannot be placed in the digester at one time, a tube is fixed to the top, and is supplied with two cocks; the lower one is first shut and the upper one is opened, when a supply of the ingredients occupies the space between them; then by closing the upper cock and opening the lower one, the supply can flow in at any required rate. A pipe and stop-cock, communicating with the digester and tube, render the pressure the same in both when the upper cock is closed

Poirrier and Chappat prepare alcoholized anilines without the use of iodine or bromine. Hydrochlorate of aniline, or any other salt of this base or its homologues, and the alcohol of which it is desired to obtain the radical, are heated in a close vessel under pressure. Alcoholic salts and aniline may be treated in the same way, with the same results. Methyl-alcohol treated with the hydrochlorate of aniline requires 175°–210° (347°–410° F.) for three or four hours, and a longer period will do no harm; but at 250°–300° (482°–572° F.), one or two hours will suffice. Hydrobromate, or hydriodate of aniline may be used, and requires only 100°–200° (212°–392° F.). The proportions are 100–150 parts alcohol to 100 parts aniline salt. The operation produces a salt of the new aniline base, according to the acid employed; this salt is decomposed by soda or potash, and yields a mixture of alkaloids, containing one or more molecules of the alcohol radical. These are separated by fractional distillation. The portion passing over at or about 192° (378° F.) is methyl-aniline (supposing methyl-alcohol to have been used), and that at 202° (396° F.) is di-methyl-aniline. The products above these points are methyl-toluols, -xylols, &c.; corresponding to the quality of aniline employed. Aniline, 100 parts; chloride ammonium, 80–100 parts; and alcohol, 100–150 parts, heated to 275°–300° (527°–572° F.), for two or four hours, yield a liquid separating into two layers, of which the oily supernatant one is their new alkaloid.

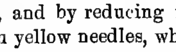
Mono-amyl-aniline. $C_6H_5.C_5H_{11}.NH$.—A mixture of aniline and bromide-amyl is allowed to stand for a few days, when crystals of hydrobromate of amyl-aniline separate out; these are decomposed by potash, when the base is obtained free by distillation. It is a colourless, oily liquid, smelling of roses, and boiling at 258° (496° F.); it forms, with many acids, crystallizable salts, not easily soluble.

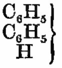
Di-amyl-aniline. $C_6H_5N(C_5H_{11})_2$.—By heating the above at 100° (212° F.) with bromide amyl, crystals of hydrobromate of di-amyl-aniline are formed; from these, the base may be obtained by distilling with potash; it boils at 275°–280° (527–536° F.), and yields sparingly soluble salts.

Acetanilide, acetaniline, or acetyl-phenyl-amine.  $\left\{\begin{matrix}C_6H_5\\C_2H_3O\\H\end{matrix}\right\}N$.—This substance may be obtained by the action of acetyl chloride or acetic anhydride upon aniline, or by the distillation of acetate of aniline, hence its occurrence in crude aniline which has been distilled without lime. According to Greville Williams, it is prepared as follows:—Glacial acetic acid and aniline are mixed in equal proportions, and distilled; the distillate is returned till it begins to deposit in crystals near the outlet of the still; when the receiver is changed, the head of the still is kept warm, and the distillation is proceeded with. The yield of acetaniline equals the weight of acetic acid employed. It is sparingly soluble in cold water, and crystallizes, from a boiling solution, in shining plates, melting at 106° (223° F.), and boiling at 292° (558° F.). It begins to volatilize at 100° (212° F.), and sublimes at 200° (392° F.).

On adding 80 parts water to a mixture of acetaniline and aceto-toluidine dissolved in four parts glacial acetic acid, the aceto-toluidine precipitates by standing, whilst the acetaniline remains in solution. This may be conveniently employed for the separation of aniline and toluidine in the examination of a sample of aniline, when greater accuracy is necessary than can be obtained by fractionizing.

Amido-azo-benzol. $C_6H_5.N_2.C_6H_4.NH_2$.—This is produced by passing nitrogen trioxide into a warm solution of aniline, and by reducing mono-nitro-azo-benzol with ammonium sulphide. It crystallizes from alcohol in yellow needles, which sublime at a high temperature; it is a weak base, forming salts of a red or violet colour. It is the commercial source of "aniline yellow" (q. v.).

Tri-amido-azo-benzol.  $N_3\left\{\begin{matrix}C_6H_4.NH_2\\C_6H_3.(NH_2)_2\end{matrix}\right.$.—The hydrochloride of this base forms the principal portion of "phenylene-brown," or "Manchester-brown," which is manufactured by adding a solution of sodium nitrate to a cold solution of para-amido-azo-benzol hydrochloride. See phenylene-brown.

Diphenylamine, or Phenylaniline.  $\left.\begin{matrix}C_6H_5\\C_6H_5\\H\end{matrix}\right\}N$.—This is formed when a mixture of aniline and aniline hydrochloride is heated under pressure. It is a crystalline solid, melting at 45° (113° F.), and boiling at 310° (590° F.); possessing a peculiar and agreeable smell; and forming salts, which are decomposed by water. With nitric acid, it yields an intensely blue liquid. Hofmann obtained it by the dry distillation of triphenyl-rosaniline. It is found in the distillate at 280°–300° (536°–572° F.), and, when mixed with hydrochloric acid, forms the solid chloride of diphenylamine, which is not soluble readily in this acid; it is purified by washing in alcohol, and crystallizing in needles from its solution in petroleum spirit; on exposure to the air, these crystals turn blue. By treatment with ammonia, it separates as a colourless, oily liquid, passing quickly into a crystalline mass.

Ditoluyl-amine, Phenyl-toluyl-amine, and Diphenylamine.—These substances are prepared in a wrought-iron spherical digester, supplied with safety valve, pressure gauge, thermometer tube, and a screw-plug, or large stop-cock connected with a condenser. The capacity of the vessel is about twice the bulk of liquids to be operated upon; small quantities should be dealt with. About 70 kilo. anhydrous aniline hydrochloride, and 50 kilo. aniline are heated together for two hours at 200° (392° F.), while the condenser is connected. The heat is gradually raised to 215°–220° (412°–428° F.); the outlet is then closed, and the heat is raised to 250° (489° F.), this pressure being 10–15½ atmos. The operation lasts twelve hours; during six hours, the heat is gradually raised from 240° to 260° (464°–500° F.), and the pressure from 3 to 5 or 6 atmos. The yield should be 60–75 per cent. on the weight of aniline employed. The liquids which pass over consist principally of water and hydrochloric acid, aniline, &c., and are not returned to the digester. After cooling, the crude mass is dissolved in 70 kilo. cold hydrochloric acid, and the solution, filtered if necessary, is poured into 300–400 lit. water, and left to settle for twelve hours. The hydrochlorate of diphenylamine is decomposed; the liberated base falls to the bottom, and the hydrochlorate of aniline, remaining in solution, is recovered by evaporation. The diphenylamine is first washed with a little boiling water, and then with a weak solution of caustic soda; it is finally crystallized from its solution in alcohol, or light petroleum spirit. If toluidine and its hydrochlorate are heated in the same way, ditoluylamine is obtained. When aniline or aniline salt is heated with toluidine or a toluidine salt, phenyl-toluylamine is obtained. Commercial diphenylamine is thus a mixture of diphenyl-ditoluyl, and phenyl-toluyl-amine; from it, diphenylamine blue is obtained, by oxidation or abstraction of hydrogen. Ditoluylamine gives a blue with a brownish-red tint, and phenyl-toluyl-amine gives a bluish or blue-violet; but a mixture of the two, in the proportions of 11 to 18, yields a fine pure blue. It is essential that the ammonia generated by the reaction should be removed from the digester; otherwise a loss of 30–40 per cent. upon the product is incurred.

Methyl-diphenyl-amine. $(C_6H_5)_2NCH_3$.—This base, according to C. Bardy (No. 376, 1870), is obtained by reacting upon diphenylamine or its salts, with methyl-alcohol, or its substitution products, at variable temperatures according to the substance employed. The product is treated with caustic alkali. Whatever process be employed, the new base is an oily substance, even at 0° (32° F.); its boiling-point is near that of diphenylamine, from which it is very easily distinguished, by the fact that with nitric acid it develops a colour identical with that of permanganate potash. It is transformed into colouring matters, by treatment with any substance capable of eliminating hydrogen, whether directly or indirectly, to which reaction it very readily submits. Nitrate mercury at about 40° (104° F.), sometimes acts so powerfully that the mixture begins to burn. Perchloride iron, at about 100° (212° F.), rapidly transforms it into a resinous substance, of brownish-red tint, which, when dissolved in alcohol, becomes a pure blue. Heated to 190°–200° (374°–392° F.) with sesquichloride carbon, it quickly gives a resinous substance, which affords a reddish-blue colour when dissolved in alcohol; hydrochloric acid precipitates the blue colour of the solution, while a violet colour remains in the mother-liquor. The proportions of the reagents may vary between wide limits without preventing the production of the colours. These latter are purified in the same way as aniline colours. Their solutions act directly as dyes.

Methyl-benzyl-diphenyl-amine.—Girard and De Laire (1869, No. 3675) thus prepare this substance: in a digester, are heated 1½–3 parts chloride or bromide of benzol, or its homologues, with 1 part methyl-aniline or its homologues, at 210° (410° F.). By using a pressure of about 15 lb. in the same apparatus, the proportions may be 1½ : 2, the operation, in each case, lasting about three hours; the same result is gained by leaving the mixture to itself for several days at the ordinary temperature. The product is purified by washing with caustic soda and water, and distilling if required.

Toluidine, Toluylamine, or Amido-toluol. $C_6H_4(CH_3NH_2)$.—There are two methods of obtaining this base on the commercial scale; by reducing nitro-toluol, and by separating bases in commercial aniline; as the pure article is not required, the latter method is the one generally adopted, the product being more or less pure according to the limits between the fractionizings. Brimmeyr takes the fraction of commercial aniline which comes over in two successive fractionizings between 195° and 205° (383° and 401° F.), and separates the bases, first converted into oxalates. Reimann divides anilines into two classes, light and heavy; light or Kuph-anilines contain 90 per cent. aniline, 5 per cent. toluidines, and none of the higher homologues; whilst heavy or Bar-anilines contain 70 per cent. toluidines, and 30 per cent. of the higher homologues. By mixing these or similar anilines together in different proportions, articles suited to all requirements may be produced.

Heavy anilines are obtained from the nitro-compounds of low-class benzols containing much toluol; the lighter oil which comes over in rectifying, is kept apart for the light anilines. Generally, two distinct kinds of heavy anilines are prepared: one from the nitro-compound of rectified toluol; another from the nitro-compound of toluol, containing more or less xylol. As a rule, the lightest anilines give little advantage over the heavier medium oils, which can be produced at much less cost, and without much sacrifice in their qualities for colour-making. From such oils, it is always easy to obtain the lighter oils, for blacks, &c., by collecting what comes over in the manufacture of magenta, &c. The manufacture of anilines is not generally carried on at tar works; but is more usually attached to a distinct branch of the business, in which the rectification of benzols, toluols, &c., forms the very important connecting link between tar-distilling and dye-making.

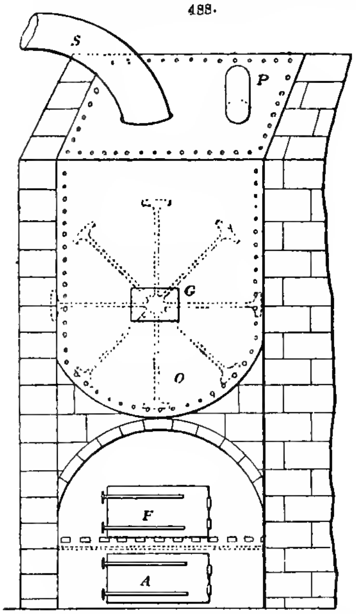
Xylidine.—This base may be formed from the nitro-compound of xylol, in the same way as aniline from nitro-benzol, as proposed by Béchamp. Hofmann and Martius have rendered it probable that coal-tar xylidine should be considered as dimethyl-phenylamine, $C_6H_3(CH_3)_2NH_2$.

Many other substances which exist in coal-tar and naphtha are intentionally omitted. With respect to the impurities and compositions of commercial anilines, a few words may be necessary; so little is known of the influence of some of these so-called impurities, that it is impossible to direct a manufacturer in the rejection of an aniline, but it is easy to indicate for particular applications what is required. An important fact to be borne in mind is, that aniline is not a definite compound to which chemical tests can be applied: purer tints and finer shades are often due to an accidental circumstance; no manufacturer, without the strictest care, can always produce exactly the same anilines, and it is doubtful whether the cost of production would be justified by the advantages which are supposed to arise. There is a point, however, to which the attention of the colour manufacturer must be directed: it frequently happens, with piece goods, that a singular variation of tint is perceptible even with the same vat of dye, and the same piece of fabric; whether the dye-stuff, or fabric, or both combined, have to answer for this, ought to be determined, otherwise aniline dyes may have to bear the blame which should be laid on a careless dyer, or they may even be used to detect admixtures of different fibres.

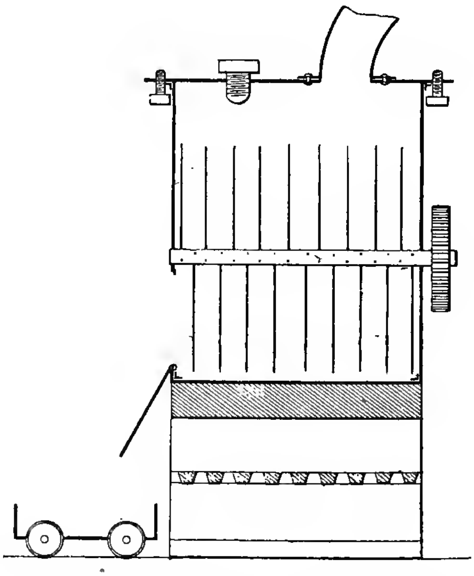
Rosaniline. $C_{20}H_{19}N_3$.—A great number of colouring matters bearing the names aniline red, magenta, azaleine, rubine, solferino, fuchsine, chryaline, roseine, erythrobenzine, &c., met with in commerce, are salts of this base in a greater or less degree of purity. By heating a mixture of aniline, toluidine, and pseudotoluidine with arsenic acid or other oxidizing agents, the crude colouring matter is produced. The proportions generally employed in this country are—aniline commercial, 1 part; arsenic acid, 75 per cent. dry acid, 1½–2 parts, by weight. On the Continent, 800 kilo. commercial aniline are mixed with 1370 kilo. solution arsenic acid, 72 per cent. dry acid. The quantity of water used must be such, that the arsenic acid solution does not deposit crystals on cooling. The aniline must contain a certain quantity of toluidine, and is known as "magenta aniline"; the most suitable for good rosaniline is that boiling between 185° and 200° (356° and 392° F.).

The most approved form of apparatus for the manufacture of magenta is that described by H. Cant, of the firm of Evans, Cant, and Co., of Stratford. It is shown in Figs. 488 and 489.

488.



489.



Aniline and arsenic acid are introduced together into a U-shaped boiler with flat ends, heated by a furnace, and set so as to avoid direct action of the fire. The furnace door F, and ashpit door A, allow of very nice regulation of the draught, which is a matter of great importance. The ends of the boiler are left exposed, and in one of them is an aperture *o*, for emptying it; through them passes the spindle of the agitator G, and at the top is an opening P, and a "goose-neck" of copper S, connected with a copper condensing worm, contained in a suitable receptacle, so as to collect the aniline and water given off during the heating. The great advantage of this arrangement is that the contents are removed by a small door, secured by wrought-iron bolts and wedges, and the framework of which prevents waste trickling down when emptying. The charge for these boilers should not be more than half the capacity of the boiler; the time required to work off a charge of 1200 lb. aniline and 2200 lb. arsenic acid is about eight hours. These proportions will yield approximately—water, 730 lb.; aniline, 370 lb.; crude "magenta melt," 2300 lb.

It is necessary that the agitators be well worked even whilst the ingredients are being added, otherwise the mixture becomes solid, and has to be removed from the stills; hence an advantage in using a large proportion of aniline proper. The fans of the agitators should be so arranged as to stir every portion of the mixture. Other oxidizing agents have been proposed, but none is so largely used as, nor more successful than, arsenic acid. The heating should not rise above 200° (392° F.). The heavier unaltered aniline is removed from the melt, before emptying, by distillation with steam. The melt is sometimes slightly moistened with steam, so as to make it leave the stills more rapidly. By knocking out the wedges which secure the small door, the melt is received in an iron pan (see Fig. 489); a piece of sheet iron, acting as a spout, prevents its trickling down over the furnace. The fire and ashpit doors being shut, the agitator is worked to assist its flowing out, the workmen then leave the spot so as to avoid the fumes. The aniline and water which come over are separated; the aniline, recovered and rectified by distillation with a little lime, is best suited for all purposes requiring a low boiling aniline. The rosaniline is separated from the crude melt either by converting it first into a salt, or by first obtaining the base, purifying it, and then converting it into a salt.

During the heating in the stills, a kind of humus is formed; this is removed from the colouring matter by boiling for four or five hours, with continuous agitation, in water heated by steam, with the addition of very dilute hydrochloric acid (7 lb. commercial acid to 350 gall. water). The humus separates out, and the liquor is drawn off, and passed through flannel in a filter press: the filtrate contains hydrochlorate of rosaniline, arsenious and arsenic acids, and some chlorides of arsenic; the addition of carbonate soda neutralizes the free acid, and the colouring matter is precipitated, with a little arseniate. An excess of hydrochloric acid facilitates the separation of the rosaniline salt.

The rosaniline converted into hydrochlorate is purified as follows:—a quantity of solution containing 1 ton of the crude salt is placed in a large iron tank, to this is added about 1¼ ton of common salt, in small quantities at a time, and dissolved by a jet of steam let into the bottom of the tank by a tube; the hydrochlorate is almost insoluble in the solution of common salt, and separates on the surface of the liquid, the arsenic and arsenious acids being retained in solution as arseniates and arsenites of soda. At the end of a few days, the colouring matter remaining in suspension collects on the top, as the liquid becomes cold, and is then removed. It is washed with a little boiling water, to remove adhering salts, and is then sufficiently pure for many purposes. Its further purification is effected as follows:—It is dissolved in boiling water, filtered through flannel, and allowed to cool in large tanks, in which are suspended threads of wool; at the end of several days, the salt has crystallized on the threads, and on the bottom of the tank; the former is sold as "pure" or "refined," the latter is generally used for the manufacture of other dyes, as green or blue.

The mother-liquor from a previous crystallization is generally used for dissolving the crude rosaniline after the separation of the humus; a crop of crude crystals is obtained, and the mother-liquor, which still holds much colouring matter in solution, is treated with milk of lime, to remove the arsenious and arsenic acids, so as to avoid the dangers of poisonous salts. Any colouring matter carried down with the lime is taken up by acetic acid. English rosaniline, made in this way, unless carefully crystallized, contains a little arseniate, which accounts for the bad effects produced on the skin by articles dyed with the impure salt. This fact proved very prejudicial to aniline dyes, especially for hose, a few years ago, and ought not to be overlooked by the manufacturers of tar colours. The advantages of this method are absence of acid fumes during the boiling, portability of salt as compared with hydrochloric acid, and economy of cost.

The method most extensively adopted is to boil the crude magenta for several hours, with a large excess of lime, under pressure in an ordinary steam boiler, with perforated agitating fans closely arranged, so as to thoroughly break up the melt; any unaltered aniline is thus carried away and condensed, the lime is converted into arsenite or arseniate (insoluble salts), and the rosaniline is obtained free by filtering whilst boiling hot. On cooling, a crop of impure crystals is deposited, the mother-liquor is repeatedly concentrated for fresh crops, or is used for boiling with fresh melt. It is better to exhaust the lime residues by boiling and washing than to extract the remaining rosaniline by acids, as is frequently done. Wilson and Cant digest the crude base with commercial benzol, which takes up the resinous or gummy matters—chrysaniline and chrysotoluidine; these are recovered by driving off the benzol, and, after purification in the usual way, are sold as "phosphine." The rosaniline is converted into hydrochlorate by the addition of acid; an excess precipitates the salt for the finer class of dyes; it is washed with solution of common salt, and recrystallized; by repeating the operation, different qualities of dye are obtained.

Treatment of Magenta Residues.—In the ordinary manufacture of rosaniline, chrysotoluidine, mauvaniline, and violaniline are simultaneously formed; the separation of these not only enables a manufacturer to enhance the beauty of his reds, but by their separation and purification, he obtains a great variety of colouring matters, at comparatively little expense. The separation of these bases depends upon their solubilities in the menstrua employed. In boiling hydrochloric acid, diluted with 2½ times its bulk of water, rosaniline is nearly insoluble, while the other bases are readily soluble; on cooling, mauvaniline, and a little rosaniline, separate out as hydrochlorates. Chrysotoluidine is soluble in an acid solution of common salt, from which mauvaniline and rosaniline are precipitated. By neutralizing this solution with soda, chrysotoluidine precipitates (or violaniline) may be separated from chrysotoluidine and mauvaniline; by dissolving these bases in aniline, and just saturating with hydrochloric or acetic acid, the violaniline is precipitated; the filtrate is diluted, and mixed with common salt, by which mauvaniline is thrown down; caustic soda in excess precipitates chrysotoluidine, and the aniline is recovered by distillation.

Girard and De Laire proceed thus:—On boiling 1000 kilo. with 12,000 kilo. water, and 500 kilo. ordinary hydrochloric acid, the violaniline is taken up; 125 kilo. of the same acid is added to the boiling filtrate, which, on cooling, deposits hydrochlorate mauvaniline, with a little rosaniline and resinous matter; 625 kilo. common salt added to this filtrate throws down a little mauvaniline, and rosaniline salts; the mother-liquor, treated with 83 kilo. carbonate soda, soon deposits salts of rosaniline, and a little chrysotoluidine; the further addition of 37½ kilo. carbonate gives a precipitate consisting almost entirely of chrysotoluidine; in this way, 5–10 per cent. of colouring matter may be recovered from the waste of the crude rosaniline. The separation is more easy and economical if all the rosaniline be extracted by boiling, as for the crude article. The further treatment of these matters with acid, common salt, and carbonate of soda, will yield different colouring matters, which will be noted in their proper places. See Rosaniline, Violet, Yellow, and Brown.

Leucaniline. $C_{20}H_{21}N_3$.—On boiling an acid solution of rosaniline with zinc, or mixing it with ammonium sulphide, it gradually becomes colourless, and a yellow resinous substance is deposited. This is crushed, washed with water, and dissolved in weak hydrochloric acid; the addition of strong acid precipitates the hydrochlorate of this base. Ammonia, added to a solution of this salt, yields the pure base, which is a white powder, easily soluble in alcohol. By oxidation, it yields brown colouring matters (q. v.).

Geranosine.—Luthringer has given this name to a red derived from magenta in the following way:—1 kilo. of the crystallized hydrochlorate is dissolved in 1000 lit. boiling water, filtered hot, and left to cool to 45° (113° F.); 4½ kilo. anhydrous binoxide barium, powdered, and 35 lit. cold water, are stirred together in an earthenware vessel; over this is poured 10 kilo. sulphuric acid, and the whole is well stirred for a minute or so. The solution of magenta is then added to this mixture, with agitation; it instantly changes to a yellow citron colour, and, after 2–3 minutes, passes to a slight reddish tint. The sulphate and peroxide barium are separated by filtering, and the filtrate is allowed to cool. It is then placed in a wooden, or tinned copper, vat, and heated to boiling; as the temperature rises, the red is developed, and reaches perfection at the boiling-point. It is boiled for two or three minutes, filtered, and left to cool; the filtrate contains the geranosine, ready for use.

Ulrich's Scarlet.—A colouring matter very similar to the above is obtained from 4 parts acetate rosaniline and 3 parts nitrate lead, dissolved in boiling water, and afterwards evaporated to dryness. The dry mass is heated at 149°–199° (300°–390° F.) until it passes to a complete violet colour. After cooling, it is boiled for some time in water slightly acidulated with sulphuric acid. The solution is then neutralized with soda or potash, and filtered whilst boiling. The colouring matter passes into the solution, and may be separated by the addition of salt, recovered on a filter, washed, and dried. It can be made to yield a rose-red substance, by ethylation or methylation; its solution in alcohol is mixed with iodide methyl or ethyl, and heated for some time in a closed vessel at 149° (300° F.); from the product, the colouring matter can be extracted in the same way as Hofmann's violet (q. v.). It is used for dyeing, in the same solvents.

Safranine.—This name is given to a colouring matter which has been used for some time for dyeing silk; it gives a fine red colour with a tinge of scarlet.

Amido-azo-benzol and amido-azo-toluol are oxidized by bichromate of potash, and the crude safranine produced is boiled in water containing soda or lime, in which the violet colouring matter is insoluble, whilst the safranine is taken up. The liquid is filtered, and slightly acidified with hydrochloric acid, by which the safranine is converted into hydrochlorate, and can be extracted by evaporation, and the addition of salt; the excess of acid may be previously neutralized by carbonate lime. If required of greater purity, it may be treated with water rendered alkaline by caustic soda.

The commercial article is a reddish-yellow powder containing hydrochlorate safranine, mixed with much carbonate lime and common salt. It can be readily purified by solution and recrystallization; the final crystallization should be from a boiling and slightly acid solution.

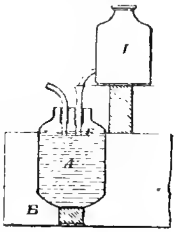
Pure safranine cannot be precipitated from its hydrochlorate solution by alkalies, in consequence of the formation of basic salts, &c., which are co-precipitated. The solution should be decomposed by oxide of silver; the filtrate from this is deep yellow-red, and when evaporated and cooled, deposits red-brown crystals, very like the hydrochlorate, and which, dried at 100° (212° F.) take a light-greenish metallic lustre. The safranine dissolves easily in water and alcohol, but not in ether. Concentrated solutions, mixed with hydrochloric and many other acids, give immediate crystalline precipitates of the salts of safranine, all of which may be recognized by the fact that when concentrated hydrochloric acid is added to their solutions, the reddish-brown colour of the liquid passes successively to violet, deep blue, deep green, and at last to a clear green; when water is added gently to this solution, the same changes of colour take place in the reverse order. Sulphuric acid acts in the same way as hydrochloric acid, and with more marked effect.

See also rosaniline brown and yellow.

Cerise.—This name has been given to a red colour from rosaniline residues; after precipitating the magenta with common salt, and filtering the liquid, carbonate of soda is added to the filtrate, and the product is washed and dried. Cerise probably contains magenta, and a little of the yellow colour from chrysaniline and chrysotoluidine. It dyes a shade between crimson and scarlet. (See rosaniline residues and leucaniline browns.) Sopp treats the resinous residues of rosaniline with 70 or 80 per cent. of hydrochloric acid. The insoluble portion is afterwards boiled in water, and treated with nitric acid, which causes a black deposit, whilst a yellow substance is dissolved, and crystallizes out on cooling; the hydrochloric acid solution first obtained is mixed with a solution of carbonate soda, producing a dark green precipitate, which, boiled in water, yields a little rosaniline; the green precipitate is well washed, and taken up by weak ammonia water and a little soap solution, when it gives a solution of very rich deep-red colour on cooling; if redissolved in hydrochloric acid, it gives a violet-blue liquid; it dyes shades which are wanting in beauty, but are solid; when applied to wool and silk, passed through permanganate of potash, it is converted into a fine chestnut-brown.

Arsenic Acid is manufactured on a large scale for this industry. The arrangement for the production of aqueous arsenic acid for magenta manufacture is thus described by H. Cant, of Evans, Cant, and Co. A series of stoneware pans A (Fig. 490) fit hermetically into an iron water bath B, heated by means of an iron coil. The pans are fitted with cemented covers, having two openings, in one of which a glass funnel F is placed, and to the other is securely attached an earthenware tube for leading away the nitrous oxide. Stoneware jars J, fitted with tubulures and stop-cocks, are filled with nitric acid (sp. gr. 1·400); the stop-cocks are opened so as to allow the acid to dribble slowly, as required, into the jars A, which contain arsenious acid mixed with a certain quantity of water. Thus the arsenious acid is expeditiously converted into arsenic acid of the degree of hydration required for magenta manufacture, whilst the nitrous fumes are collected in a series of large Woulfe's bottles. By means of an aspirator, these vapours are drawn out of the pans A accompanied by air, and are thus oxidized into nitrous acid, and ultimately into nitric acid for re-use. An outlet near the bottom of the pans allows the arsenic acid solution to be drawn off as required. This method of producing arsenic acid, and converting the nitrous oxide into a profitable product, enables arsenic acid to be produced for a trifle more than the cost of the arsenious and nitric acids, and removes the objectionable features of the manufacture; several attempts to utilize the refuse arseniates and arsenites, resulting from the manufacture of rosaniline salts, have been made, but with little success.

490.



Nicholson (No. 519, 1878) proposes nitric and hydrochloric acids, instead of arsenic acids, for the production of colours having rosaniline for their base. Three parts by weight of commercial aniline (such as is generally used for the production of red aniline dyes), about one part nitric acid (sp. gr. 1·420), and one part hydrochloric acid (sp. gr. 1·160), are heated at 177°–204° (350°–400° F.) until the desired colouring matters are produced; this is ascertained by withdrawing samples as the operation proceeds. The contents are removed, and the colouring matter is extracted by boiling water; it may be used direct, or purified; or the base, rosaniline, may be separated by means of an alkali or alkaline earth. Though the extra trouble, and modification of plant, required by this process may operate against its introduction, there can be but one opinion on the merits of an invention which dispenses with a seriously poisonous product.

An improvement in the same direction, by the recovery of the arsenic from the waste products of this manufacture, converting it at the same time into a source of profit, is to separate the rosaniline base by means of ammonia, by which the arsenious and arsenic acids contained in the "melt" are converted into arsenite and arseniate of ammonia, both of which are soluble; from these salts, it is proposed to expel the ammonia by heat, and collect it for use over again, obtaining the arsenic in a form ready for reconversion into arsenic acid. The objectionable feature in this is the handling of a readily soluble poisonous material.

Toluidine, or Coupier's Reds.—Coupier prepares his reds from (1) pure aniline and pure nitro-toluol; (2) ordinary commercial aniline and ordinary nitro-benzol; (3) nitro-toluol and toluidine, or nitro-xylol and xylidine; using iron and hydrochloric acid in each case. The products from the first two yield reds identical with ordinary rosaniline; to the last, he gives the name "rosatoluidine," "toluidine red," or "xylidine red." The apparatus and procedure may be as for rosaniline.

Erythrobenzine.—Laurent and Casthelaz gave this name to a red colouring matter obtained from nitro-benzol, iron filings, and hydrochloric acid, no aniline being added, although in the reaction it may be produced; it agrees with rosaniline, with which it is probably identical. Equal parts by weight nitro-benzol and aniline are gradually heated together in an enamelled iron vessel to about 200° (392° F.); the heat is continued until the mass becomes pasty, and will solidify, on cooling, to a brittle body resembling crude rosaniline. It is powdered, boiled in water with carbonate of soda to precipitate the colouring matter, and further treated as for purifying rosaniline. This yields a fine red colouring matter, and, as regards the aniline used, is equal in yield to the arsenic acid method. Nitro-toluol and aniline give a colour approaching that of rosaniline; toluidine and nitro-toluol give a red with a decided violet shade. The reds obtained in this way are better adapted for confectionery, colouring liquids, &c., than "rubine," which is made with nitrate of mercury instead of arsenic, and has been largely used for the above purposes.

Xylidine Red.—Hofmann's xylidine red is obtained by heating pure xylidine and pure aniline with an oxydant capable of forming rosaniline; it gives a splendid crimson. It is manufactured and purified as rosaniline (q. v.).

Rosaniline and the bases formed in its manufacture are capable of combining with the ethyl and methyl radicals, and from some of them important colouring matters are obtained. See Hofmann's Violet, &c.

Tannate of rosaniline is formed as a bright red precipitate, by adding a cold and dilute solution of a salt of rosaniline to a solution of tannic acid; from warm and concentrated solutions, a brownish-red brittle mass is produced. By dissolving in alcohol or wood-spirit, it dyes yellowish or orange-red tints. Treated with nitric or hydrochloric acid, it yields a colouring matter passing gradually from violet to blue; by regulating the supply of acid, any desired tint may be obtained. It is purified by washing with water, and dissolved in wood-spirit; its solution diluted with water can be used for dyeing.

BLUE COLOURING MATTERS. PHENYL-ROSANILINES.—When a rosaniline salt is heated with aniline, hydrogen is replaced by phenyl, and ammonia is given off, producing monophenyl-, diphenyl-, and triphenyl-rosaniline; the salts of the first have a reddish-violet colour; those of the second, bluish-violet; and those of the third, a pure blue colour, and are known as "candle blue" or "night blue," since their colour is unaltered by artificial light. For the manufacture of aniline blue, the purer the aniline itself, the better will be the colour of the dye produced. The aniline which passes over in the preparation of magenta is generally used for the better kinds of blue, on account of its freedom from the higher homologue bases. Commercial anilines may be fractionized, and the product coming over at 182°–185° (360°–365° F.), may be retained for the preparation of the finest blues.

These blues are more readily formed when weak organic acids, such as acetic, benzoic, &c., are present; in their dyeing qualities, much is gained by selecting an aniline of low boiling-point. The proportions of the ingredients vary; but, as a rule, free aniline is used in large excess. On the Continent, they are prepared in a series of enamelled cast-iron pots, heated in an oil bath over a furnace. The covers are secured by clamps, and supplied with a small opening for withdrawing samples, and a bent tube for leading away vapours to a condenser. Sometimes these tubes are inclined so that the condensed vapours are returned. If the heating is carefully conducted, the volatilized aniline should be trifling. Each pot is provided with an agitator, and has a capacity of about 20 lit. When starting, they are half-filled with the materials, and the covers with their appendages are fitted on, and secured. The covers, tubes, and stirrers are best arranged so that they hoist out together when the pots are opened. A thermometer is placed in the oil bath. A charge may be about 5 kilo. rosaniline salt (acetate, or hydrochlorate), and 10 kilo. aniline; the temperature of the bath should be kept between 190° (374° F.) max., and 165° (329° F.) min.; the aniline must not boil. The operation lasts about two hours. The free aniline is recovered by distilling with a current of steam, or removed by means of an acid, or the colouring matter is taken up by alcohol or wood-spirit. In this country, a small magenta-still is used instead of the series of pots.

By the subsequent purification of the crude product, the following colours are obtained:—

Direct Blue.—This is the crude colour deprived of the free aniline by a current of steam, or by washing with weak hydrochloric acid, in enamelled iron pans; the acid poured off one is added to the next, and so on. The aniline is recovered by distillation with lime.

Purified Blue.—The product in the still is liquefied with wood-spirit, and allowed to trickle into dilute hydrochloric acid. The free bases are taken up, and the colouring matter falls to the bottom; it is collected on flannel trays, and well washed with acidulated boiling water.

Night Blue.—So called from the absence of violet when viewed by gas or candle light. The crude product is well washed with wood-spirit, and sometimes boiled after being well divided. It is easier and cheaper in all cases to work upon the previously purified product for the next purification. Percolation with alcohol or wood-naphtha will purify the "direct blue" to any required degree, after the heavy anilines have been removed by hydrochloric acid.

By varying the proportion of materials and further purifying, the following different qualities of these blues are obtained:—

B Blue.—This blue is obtained by heating for two hours, at 180° (356° F.), a mixture of 2000 grms. pure rosaniline, 3000 grms. aniline; distilling at 182°–185° (360°–365° F.); and adding 270 grms. glacial acetic, or benzoic, acid. The products from benzoic acid are always more tinted with green than those from acetic acid; the former are used for silk, the latter for wool. The colour may be made purer by pouring it gently into an enamelled iron pot containing 10 kilo. hydrochloric acid, with brisk and continuous stirring. The precipitate is filtered, and well washed with boiling water acidulated with hydrochloric acid, till it is reduced entirely to powder; the yield is about 3500 grms.

BB Blue.—This is produced from pure rosaniline, 2000 grms.; pure aniline, 5000 grms.; benzoic, or glacial acetic, acid, 270 grms.; treated as above. The crude product is thus purified: the boiling mass is turned into an enamelled iron pot, and cooled by being placed in water; 7–8 kilo. concentrated alcohol are added, and the mixture is stirred till well incorporated; the vessel is heated in a salt-water bath till the alcohol begins to boil; it is then allowed to cool a little, and stirred, adding 10–12 kilo. strong hydrochloric acid; the mass becomes warm from the formation of hydrochlorate of aniline, and at the same time the pure blue separates. To obtain a product of constant colour, the filtering should always be made at the same temperature—45°–50° (113°–122° F.); the blue is washed with plenty of water, and dried. The product should be about 1320 grms.

This blue can also be made from B, by treating one part of the latter with 1¼ part strong alcohol, and 5 parts rectified benzol, introducing the whole into an apparatus supplied with an agitator and cohobator, and boiling for one hour.

BBB, and BBBB Blues.—These are prepared by a further purification of BB, 1 kilo. of which is boiled with agitation for two hours with 36 kilo. strong alcohol; 2 kilo. of an alcoholic solution of soda, containing 20 per cent. alkali, are poured in, when the soda sets the base free. The alcoholic solution is filtered, when a certain quantity of inferior blue is left in the filter. With the alcohol solution still warm, 280 grms. concentrated hydrochloric acid are well mixed; by leaving the whole to settle for about two hours, BBB is deposited in a crystalline form; this is filtered, pressed, and when dry, should yield 600–690 grms. By repeating this operation on the same product, BBBB is obtained. From the mother-liquor from which BBB has been precipitated, a further quantity of an inferior blue can be obtained.

A better plan is to dissolve 1 kilo. BB in a mixture of 1 kilo. alcohol, and 2 kilo. aniline, stirring till blended, pouring the whole into 25 kilo. alcohol, and heating till the alcohol boils; finally adding an alcoholic solution of soda, and filtering. This gives much less insoluble matter. To the filtrate is added a little excess of hydrochloric acid, when a superior blue is thrown down; at the end of forty-eight hours it is filtered off, pressed, washed several times with boiling acidulated water, and dried. It yields about 800 grms. BBB.

Nicholson's Blue.—Triphenyl-rosaniline-sulphonic acid is obtained by dissolving triphenyl-rosaniline in concentrated sulphuric acid, and adding water to the solution; a dark blue mass is formed which dries up into grains, having a beautiful metallic lustre. Its sodium salt is "Nicholson's" or "Alkali" blue, a dark-grey amorphous mass, dissolving in water with a fine blue colour. By the further action of sulphuric acid, other sulphonic acids are formed, and occur, as sodium salts, in several soluble aniline blues. The ammonium salt is Nicholson's ordinary "soluble" blue.

To prepare Nicholson's blue, "Blue de Lyons," or "Azaline," is boiled in water containing about 4 oz. sulphuric acid to 1 gall. water; when the soluble matter is nearly all taken up, the insoluble residue is dried, and reduced to powder, and about four times its weight of sulphuric acid (sp. gr. 1·845) is added to it; the temperature is raised to about 149° (300° F.); the mixture is stirred till solution is complete, and is kept at this temperature till a sample is entirely dissolved in water. If the temperature be raised too high, sulphurous acid will be evolved, to the destruction of the dye. Its dilute acid solution is used for dyeing and printing in the ordinary way. By the use of an excess of lime or alkali to neutralize the acid, it is thrown down, and a colourless solution is obtained, which, on addition of a weak (organic) acid, develops a soluble blue.

By varying the proportion of sulphuric acid, the heating may be curtailed or prolonged: it is best to work on small quantities, so as to limit the generation of heat. The tints are improved by increasing the acid; but when very large quantities are used, the colours are more fugitive; the proportions giving the most durable colours are those required to produce mono- and di-phenyl-rosaniline sulphonic acids, and heating to 100° (212° F.); these colours, however, are not so soluble as when the heat has been raised to 149° (300° F.). Anhydrous sulphuric acid may be used instead of concentrated acid, without heating. Caro (1877, No. 3731) converts the crude magenta bases into sulpho acids in the same way. The advantage of these dyes is that they can be used in presence of acids or acid mordants.

Diphenylamine Blue.—Girard and De Laire (1866, No. 2686) prepare a blue from diphenylamine and sesquichloride of carbon, by heating a mixture of 2 parts of the former and 3 of the latter, for five to six hours, in an enamelled iron vessel, to 170°–190° (338°–374° F.). The apparatus used is the same as for making diphenylamine.

Besides diphenylamine, ditoluylamine, phenyl-toluylamine and diphenyl-amyl-amine may be used. These may also be treated with oxalic acid for the same purpose. The development of colour is watched by drawing samples; it is complete when a copper red is produced, and the cooled mass becomes hard and brittle, and dissolves in alcohol with an intense blue. It is purified by dissolving at 100° (212° F.) in double its weight of aniline; the solution is thrown into a large quantity of benzol, kept well agitated; the vessel is kept cool, so as to avoid loss of benzol. The blue is precipitated as a very fine powder, collected on a canvas strainer to drain, and well pressed; it is repurified in the same way without being pressed, and is washed on the strainer with benzol. It may be further purified by dissolving in boiling aniline; precipitated by hydrochloric acid, the aniline salt is washed out with boiling water. The free base is obtained by caustic soda, and purified by solution in alcohol.

The separation of blue from violet colouring matter is effected by dissolving in ten times its weight of oil of vitriol heated to 30°–60° (86°–140° F.). Water is added to precipitate the blue, whilst the violet remains in solution; it is thrown on to an asbestos filter, and washed with dilute acid, then water; it is drained and pressed, and if required with greater purity, the previous process is carried out.

Toluidine Blue, or Tri-toluyl-rosaniline.—The composition of this blue is analogous to that of tri-phenyl-rosaniline, and its mode of preparation is similar. Equal parts of rosaniline and crystallized toluidine are heated for five or six hours to 150°–174° (302°–346° F.). Its extraction and purification may be effected with hydrochloric acid and water. It dissolves in alcohol with a beautiful blue colour.

Bleu de Coupier, or Triphenyl-roso-toluidine.—Toluidine red heated with aniline yields a blue colouring matter, known by this name. It is prepared in the same way as Coupier's reds (q. v.), by substituting his toluidine red for rosaniline.

Bleu de Paris.—This is obtained from methyl-anilines and anhydrous bichloride of tin; it is a triphenyl-rosaniline. (See Violet de Paris.)

Aldehyde Blue.—This colouring matter is a valuable source of green, and although its merit as a blue does not entitle it to the notice of the dyer, its preparation must be noticed here. A solution of 20 grms. rosaniline, in 280 cc. ordinary hydrochloric acid, is diluted with an equal volume of water, and mixed with 100 cc. crude aldehyde. After twenty-four hours, the blue is precipitated by caustic soda in excess, collected on a filter, washed, purified by solution in alcohol, and dried. A yellow resinous matter is removed by carbon bisulphide. Its solution in wood-spirit dyes well, but not deeply. (See Aldehyde Green.)

Bleu de Mulhouse.—This product, having the colour of ammoniuret of copper, is obtained by boiling 50 grms. bleached shellac, and 18 grms. soda crystals, in 1 lit. water, and adding 50 cc. solution of magenta (1 part magenta in 4 parts water, and 4 parts alcohol), boiling for one hour, and adding water and spirit as they boil away.

Azurine.—Blumer Zweifel makes this colouring matter as follows:—100 grms. starch is boiled in 1 lit. water, and whilst boiling, 4 grms. chlorate potash, 3–4 grms. sulphate iron, and 10 grms. sal-ammoniac, are added. When the mass has cooled and set, 60 grms. of a salt of aniline is added, and well mixed and dissolved. Its tints are altered by varying the proportions.

Triphenyl-Mauvaniline.—This base is converted into ethyl, methyl, and phenyl compounds in the same way as rosaniline; it is soluble in alcohol, and its salts yield splendid blue colouring matters. (See Triphenyl-rosaniline, Rosaniline residues, and Mauvaniline.)

Mauveine, Mauve, Aniline-blue, or Perkin's Violet. $C_{27}H_{24}N_4$.—The production of this interesting colouring matter depends upon the action of an oxidizing agent on aniline, or a salt of aniline, such as the sulphate or chloride. A cold saturated solution of sulphate aniline is mixed with an equal quantity of a cold saturated solution of bichromate potash, and allowed to stand for 10–12 hours. The quantity of potash is such as to produce, with the sulphuric acid from the aniline salt, the neutral sulphate. The mixture is thrown on to a filter, and washed until the potash-salt is all removed; the residue is dried at 100° (212° F.). The adhering resinous matter is washed away with coal-tar naphtha or petroleum, and when the naphtha has evaporated, the washed mass is dissolved in wood-naphtha or methylated spirit. Instead of washing away the resinous matter, it is more economical to treat the crude mass with slightly dilute wood-naphtha or methylated-spirit; as the resinous impurities are but slightly taken up, the larger proportion of the spirit is recovered by distillation, and an aqueous solution of the colouring matter remains; by evaporation, it can be obtained either in a dry crystalline state, or in paste. Caustic potash, added to a solution of the sulphate, precipitates the mauveine, which is almost insoluble in water, but dissolves readily in alcohol, yielding a bluish-purple colour. It is a powerful base, combining with acids to form well-defined salts, which have a fine metallic lustre; it expels ammonia from its combinations.

When the base is heated with aniline, ammonia is given off, and a blue colouring matter is formed. It has been proposed by Perkin to obtain an ethyl compound, by heating equal parts of mauveine and iodide ethyl together, for the general carrying out of this (see Hofmann's violet, &c.); it was largely used a short time ago, but the replacement of iodine by less costly methods of introducing the alcohol radicals must eventually restrict its use. It dyes deeper and finer shades of mauve.

By oxidizing a hot solution of mauve with sulphuric acid and manganic oxide, a beautiful red colouring matter is produced; it is very soluble in water, and forms crystals having a fine beetle-green lustre. In concentrated sulphuric acid, it dissolves with a dark green colour, which, on adding water in small quantities, changes into bluish green, pure blue, violet, purple, and at last into pure red. This was originally called "safranine"; but the colouring matter now met with in commerce under that name is obtained from a very different source.

Phenyl Violets.—In the purification of di-phenyl-rosaniline blues, blue and violet colouring matters are obtained. The blue obtained by heating equal parts of rosaniline and aniline for four hours at 149°–160° (300°–320° F.) is, whilst being boiled with dilute muriatic acid (1 acid to 9 water), freed from the unaltered bases, which contain the violet. This violet is not pure, but, according to the purification, are obtained violet-red or dahlia, and violet-blue or parme; between these are found all shades of violet. By even the most careful manipulation, it is not always possible to get the same shades, consequently the exact shades required are obtained by mixing the blues and reds.

Mono-phenyl-rosaniline (red-violet).—Rectified aniline, 14 kilo., is gradually added to acetate of rosaniline, dried at 100° (212° F.), 10 kilo., in a still, so as to collect the aniline which comes off. The rosaniline salt is first heated gently by itself; the cohobation with aniline is continued for one hour, when the heat is raised to 190° (374° F.). Samples of the product are drawn out every few minutes, so as to watch the production of colour, which should be a very red violet. The mixture is allowed to cool a little, when it is softened with a little benzol, which removes the aniline, and a brown colouring matter, whilst the rosaniline and other products are precipitated. The precipitate is thrown on a strainer, dried, and dissolved in hydrochloric acid; from this, the violet is thrown down by the addition of a large quantity of water, well washed, and dried.

Di-phenyl-rosaniline (blue-violet).—Rosaniline salt, 10 kilo., and aniline, 20 kilo., are treated, as above, for at least one and a half to two hours. Acetate rosaniline is sometimes used. The product is examined from time to time, and when the tint is obtained, the vessel is removed or allowed to cool. Alcohol, 4–5 lit., are added, to soften it, and the whole is poured into a large quantity of alcohol, to which hydrochloric acid is added. The colouring matter is precipitated by adding a saturated solution of common salt, and is well washed on a flannel strainer with acidulated water.

Ethyl and methyl rosanilines.—Ethyl and methyl violets are now largely made from methyl-aniline (see Violet de Paris), so that the costly production of Hofmann's violets from iodides of ethyl or methyl has become of interest principally as a source of other important colours. The modus operandi (No. 1291, 1863) is as follows:—One part by weight of rosaniline, 2 parts by weight of iodide of ethyl, and about 2 parts of strong methylated spirit are heated together in a suitable vessel, to a temperature of 138° (212° F.), for three to four hours, or until the whole of the rosaniline is converted into the new colouring matter. The syrupy mass obtained on cooling is dissolved in methylated spirit or alcohol, and may be used at once for dyeing and printing. The iodine is thus recovered:—The product either before or after dissolving in spirit is boiled with an alkali, by which the base is precipitated, whilst iodide potassium remains in solution. The base is washed and dissolved, together with an acid (as hydrochloric), in alcohol, or in place of hydrochloric acid and alcohol, acetic acid and water; these solutions can be employed for dyeing and printing, giving to silk and wool beautiful violet, blue-violet, and red-violet tints. Instead of iodide of ethyl, the iodides and bromides of methyl, amyl, propryl, and capryl may be employed, but not so conveniently, as they are more expensive. Three shades of violet, viz. R, reddish violet; B, blue-violet; and BB, a light-violet, were formerly supplied in this material. For red-violet.—Ten kilo. of rosaniline, 100 lit. alcohol, 8 kilo. iodide of ethyl or methyl, and 10 kilo. caustic soda or potash; the mixture is heated for two hours at 115°–130° (239°–266° F.). For blue-violet.—Ten kilo. of rosaniline, 100 lit. alcohol, 5 kilo. iodide methyl, 5 kilo. iodide of ethyl, and 13 kilo. caustic soda or potash. For light-violet.—Ten kilo. of rosaniline, 20 kilo. iodide of methyl, 100 lit. ethylic alcohol, and 10 kilo. caustic potash. The solutions of iodide ethyl and methyl should be added very gradually, as also the caustic solutions. Other intermediate shades may be obtained by varying the proportions. Iodide of methyl gives a more decided blue shade than the iodide of ethyl, and the colouring matter is also more soluble in water than the iodide of ethyl product. The products are the iodohydrate of ethyl-rosaniline or of methyl-rosaniline; both are purified in the same way. The salts of both bases are soluble in alcohol, wood-naphtha, acetic and mineral acids; the colours obtained from the salts of trimethyl-rosaniline are much brighter than those from salts of the other base, whilst salts which contain both bases are still more beautiful as dyes.

Mauvaniline (see Rosaniline residues).—The precipitates containing rosaniline and mauvaniline are submitted to the action of hydrochloric acid, salt, &c., so as to separate them as completely as possible; the mauvaniline is washed with benzol, and digested in a cohobator with alcoholic potash, by which the free base is obtained. It is washed with water, and when dissolved in acid, dyes magnificent mauve shades. According to Girard and De Laire, 12 per cent. of this is obtained from rosaniline refuse.

Triphenyl-mauvaniline yields salts soluble in alcohol; they have a beautiful blue colour.

Ethyl-mauvaniline.—By treating mauvaniline with iodide of ethyl, Girard and De Laire obtain a violet colour, which is bluer according as the iodide is in greater proportion to the mauvaniline salt. It may be made in the same way as Hofmann's violet (q. v.), with 1 kilo. mauvaniline, 10 lit. wood-spirit, 3 kilo. iodide ethyl (or methyl), and 1 kilo. potash or soda.

Violet de Paris.—Poirrier and Chappat's violets are obtained from methyl-anilines; according to the predominance of blue or violet tints, reddish blues, blues, and pure violets are produced. It is highly probable that for blues and violets, this is destined to become a very important source. To obtain violet, violet-red, and violet-blue, from methylic, methyl-ethylic, and methyl-amylic anilines, 1 part methyl or dimethyl-aniline, and 5–6 parts anhydrous bichloride tin are mixed in a still, heated up to 100° (212° F.) for some hours, and well stirred until hard; the mass is treated with caustic alkali, washed and filtered; the precipitate is boiled in water, and neutralized; from this solution, filtered when cool, common salt throws down a green precipitate, which is collected on a filter, and may be further purified by crystallizing from solution in alcohol; its solution in boiling water dyes a magnificent violet.

If the heating has been sufficient, the mixture is found as a black tarry mass. Instead of bichloride tin and bichloride mercury, arsenic acid may be used; or if 100–150 parts chlorate potash, 100 parts methyl-aniline, and 100 parts water are used, the reaction which follows from the splitting up of the liberated chloric acid yields the colour. Chloride iodine diffused in 5–10 parts of water may also be used; or a mixture of 80 parts chlorate potash, 20 parts iodine, and 100 parts methyl-aniline. Iodates, bromates, and iodic and bromic acids react on methyl-aniline salts with the same development of colouring matter. Bichloride of mercury alone develops very little colour; terchloride benzol and terchlorophenic acid develop a violet, at 150° (302° F.). Red violets are obtained by employing methyl-aniline and bluer violets, when dimethyl-aniline, or higher methylic homologues, are used. After purification, these violets are all soluble in water, alcohol, and acetic acid, and are used for dyeing and printing as other aniline dyes. Brooman's improvements (1866, No. 3195) consist in treating chlorides of methyl-anilines with nitrate or chloride of copper for violets, which yield bluer shades according as the heating is prolonged. The oxidation products from these violets give, with chloride-benzyl, still bluer shades of violet. The methyl and ethyl violets met with in commerce are R. B. BB., to 6B. Bardy obtains violets from methyl-diphenyl-amine (q. v.), which are also capable of yielding mixtures of blue and violet.

Girard and De Laire's violet from methyl-benzyl-phenyl-amine may be thus produced:—Methyl-benzyl-diphenyl-amine, 15 lb.; chlorate potash, 2½ lb.; water, 40 lb.; and non-calcareous sand, 100 lb., are well mixed, placed in a cohobating apparatus, and heated; a solution of sulphate of copper (5 lb. to 15 lb. water) is added during the heating, in small portions at a time. The temperature is kept for twenty-four to thirty hours at 50°–80° (122°–176° F.); when the reaction is complete, the mixture is carefully neutralized with caustic soda or potash, or lime water, and the unaltered portions of the bases are removed by distilling with a jet of steam. The mass is then treated with hydrochloric acid in slight excess, and the colouring matter is removed by hot water, and thrown down with common salt; it is then converted into a base by soda or potash; this is well washed, and again converted into hydrochlorate or acetate. These salts are soluble in water, and dye blue-violet. The colours obtained from the corresponding compounds may be produced in the same way by substituting the alkaloid or its salt; benzyl-diphenyl-amine gives a bluish green or greenish blue; benzyl-phenyl-toluyl-amine, orange; benzyl-ditoluyl-amine, brown or chestnut; methyl-diphenyl-amine, blue. This same process is, according to Bolley and Kopp, employed by Poirrier for the manufacture of violets from methyl and di-methyl-anilines (q. v.; also violet de Paris).

Violaniline (see Rosaniline residues).—This base forms salts soluble in alcohol; the solutions dye silk and wool a rusty black with a shade of violet.

GREENS.—The green colouring matters obtained from coal-tar are produced by certain reactions on other aniline or toluidine colours.

Aldehyde, or Usebe's, Green.—Sulphate rosaniline, 150 grms., are dissolved in a cooled mixture of

3 kilo. oil of vitriol and 1 kilo. water; 225 grms. crude aldehyde are gently added, with continued stirring; the whole is heated in a salt-water bath, till a drop let fall into dilute acid appears green; 450 grms. hyposulphite soda, dissolved in 30 lit. boiling water, are added very gradually, and the whole is boiled for a few minutes; the green liquid is filtered from the sulphur which separates from the hyposulphite, and is ready for use.

Lucius' method of obtaining aldehyde green differs from the foregoing mainly in the use of sulphuretted hydrogen, and an alkaline sulphite instead of hyposulphite soda; 1 lb. sulphate rosaniline is dissolved in a mixture of 2 lb. sulphuric acid with 2-4 lb. water, adding 4 lb. aldehyde, and heating to about 50° (122° F.), till a sample dissolved in about fifty times its weight of alcohol yields a greenish-blue solution; to this is added 300–500 lb. saturated aqueous solution sulphuretted hydrogen, gradually increasing the heat to 90°–100° (194°–212° F.), adding 10 lb. saturated solution sulphurous acid, and filtering the liquid from the blue colouring matter which has been precipitated. The green remains in solution, and is obtained in the solid form.

Aldehyde green, when kept for any length of time, loses much of its beauty, and may even become useless; on this account, it is best prepared as wanted. It is sold in two forms: dry, and in paste; in the dry state, it is an amorphous powder, insoluble in water, readily soluble in a mixture of dilute sulphuric acid and alcohol, and sparingly soluble in alcohol alone. To produce the powder, it is precipitated from solution by neutralizing with carbonate soda, or by adding common salt; it is washed by decantation, and finally dried at or below 100° (212° F.). As the paste is more readily soluble than the powder, and appears to keep better and longer, it is the preferable form, especially as the difficulty of drying is then dispensed with.

Toluidine Green may be obtained by treating Coupier's red, or rosotoluidine, with aldehyde in the same way.

Gas Green.—This colour is so called from its appearing green in artificial light. Luthringer gave this name to a green obtained by mixing a yellow with blue (see Yellows). Different shades of green are obtained in printing and dyeing, by superposing one colour on the other.

Hofmann's Green.—This colour is obtained from Hofmann's violet, either by direct treatment, or by reactions in which ethyl-rosaniline appears as an intermediate product. One part acetate rosaniline, 2 parts pure iodide methyl, and 2 parts methylic alcohol, are placed in an enamelled digester withstanding a pressure of 400 lb. a sq. in., and heated to 100° (212° F.) for twelve hours in a water bath. The green and violet colours formed dissolve in the methylic alcohol; when the digester is opened, the volatile products escape; a gentle heat is applied to drive off the free methylic and methylic-acetic ethers, leaving the residue as a paste, which, when thrown into boiling water, gives up the green colour; the small quantity of violet dissolved is removed by addition of common salt and a little carbonate soda. The solution is filtered through sand or asbestos, and precipitated by adding cold saturated solution picric acid. In commerce, it is met with in paste as picrate, which is readily soluble in alcohol.

The soluble green, manufactured by Girard and De Laire, is a double zinc salt, produced by adding to a solution of the colour, sulphate, chloride or acetate of zinc; it is soluble in water, and in addition to the saving of alcohol as a solvent, it dyes fibres with a purer green than does the picrate. Pure crystals are obtained by dissolving in boiling, absolute alcohol, and precipitating by anhydrous ether; the precipitate is dissolved in boiling alcohol, which, on cooling, deposits crystals. This green has been greatly replaced by methylaniline green (q. v.).

Paris Green.—Under this name, Poirrier, Bardy and Lauth, prepare a green colour from anilines derived from benzol or toluol, or mixtures of these, by oxidizing with bromine, chlorine, or iodine, or their compounds, or with nitric acid, nitrates, arsenic acid, &c. The usual process is as follows: —100 lb. aniline, 80 lb. chlorate potash, and 20 lb. iodine, are heated to 100° (212° F.); in order to subdivide the mass, sand may be added, when the reaction requires less heat; after a few hours, when the mass has become hard and brittle, it is first treated with boiling water, and afterwards with a boiling solution of potash in alcohol. By this means, the product is obtained in a tolerably pure basic condition. This base is then treated with strong acetic acid to convert it into a neutral salt; in this state, the green colour, dissolved in alcohol, can be used for dyeing and printing. It may be further purified by redissolving in alcohol, filtering, precipitating by soda, treating again with glacial acetic acid, and redissolving in alcohol.

Methylaniline Green.—This is obtained from Poirrier's methylamine violet. The violet is first precipitated by chloride zinc and subsequent saturation with carbonate soda; the filtrate is concentrated, and, on cooling, deposits crystals of a double compound of the aniline green and zinc.

ANILINE BROWNS.—The processes for the production of these colours depend upon the reducing action of certain bodies upon magenta or rosaniline, or their mother-liquors, with or without aniline, or by making a salt of aniline react on magenta at a high temperature.

Levinstein heats 1 part rosaniline with 1 part formic acid, to 180°–200° (356°–392° F.), when the mixture appears dark brown; dissolved in alcohol or wood-spirit, it becomes scarlet; by heating to 258° (496° F.), and then dissolving as above, it becomes red-orange; and when heated to about 265° (510° F.), and dissolved as above, yellow-orange is produced. In order to prepare a brown, when the mixture has become scarlet-red, it is left to cool, and is then mixed with 3 parts aniline; the whole is heated at 189°–210° (356°–410° F.), and the excess of aniline is separated. Sopp obtains a brown from rosaniline residues by oxidation.

Girard and De Laire obtain brown matter from rosaniline residues (q. v.). The precipitate obtained by treating the residues with soda in excess consists principally of chrysotoluidine. It is dissolved in clear lime water, boiled three or four hours, filtered into dilute hydrochloric acid; on cooling, a salt crystallizes out, which is met with in commerce as "yellow fuchsine." The residue contains nearly pure chrysotoluidine, the lime is taken up by boiling in an iron vessel with hydrochloric acid to exactly neutralize it, the base fuses and rises to the surface; this is purified by solution and precipitation with carbonate soda, and is converted into sulphate. These substances dye silk and wool yellow; with more or less rosaniline it gives orange, deep yellow, and browns; the less purified product is used for dyeing leather, &c. Their "maroon" is prepared as follows:—4 parts anhydrous aniline hydrochlorate are fused, and 1 part dry aniline violet or blue is added. When entirely dissolved, the temperature is raised to 240° (464° F.), and maintained till the colour suddenly becomes brown. The operation lasts one to two hours, and is complete when yellow vapours condense on the sides of the apparatus. This brown is soluble in water, alcohol, and acids, and may be used without further treatment; it is precipitated from its solutions by alkalies and neutral salts. It dyes beautiful shades of brown on silk, leather, and wool. Instead of aniline dye, material for producing the dye may be substituted, e. g. arseniate aniline may be treated with hydrochlorate aniline. By oxidation, brown shades are produced, more or less orange, according to the degree of oxidation (see Leucaniline).

Durand's brown is produced in the same way as some aniline blacks, by oxidizing an impure leucaniline in the presence of copper salts. The cheapest and best source is the article known as cerise (q. v.). This is boiled with zinc and dilute sulphuric acid; the solution, when saturated with common salt, deposits a brownish colouring matter, which, dissolved in dilute acids, alcohol, &c., dyes yellowish shades, nankin, tan, and browns.

Siberg obtains a brown from the impure matter precipitated from the mother-liquors of magenta; 1 part hydrochlorate aniline is melted, and to it is added ½ part of the colour residues; the whole is heated on a sand bath until the brown colour appears. The product is mixed with 2 parts crystallized carbonate soda dissolved in 25 parts water, and well stirred; the liquid is left to settle, and the colour is washed several times. When dry, it is brownish black. For use, 1 part of this resinous substance is dissolved in 9 parts alcohol, and the solution is mixed with 13 parts water.

Manchester Brown.—Robert, Dale, and Co., of Manchester, manufacture a brown known by this name. A cold, weak, neutral solution of phenylene hydrochloride is gently added to a neutral solution of a nitrite; a deep-red crystalline mass separates out; this is first washed with water, and is afterwards treated with concentrated hydrochloric acid, in which it dissolves, and afterwards separates out as a tarry mass. This compound of colour and hydrochloric acid is dissolved in water, and mixed with a solution of ammonia, which precipitates the colour as a brown crystalline mass. Its aqueous solution dyes wool and silk without a mordant; the colour is orange or yellow-orange; but, in contact with the atmosphere, or on rinsing in dilute hydrochloric acid, it passes to a deep reddish brown. The acetic acid solution of the brown colour also dyes reddish brown if somewhat concentrated, and yellowishbrown if dilute.

Aniline Yellows.—In 1864, Simpson, Maule, and Nicholson offered a yellow dye stuff under the name of "Aniline Yellow," which is an oxalate of the product obtained by the action of nitrous acid on aniline (see Amido-azo-benzol). Aniline is dissolved in three times its weight of alcohol, and nitrous acid is passed into the solution until the liquid becomes deep red; this is afterwards mixed with a large excess of slightly dilute hydrochloric acid, to separate the colouring matter; the crystalline product is filtered, washed with very weak alcohol, and boiled several times in water; the solution is mixed with ammonia, and the product is purified by recrystallization; its solution in alcohol is used for dyeing. By heating the acid, a shade between garnet-red and brown is produced.

Schiff's yellow is met with in commerce as a paste; dissolved in weak acids, it dyes a yellow, which is rendered more solid by passing through a solution of carbonate of soda; 3 parts stannate soda, 1 nitrate aniline, in 10 of water to which a little carbonate soda is added, are heated to 100° (212° F.); a strong reaction sets in; as soon as acids produce a red coloration, the process is complete. On adding strong hydrochloric acid, the colour is deposited as a resinous mass.

Zinaline.—This is obtained by acting with nitrous acid on solutions of rosaniline, Hofmann's and ordinary violets, Usebe's green, and Girard's aniline brown. Different tints are developed according to the amount of gas passed through, the highest shade being a yellowish red. Evaporation in a salt-water bath produces a red powder. Its solution in alcohol with a little ammonia gives, on silk and wool, bright shades of orange. With indigo-dyed goods it gives a green.

Sopp's yellow, or jaune de Lyon.—(See Cerise).

ANILINE BLACKS.—These are produced by the action of oxidizing agents on anilines, generally in contact with the fabrics to be dyed, though paste blacks are sent out by some makers. The anilines employed in blacks and greys for calico-printing, &c., generally contain 60–65 per cent. liquid, boiling at 180°–185° (356°–365° F.)—pure aniline, 18–22 per cent., boiling at 185°–192° (365°–377° F.); aniline and toluidine, 8 per cent., boiling at 192°–198° (377°–388° F.); toluidine; and 4–6 per cent. xylidine, &c. Their sp. gr. should be 2°–3½° B.; those of higher sp. gr. may contain nitro-benzol, while in those below 2° there is much toluidine, which injures the black. When fractionized, these anilines should distil almost entirely at 180°–190° (356°–374° F.). Coupier's anilines, which distil at 180°–185° (356°–365° F.), are said to produce the richest blacks. Pseudotoluidine, and the products boiling at 185°–192° (365°–378° F.), give "blue-blacks." Toluidine, and the products boiling above 192° (378° F.), give rusty blacks; on this account, they are rejected.

The salts of aniline cannot be used indiscriminately for producing blacks; nearly all the salts with organic acids give very unsatisfactory results, as do even those obtained with mineral acids, if perfectly neutral; the solution must be acid, and in this way, it is possible partially to regulate the character of the black. The hydrochlorate and disulphate with excess of acid are usually employed.

A description of Lightfoot's and similar methods of obtaining aniline blacks belongs more appropriately to the department of the dyer, and will be treated in the article on Dyeing and Calico-Printing.

Attempts have been made to prepare a black dye from aniline in the same form as other colours. Coupier proposes to mix 175 parts commercial aniline with an equal quantity nitro-benzol, adding 200 parts hydrochloric acid, 16 parts iron filings, 2 parts copper filings, and heating the whole for six to eight hours at 160°–200° (320°–392° F.) in an enamelled iron pot fitted with a condenser. The operation is complete when the mass can be drawn into threads. This black is soluble in acids, alcohol, and wood-naphtha; for use, it is dissolved in sulphuric acid.

Lucas' black is a soft, black mass, composed of hydrochlorate aniline and acetate copper. It produces a black of very good tone, and can be obtained at a low price.

The black supplied by A. Müller, of Zürich, is obtained by dissolving in ½ lit. water, chlorate potash, 20 grms.; sulphate copper, 30 grms.; chloride ammonium, 16 grms.; hydrochlorate aniline, 40 grms. The mixture is heated in a salt-water bath at about 30° (86° F.); after a few minutes, it froths and swells up; if, at the end of some hours, it becomes pasty without turning quite black, the heating is continued. The paste is exposed to the air for some days, washed on a filter till no salts are found in the filtrate, and is removed from the filter as a deep-black paste, containing about 50 per cent. of dry colour. A blue-black is obtained from this, by finally washing with 20 grms. soluble blue in 1 lit. water. These colours are mixed up with much albumen, which is the principal drawback to their use. The dry black, ground up, and mixed with a solution of gum, is said to equal the best Indian-ink. Müller's black is largely used.

ANILINE GREYS.—Abel's grey is thus obtained:—2 lb. aniline, boiling at 188° (370° F.), is mixed with 10 lb. solution arsenic acid (sp. gr. 1·375), and heated in a water bath till the mixture thickens and rises. The vessel is then withdrawn from the fire, and a little water is poured in, to prevent boiling over. The product is thick and blackish, and is insoluble in water. It is purified by adding 18 qts. water and 2 lb. hydrochloric acid, boiling for about half an hour, and filtering; the precipitate is washed with boiling water, and finally with a weak solution of sodic carbonate, so as to neutralize the acid, after which it is dried, and remains as a fine black powder. Its solution is effected in alcohol, to which 10 per cent. sulphuric acid may be added, and will produce many shades of grey by addition of the requisite mordants to the bath.

Greys are obtained from weak solutions of some blacks. One is prepared by Casthelaz by mixing 10 parts by weight of Perkin's violet with 11 parts oil of vitriol, and 6 parts aldehyde, and heating for four to five hours. The colour is precipitated, from its dilute solution, by an alkali, and washed.

A recent application of the aniline dyes is for the production of coloured lacquers; the salts used should be as free as possible from water. They are also employed to separate cotton from woollen rags, the former taking no colour from a dye which produces a pronounced tint in the latter.

Carbolic Acid.—(See also p. 41.) This compound is now regarded as benzol, one atom of whose hydrogen has been replaced by the radical HO; its formula is therefore $C_6H_5(HO)$, benzol being C_6H_6. When in a pure state, it consists of colourless acicular crystals, and has a sp. gr. of 1·065; Calvert's "Pure Medicinal" acid fuses at 42° (108° F.) to an oily liquid, and boils at 182° (359° F.). Carbolic acid is one of the most powerful antiseptic and antizymotic agents at present known, and exhibits strong anæsthetic and escharotic properties. In the animal kingdom, it is found in the urine of men, horses, and cows; in the vegetable world, it exists in the castor plant, in the *Andromeda Leschenaultii,* a plant growing on the high lands of India, and in the resin of the *Zanthorrhœa hastilis;* among minerals, coal seems to be the only one in which it has hitherto been discovered. It may be produced by the action of nitrous acid on aniline, and by the dry distillation of gum benzoin, quinic acid, and chromate of pelosina; there is besides the ordinary commercial process of extracting it from the oils of coal-tar.

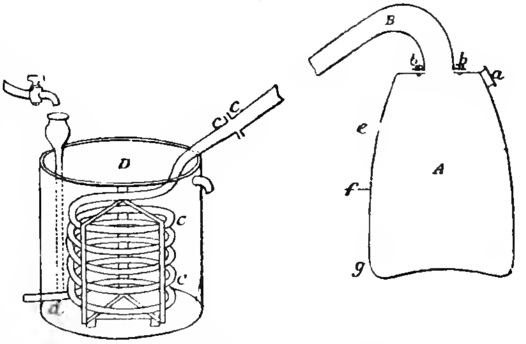
Early Methods of Manufacture.—So long ago as 1834, carbolic acid was discovered by Runge to be a constituent of coal-tar oil; and about seven years later, Laurent made further investigations into its properties, and succeeded in separating it. He considered it to be a hydrated oxide of a peculiar compound radical, phenyl, whence he named it hydrated oxide of phenyl. Mansfield, in 1847, and Bobœuf, in 1856, made some improvements in the processes of extraction; but it was reserved for the late Dr. Crace Calvert and his partners to work out the manufacture, to such perfection as would enable the acid to be produced at a saleable figure on a large scale; and his firm is now the largest, as it is undoubtedly the first, in this branch of chemical industry.

Laurent's method of preparing carbolic acid from coal-tar consisted in submitting the light oils to a fractional distillation, and then treating those products which had distilled over at temperatures varying from 160° to 218° (320° to 424° F.) with a concentrated solution of potash, separating the alkaline solution from the hydrocarbons which floated on it, and afterwards neutralizing the alkali by an acid, which last process liberated the carbolic acid from the alkaline solution. Pure carbolic acid was present, however, only in very small proportion. The product was, in fact, a mixture composed chiefly of different liquids, similar in properties and composition to carbolic acid; and, though Laurent succeeded in obtaining solid carbolic acid, the process devised by him was too expensive to answer on a manufacturing scale, and his mode of operation was too complicated. The modifications suggested by Mansfield, and later by Bobœuf, consisted principally in employing caustic soda instead of potash, and in treating the whole of the light oils, instead of only a special portion of them; still the result was a highly impure acid, from which it was very difficult to extract the pure acid. Commercially, however, their process was a step in the right direction, and was employed by Clift, under Dr. Calvert, in manufacturing some carbolic acid, about thirty years ago. This impure acid was successfully used, by Dr. Calvert, in producing picric acid, in preventing the transformation of tannic acid into gallic acid, in tanning, and in the preservation of subjects for the dissecting-room.

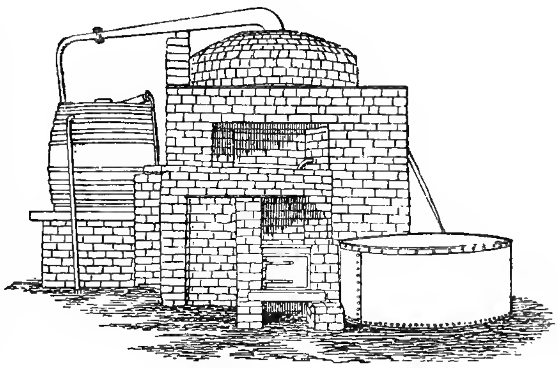
In 1859, a demand arose for a purer acid. From experiments instituted by Dr. Calvert, it was found that the best mode of preparation was not by treating light or heavy oils of tar with concentrated alkalies; but, on the contrary, by treating the impure benzols or naphthas of commerce —distillates from the tar oils—with weak alkaline solutions. By this means, was produced a blackish fluid, a little heavier than water (sp. gr. 1·060), and containing 50 per cent. of real carbolic acid, which latter was separated in part by careful distillation. This acid continued in use for colour manufacturing till 1861, when aniline colours of such fineness and brilliancy were produced, that, in order to keep pace with them, it became necessary to still further improve the quality of the carbolic acid. After some trials, white detached crystals of the acid, melting at about 29° (85° F.), were obtained. In 1863, this relative purity was again found to be insufficient, and further efforts to increase it resulted in the production, on a commercial scale, of Laurent's "phenylic alcohol," a substance melting at 35° (95° F.), and boiling at 186° (367° F.). Repeated attempts to draw the attention of the medical profession to the remarkable therapeutic qualities of this acid were then made; but the tarry and sulphuretted odours which it still possessed were serious obstacles in the way of its application. Dr. Calvert soon succeeded, however, in removing these objectionable features, and was able, in 1864, to manufacture an acid quite free from sulphuretted smell. Still he did not stop his researches; but, two years later, discovered a process which enabled him to show an acid completely deprived of all disagreeable odour and tarry flavour, and as pure, though extracted from tar, as if it had been produced by the help of the reactions noticed by Wurtz and Kékulé, based upon the direct transformation of benzol into carbolic acid, or by the well-known changes by which it may be obtained from salicylic or benzoic acids. This new phenylic alcohol, or carbolic acid, was, however, in some respects distinguished from Laurent's. Thus, it was soluble in 12½ parts of water instead of 33; was fusible at 42° (108° F.), instead of at 35° (95° F.); and boiled at 182° (360° F.), instead of at 187° (368° F.). Nevertheless it gave, like Laurent's, the blue colour described by Berthelot as being produced on mixing ammonia with it and adding a small quantity of hypochlorite to the solution, the same effect being produced by exposing to hydrochloric acid vapours a chip of deal that has been soaked in this pure carbolic acid. It was supposed that, as Laurent's acid had constant boiling and crystallization points, it was a pure and definite substance; but the production of this pure acid proved it to be nothing of the kind, Laurent's article being only a combination of pure carbolic acid with a liquid homologue; for when a certain proportion of water is added to Laurent's acid, and the mixture is exposed to a temperature of 4° (39° F.), it deposits large octahedrons of a crystalline substance, which is a hydrate of carbolic or phenylic alcohol, that is to say, carbolic acid combined with an equivalent of water of crystallization. This fact is highly interesting from a chemico-theoretical point of view, for it exhibits the only example known of an alcohol which, combining with water, forms a crystalline hydrate. By removing from this hydrate the equivalent of water, as well as the traces of sulphuretted compounds, and coal-tar bases, which it contains, carbolic or phenic acid is obtained in its purest state.

Present Method of Manufacture.—To procure crude carbolic acid, the coal-tar is distilled in a still much resembling in all respects that used for the distillation of the acid (to be shown presently), only of about twenty times as great a capacity. The distillate from the coal-tar is collected in various portions, as already indicated, the largest proportion of the carbolic acid being generally present in the "light oils," a black spirit having a powerful, unpleasant, tarry odour. This tar oil is mixed with a caustic soda solution at 12° Tw., made from cream caustic soda, and is put into a barrel-shaped boiler fitted inside with arms, which are made to revolve on a spindle, and thus thoroughly agitate the mixture. The result of this process is that the caustic soda dissolves out the whole of the carbolic acid, while the separated and undissolved oily matters, known as creosote oil, float on the surface of the solution when it is allowed to settle. The alkaline solution is then run off from the supernatant oils, and is treated with brown oil of vitriol (sulphuric acid at about 140°-150° Tw.), in just sufficient amount to completely neutralize the soda, without being in excess. This acid forms a salt with the soda—sulphate of soda—which sinks, while the carbolic acid rises to the surface. Generally, the sulphate of soda is allowed to settle out twice, so as to leave the carbolic acid as free from it as possible. At this stage, it is known as "crude" carbolic acid, and, though considerably purified, it still retains a deep black colour, and an unpleasant odour. The product is received, in this state, from the tar distillers. The proportion borne by this acid to the amount of tar treated in its production is about 1-3 per cent. The impure or crude carbolic acid consists of carbolic and cresylic acids, and their homologues, together with a variety of impurities. It is next subjected to a process of fractional distillation, which separates the carbonaceous matters and the water, the latter amounting to about 15 per cent. of the whole. This operation is conducted in the apparatus shown in Fig. 491; A is a circular still of wrought iron, 4 ft. in diameter, 6 ft. high, and provided with a dished bottom; it is set in brickwork (as shown in Fig. 492), with a double series of flues, one to heat the upper portion of the sides, viz. the space included between *e* and *f*; the other, to heat the sides from *f* downwards to *g*; above the level of *e*, the still is furnished with a manhole *a*; on to the top of the still, a cast-iron head and arm B is bolted, as shown at *b b*, the head B being fitted with a flange for that purpose; at *c*, another flange is cast on the arm B, for the reception of a flange *c* of the leaden condensing worm C; this condensing worm is of 2 in. bore at the commencement, diminishing to 1½ in. at the outlet *d*.

491.

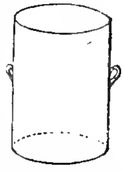


492.



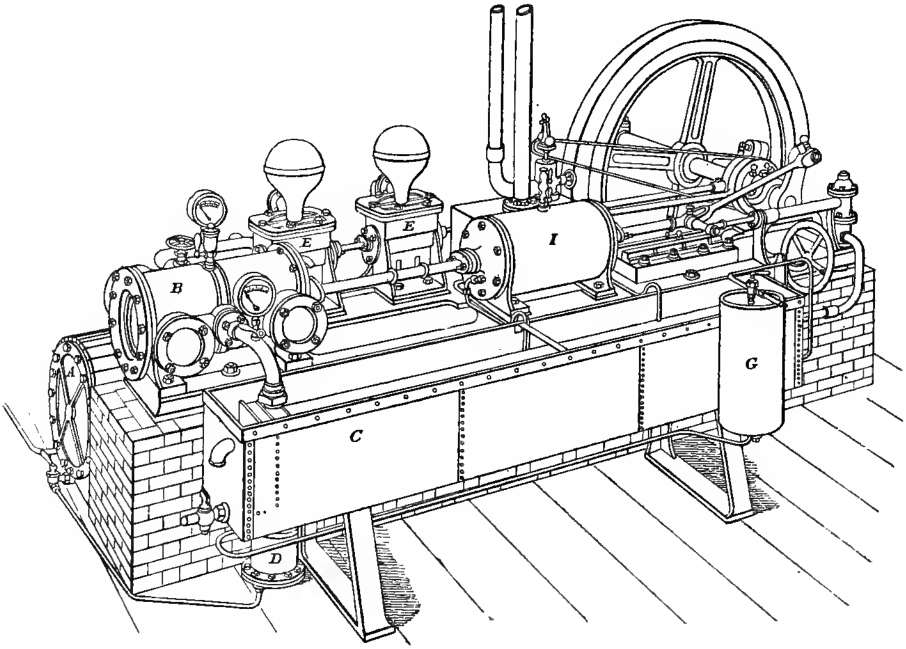
The distillate which escapes at *d* is collected in metallic coolers, about 22 in. high, holding about 12 gallons, and of the shape indicated in Fig. 493. They are placed in troughs, and surrounded by a refrigerating mixture, produced by some cooling apparatus, such as Kirk's, or Siddeley and Mackay's, refrigerating machine. The last is shown in Fig. 494; A is the refrigerator; B, the vacuum pump; C, the condenser; D, the ether meter; E E, the water pumps; F, the hand pump; G, the hand-pump condenser; I, the

493.



steam engine. The refrigerator A, a copper tubular vessel, is charged with the requisite supply of liquid ether, which, by the action of the vacuum pump B, is evaporated, drawn away in the form of vapour, and passed into the copper tubular condenser C; here, under slight pressure, and by the aid of a stream of water, it is again reduced to its liquid state, and is thence returned through the ether meter D to the refrigerator A, to be re-evaporated. Thus the same ether is used continuously, with inappreciable loss. The ether meter D regulates the flow of the liquid ether to the refrigerator, rendering the machine self-acting. To utilize the cold produced by the evaporation of the ether, an uncongealable liquid, such as very strong brine, or a solution of calcic chloride, is forced by the pump E through the tubes of the refrigerator A, parting with its heat to the ether vapour on its passage, and leaving that vessel at a temperature of — 10° to — 7° (14° to 20° F.)—thus many degrees below freezing point—to be used in the freezing tanks, where the coolers represented in Fig. 493 are placed. The carbolic acid requires a long time for cooling; but solidifies finally in the form of thick acicular crystals of impure acid, which have lost their carbonaceous impurities so far as to be only slightly drab-coloured; and, though strongly odoriferous, their smell is by no means unpleasant. After removal from the freezing tank, the coolers are drained, by withdrawing the cork that is inserted in the aperture at the bottom. The liquid present escapes, and leaves a perfectly white acid, of indefinite crystalline form, fusing at about 29° (85° F.), but still possessing a strong odour. This is known as Calvert's "No. 3" acid.

494.



Neglecting this "No. 3" acid for the present, it will be well first to follow the mother-liquor which has been drained from it. This is placed in a still, similar in all respects to that already described; 300 gallons of the liquid, of which a very variable proportion will be water, are redistilled, until there only remains in the bottom of the still about 30 gallons of a pitchy residue, which is run off, while hot, in a fused state. The distillate is conducted through a leaden worm surrounded by water, for condensation, and thence into coolers. In this product, there is present a certain amount of crystallizable carbolic acid, as well as more or less of cresylic acid. This latter, which is soluble in about 80 parts of water, and whose boiling point is 190°–200° (374°–392° F.), is a constituent of all impure commercial carbolic acids, and is extensively used as a disinfectant, being frequently sold, for this purpose, under the name of "crude" or "liquid" carbolic acid. It may here be mentioned that there has grown up a practice of passing off, under this name, mixtures of tar oils, containing usually only a small percentage of carbolic acid, and sometimes even none at all, their general appearance and odour preventing their ready distinction, by the unscientific public, from the genuine acid. Now the value of the liquid for disinfecting purposes depends upon the quantity of carbolic and cresylic acids present in it, and upon its freedom from tar oils, for these, even if containing a small percentage of carbolic acid, are themselves comparatively valueless for disinfection, and, being insoluble in water, hinder the solubility of the carbolic acid. No *liquid* carbolic acid should be purchased, therefore, without a guarantee from the vendor as to its composition.

A ready method of testing liquid carbolic acid, to ascertain its genuineness, is to measure off a given volume in a graduated glass, and then to add to it twice its volume of a pure caustic soda solution of 14° Tw. at 15° (60° F.). As carbolic and cresylic acids are both soluble in this solution, the "liquid" acid should, if genuine, entirely dissolve, on shaking the mixture well together. The test for the crystallized acid is its fusing point; and, for the liquid acid, its solubility.

F. C. Calvert and Co. do not sell this liquid acid in its impure state; they subject it to another distillation, and remove all traces of sulphuretted hydrogen, producing a very slightly-tinted, clear liquid, having a much less rank odour. This they distinguish as "No. 5" acid, which they sell in bulk (casks, &c.); 6*s.* per gallon is the retail price. By redistilling this "No. 5," they get a still purer acid, called "White No. 5," which is the ordinary liquid acid sent out by them in bottles. This, as well as the preceding quality, is guaranteed to contain not less than 85 per cent. of carbolic and cresylic acids, and to be free from tar oils and sulphuretted hydrogen.

To return to the "No. 3" acid, fusing at 29° (85° F.). This is redistilled in the same kind of still; but the worm for condensing the gases as they are evaporated has now to be made of zinc, instead of lead, as the latter metal would colour the product. The distillate is run into coolers of tin or zinc, where it is allowed to cool in the air down to 32° (90° F.). The coolers are then pierced, to drain off the liquid for reworking, leaving a mass of pure white crystals, fusing at 35° (95° F.), and corresponding with the acid produced by Laurent. This is Calvert's "No. 1 Commercial" acid, used chiefly for the manufacture of the various carbolic acid colours. It is frequently sold as purporting to be "B. P." quality; but to obtain the real B. P. acid, it is necessary to remove from this commercial acid all traces of sulphuretted compounds and coal-tar bases, and to rectify it in ordinary glass swan-neck retorts of about 4 gallons capacity, and having long glass tubes as condensers for the distillate. Here the acid must be treated and evaporated almost to dryness. The cooled distillate has the same fusing point as the acid whence it is derived. It is soluble in 20 parts of water, and should be used exclusively for surgical applications. It forms Calvert's "No. 2 Medicinal" carbolic acid, and is the only one which fulfils all the conditions of the British Pharmacopœia, drawn up by the late Dr. Crace Calvert.

In order to produce a more perfectly pure carbolic acid, advantage is taken of Lowe and Gill's patented invention (1874), whose object is to effect and facilitate the separation of carbolic acid from the cresylic and other liquid tar acids contained in mixtures of these products, which, when dehydrated by distillation in the usual manner, are crystallizable at 17°–35° (62°–95° F.). The following method is adopted:—It is first ascertained whether the acids are partially or wholly hydrated; should they be in a dehydrated state, they must be hydrated by the addition of water to the amount of 5–30 per cent. The hydrated acids are then placed in suitable vessels surrounded by a cooling mixture, or circulating fluid, of a temperature sufficiently low to effect the separation of more or less hydrated carbolic acid crystals, say − 9° to 13° (15° to 56° F.). This refrigerating process being complete, the mother-liquors are drained or otherwise separated from the crystals, and are rectified in the manner already described, to bring them within the limits of the crystallizable temperatures for re-treatment.

The crystals may be purified from all traces of the mother-liquors, by re-crystallization, either by partial fusion, or by solution in water and subsequent refrigeration of the water solution to a temperature of about 1° (33° F.). The crystals are then dehydrated by fractional distillation, and thus is produced a carbolic acid crystallizing at 38°–42½° (100°–108°·5 F.), and boiling, with thermometer in liquor, at 181°–182° (358°–360° F.) under an atmospheric pressure of 29·26 in. of mercury. Calvert and Co. drain away the mother-liquor from this acid, and subject the latter to a special treatment, rendering it perfectly free from traces of sulphuretted compounds and coal-tar bases, then to a further rectification in glass, producing a chemically pure acid, fusing at 42°·2 (107°·9 F.), boiling at 182° (360° F.), and soluble in 12½ parts of water. This pure acid is composed of acicular crystals, and is entirely free from tarry taste and odour; it is known as "No. 1 Medicinal" acid, and is used nearly exclusively for internal administration. It is sold in bottles of 1 oz. and upwards, the retail price being 10*s.* per lb.

Besides Calvert's soaps, containing specific proportions of carbolic acid, there are two preparations of the acid which call for a short notice, viz. carbolized powder and carbolized tow. The former consists of a mixture, in the proportion of 15–20 per cent., of liquid carbolic and cresylic acids, and an inert base, such as silica. Perhaps silicate of alumina, or china clay, is the best; lime, which is sometimes used, is not so suitable, on account of its destructive nature to carpets, &c., should it by accident be spilled on them; it would also set free ammonia, if present in the matter to be disinfected. In this manner, is produced a disinfecting powder, in which the acid is left in a free state, thus allowing it to act by direct means, or by evaporation.

In order to readily detect the amount of real carbolic acid in a disinfecting powder, R. Le Neve Foster, F.C.S., has devised the following rough method:—Place 1000 gr. of the powder in a small tubulated retort; heat the retort gradually, until the liquid distillate ceases to drop (a brisk heat is required towards the end of the operation); collect the distillate, which will condense in the tube of the retort, in a graduated cylinder grain measure, and allow it to settle for one hour, when the amount of oily liquid and water may be read off; the oily liquid should represent the amount of carbolic acid; to ascertain if this be so, to one volume of it, add two volumes of a solution of pure caustic soda, 14° Tw. at 15° (60° F.), which will entirely dissolve the carbolic acid; if any remains undissolved, it will probably consist of either heavy or light oil of tar, the most frequent adulterants of carbolic acid, and, in some cases, entirely substituted for it. The above process will, if carefully worked, give within ½ per cent. of the amount of carbolic acid really contained in the powder.

Carbolized tow is a preparation of tow with carbolic acid; it is recommended by the 'British Medical Journal,' in decided and unqualified terms, and may with advantage be used for most of the surgical purposes to which lint, sponge, and cotton wool are now applied.

Other Processes.—Schnitzler proposes to produce colourless crystallized carbolic acid, in the following manner. Raw phenate of soda is thoroughly heated in a copper still; water, naphthalene oils, and a little carbolic acid pass over, and the fire is removed when the distillate begins to run milky: 15 kilos. require about ten hours. The greater part of the carbolic acid remains combined with the soda, as a solid mass; the temperature of the vapour during distillation may reach 170° (338° F.); the solid residue is afterwards dissolved out in triple the quantity of water necessary. This liquid is allowed to settle for some days, when certain impurities are deposited. Dilute sulphuric acid is then added to the clear liquid, the carbolic acid is decanted and distilled in glass vessels; water passes over first, then pure carbolic acid, which crystallizes entire, and lastly a less pure carbolic acid, which, even after crystallization, retains some oily impurities. In order to obtain carbolic acid in a dry state, recourse must be had to digestion with chloride of calcium, followed by a new rectification; if required pure, only that portion which boils at 188° (370° F.) must be received; the distillate, by refrigeration, furnishes crystals of the acid, which must be drained, dried, and preserved from contact with the air.

To ascertain the percentage of carbolic acid in dead oils, &c., there is a simple method, based upon the boiling point of the acid. The substance is heated in a still, and the oily liquid distilling at 150°–200° (302°–392° F.) is well mixed with a solution of caustic soda, which combines with the carbolic acid, forming a compound which may be readily decomposed by any strong mineral acid. Briefly, the process amounts to a preparation of carbolic acid, carried on so carefully as to render it suitable for ascertaining quantities.

Professor Church remarks that the rank of carbolic acid as a most valuable contribution from chemistry to medicine is so well assured as to require no confirmation, yet there is an objection urged against the substance, which has some apparent force, simply because the preparations of commerce are so seldom free from a gas-like or naphthalic odour, which, though entirely foreign to carbolic acid itself, has condemned its use in some quarters. He adopted the following simple plan of purifying such acid:—1 lb. of carbolic acid is poured into 20 lb. of cold distilled water, taking care not to permit the *whole* of the acid to enter into solution. With a good sample, if after repeated shaking at intervals, 2–3 ounces of the acid remain at the bottom of the vessel, this will be sufficient to hold all the impurities; with bad samples, less water or more acid must be used. The aqueous solution is siphoned off, and filtered till perfectly clear; it is then placed in a cylinder, and common salt is added with agitation till it no longer dissolves. On standing, the greater part of the carbolic acid will be found, as a yellow oily layer, on the top of the saline liquor, and may be removed for use. As it contains 5 per cent. or more of water, it does not generally crystallize; but it may be made to do so by distilling it from a little lime. The portion collected up to 185° (365° F.) or thereabouts has, at ordinary temperatures, scarcely any odour, save a faint one resembling that of geranium leaves. The saline liquor remaining may be distilled, to yield a second portion of pure carbolic acid, which will serve as a disinfectant and deodoriser.

Impurities.—One of the most common impurities found in carbolic acid is coal-tar oil. This can easily be detected by mixing the suspected acid with a solution of pure caustic soda, 14° Tw. at 15° (60° F.), one volume of the former to two of the latter, and agitating. If pure, the solution will be complete; the amount left undissolved after settling will indicate the proportion of impurity. Pure carbolic acid gives a blue colour to pine wood previously treated with hydrochloric acid: a green colour indicates aniline; and a brown, pyrrhol.

Poisoning and Antidotes.—In cases of poisoning with carbolic acid, Dr. Calvert recommends the administration of copious doses of castor and sweet oils. In cases of external burns, glycerine should be immediately applied, and the affected parts should be repeatedly washed with it. Dr. J. Hasemann recommends a strong solution of saccharate of lime, as an antidote. Carbolic acid is a most powerful poison; it can cause death even when it acts only upon the skin, and it should never be sprinkled upon floors, nor upon any surface likely to be used as a seat, unless it be in perfect solution in water. In an impure state, or in solution, it has been swallowed in mistake for porter or spirits. The signs indicating poisoning by carbolic acid are especially the whiteness of the mouth, tongue, and fauces, and the characteristic odour. Dr. Sansom recommends the immediate administration of the white of eggs.

Tests.—Besides the tests already indicated on p. 41, attention is directed to the following:—(1) Dr. W. F. Koppeschecar's method of estimating volumetrically, by the aid of a titrated volume of hydrobromic acid, fully detailed by him in the 'Moniteur Scientifique,' April, 1878. (2) Prof. E. W. Davy observes that a solution of molybdic acid in sulphuric acid produces a light-yellow or yellowish-brown tint, developing into purple. This test appears not to be interfered with by the presence of organic substances, and affords a means of distinguishing creasote from carbolic acid, a matter of commercial importance, much of what is sold as creasote being little else than carbolic acid. Recent files of the 'Analyst' may also be consulted with advantage.

Uses.—The next consideration will be some of the uses which may be made of carbolic or phenic acid (or rather alcohol, for its properties are alcoholic rather than acid), for sanitary, domestic, agricultural, and manufacturing purposes.

The antiseptic or germ-killing properties of this substance are very remarkable. Research and discovery have shown that all fermentation and putrefaction are due to the presence of microscopic animals or vegetables, which, during their vitality, decompose or change organic substances, so as to produce the effects which are witnessed. As carbolic acid exercises a most powerful destructive action upon these microscopic and primitive sources of life, it is therefore an antiseptic and disinfectant, much more active and much more rational than those generally in use.

It is necessary here to make a few remarks, explanatory of the distinctions between deodorizers, disinfectants, and antiseptics. All substances acting merely as deodorizers are neither disinfectants nor antiseptics, as they simply remove the noxious gases and odours emitted from organic matters whilst in a state of decay or putrefaction, without having the property of arresting decomposition or fermentation. It has been proved that the source of infection does not lie in the noxious gases and bad smells (which are simply indicators of its probable existence), but in microscopic spores floating in the atmosphere, and which are ultimately developed and propagated.

Disinfectants are those bodies which prevent the spread of infection. Under this head, may be classed bleaching powder or chloride of lime, sulphurous acid, and permanganate of potash. They act first as deodorizers, and then as disinfectants; but they must be employed in large quantities to thoroughly oxidize or burn up organic matters, so as to prevent them from again entering into decomposition when exposed to the atmosphere. They are, in fact, rather destructive agents than disinfectants properly so called, and are never antiseptics.

Antiseptics, such as corrosive sublimate, arsenious acid, essential oils, carbolic acid, &c., act as such by destroying all source of decay and decomposition, that is to say, they destroy or prevent the formation of the germs of putrefaction and fermentation, without acting upon the animal or vegetable matters present. The advantage of their use is, therefore, that they act, when used in small quantities, upon the primary source of a state of decay in all organic matters. Further, they are deodorizers, inasmuch as they arrest the progress of that decomposition which generates offensive odours; thus, while an antiseptic is, of necessity, at the same moment, a deodorizer and a disinfectant, these latter are not necessarily, and probably never are, antiseptic.

Now disinfectants, such as chlorine, permanganate of potash, or Condy fluid, operate by oxidizing not only the gaseous products given off by putrefaction, but also all organic matters with which they may come into contact; whilst carbolic acid, on the contrary, merely destroys the causes of putrefaction, and, at the same time, sterilizes the organic matter, rendering it inert as a pabulum for the reproduction or the nutrition of disease germs. The great difference which distinguishes them, therefore, is that the former deal with the effects; the latter, with the cause. Again, these microscopic ferments are always in small quantities, as compared with the substances on which they act; as a very small quantity of carbolic acid suffices to prevent the decomposition, its employment is both efficacious and economical. Moreover, carbolic acid is volatile, it meets with and destroys the germs or sporules as they float in the atmosphere; but this cannot be the case with Condy fluid, nor with chloride of zinc or iron, which are not volatile, act only when in solution, and are mere deodorizers. This is why carbolic acid was used with such marked success, in England, Belgium, and Holland, during the prevalence of cholera and cattle plague. Professor Crookes did not meet with a single instance in which the plague spread on a farm where the acid was freely used.

The antiseptic properties of carbolic acid are so powerful, that one-thousandth, and even one five-thousandth, part will, for months, prevent the decomposition, fermentation, or putrefaction of urine, blood, glue solution, flour paste, fæces, &c., &c.; and its vapour alone is sufficient to preserve meat in confined spaces for weeks; and even a little of its vapour in ordinary atmosphere will preserve meat for several days, and prevent its being fly-blown. Indeed, one ten-thousandth part has been found sufficient to keep sewage sweet, for Dr. Letheby found that, through the use of such a quantity of carbolic acid in the sewers of London, during the existence of cholera in 1866, the sewers of the city were nearly deodorized.

Some experiments made by Dr. Calvert, on the comparative powers of various products ordinarily used as antiseptics, consisted in placing in bottles (not corked) solutions of albumen and flour paste; to these were added various proportions of some substances patronized as antiseptics; the following table shows the results obtained:—

Antiseptic employed.	Percentage of Antiseptic.	Time in which it acquired an offensive odour. Temperature from 70° to 80° F.	
		Albumen.	Flour Paste.
McDougall's disinfecting powder	5	11 days	25 days
Carbolic disinfecting powder (15 per cent. acid)	5	Remained sound	Remained sound
Chloralum (made lately)	2	9 days	10 days
Chloride of zinc	2	15 days	Remained sound
Chloride of lime	5	16 days	14 days
Permanganate of potash	5	4 days	6 days
Tar oil	2	11 days	25 days
Carbolic acid	2	Remained sound	Remained sound
Cresylic acid	2	Remained sound	Remained sound
None	..	5 days	7 days

These figures show clearly that the only true antiseptics are carbolic and cresylic acids, for they continued their action till the albumen solution and paste dried up; and these results coincide with those obtained by Professor Crookes, and by Drs. Angus Smith and Sansom.

It may be remarked that disinfectants are of two classes, those which act by oxidation, destroying the organic substances which give rise to the infection, such as permanganate of potash, bleaching powder, and nitric acid; and those which act by their presence, undergoing no decomposition themselves, but appearing to poison, or render innocuous, the germs of disease. To the latter class belong camphor, and sulphurous and carbolic acids.

If deodorizers are merely intended to remove the noxious odour from any mass of matter in a state of decay or decomposition, they may be used with advantage: such are chloride of manganese, chloride of lime, sulphate of iron, permanganate of potash, chloralum, &c. But if it is desired to prevent the decomposition of organic matter, and to render it inert for the reproduction and nutrition of disease germs, carbolic and cresylic acids seem to be the only two substances to be relied on.

As the products given off from decaying organic matter are well known to facilitate the decomposition of similar classes of substances to themselves, if placed in close proximity (the atmosphere, no doubt, conveying the germs), Dr. Calvert made the following experiments, with a view of ascertaining which of the undermentioned products would possess the most active power in destroying such germs, and thus preserving the animal substance from decay. At the bottom of wide-mouthed pint bottles, he placed a known quantity of each of the antiseptics, and suspended over them, by a thread, a piece of sound meat. By daily examination, it was easily ascertained when the meat became tainted, and when putrid. The subjoined table indicates the results:—

Antiseptic used.	Became Tainted.	Putrid.
Permanganate of potash	2 days	4 days
Chloralum	2 days	10 days
McDougall's disinfecting powder	12 days	19 days
Chloride of lime	14 days	21 days
Tar oil	16 days	25 days
Chloride of zinc	19 days	..
Carbolic disinfecting powder (15 per cent. acid)	Did not become tainted, but dried up and became quite hard.	
Carbolic acid	Ditto	Ditto
Cresylic acid	Ditto	Ditto

The following account of a series of experiments, undertaken by Hare and Longstaff, with a view of determining the relative merits of a few so-called disinfectants recently introduced, as compared with others that have been long before the public, will be of interest. It should be premised that they only deal with the relative values as antiseptics.

A quantity of urine was well mixed with a sufficient quantity of water to prevent the deposition of urates; 100 c.c. of this mixed urine was placed in each of thirty-four vessels. To two of them, 5 c.c. of tap-water were added; and to the others, the various antiseptics in the following amounts:—Of the solids, 0·1 grm. with 5 c.c. of water; of the liquids miscible with water, 5 c.c. of a solution containing 0·1 c.c. of the antiseptic; and, in the case of the liquids not miscible with water, 5 c.c. of a recently agitated emulsion of the same strength. Thus, in each case, the amount of antiseptic used was 0·1 per cent. of the volume of urine experimented on. All the experiments were in duplicate (I. and II. in tables). The only phenomena looked for were the appearance of mould, and a distinct putrefactive odour:—

Antiseptic, 0·1 per cent.	Day on which Mould appeared.		Day on which Putrefactive Odour was distinct.	
	I.	II.	I.	II.
Water only	9	9	14	13
Terebene (Dr. Bond's)	10	10	13	18–23?*
Carbolic acid (Calvert's No. 5) ..	None by	75th day	None by	75th day
Burnett's fluid	9	9	12	12
Condy's red fluid	10	10	15	10
Turpentine	13	14	18–23?	18–23?*
Chloralum	8	8	10	11
Borax	8	9	18–23?	18–23?*
Cupralum (Dr. Bond's)	8	8	12	12
Ferralum (Dr. Bond's)	None by	14th day	8	8
Sodium salicylate	10	10	14	14
Sanitas (aromatic, No. 3)	8	9	9	10
Sanitas (inodorous, No. 3)	9	9	15	11
McDougall's fluid	12	9	13	12
Sanitas (aromatic, No. 1)	9	9	14	14
Sanitas (inodorous, No. 1)	9	8	15	11

* Some uncertainty as to exact day, owing to absence.

As regards mould:—Burnett's fluid, chloralum, borax, cupralum, and sanitas failed to delay its appearance; terebene, Condy's fluid, sodium salicylate, and McDougall's fluid had but little effect; turpentine delayed it four or five days; ferralum was only under observation fourteen days, during which no mould appeared; carbolic acid appeared to prevent it entirely, since, after seventy-five days, the urine had evaporated nearly to dryness, without the slightest trace of mould having been observed.

As regards putrefactive odour:—Its appearance was delayed a few days by terebene (one experiment), turpentine, and borax; no putrefactive odour appeared where carbolic acid had been added; the other substances had no effect.

A few experiments were made with the fluids after they had become putrid, by adding more of the antiseptic until the odour was removed, and then noting when it again became perceptible. These indicated that terebene, cupralum, sodium salicylate, and McDougall's fluid rank highest as deodorizers, while Condy's fluid and sanitas (aromatic, No. 3) have least power. But too much value must not be given to experiments which depend solely on the sense of smell, since it is very deceptive, and different observers disagree about odours. Indeed, in the case of McDougall's powder, which has a very disagreeable smell of its own, it was found impracticable to decide whether an additional odour of putrefaction was or was not present.

The medicinal applications of carbolic acid are numerous. It is used as a caustic; for pulmonary diseases; in several skin diseases; in the treatment of burns and scalds; and in many other ways.

From a hygienic point of view, the uses and applications of carbolic acid are more general than those of any other article, or perhaps even than all the other agents taken together. The trifling disadvantage of its disagreeable odour is removed in proportion as the oils and other tarry matters are more perfectly separated; and, in the best crystallized samples, there scarcely remains any odour at all, and that by no means disagreeable to persons in general. All the evidence that can be collected goes to show that the odour and vapour are wholesome and never hurtful, even by prolonged exposure to a saturated atmosphere. It is said to be a tonic to those who work in it, and to have a general tendency to robust health. Its antiseptic or preservative powers have been long known, though but recently investigated; and generations of men have protected and preserved their meats and fish through its agency as derived from smoke. Small animals, insects, &c., killed by it, dry up in the air without putrefaction; by its use, crawling insects of all kinds can be prevented from attacking trees.

Its employment in stables, shippons, slaughterhouses, pigsties, kennels, middens, and privies, does not cause the manure to deteriorate. For foot and mouth disease, scab, and foot-rot, it is an efficacious remedy. By its use, the trade in skins and bones from Australia, South America, &c., is being benefited. Often the refuse of cattle, especially the bones, come to this country in a half putrid state, emitting an insupportable odour, and fit only for manure; with carbolic acid treatment, they arrive perfectly preserved, and can be employed for all the uses to which green or raw bones are usually applied, thus increasing their value very considerably. Hides also frequently arrive putrid, although they have been dried or salted; it is only necessary to immerse them for twenty-four hours in a solution of two per cent. of carbolic acid, and to dry them in the air, to secure their preservation. It is probable that, in a short time, the blood, intestines, and other parts of the animals slaughtered in such numbers in stock-raising countries, will be treated with carbolic acid, and shipped to this country for manure. The acid is already used in the preservation of guts at the gut works; for keeping anatomical preparations; and for the preservation of all animal matter. It is also used for preventing the decomposition of the various albumen, flour, and starch thickeners used in calico printing, as well as for gelatine or bone size, employed for sizing fustains and other cotton goods.

Derivatives from Carbolic Acid.—Of these, the most important is carbazotic, picric, or trinitrophenic acid (see p. 40). From this acid, are produced several useful compounds employed as dyes, explosives, and therapeutic agents.

Picramic Acid.—This was obtained in the first instance by Wœhler, by the action of sulphate iron on picric acid, and neutralizing with caustic barytes; a deep brown salt was produced, from which the baryta was separated by sulphuric acid, leaving an acid which was called "nitrohæmatic." But the process by which picramic acid is now manufactured is due to Aimé Girard, and depends upon the action of hydrosulphate of ammonia on picric acid. Picramic acid imparts to silk a series of brown tints, similar to those obtained from catechu.

Isopurpurate Potash.—This is obtained by mixing a solution of 2 parts cyanide potassium in 4 parts water, with solution 1 part picric acid in 9 parts boiling water, with constant agitation; on cooling, it solidifies to a red crystalline pulp; this is strained, pressed, triturated, filtered, washed, redissolved in boiling water, filtered, and left to crystallize, when it forms reddish-brown scales, with a green lustre; these dissolve in water and alcohol, yielding a purple-red colour.

Isopurpurate ammonia, Murexid, or Soluble Garnet.—This is formed by decomposing isopurpurate potash by means of ammonium chloride.

Isopurpurate aniline.—This results from a mixture of 42 parts hydrochloride aniline, and 100 parts isopurpurate potash, and yields browns and reds.

Picrates Ammonia, Potash, and Soda.—These are formed by neutralizing a hot solution picric acid by one of the agents named. Their chief use is owing to their explosive qualities, but the ammonia salt has been highly spoken of as a therapeutic successor to sulphate quinine.

Rosolic Acid, Aurine, or Yellow Coralline.—This may be produced by the direct oxidation of carbolic acid. The process generally adopted for its manufacture is due to Jules Persoz:—A mixture is made of about 3 parts carbolic acid, 2 parts oxalic acid, and 2 parts sulphuric acid. The oxalic acid is added by degrees, and the whole is heated for some hours at about 160° (320° F.). The heating is best effected by Bunsen burners. During the reaction, more or less lively effervescence is produced, due to the disengagement of carbonic oxides, arising from the decomposition of the oxalic acid. The mass thickens and becomes reddish-brown. The operation is terminated when a sample thrown into ammoniacal water dissolves with a reddish-purple colour; the fire is then withdrawn, and the compound is run off by a leaden siphon into cold water, to separate the greater part of the excess of sulphuric acid and the sulphophenic acid formed. It is steamed up several times to complete the purification, and is then a pasty cantharides-green mass. This is dried in jacketed enamelled pans, by which it becomes hard and brittle. The whole process occupies about a week. It is soluble in alcohol, but not in water. Dr. Calvert discovered, in 1863, that rosolic acid thus prepared could be employed directly as a dye, and introduced it to dyers under the name of "aurine," and to printers to produce upon silk and albumenized cotton magnificent orange colours, like those of basic chromate of lead, or of turmeric. The calcium lakes of aurine are largely used by paper stainers.

Peonine, or Red Coralline.—In 1860, Persoz discovered that rosolic acid, heated under pressure with ammonia, gave rise to a red substance which he called "Peonine." Gunion, Marnas, and Bosauet perfected the manufacture, and gave it the name of "Red coralline." It is prepared by introducing into a digester 1 part rosolic acid, and about 3 parts commercial ammonia, and heating the mixture with an oil bath for three hours at a temperature not exceeding 150° (302° F.). The mass, withdrawn from the apparatus after cooling, forms a thick liquid of golden-crimson colour, which is precipitated on addition of hydrochloric acid. It imparts a brilliant scarlet to silk and worsted.

Azuline—The same firm introduced, towards the end of 1860, a blue dye, derived from rosolic acid, which they called "Azuline." This is prepared by heating for several hours, at about 180° (360° F.), a mixture of 5 parts rosolic acid and 6–8 parts aniline, and which is purified by repeated treatment with sulphuric acid and benzol, constituting, when dry, a red mass having gold-coloured tints. Though discovered before the aniline blues, which have since become formidable rivals, it is still manufactured in competition with them.

Veridine.—In 1863, was produced the first green derived from carbolic acid; but it has not been able to compete with aniline greens. It was obtained from a mixture of aniline, and benzoic and rosolic acids.

Phenicienne.—This was discovered, in 1863, by M. Roth; it produces fast colours, from a garnet-rod to a golden-buff, and is obtained by the action of nitro-sulphuric upon carbolic acid.

Sulpho-carbolic Acid and its Salts.—When one equivalent carbolic acid is slowly mixed and heated with two equivalents concentrated sulphuric acid in an earthenware pan, a definite compound is formed, called sulpho-carbolic acid $C_6H_6SO_4$, which is dissolved out by the addition of water. The heat must be applied carefully, on account of the carbonizing influence of the sulphuric acid. The sulpho-carbolic acid is freed from sulphates by adding carbonate of baryta, which falls to the bottom of the vessel as sulphate of barium, and the liquid acid may be decanted. It forms a great number of definite salts, every one of which is soluble in water. The most important are those of soda, potash, zinc, iron, magnesia, and lime; all are largely used for pharmaceutical purposes.

Salicylic Acid.—Salicylic acid (to which much attention has lately been drawn), originally a product obtained in the laboratory in small quantities from the plant called Wintergreen (*Gaultheria procumbens*), is now being produced from carbolic acid on a commercial scale on the Continent, by the process of Professor Kolbe, of Leipzic. Carbolic acid is heated with solid hydrated oxide sodium in a closed iron retort, the temperature being maintained at about 183° (361° F.), till the water, and the excess of carbolic acid, have passed over into a receiver, dry carbonic gas being passed into the contents of the retort in a continuous stream. The temperature is finally made to exceed 200° (392° F.), the mass becomes solid, and the operation is terminated when but little residual acid distils over. The contents of the retort, after the above operation, contain some salicylate of soda and free carbolic acid; they are dissolved in water, and by the addition of slight excess of hydrochloric acid to the solution, the salicylic acid is precipitated. It is then washed, and thus purified from all traces of the hydrochloric acid. The salicylic acid thus produced is a yellowish-white powder, devoid of smell, fusing, when pure, at 158° (316° F.), sparingly soluble in cold water, but readily soluble in boiling water. Its chemical composition is $C_7H_6O_3$; or, in other words, 1 equivalent carbolic acid + 1 equivalent carbonic acid. It may be sublimed unaltered; but when heated strongly with powdered glass or sand in a retort, it is resolved into carbolic and carbonic acids. It possesses antiseptic properties, though in a less degree than carbolic acid. As a general disinfectant, it cannot become a rival to carbolic acid, owing to its lesser antiseptic power, and its higher price, this latter being entirely dependent on the cost of the carbolic acid from which it is manufactured. It is, however, being now employed in some of the German hospitals.

NAPHTHALENE DERIVATIVES.—Clavel (No. 2296, 1868) obtains a red colour from napthylamine (q. v.), which is acted upon at 121° (250° F.) with equal parts by weight glacial acetic acid and nitrite of soda, until the red colour is produced. The colour, after treatment with water, is dissolved in warm diluted acetic acid, from which it may be separated again, by common salt, for purification. Its solution in alcohol or weak acid may be used for dyeing or printing; it is less altered on exposure than rosaniline reds. A scarlet has been obtained by treating the sulphate of naphthylamine with nitro-muriatic acid.

Magdala Pink, or Hofmann's Naphthalene Red.—This colour is obtained by heating together amido-azo and amido-naphthalenes (q. v.), and is sold as a brown crystalline powder, which is the hydrochlorate, soluble in alcohol with a deep-red colour, almost insoluble in cold water, but soluble in boiling water. Its alcoholic solution is precipitated by ether in a crystalline, brownish powder. Its dilute solutions have a splendid bright-red fluorescence. A few drops of a concentrated solution dropped into a test-tube full of alcohol, will take, by reflected light, a bright-red cloudiness, as if turbid; but by transmitted light, will appear perfectly clear, with a fine rose-red tint. This is the most important colour from naphthalene; but its manufacture being more troublesome than that of the aniline colours, it has not been much taken up. It does not equal aniline colours in deeper shades, but gives brighter tints. It has been pointed out as a source of other colours.

Napthylamine Violet.—By using the same reaction as with aniline, arsenic acid, &c., violet colours have been obtained, but they are wanting in brilliancy and freshness. Ballo obtains a very fine violet, by heating acetate rosaniline with naphthylamine; its alcoholic solution dyes equal to the aniline colours.

Violacine.—A blue dye of this name is obtained from an impure naphthalene by treating with strong caustic alkali, and submitting the product to oxidation (No. 3080, 1873). It is said to dye a fast blue colour with a reddish tinge, which, by complete purification, turns yellowish. By oxidizing naphthalene with chromic acid, a beautiful red matter is produced, to which Laurent has given the name of "Carminnaphte"; it dyes silk and wool violets having orange or reddish shades.

Naphthalene Yellows.—Price (No. 89, 1869) produces a sulpho-acid by heating at 100° (212° F.) about 1 lb. naphthalene with 1 lb. concentrated sulphuric acid, till most of the former is converted into sulphonaphthalic acid, which is neutralized by an alkaline solution. By evaporation and fusion with an alkali, naphthol is obtained on precipitation with a dilute acid. The naphthol or naphthylic alcohol is then dissolved in strong sulphuric acid, to which warm dilute nitric acid is added. The solution passes through different tints, and finally assumes a yellow; on cooling, the colouring matter crystallizes out. It may be purified by solution in alkali, and reprecipitation with muriate of ammonia.

Manchester Yellow.—On the large scale, this is obtained by adding sodium nitrite to a solution of amido-naphthalene and hydrochloric acid, and boiling the diazo-naphthalene chloride thus formed with nitric acid. Ballo heats 1 part naphthylamine with 4–6 parts nitric acid (sp. gr. 1·35), as long as brown vapours are produced. The dinitro-naphthol thus formed dissolves in alcohol, ether, and benzol; and crystallizes in fine citron-yellow needles. It is the finest and purest yellow known; it dyes silk and wool all shades of yellow from bright citron to orange, and is largely used for dyeing wool and leather, and printing felt carpet; 1 lb. will dye 200 lb. wool an intense yellow.

Chlor-oxy-naphthalic Acid.—Laurent and Casthelaz have adopted this substance for dyeing (1865, No. 1605). It dyes unmordanted wool an intense red; by boiling with zinc in an alkaline solution for fifteen or twenty minutes, the liquid becomes yellow, from which hydrochloric acid deposits a brownish flocculent precipitate; its alcoholic solution dyes wool and silk violet; on cotton, the same may be fixed with albumen. The dilute solution dyes blue on wool, silk, and mordanted cotton; acids redden it.

Phthalic Acid, or Anhydride; $C_8H_6O_4$.—This is formed by strongly oxydizing naphthalene. It melts at 175° (347° F.) from boiling water, and crystallizes in plates or thick prisms. It has the same relation to benzoic acid as the latter has to benzol. When calcium phthalate is heated with quicklime to 300° (572° F.), it is converted into calcium benzoate; but, at higher temperatures, pure benzol is formed. Laurent and Casthelaz have proposed to obtain artificial benzoic acid by this reaction.

Quinizarine; $C_{14}H_6O_2(OH)_2$.—When phenols are treated with phthalic anhydride, or when sulphuric acid, phthalic anhydride, and hydroquinone are heated together, quinizarine is formed; it crystallizes from ether in yellowish plates, and from alcohol in deep red needles. It resembles alizarine, but gives a different absorption spectrum.

Galline; $C_{20}H_{12}O_7$.—By heating at 190°–200° (374°–392° F.), till the mass acquires a pasty consistency, 2 parts pyrogallic acid and 1 part phthalic anhydride, the mixture turns red. It dissolves in alcohol, and, when filtered, may be precipitated with water; this method may be used for its purification. On alum mordanted cloths, it dyes red shades resembling those of Brazil wood.

Cœruline; $C_{20}H_{10}O_7$.—This is obtained by heating gallin with 20 parts sulphuric acid to 200° (392° F.); the process is terminated when a sample heated with water gives brown flocks and a colourless solution; the mass is then turned into a large quantity of water, and washed with boiling water. It dyes alum-mordanted fabrics a greenish colour; and those mordanted with salts of iron, brown.

Resorcine, $CH_4(CH)_2$, is obtained by fusing several resins; its source is disulpho-benzolic acid, which, by fusion with caustic alkali, yields a mixture whence the resorcine is extracted by ether. Bindschedler and Busch give the following for its preparation:—90 kilo. fuming sulphuric acid (80° B.), and 94 kilo. pure benzol, flow gently together through a cohobator into a cast-iron still, and are constantly agitated; the vapours are condensed, and fall back again into the still; at the end of two or three hours, sulpho-benzolic acid is formed. The cohobator is closed, the still is connected with a condenser, and the temperature is raised to 275° (527° F.) for about twenty minutes; the disulpho-acid thus formed is thrown into about 2000 lit. water and boiled; the excess of sulphuric acid is removed by lime; the solution contains disulpho-benzolate lime. This is converted into a soda salt, which after filtering is evaporated to dryness; 60 kilo. are placed in a cast-iron boiler containing 150 kilo. caustic soda at 76° B.; the whole is heated for eight or nine hours to 270° (518 F.), with constant stirring. It is cooled, dissolved in 500 lit. water with hydrochloric acid in slight excess, and kept boiling; when cool, it is filtered into copper cylinders, about 250 lit. capacity, supplied with agitating fans; a current of ethylic ether percolates slowly through the liquid, taking up the resorcine. This solution is received in an enamelled still, where the ether is evaporated and returned to the cylinders; this is continued until all the resorcine is taken up. The resorcine remains in the still, which is finally heated to 215° (419° F.); the resorcine then passes over almost chemically pure.

Fluorescine, or Resorcine-Phthaline; $C_{20}H_{12}O_5$.—This is formed by fusing 100 parts resorcine with 75 parts phthalic anhydride to 193° (380° F.), heating together for one hour; on cooling, it is powdered, and is ready for use. It forms dark brown crystals, dissolving in ammonia with a red colour; this solution exhibits, even when dilute, a most beautiful green fluorescence. It dyes silk and wool a splendid yellow. It is used principally as a source of eosine.

Eosine.—When fluorescine is heated with bromine, a substance is produced, which, when treated with potash or soda, dried, and powdered, has a brick-red colour ; it dissolves in water, and dyes beautiful scarlet shades.

Yellowish Eosine.—To one kilo. fluorescine, stirred into 10 lit. alcohol, is added in a gentle stream 1·1 kilo. bromine with constant agitation. This converts the fluorescine into a soluble brown compound, which, by the further cautious addition of 1·1 kilo. bromine, is converted into a crystalline precipitate of tetra-brom-fluorescine, this is washed with a little alcohol, stirred up in warm water, and taken up with caustic soda or potash, taking care to avoid an alkaline reaction. The solution is evaporated, when the tetra-brom-fluorescine salt of sodium or potassium is obtained as a crystalline deliquescent powder. It dyes a fine scarlet with a yellowish tint.

Blueish Eosine.—Fluorescine, and the necessary quantity of iodine are dissolved separately in alkaline water, and mixed. An acid is added, which, by setting free both the iodine and fluorescine, causes them to combine. A crystalline precipitate is deposited, soluble in dilute alkali, and forming the tetra-iod-fluorescine salt of sodium or potassium. It gives a blueish scarlet eosine, soluble in alcohol. Alcoholized derivatives are obtained by heating with alcohol and sulphuric acid in a cohobator. The methylic compound is more yellowish than the ethylic. These compounds are soluble in equal parts alcohol and water. Other eosine colours are obtained, but they have not yet met with much demand. The commercial salts are generally those of sodium.

Griess (1877, No. 3698; 1878, No. 4728), obtains colouring matters by acting upon the diazo compounds of the nitro-phenols with certain derivatives of the phenylic series. Picramic acid is converted into its azo derivative, and, by treatment with carbolic acid, yields yellow or brown colouring matters ; a maroon is obtained by using resorcine or orcine instead of carbolic acid. Beta naphthol and the azo derivative of picramic acid gives purple ; either alpha naphthol or the sulphonapthalic acids may be used instead.

Poirrier, Rosenstiehl and Roussin (1878, No. 4489), convert phthalamine into a sulpho conjugate body, which is afterwards nitrated into a diazo derivative ; this is united directly with phenols or amines for the production of direct colouring matters. With beta naphthol, a material is obtained which dyes wool a very intense red, as if produced by orchel.

Alizarine; $C_{14}H_6O_2 + (HO)_2$.—This substance is found in the *dried* roots of *Rubiaceæ*, and forms the principal portion of the colouring matter of the madder plant (see Dye Stuffs). The very large consumption of madder in this country made the artificial production of the dye a matter of importance, hence England has taken the lead in developing the production of the colour from coal-tar. The source of artificial alizarine is anthracene, a product from which many other colours are probably destined to be derived. The only firm engaged in the manufacture in this country is that of Burt, Boulton, and Heywood, Silvertown. The anthracene is first converted into di-brom-anthraquinone, di-sulpho-anthraquinonic acid, or di-nitro-anthroquinone (q.v.), which on fusion with potash, maintained until the mass assumes a fine violet colour, yields a melt from which the colouring matter is dissolved out by water ; this solution, treated with an acid, deposits alizarine as a yellow precipitate.

The fusion with alkali is the most important step in the manufacture. The addition of water, the temperature, and the duration of melting, are of great moment. Too much water and too little heating will lead to the formation of hydro-products, or only oxyanthraquinone ; too great a heat burns the melt, and yields a dirty-green paste, which dyes greyish shades. If heated for too long or too short a time, a part of the sulpho-salt is reduced to anthraquinone, which cannot be easily separated from the alizarine, on account of the difficulty of filtering the alkaline solutions. The purity of the tones depends on the quality of the alizarine ; if a fine or blue alizarine is required, it is best to work on the " silver salt," which is the mono-sulph-anthraquinonate of soda. To detect whether thorough conversion into alizarine has taken place, a sample of the melt is dissolved in water, neutralized, and filtered ; the filtrate is shaken up with ether, which dissolves the alizarine and isopurpurine, whilst the sulph-anthraquinonic acid is retained by the water, and can be detected by the blue colour it gives with potash. An aqueous solution of the melt is heated with caustic lime, boiled, and filtered ; if the filtrate is orange, and deposits yellow flocks on the addition of an acid, oxyanthraquinone and anthraflavic acid are present. This will not only guide a manufacturer in its production, but forms a most useful test for its commercial value.

One part of dibrom-anthraquinone is heated in an open vessel of enamelled iron or glass to 180°–200° (356°–392° F.) with 2–3 parts caustic potash, and sufficient water to dissolve the alkali ; the heating is continued until the mass acquires a deep-blue colour ; when cool, it is dissolved in water and filtered ; from the filtrate, alizarine is precipitated by an organic acid ; the yellow flocks are collected in a filter, and well washed with water.

Disulph-anthraquinonic acid is mixed with about twice its weight of caustic potash or soda, and heated at 180°–210° (356°–410° F.) till its aqueous solution gives a copious yellow precipitate on addition of hydrochloric acid. It is now dissolved in water, acidulated with sulphuric or other acid, to precipitate the colouring matter, which is filtered off, and washed with slightly acid water.

From the yellow filtrate, colouring matter can be obtained by neutralizing with soda, and leaving it to settle, when it will form a dark-brown powder; its solution may be precipitated with alumina to form pigments or lakes.

Dinitro-anthraquinone is heated in a concentrated (sp. gr. 1·3 to 1·4) solution caustic soda or potash at 170°–220° (388°–428° F.) until the blueish-violet colour ceases to become more intense. The cooled mass is dissolved in boiling water, and filtered. The hot filtrate is treated with hydrochloric acid, which gives rise to a brownish-yellow precipitate; this, after it has been well washed, is ready for direct dyeing and printing.

The residue on the filter consists principally of "regenerated" anthraquinone, which, by transformation into nitro-anthraquinone, becomes a further source of colouring matter, from which pure alizarine can be obtained, by extraction with ether or other suitable solvent.

Alizarine is sold in the form of a yellowish-brown thick solution, or pasty fluid, containing 10, 15, or 20 per cent. of colour, and is sent out in wooden casks. Quite recently, methods have been discovered by which a product containing 80 per cent. of pure, perfectly soluble colouring matter can be obtained. Dry alizarine could be easily prepared; but, owing to the difficulty of reducing it to a powder or paste again with water, the goods become spotted, and a larger quantity is consumed; it is on this account also, that it contains rarely so much as 20 per cent. dry alizarine. It is used for dyeing violets, lilacs, and Turkey reds. The paste dissolves readily in caustic soda, yielding a splendid violet-blue solution.

Pure alizarine can be obtained from this paste, by dissolving in weak caustic soda solution; on adding chloride barium, and boiling, a dense precipitate is formed, which is filtered off and well washed with water; it is then diffused in water, and decomposed with an acid, when the orange precipitate, after filtering, washing, and drying, consists of nearly pure alizarine.

Kopp separates yellow alizarine from alizarine verte by dissolving in hydrocarbon and treating with alkali.

Isopurpurine, Anthrapurpurine, or Yellow Alizarine.—This is obtained from the alizarine prepared by Gessert Bros., by dissolving in ammonia, and adding hydrate baryta; the precipitate is boiled in water, and the red liquid is filtered; from this the isopurpurine is precipitated by an acid, filtered off, and washed, the process being repeated. If sulphuric acid is used, the isopurpurine is taken up with alcohol, from which it can be obtained in crystals. It is an orange-red substance with all the properties of alizarine, but it dissolves in soda with more of violet-red coloration; in ammonia, it gives a reddish-brown colour. In dyeing, its shades of red are similar to alizarine, but purer; the purples are more blue; and the blacks, more intense. When used to dye Turkey-red, it produces a brilliant scarlet of remarkable permanence. Its alkaline solution gives a spectrum resembling that of alizarine.

Perkin obtains it from crude alizarine, by the following process:—The latter is first dissolved in water containing a little carbonate soda; the solution is shaken with recently precipitated alumina, which combines with the alizarine, settles as a lake, and is filtered off; the filtered liquid is heated with hydrochloric acid, and the colouring matter thus precipitated is filtered off, washed, and dried. It is further freed from anthraflavic acid, and other impurities, by repeated boiling with alcohol, digesting with a boiling solution of soda, and washing with the same. It is then dissolved in boiling water, and precipitated with chloride barium; it is collected on a filter, washed with warm water, and decomposed by boiling with carbonate soda; from this solution, when filtered, hydrochloric acid precipitates the anthrapurpurine.

Caro (1876, No. 1229) obtains alizarine orange, by acting on commercial alizarine with nitrous acid. From this is obtained a material having the properties of purpurine, by dissolving it in 10 parts by weight sulphuric acid (sp. gr. 1·848), and heating to 150° (302° F.), until gases cease to be evolved, when the colouring matter is found in solution. On addition of water, it is precipitated.

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R.L.N.F., T.T.P.B.W.

COCOA, or CACAO. (Fr., *Cacao;* Ger., *Cacao*)

This product is the fruit of the "Cocoa-" or "Chocolate-tree" (principally *Theobroma Cacao*), a tropical evergreen shrub, belonging to the order *Byttneriaceæ*. It is altogether distinct from the "Coco-" or "Coker-nut" (*Cocos nucifera*)—see Nuts; and from the "Coca" (*Erythroxylon coca*)—see Narcotics.

The husks of the fruit-pods of the cocoa-tree contain a number of seeds, very closely packed in a little pulp. The seeds, or "beans," after being dried, roasted, and ground, constitute "cocoa"; if merely broken up after roasting, "cocoa-nibs"; mixed with starch and very finely ground, "soluble cocoa"; the same made up into a paste, and flavoured, "chocolate." (See Beverages—Cocoa.) The pulp is commonly used for food and confectionery, and from it have also been prepared jellies, spirits, liqueurs, vinegar, &c. The pods also yield an oil, called "butter of cacao"—(see Oils). The wood is porous and light, but capable of taking a high polish. The tree is indigenous to tropical America, originating probably in Mexico; its height is 15–40 ft., seldom exceeding 17–18 ft. when under cultivation; its range of altitude extends to nearly 2000 ft.; it grows wild between lat. 17° N. and 17° S., but the cultivation has been extended 8° farther in both directions.

Varieties.—The following table will show the principal species of *Theobroma*, their habitat, the commercial name of their produce, and the material in which the "beans" are packed for transport:—

Botanical Name.	Where Grown.	Commercial Name.	Packing.
T. angustifolia.	Mexico.		Cotton or hempen sacking.
T. bicolor.	Brazil.	Maranhan. Bahia.	"
	New Granada.	Magdalena.	
T. Cacao (*sativa*).	Australia.	The name of each country.	
	Bourbon.		Matting.
	Ceylon.		
	Cuba.		
	Dominica.		
	Guadaloupe.		
	Guatemala.	Central American.	
	Guinea.	African.	
	Hayti.	The name of each country.	Barrels and sacking.
	India.		
	Jamaica.		Sacking.
	Java.		
	Madagascar.		Barrels and sacking.
	Martinique.		
	Mauritius.		
	Philippines.		
	St. Croix.		
	St. Lucia.		
	St. Vincent.		
	Trinidad.		
	Venezuela.	Maracaibo. Carácas.	Sacking. "
T. glauca.			
T. Guyanensis.	Cayenne.	Berbice.	Barrels and sacking.
	Surinam.	Surinam.	Sacking.
T. microcarpa.	Ecuador.	Esmeralda.	Coarse sacking.
	Peru.	Guayaquil.	"
T. ovalifolia.	Mexico.	Soconuzco.	Hides.
T. speciosa.	Brazil.	Para.	Sacking.
T. sylvestris.	Brazil. Jamaica.		

Besides the above-mentioned species, distinguished by botanists, *T. Cacao*, which is the most widely and largely cultivated, is divided by cocoa-planters into several varieties, the differences observed being mainly due to the long-continued influences of varied climates, soils, and modes of culture. The best of these is the "Creole" (or *Criollo* of the Spanish inhabitants of America). The pods are small; but the beans are thick, short, and almost globular, pale crimson in colour, and of slightly bitter, but agreeable, flavour, soft and oily. The beans require about three days for fermentation. This much-prized sort is become very scarce, chiefly through the bad policy of replacing decayed trees by inferior specimens. The next variety is the *Forastero*, the best kinds of which are the *Cundeamar*, of two descriptions, one with yellow, the other with red pods; the former is the better, containing large seeds, which, in colour, and the ease with which they are fermented, resemble the *Criollo*. The third variety is the *Amelonadò*; and the fourth and lowest is the *Calabacillo*, whose seeds are small and very bitter, and of very dark crimson colour; it has a very low market value, but many planters grow it, on account of its heavy yield; it should be avoided on all new estates. All the varieties except the *Criollo*, which is probably confined to Venezuela, are known collectively as *Trinitario* or "Trinidad"; they are drier and more bitter than the *Criollo*. The best of the *Trinitario* sorts are but little inferior to *Criollo* in the matter of quality, and are superior on the score of fruitfulness. Hence Trinidad forms the principal nursery whence plants or seeds are procured for the establishment of new plantations. The various descriptions of cocoa may be placed in about the following order of merit:—Soconuzco (Mexico), and Esmeralda (Ecuador), all consumed at home; Carácas and Puerto Cabello (Venezuela); Trinitario; Magdalena and Carthagena (New Granada); Para; Bahia.

Production and Consumption.—A rough idea of the sources whence the principal supplies of cocoa are drawn may be gained from the following figures, which do not, however, refer to the same year in all cases, and are not, therefore, strictly comparative: Ecuador, 28,000,000 lb.; Trinidad, 11,000,000; Brazil, 7,000,000; Venezuela, 7,000,000; Grenada, 2,000,000; Mexico, 2,000,000; Martinique, 700,000; St. Vincent and Hayti, 550,000; Celebes, 250,000; St. Lucia, 250,000; Guadaloupe, 200,000; Dominica, 200,000; Cayenne, 65,000; Jamaica, 50,000. In 1878, the imports of cocoa into the United Kingdom amounted to more than 18,000,000 lb., valued at 687,285*l.*; more than half was entered for home consumption; over 10,000,000 lb. were contributed by the British West Indies.

Cultivation.—The climatic conditions of some countries necessitate certain modifications in the method of cultivation, which will be categorically alluded to presently; the main points, however, in the culture of cocoa remain the same, and may be described once for all.

Planting.—The first care is to form a nursery for the young plants. This should be a choice patch of moist land, well cleared of weeds. The cocoa-seeds are carefully extracted from fine fully-ripe pods, and are sown 1 ft. apart, in furrows 2 in. deep, and are lightly covered with earth. Plantain-leaves are then spread over the ground, and left for about a fortnight, by which time the cocoa-plants should make their appearance. The ground is thoroughly weeded till the plants attain a height of 12–18 in., when they are taken up very carefully, and transplanted to the cocoa estate. The soil chosen for this purpose must be rich and flat, and convenient for irrigation. The trees thrive best on gentle slopes, facing away from prevailing cold winds. When the land has been cleared and burned, it is planted at intervals of 25–40 ft. with seeds or suckers of varieties of the coral-bean tree (*Erythrina Corallodendron*), called "shade," or "*madre di cacao*"; these grow to a great height, and afford the permanent shade required by the cocoa. This done, the young cocoa-trees are planted in regular lines, at about 12–30 ft. apart, the distance depending upon soil, climate, and the character of the species under cultivation. As the coral-bean trees do not immediately afford the necessary shade, coffee, plantains, and manioc are planted among the cocoa-trees for this purpose, until the coral-bean trees are sufficiently advanced, when the plantains and manioc are dispensed with, and the coffee only is left. In the second year, the cocoa-trees begin to put forth flowers, which are removed; at the third year, they require air, and no other crop must remain with them.

Pruning and Weeding.—One of the most important details of the cultivation is the proper pruning of the trees, so as to induce a trichotomous growth—a straight, single stem, crowned by a well-formed head. The estate needs weeding at least twice a year, the weeds being chopped off with a cutlass, as hoeing is not required.

Diseases and Enemies.—The tree is sometimes attacked by a disease called *mancha*, which first destroys the roots, and quickly causes death; it spreads so rapidly on an estate that thousands of trees are thus destroyed in a single night. The plant is also subject to several insect pests: ants prey upon the young leaves, boring grubs injure the bark, and the larvæ of moths devour the matured beans. Wind is a great foe: whole plantations have been destroyed by one storm.

Harvesting.—The cocoa harvest takes place principally in June and December, the crops being known respectively as "St. John's," and "Christmas." In the tropics, however, the fruit continues to ripen throughout the year, on which account the trees are visited every fortnight, to gather any matured pods, and to prune where necessary. The pods are carefully selected, and are detached by a knife mounted on a pole; the stem must be cut clean through, without injuring the branch whence it springs. Women and children gather them into heaps, and convey them away for preparation.

Production.—Unless under exceptional circumstances, there should not be more than 900 trees to an acre. The average annual produce is estimated at 4–6 lb. from each mature plant; instances are recorded of an average of 11 lb. a tree in one season, and 15 to 18 and even 20 lb. from individual trees. The fruit is allowed to ripen at the 4th or 5th year; but the crop is not plentiful until the 7th–10th year, after which the trees continue prolific for 15–40 years. The cultivation is considered profitable for large capitalists, or gardeners, as the plant requires less outlay and trouble, and yields a larger return, than perhaps any other tropical crop; nevertheless, the risks from storms and the attacks of insects render it very uncertain.

Preparation.—The gathered pods, resembling gherkins in size and shape, and varying in colour from purple to lemon, are submitted to a process of "curing," which requires much experience and delicate skill, as upon it depends the preservation of the cocoa, and the development of its flavour. The essential objects of the curing are (1) fermentation, to reduce the glutinous, saccharine pulp surrounding the seeds, thereby giving tone to their colour, and modifying their flavour; and (2) drying the fermented "beans," to ensure their keeping. The process admits of several modifications, dependent upon the market for which the product is destined. The seeds are first carefully extracted from the pods, and placed to ferment. If for Europe, they are fermented in barrels, troughs, or heaps, covered by plantain leaves or by sacks, within the "sweat-house," a closed chamber, exposed to the sun, and raised on walls about 6 ft. above the ground. The sweating is best performed in deal boxes, 3 ft. long, 2 ft. wide, and 3 ft. deep, provided with covers, and holding about 500 lb. raw beans; the sides are perforated near the bottom, to admit of the cocoa draining. Here the seeds remain for 3–10 days, at a temperature of about 60° (140° F.), losing much water, and their bitter and astringent principle, becoming lighter, acquiring a mild, agreeable flavour and a fine cinnamon hue, and admitting of their easy separation from the husk by a slight pressure. The liquor which drains out in the process is often thrown away, but may be utilized for the making of vinegar and spirits. They are then transferred to the "drying house," a wooden shed, provided with a movable roof, and thoroughly ventilated. Here they are spread evenly on mats, or on a platform, after having been rubbed with a little red earth. Excessive heat is avoided, and the beans are constantly stirred about, one attendant sufficing for a house 50–60 ft. long by 18 ft. wide. The beans remain here until perfectly dry, and should show no trace of mildew. They are then placed in bags. Efforts should be made towards effecting the drying under a glazed roof, with abundant ventilation, thus saving labour, preventing pilferage, and improving the colour of the product.

Another mode of fermenting the beans is known as "claying." They are placed in holes or trenches in the ground, covered with clay or sand, and stirred at intervals, while great care is taken to prevent the fermentation proceeding too rapidly. When it has reached its proper point, the beans are dried as described.

The fermentation process is apparently indispensable to the production of fine cocoa; but it is attended with some risk in wet weather, when the beans are liable to blister. According to some authorities, the chief object in claying the beans is to preserve them; but it seems to originate in the demands of fashion rather than in any real utility. The essential characteristics of good cocoa beans are—clear, reddish-brown colour internally; dry crispness, allowing the easy separation of the "nibs," or plates, from the kernel; the nibs of a dull-purplish hue externally, with a glaucous purple-brown fracture, dissolving readily when chewed, and manifesting a slightly warm, astringent, full chocolate flavour.

Cost of Production.—The amount of labour required for the cultivation and preparation of any specific quantity of cocoa may be estimated from the basis that, on the average, 15–20 labourers suffice for each 30,000–40,000 trees, entailing an annual expenditure of about 200*l*.–240*l*.

Local Variations and Details.—Those chiefly worthy of notice are the following:—

Africa.—Some very fine cocoa has been sent from Monrovia, in Guinea, and fetched the highest price of any in the market.

Bolivia.—The cocoa growing on the banks of the Mamoré is equal, if not superior, to Maravilla or Carácas, and may be exported in large quantities when the railway is sufficiently extended. At present, every trader to Para takes a full load of cocoa in hide seroons, and finds a ready sale for the article, as it is so much better than that grown in Brazil.

Bourbon.—In this island, there are about fifty acres under cocoa cultivation. The product is of good quality, being of the Carácas description; it used to be grown in connection with coffee.

Brazil.—The plant is indigenous to the districts of Valencia, Camanu, and Ilheos, in the province of Para, and is very abundant in the neighbourhood of the Amazon, Madeira, and Salimoes rivers. Throughout large tracts the plant grows wild; but its culture is steadily increasing. Near the Layes rapids, on the Madeira river, wild cocoa trees are exceptionally abundant, and produce fruit of very superior quality. It would need very little labour to organize an excellent plantation here. The chief supplies come from Para; the cultivation is being extended also southwards to Bahia, and even to Rio Janeiro. The exports fluctuate greatly; this is to be attributed chiefly to floods preventing the harvest. The cultivation in this country is marked by great carelessness; no nurseries are formed for the young plants, and the only shade provided appears to be that of bananas and plantains; the ripe pods are knocked off the trees, and piled in heaps on the ground for fermenting; after 3–4 days, the pods are opened, and the extracted beans are spread to dry on the ground, or on mats. The dual harvests take place in December-January and May–June, the latter being the more abundant. The climate seems to be peculiarly suited to the tree, for in spite of severe floods, and careless culture, or no culture at all, it flourishes exceedingly, and continues prolific for 50–60 years.

Cayenne.—The extent of land under cocoa in Cayenne does not exceed about 650 acres, the exports, in 1874, being less than 600 cwt. The product is dried in the sun, or by currents of air, and has a softness of character which renders it valuable to mix with the drier, aromatic, *Carácas* growth, for purposes of chocolate manufacture.

Ceylon.—The culture in Ceylon has not hitherto been extended to such a degree as could be wished. Samples that have reached English markets have been reported as of very fair quality, well-cured, and thin-skinned, and by no means common; but, at the same time, not of the richest character, and not so carefully grown as they might be. Plantations, formed in parts of the island too hot for successful coffee-growing, have come on well, and importers are anticipating the development of this new source of supply, which will make them less dependent upon the Trans-Atlantic crops. The seeds were chosen from the best varieties grown in Trinidad, and, in 1874, more than 40,000 seeds and plants were distributed from the Botanic Gardens at Peradeniya. There will before long be a very large area of land under cocoa, in the warmer parts of the island.

Costa Rica.—The exports from San José in 1878, were 5836 lb.

Ecuador.—This state yields the greatest quantity of cocoa. The kind chiefly grown is *Guayaquil*, an inferior variety, costing only half as much as *Carácas*, and very largely consumed in Germany. A second variety, *Esmeralda*, is considered superior to *Carácas*, but it is confined to home consumption. Cocoa is the staple of the country; but the crop of 1878 was the smallest on record, on account of continued rains. The exports from Guayaquil for 6 years, stated in quintals of 220 lb., were, in 1873, 251,812; 1874, 250,216; 1875, 176,207; 1876, 224,739; 1877, 203,131; 1878, 98,765. The value in 1877 was 45*s.* a quintal; in 1878, 65*s.* The 1878 export was thus distributed:—Continental Europe, 59,000 quintals; England, 20,714; United States, 7761; Central America and West Indies, 7000; South America, &c., 4200.

Guatemala.—The cocoa export of 1878 was only 2300 lb.; valued at 1 dol. a lb., and all sent to Central America.

Honduras.—The *Soconuzco* variety, which, during the Spanish occupation of Mexico, was reserved for the Court of Madrid, is said to grow wild here, with fruit measuring 2–2½ in. thick, and 6 in. long. When cultivated, the dimensions increase to 3–3½ in. × 8 in., and the trees bear in 6–7 years.

India.—The Indian Government has raised large numbers of seedlings, in Botanical Gardens, for distribution throughout the peninsula. The plants have been put out in the Neilgherry Hills, and in the Terai, and have been found to grow well while looked after. The tree has been very successfully reared in Coorg; the plants are grown from seed in nurseries, and transplanted, when 18 in. high, into large pits, 12 ft. apart.

Malay Archipelago.—The cocoa tree was introduced here by the Spaniards, more than three centuries ago. In 1854, Celebes produced nearly 200,000 lb., which figure has since increased. The yield averages 5–6 lb. a tree. Small quantities of Java cocoa have occasionally appeared at London sales, and elicited similar opinions to those expressed on Ceylon produce. In the Philippines, cocoa is commonly grown for local consumption. The trees, which here attain but very dwarfed stature, are commonly found in the gardens, planted very closely, in order to keep down weeds. Instead of a nursery for rearing the young plants, the natives cover the kernels, when they begin to sprout, with a little earth, and place them in spirally rolled leaves, which are hung beneath the roofs of dwellings till the plants are ready for putting out. The best cocoa is produced in the small island of Maripipi, and never comes to market; the next best is the Albáy growth, which is reckoned equal to Carácas; the samples produced in Cebu and Negros are fairly good, but in trifling quantity; so that these islands have to import from their neighbours, Ternate and Mindanao. It thrives as well in the Spice Islands as in Mexico, and is supplanting the less profitable clove-tree.

Nicaragua.—Several important plantations have recently been commenced here by Frenchmen.

Peru.—Besides being cultivated in all the gardens of the Montana, cocoa grows spontaneously and abundantly in the forests of that province. The exports from Mollendo, the chief port, in 1878, were but 1500 lb.

Surinam.—The cultivation here has been considerably extended of late years, the estates being worked hitherto mostly by Creole labourers; but these have proved so unreliable, that coolies have been substituted. The severe drought of 1877 injured the plantations in an extraordinary degree. The production was, in 1875, 1,322,811 kilos.; 1876, 1,322,674 kilos.

Venezuela.—The cocoas of Venezuela, known as *Carácas*, and *Maracaibo*, are considered the best of all produced in the western hemisphere, and though the bean was first imported to Spain from Mexico, it has subsequently been largely exported to the latter country from Venezuela. In this country, the tree is said to thrive best in damp, level soil, and bears about 1 lb. of fruit at the fifth or sixth year; near the sea-coast, it is in full bearing at the eighth year, but in the Guique districts on the Lake of Valencia, and in the province of Carabobo, it is not matured till a year later. Experienced planters state, however, that it should cover all expenses from its sixth year. The quality of the Venezuelan cocoa has been greatly spoilt by the introduction of the much more prolific but very inferior *Trinitario*, or "Trinidad," beans. The latter is now the staple product from the district of Güiria, Maturin, Carupano, and down the coast as far as the Rio Chico; but the *Criollo*, or "Creole," plant is still cultivated upon some few estates. The *Trinitario* seed is also sown, to some extent, in the valleys of the Tuy, although the majority of the estates there are sown with *Criollo* seed, and good cocoa can still be procured thence. From the port of La Guayra westward towards Puerto Cabello, and particularly at Ghoroni, O'Cumar, Turiamo, Patanemo and Borburato, lie the districts yielding the best produce, the choicest of all being from the estate of Chuao near Ghoroni. From the neighbourhood of San Felipe, the capital of the state of Yaracuy, a very superior mixed cocoa is exported, to the amount of about 4000–6000 cwt. annually. The Trinidad seed has, since 1854, been introduced into Chichiriviche, formerly one of the finest cocoa districts. Many plantations were damaged, and some entirely destroyed, by the great drought of 1868–69.

On some of the Carácas estates, where Trinidad cocoa has been introduced, the produce has fallen into great disrepute, and some of the planters import the red soil of Ghoroni with which to colour the beans. The finest Venezuelan cocoas sent to Europe are the Puerto Cabello and the Carácas varieties; the latter, which is the dearest and best, is of four kinds, Chuao, Ghoroni, O'Cumar, and Rio Chico. In the matter of cocoa production, one of its richest and most valuable crops, Venezuela seems to be now scarcely as advanced as it was a century ago; not only has the quality of the product deteriorated, by reason of the substitution of Trinidad for native seed, but the quantity has also fallen off.

The best brands now exported are absorbed by Spain and France. They are grown almost solely in the coast districts, and hence are called *Cacao de la costa;* the beans are full-coloured, and larger, richer, and more oily than other sorts. The so-called "mixed cocoa" (*Cacao mezelado*) is the produce of estates where the native and Trinidad seeds have been sown indiscriminately; it is much inferior to the preceding, though the foreign trees have greatly improved in the more favourable soil; the produce goes chiefly to England and Germany. A third quality is the fruit of the Trinidad tree alone. The relative prices of the qualities on the spot is approximately 7*l.*–8*l.*, 4*l.*–5*l.*, and 2*l.* 8*s.*–3*l.* 12*s.* a cwt. The flavour of cocoa depends principally upon the soil; the finest Venezuelan cocoa all comes from one estate, and though the seed has been tried within a mile of the spot, no such quality can be produced. It is never exported, as it fetches twice as high a price in the country as it does in Europe.

There is no doubt that the soil and climate of Venezuela are eminently fitted for this branch of agriculture. The land lies low, being subject to inundation, and retaining its moisture in the height of summer. The climate is hot, but at the same time very humid. The trouble and expense of irrigation are thus avoided, without any detriment to the crop. The ground is prepared in the months of January–March, before the commencement of the winter rains in April–May, when the bananas and the "shade" plants, locally termed *bucare*—(*Erythrina umbrosa*, and *E. velutina*), are planted. When laying out good virgin soil with "creole" plants, it is usual to place one at each angle of a space 12½ ft. square. In poorer land, this distance is reduced—a proceeding based entirely on false economical grounds. An important operation in this climate is the provision of trenches between the rows, in order to carry off the excess of water during heavy rains, as nothing is so injurious to the health of the tree as stagnant water. This draining forms one of the chief items in the cost of the cultivation. Between the appearance and the ripening of the fruit, there is an interval of nine months. The average yield is 1–1¼ lb. from each tree. The life of the tree is reckoned at 35–40 years on good soil, 20–25 only on poorer land.

The pods vary in size and shape. The so-called "cows'-tongues," 9 in. or more long, are preferred, because the husk is thinner and the pod contains more beans; more commonly the pods are shorter and rounder, but larger, and are called "*angolitas*." In dry weather, a single night will suffice for the fermentation; but in wet weather, the beans may be left for two or three days without inconvenience. They are then dried in the open air, exposed to the sun, in a courtyard or on drying frames; 8–10 hours of sun is generally enough; they are housed at noon when the sun is at the hottest; and are left in the store for a day or two to complete the drying. Some growers dry the beans on large sheets, which can be readily housed in case of rain.

The above remarks refer especially to the "creole" plants, which were formerly so much grown, and whose produce was so highly esteemed. This is now largely replaced by the Trinidad variety, whose violet-tinted, sharp and bitter-flavoured beans are made to assume the colour, odour and flavour of the "creole" cocoa, by prolonging the fermentation to four days or more, and by the application of red earth, brick-dust, and vermilion.

West Indies.—The best months for pruning, in the West Indies, are March–April; but large branches may be trimmed in August–September, should there be no young fruit to sacrifice. The tree does not thrive where exposed to easterly and northerly winds.

Dominica.—The cultivation here, though established some thirty years, is still but little developed. The trees have been crowded together at intervals of only 2–4 ft., with the effect of choking each other for lack of room; and pruning seems to have been systematically neglected. No attempt has been made to provide shade, as in Trinidad and Venezuela, but the cocoa has been rather planted to afford shade to coffee. Shade and shelter would doubtless be needed by the more delicate Trinidad varieties in sunny spots. Care is not taken in the fermentation and claying of the beans. The produce is shipped to Barbadoes and Martinique, partly for local consumption, and partly for re-shipment to England, France, and America. An export duty of 13½*d.* a cwt. is charged.

Grenada.—There are at least 4000 acres under cocoa in this island. The export duty is 6*d.* a cwt.

Guadaloupe.—After much neglect, attention is again being directed to the cultivation here, the plantations being formed with trees imported direct from Venezuela.

Jamaica.—Two centuries since, the produce, in exceptional years, was reckoned at 20 lb. a tree, and averaged 8 lb. a tree, at 18 ft. apart, in fairly good soil. The import duty, then placed on cocoa by the British Government, crushed the industry; under the present more favourable conditions, however, efforts are being made to resuscitate it.

Martinique.—Owing to the disastrous failure of the crop many years since, cocoa cultivation was long discontinued here; lately, however, it has been resumed and extended, and the produce is of good quality.

St. Domingo.—The exports were, in 1878, to France, 17,200 lb.; West Indies, 6000; Italy, 4800; United States, 1600.

St. Lucia.—This island has about 450 acres under cocoa; the exports are almost stationary.

St. Vincent.—The export duty here is 8*d.* a cwt.

Trinidad.—Cocoa is the second great staple of production. The high cultivation bestowed upon the native seed has greatly improved it, so that in some districts it is almost to be compared with the "creole" of Venezuela. A recent writer from the island says the trees yield 15 lb., and in very good years, 18 lb., clean, dry cocoa at a crop; but the average yield of the best estates is about 2 lb. a tree per annum, which, at 12 ft. apart, gives 600 lb. an acre. The average of the whole island is 500 lb. an acre. The best qualities fetch 6*l.*-7*l.* a cwt.; the inferior, about half as much. The export duty is 11¾*d.* a cwt. The shipments for the last four years have been as follows:—1876, 8,706,500 lb.; 1877, 8,103,779; 1878, 9,392,324; 1879, 11,791,032.

General Considerations.—The points essential to success in cocoa cultivation are;—1, Judicious selection of seeds; 2, Careful attention to pruning and draining; 3, Plucking the pods at the right stage; 4, Nicely regulating the fermentation; 5, Subjecting the beans to complete desiccation; this is, perhaps, the most important consideration of all: they should rattle distinctly on being disturbed; 6, Hand picking the dried beans, so as to eliminate leaves, stems, and other rubbish, which greatly lower the value of the sample; 7, packing while *thoroughly* dry, in double sacks, or sound barrels (*not* hogsheads). Steamer transport is adopted wherever available, the advanced cost being more than compensated for by the higher price realized, by reason of the superior condition attained under shortened transit.

The consumption of cocoa is constantly increasing, especially in Latin Europe, and there is no reason to fear over-production for many years to come. In the autumn of 1878, the prices of cocoa advanced 25-75 per cent. according to quality, owing to the failure of the Ecuador crop. The duties on cocoa importations into the United Kingdom are as follows;—Cocoa, 1*d.* a lb.; husks and shells, 2*s.* a cwt.; paste or chocolate, 2*d.* a lb. The price of cocoa now varies between 71*s.* and 108*s.* a cwt., according to quality.

The following shows the relative prices (in shillings per cwt.) of the principal brands brought into the home market in 1878 and 1879:—*Trinidad*—sup., 120-5, 91-108; mid. to fine red, 116-9, 81-90; grey and mixed red, 114-5, 75-80. *Grenada*—110-4, 78-86. *Dominica and St. Lucia*—110-2, 72-8. *Surinam*—116-9, 80-90. *Carácas*—116-123, 85-105. *Para*—115-20. *Bahia*—115-20. *Guayaquil*—112-130, 71-90. The Guayaquil and Carácas varieties find the readiest market on the Continent, where they are used chiefly for chocolate manufacture; the Colonial descriptions—Trinidad, Grenada, Dominica, &c.—take the lead in the home market; Bahia, Surinam, &c., are pretty equally distributed. The consumption in this country is now calculated at about 0·3 lb. per head of population. The total imports were, in 1874, about 18 million lb.; 1875, 16 million; 1876, 20½ million; 1877, 17 million; 1878, 18 million. The imports in 1878 were contributed as follows:—British West Indies, 10,434,608 lb.; Brazil, 2,518,703; Ecuador, 1,655,867; San Domingo, 792,602; France, 743,659; Holland, 563,558; Germany, 288,705; British Guiana, 276,533; West Coast Africa (foreign), 185,197; Venezuela, 149,845; Surinam, 106,256; United States, 35,903; other countries, 270,190.

Guarana.—A substance which, though not a cocoa, yet bears in many respects a close resemblance to that product, is guarana, a so-called "bread," yielded by the *Paullinia sorbilis*, a plant of the order *Sapindaceæ*. It is a native of Brazil, and grows abundantly in the province of Amazonas, along the banks of the rivers Tapagos, Rio Negro, &c., as well as in Guiana and Venezuela. The genus, indeed, is a large one, and it is probable that the seeds of *P. Cupana* of the Orinoco, as well as those of many of other species, may be used for alimentary purposes. Guarana is manufactured by the Muras, Mondrucas, and other tribes of Indians, and is much esteemed, both as a food and as a medicine, throughout Guatemala, Costa Rica, Brazil, and other parts of South America.

The preparation is conducted in the following manner:—The fruit, which is scarcely as large as a walnut, is gathered when ripe, and roasted intact. Its seeds, numbering about half a dozen, are then taken out, and, after being pounded between stones or mallets, are formed into a thick paste with water, and moulded into cakes and rolls of various forms. These are dried in the sun, or by the fire, by which they become extremely solid and difficult of fracture, and will keep good for any length of time. For use, the rolls are grated to powder, which is very like cocoa in appearance, or they are ground in water, and sweetened; the beverage thus produced is analogous in its effects to tea and coffee.

The city of Santarem annually exports about 16,000 lb. of guarana, valued at 8*d.* or 9*d.* a lb. at the port, but selling for very much less in the neighbourhood of its production. It figures among the non-officinal substances of the United States Dispensatory. In Europe, it is but little known as yet; it is included in the French Pharmaceutical Codex, and its alleged medicinal virtues have occasionally found buyers at as much as 1*l.* an oz.

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(See Beverages—Cocoa; Oils.)

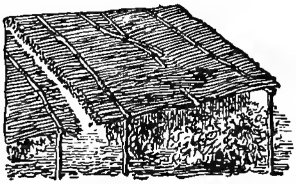
COFFEE. (Fr., *Café;* Ger., *Kaffee.*)

Coffee is the fruit of a series of plants belonging to the family *Rubiaceæ.* The genus, known as *Coffea*, is divided by botanists into some sixty species, of which about twenty-two are referred to America, fifteen to Africa, and seven to Asia. There is abundant reason for supposing, however, that the majority of these so-called species are mere varieties, due to different conditions of soil, climate, and cultivation. For all practical purposes, it will be sufficient to distinguish two species only, *Coffea Arabica*, and *C. Liberica* (*Liberiana*). The former is the well-known coffee-shrub. It attains a height of 15 to 20 ft., and its foliage resembles that of the Portugal laurel; the small, white blossom is not unlike that of the jessamine in form and scent; the berries are at first dark-green, changing, as they mature, to yellow, red, and finally, deep crimson. Beneath the skin of the ripe berry, or "cherry," as it is called, is a mucilaginous, saccharine, glutinous "pulp," closely enveloping the "beans," usually a pair of oval, plano-convex seeds, though sometimes there is but one seed, called, from its shape, "peaberry"; these beans are coated with a cartilaginous membrane, known as "parchment," and beneath this by a very delicate, semi-transparent, closely adhering jacket, termed the "silver-skin." The range of this species is at elevations of 1000 to 4000 ft., between latitudes 15° N. and 15° S., and its cultivation may be extended to 36° N. and 30° S., in localities where the temperature does not fall below 13° (55° F.). Perhaps the most favourable climate would be a temperature ranging from 15° to 27° (60° to 80° F.) in the shade; and as to humidity, there should be no month in the year entirely devoid of rain, the total of which may be 100 to 150 in. per annum—absence of extremes of temperature, with a constant supply of moisture. The shrub is cultivated chiefly in Brazil, Java, Ceylon, India, the Central American Republics, West Indies, Arabia, Natal, and recently in Australasia. It furnishes almost the whole of the coffee of commerce. Increasing attention is, however, being devoted to *C. Liberica.* This species is a native of Liberia, and is distinguished from the ordinary shrub by much more vigorous growth, by affecting flat and coast lands as well as hill-sides, by attaining greater size and age, and by withstanding greater extremes of climate. It possesses additional advantages in that it is capable of improvement by cultivation, and, though as liable to disease as *C. Arabica*, seems to be affected in a minor degree. On the other hand, the produce is much coarser flavoured than ordinary coffee, though that is no drawback to its being used for admixture with better sorts, producing a cheap, yet genuine, beverage for the million. From experiments tried in Ceylon, great benefits are anticipated from grafting the fine-flavoured *C. Arabica* on stocks of the hardy *C. Liberica.*

Cultivation.—The following remarks refer to the commonly cultivated varieties of *C. Arabica.* The main principles are subject to but slight modifications, which will be noticed presently under the head of each coffee-growing country. Full details concerning *C. Liberica* will be found under *Liberia.*

Nurseries.—For this purpose, should be selected a patch of gently sloping virgin soil, warm and dry, but close to water, soft, and not richer than that to which the plants will be subsequently transferred. The seed-beds may be somewhat shaded, but not so as to entirely exclude the sun, nor so that the shading tree gathers rain and sends it in streams upon the bed. The seed-bed is cleared of all but the largest stumps, thoroughly dug to a depth of 9 to 12 in., and made very friable. The beds are slightly raised to promote drainage, and are divided by paths into narrow strips. A deep trench is cut above the bed, in an oblique direction, to prevent damage by rain and wash. The seeds are sown in rows 6 to 9 in. apart, and about 2 in. deep. The seeds are strewn about 1 in. apart, lightly covered with mould, and shaded; a cheap and efficient shading may be secured by laying branches across a light framework as shown in Fig. 495. Watering must be done in the morning, or towards sunset. A bushel of seed should give 20,000 to 30,000 plants; the best is "parchment" coffee, picked when fully ripe, pulped by hand, unfermented, unwashed, and dried in the shade. The nurseries proper are prepared in much the same way, but not shaded. When the plants have two to four leaves (exclusive of the seed-leaves), they are carefully loosened, and transplanted, in damp, cloudy weather, from the seed-beds to the nurseries, and placed 9 to 12 in. apart. Care must be taken not to double up the tap-root, and not to leave a space for water to accumulate and rot the roots. If the tap-root is very long, it is best shortened by an oblique cut, and soon shoots again. When transplanting from seed-beds to nurseries is not practised, the plants are left in the seed-bed until larger; but Stainbank and others strongly recommend the former plan, as, by checking the growth, the young wood becomes hardened, and better able, when finally planted out, to resist insects and unfavourable weather. A practical suggestion for preventing young seedlings being eaten off at the surface of the ground by grubs, is to lightly wrap round a piece of paper about 3 in. broad, where the stem joins the root, on planting. The risk of having young seedlings burnt up just after planting is guarded against by various simple measures for shading them. In about a year, the plants are ready for transfer to the permanent estate, which is meantime being prepared for their reception.

495.



Selection of Estate.—The points which determine the value of a plot for coffee culture are:—1. Elevation; 2. Aspect; 3. Shelter from wind; 4. Shelter from wash; 5. Temperature; 6. Rainfall; 7. Proximity to a river; 8. Character and richness of soil. Most of these are necessarily subject to variation according to locality. Shelter from wind is perhaps of paramount importance, and should not be sacrificed for richer soil, as the latter can be artificially obtained much quicker than the former. In wooded country, the estate may be laid out in blocks of 50 acres, encircled by natural belts of forest. Flat land must be avoided; a wet soil is fatal to coffee, and flat lands would entail great expenditure for drainage. Steep slopes, on the other hand, are objectionable, on account of the wash occasioned by rains carrying away soil and manure, and exposing the roots of the shrubs. The surface soil must be fairly good; the subsoil may be poor, but must never be stiff clay; the shrub is essentially a lateral feeder. As a general rule, virgin forest land has been found most suitable to break up for coffee estates; it has become naturally enriched by decayed vegetable matters, and the burning to which it is subjected frees it from insects and from weeds. Exceptional patches of land that has once been under cultivation and then allowed to run wild have formed good properties; but the soil is rarely rich, is generally exposed, and always entails great trouble and expense to keep down the weeds. A temperate climate within the tropics is to be preferred on all scores; a certain degree of warmth and humidity combined is essential. An atmosphere resembling that of an English hot-house produces the finest crops, perhaps; but it is inimical to the planter, and favourable to weeds. The most suitable climate is precisely that which Europeans prefer. Frost, even though it be only at night, and for a short period, is fatal. The presence of water, preferably a perennial stream, is essential for watering the young plants, and for the "pulping" process.

Clearing and Burning.—When forest land is taken into cultivation, the first step is to effectually clear it of timber and underwood. The latter is first cut, by means of the "cattie," shown in Fig. 496; the large trees are then felled on the top, and their branches are lopped off, so as to compact the pile, otherwise the burn will be only partial. A fine day, after the night's dew has evaporated, is chosen for putting fire to the prostrate mass. The advantages of a thorough burn are, that subsequent operations are greatly facilitated, and that weeds and insects are destroyed; the disadvantage is that the upper soil is burnt, and rendered unfit for filling into the holes. This injury might to a great extent, be obviated by "lining" and "pitting" the land beforehand. By this means, the surface soil would be mostly covered over with the earth taken out of the pits, and thus protected from the fire. On the other hand, of course, the lines could not be marked out with accuracy or regularity, and the estate would subsequently suffer to some extent in appearance, though it is a question how far this drawback is worth considering, in comparison with the advantage gained. When there is not sufficient timber to make a good burn, the bush is felled, and burnt in heaps, after which the ground is carefully gone over for the purpose of rooting up the tree-stumps which remain. These are sometimes so difficult to eradicate that they are left to decay, care being taken to knock off shoots as fast as they appear. It is, however, a bad plan, and one

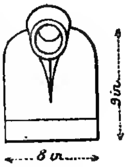
496.

seldom followed, as the rotting stumps harbour vermin of all kinds. After burning, the wood ashes should be scattered evenly over the ground as a manure.

Lining.—Soon after the burn, the estate is "lined out" for the reception of the plants. The two following methods are in vogue:—(1) A base line is laid down, as nearly as possible straight up and down the slope; a cross line is set off exactly at right angles; on this line, stakes are driven into the ground at the distances determined upon for the position of the plants; to each stake, a rope is fixed, and stretched parallel with the base line and as straight as possible; small stakes are provided along these lines; a rope is finally held across them at succeeding stages of equal width, as guided by measuring poles, and the small stakes are put in where the movable rope crosses the fixed ones, each stake indicating the site for a plant. (2) A rope is furnished with bits of scarlet rag at the distances fixed upon between the plants; it is stretched across the plot, and stakes are inserted at each rag; the rope is then moved forward a stage at a time, gauged by measuring rods. The first plan is the better, especially in broken ground, but is more laborious; the second is available on even grass land, but the stretch of the rope must be estimated and allowed for. The great object sought is to have the lines perfectly regular; and instead of making any deviation where stumps or other obstacles occur, the rope is laid over them, and the corresponding plant is omitted. Yet another method of holing is that known as "quincunxing," i. e. placing the plants so that alternate lines are opposite; it was recommended by Laborie, but is open to several objections, and is quite out of favour.

Distances of the Plants.—Scarcely any two planters are agreed as to the best distance to allow between the plants. The question is governed in some measure by the richness of the soil and by the climate. The object in view is that, with the greatest convenient number of trees in a given space, none shall incommode its neighbour. In cold or exposed situations, where the plants cannot attain any great size, close planting is necessary; the reverse being the case where the climate is warm and humid and the soil is productive, and consequently likely to produce large bushes. In the West Indies and Java, the space is often 10 to 12 ft., but other crops are there usually planted with the coffee. In Ceylon and Southern India, distances vary from 4 ft. each way to 8 ft., the best being, perhaps, 7 ft. between the rows and 6 ft. between the plants. The number of trees contained in an acre planted 6 ft. × 7 ft. will be 1037; 6 × 6, 1210; 6 × 5, 1452; 5 × 5, 1742; 5 × 4, 2178; 4 × 4, 2722. Advantages in wide planting are that field labour is facilitated, and the shrubs grow larger; a disadvantage is that more room is left for weeds.

498.



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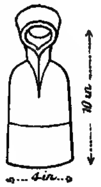


Holing or Pitting.—Around or beside each stake, a hole is dug, its size depending much upon the kind of soil. In stiff, poor land, 2 ft. each way is not too large; in good, light ground, 18 in. will suffice. They had better be too deep than not deep enough. The implements commonly used by coolies for this purpose, are the *quintannie*, or grubbing hoe, Fig. 497; the *mammotie*, Fig. 498; and the *alavangoe*, or spade-bar, Fig. 499. The earth thrown out is left to mellow until just before planting. The hole is then "filled in" with the best of the mould, which has been carefully freed from stones, roots, &c., and mixed with a little manure. The filling in must be done very lightly, and the loose earth should rise in a heap above the hole. The operation is best performed while the ground is moist; it is also a good plan to break down the sides of the hole somewhat, especially if they are hardened.

499.

Planting.—When the holes have been duly prepared, the young plants are removed from the nurseries with the same care as they were transplanted to the nurseries from the seed-beds. For taking up the plants, an ordinary prong is much superior to the spade-bar; hand-pulling must be rigidly guarded against. The fibrous roots of each plant, as taken up, are carefully pruned off to about 4 in., so that they may not be doubled up in the planting; the tap-root is also shortened to about 9 in. by a clean sloping cut, for the same reason. A ball of earth should surround the roots; and if the plants are exposed to the air for more than a few minutes, the roots should be covered with wet moss, or some other damp material. A dull cloudy day should be chosen whenever possible; in bright sunshine, the plants would all be burnt up. The plants are carried in batches on trays to the estate. They are placed in the ready prepared holes by hand, great care being taken that no roots are doubled up, that the plants are upright, and that they are no deeper in the ground than they were before. In treading the earth down round the plant, every precaution is necessary to prevent leaving holes for the accumulation of water round the roots. The surface should be made firm and as level as possible. On a steep slope, the outer edge may be made slightly higher than the inner, to check the effect of wash; but in subsequent weeding, it will be necessary to guard against exposing the lateral roots.

There is some diversity of opinion as to the size and age most suitable for putting out nursery plants. When dull, rainy weather can be depended on for some little time, nursery plants of the second year are the most satisfactory. Plants of one season only are too tender for the operation. Under ordinary conditions, and with due care, no serious loss of plants should be incurred in this way. A novel plan, which may be advantageously adopted in small plantations, is one resembling the method of planting cinchona. A number of calabashes are deprived of their small end and emptied of their contents; into these, the seedlings are placed, gradually exposed to the sun as they grow, and finally planted in the calabashes; the latter soon rot, and form manure for the plants.

A plan that has been much followed is the substitution of "stumps" for nursery plants. Plants that have been in the nursery for about three years are dug up and pruned back, leaving only about 6 to 8 in. of stem. They are hardier and safer in a general way than whole plants, more especially in uncertain weather. They will strike readily, even without rainfall for some little time after being put in, provided the ground has become sufficiently moist to prevent their being burnt up; but they cannot be used with success in districts where a long period of drought may be expected to succeed the wet season. The planting is performed in the usual way. The plants send up several shoots from the parent stem; of these, the finest is retained to form the future tree, and the rest are pulled off carefully. The shoot that is left grows rapidly; but, from the way it springs from the stem, it is liable to be accidentally broken off, either by a high wind or by the weeders. The crookedness of the stems of stumps from native grown seed renders them very inferior. The best size for stumps is the thickness of a common pencil.

Dibbling.—Where the land is very rich and friable, holing may be replaced by the less expensive plan called "dibbling." It is performed in two ways:—(1) By the aid of the spade-bar, is made a sufficiently deep hole, into which the plant is dropped, and secured by treading the earth lightly round; (2) A patch of ground measuring about 1 ft. each way is thoroughly loosened, without the soil being taken out; in the disturbed earth a hole is made with the hand, the plant is inserted, and trodden round as before. The latter method is preferable. Dibbling is only practicable in exceptionable cases. It is, moreover, open to objection, as a hole is often left, in which water may accumulate and rot the plant; and the roots are more liable to injury than in ordinary planting. On the other hand, very much labour is saved.

Staking.—When the plants are exposed to wind, they should be provided with supports as soon as they are 10–12 in. high, and present a resisting surface. For first season's plants, lining pegs may be used; but larger plants will need strong, inflexible stakes, 3–3½ ft. long, entering the ground on the windward side, at about 6 in. distant, and at such an angle as to meet the stem at about its middle. The plant is attached to the stake by a broad loop of some vegetable fibre, firmly tied to the stake, but loose around the stem. If the plants have already been worked by the wind, they will need earthing up 5–6 in. as well. The ties may be brushed with coal-tar, as a protection against theft, insects, and decay.

Supplying Vacancies.—Every precaution should be taken to guard against failures, as "supplies," as they are called, will seldom if ever do as well as young plants put into virgin soil. In new land, failures can be almost entirely guarded against by care. Their number may subsequently be limited by keeping the ground free from weeds, and by good draining, manuring, and pruning. A certain number of vacancies, however, will occur from time to time, and they must be filled up in the following manner:—The original pit, having been re-emptied, should be enlarged an inch or two all round, and especially in depth. This should be done in the dry weather, the pit being left open for some time, and only filled in when the time for planting has arrived. In most cases, it will be desirable to refill the pit with the soil which has been taken out of it. Where the vacancy is in the midst of old trees, a large pit is necessary, to protect the new plant from being interfered with by their roots, and it is well to isolate the young plant by surrounding it with a ring trench, 6–8 in. wide, and 1 ft. deep. It is also desirable to put a basketful or so of new soil from the forest into the pit, near the top; where this cannot be managed, a few handfuls of manure should be mixed with the surface mould. Only strong, healthy plants may be used for this purpose. Stumps are often considered more suitable than nursery plants, as being hardier; they throw out three or four "suckers," the best of which is selected when they have attained a height of 6–9 in., the others being carefully pulled off. Well-formed nursery plants, with three or four pairs of primaries, and about 12–15 in. high, put in just as they come from the beds, with a good ball round the roots, are to be preferred when steady wet weather can be calculated on for some time. In any case, supplies ought to be put in early in the wet season, so as to give them every advantage. They should always be marked by a tall stake; and should be allowed to bear a maiden crop before being topped.

Shelter.—The worst enemy of the coffee shrub is wind. Its effects become apparent in pinched and stunted growth, or in lack of foliage. In situations where the soil is soft and yielding, it does equal mischief by working the stems in the ground, so that in a short time a funnel is formed round the neck of the plant, and this being continually chafed, the bark is worn off, the roots are loosened, and the plant dies "wind-wrung." Should it be rescued before the bark is entirely worn off, the plant may live; but it will be extremely liable to attacks from "bug," "worm," or any other blight prevalent in the locality. Belts of jungle are sometimes left standing, as a protection; but opinions differ as to the advantage of this plan, some planters holding that more harm is likely to result from the wind being concentrated into eddies, instead of taking its natural and more equable course. This question can only be decided by the local circumstances of each case. Such belts, being sure to form nurseries for weeds and vermin, are not intended to be permanent, and should gradually give way to fruit or other useful trees. Sometimes artificial shelter is erected, but it is too costly to find general favour. Indeed, in moderately sheltered situations, staking, combined with low topping, ought to be sufficient to secure the stability of the plant; where they are not, the situation has little to recommend it for coffee culture.

Shade.—This is a consideration of great importance, and the opinion now generally adopted is, that the wholesale felling of the forest in some places has been altogether a mistake, and that plantations which are now extinct might still be flourishing, had the forest shade been at least partially retained. The history of coffee cultivation in the East proves that, in hot climates, and where prolonged seasons of drought may recur, coffee will not flourish permanently, except under shade. In a state of nature, the plant almost universally affects shade; this is the more remarkable, that the seeds are deposited by wild animals and birds as freely on open grass lands as in forests. A suspicion that the borer, leaf-disease, and other immediate causes of decay, are only induced by the weakened state of the shrubs, consequent upon their exposure to lengthened periods of drought, is supported by the fact that where shade trees are found standing upon an abandoned estate, they are surrounded by a surviving remnant of coffee bushes.

The question as to where shade is necessary is one of climate; it is not universally beneficial. The advantages to be derived from it, in very hot climates, are:—Diminished exhaustion, and consequently increased longevity of the plant; reduced cost of cultivation; a conservation of the nutritious properties of the soil, and an actual increase of them, as the cover given to the ground causes the surface vegetable matter to decay more rapidly; and, provided the tree be a sub-soil feeder, the shedding of its leaves will yield a positive gain of surface matter, which the roots of the coffee would otherwise never have reached. In addition to this, there is the direct value of the timber grown. The only drawback to shade would seem to be a diminished yield of coffee; but this is atoned for by the increased longevity of the plant. The most suitable trees for affording shade will be alluded to under the local headings.

Roads.—Efficient roads not only greatly facilitate the working of a plantation, but they should be so laid out as to serve the additional purpose of drainage. A cart road should pass through the centre of the estate, wherever it is possible to avoid a steeper gradient than 1 in 15, emerging upon the main highway. From this, branch roads should be cut at right angles, with as easy gradients as possible, and not more than 100–150 ft. apart. These branch roads should cross the lay of the ground, so as to check, to the fullest extent, the effects of waste. A boundary path encircling the estate is useful for many reasons. The main central road should be set out before pitting and planting. Wire tramways commend themselves as eminently suited to minimize labour on coffee estates. An excess of road accommodation, as regards both the number and the width of the paths, is far preferable to insufficient roading, despite the extra first outlay. If the ground be rich, it may cost a good deal to keep the roads clean and free from weeds. This, however, may be greatly lessened by ploughing them up and planting them with an annual crop, until the land is exhausted; not only will the roads be rounded by the ploughing, but weeds will not so readily grow.

Drains.—Nothing is more important than the thorough draining of a coffee estate, in order to carry away the excess of moisture during heavy rains, without allowing the surface soil to be washed away. Continuous open trenches are cut in parallel lines across the face of the slope, and at 10–15 yards apart; their gradient should never exceed 1 in 12, and 1 in 20, or even 30, will be better; their width may be 15–18 in.; and their depth, not less than 1 ft. at the lower side. They need constant cleaning out and repair, especially after a heavy shower. They must in all cases empty into a natural or artificial channel amply capable of carrying off the water; if furnished with breaks to catch the suspended soil, so much the better, as the latter can then be collected and returned to the estate as a dressing.

Catch-Crops.—Much has been said both for and against the growing of other crops among the coffee shrubs. In the West Indies, the culture of plantains, yams, cocoa, &c. was carried to such an extreme that the coffee became, in fact, of secondary importance, or was even killed out. In Ceylon, too, catch-crops were long in vogue; but they seem now to have gone out of fashion, as they exhausted the soil, and produced too much shade. There is nothing to object to in the simultaneous cultivation of several crops so long as each has due space, and sufficient manure, and the plants are not antagonistic to each other, as the failure of one crop may be compensated for by the success of another. Rice and tobacco have been found to yield good returns as catch-crops but they possess a disadvantage in not affording any shade to the young coffee plants. Cocoa, yams, and plantains are, perhaps, even less advisable; and similar attempts with cotton have proved altogether failures. Maize, on the other hand, is highly spoken of by Stainbank, from experiences in Natal. It should be planted thinly in three rows, 18 in. apart, between the coffee rows, and two plants in the coffee rows between the coffee plants. The seed should be sown immediately after the coffee is planted. It grows very quickly, and should early be thinned out to 18 in. apart in the rows; it will soon be high enough to completely shelter and partially shade the coffee, which will grow all the faster in consequence. The latter will also be benefited by the extra working of the ground. In the autumn, a dressing of manure is applied, and the ground is ploughed, or deeply hoed, preferably the former. The crop may be repeated in the following spring, reducing it, however, to two rows and one plant, and repeating the manuring and ploughing or hoeing; this time the choice between plough and hoe will be governed by the size of the coffee shrubs; the same manure will suit both coffee and maize.

Weeding.—By "weeding," is meant the eradication of every plant which is not being intentionally cultivated. The operation is performed in different ways, according to the nature of the soil. On light soils, and sloping situations, hand weeding is much the best. The labourer is provided with a pointed stick, to help in getting up obstinate roots, and carries at his waist a small bag, into which the weeds are at once thrust. They are turned out of the bags into pits dug at convenient intervals, or are heaped up in the roads, and are finally buried or burned, the latter being the surer way to destroy them. By weeding early, and repeating as often as necessary, the ground may be kept clean by hand. When hand weeding will not suffice, recourse must be had to "scraping" the ground, which is attended with a serious drawback, viz.:—that the first inch or more of the best surface mould is removed at the same time, thus robbing the plants of food, and exposing the earth to the full effects of wash. On stiff clay soils, on level plantations, and in damp, cool climates, on the other hand, hoeing is not only necessary for the perfect eradication of the weeds, but is of itself exceedingly beneficial to the soil, and, except during the dry season, should be regularly done whether weeds are present or not. When scraping or hoeing, it is imperative that the operation should be conducted from the outside towards the tree, so that the roots may be kept well covered, and the wash may easily escape into the gutters.

Pruning.—The kind of pruning first required by coffee bushes is that known as "topping." The age and height at which this operation is performed, depend in a great measure upon local circumstances; the question is also a much debated one. The object of "topping," or removing the top of the bush, is to restrain its upward growth within convenient limits, and, as a natural consequence, to strengthen and concentrate its lateral growth. According to Sabonadière, topping is commenced, in Ceylon, at the age of 12–18 months, the maximum ordinary height being 4 ft., sometimes reduced to 2 ft. He prefers to postpone the operation till the shrubs have borne the maiden crop, even though extra staking is required to withstand the wind. His plan is to remove the two primaries at the required height, by a sloping outward cut close to the stem, and then to remove the top by an oblique cut, so that the stumps resemble a cross, and a firm natural knot remains to guard against the stem splitting down. Hull (Ceylon) contends that the plants should be topped as soon as they have reached the required height, when the soft wood is easily severed by a pinch between the finger and thumb. In Natal, the shrubs are topped either at their full height—4½–5 ft.—or at 3 ft., allowing a sucker to grow up on the weather side to complete the height. The latter plan is preferred. There is much advantage gained in limiting the height to 5 ft., not only is the crop gathered more easily and without damage to the tree, but it is actually heavier, and the shrubs are more readily made to cover the ground.

The first result of topping is to induce the growth of a number of shoots, the removal of which is termed "handling" or "searching." The first to appear are vertical suckers or "gormandizers," from under the primary boughs; these are immediately rubbed off without injuring the bark. From the primaries, spring secondary branches, in pairs, and at very short intervals. All such appearing within 6 in. of the main stem are removed at once, so that a passage of at least a foot is left in the centre of the tree, for the admission of air and sun. The object of pruning is to divert the energies of the tree from forming wood, and to concentrate them upon forming fruit. The fruit of the coffee tree is borne by young wood; and, as the secondaries are reproduced when removed, they are cut off as soon as they have borne, and a constant succession of young wood is thus secured. In order that this may be regular, and to avoid weakening the shrub, the secondaries that grow outside of the foot space are left on alternate sides of the primary, their opposites being removed each year in turn; thus one is growing while the other is bearing. The one point in view must be the equal development of the tree, and the yearly growth of as much as it will bear, but no more. Branches must not be allowed to grow into or cross each other; if two or more secondaries spring from one spot, the strongest only must be retained; where a gap occurs, tertiaries may be trained to fill it, in the same way. When practicable, the bushes should be handled twice before the crop; and the pruning should be commenced immediately after the crop, and finished before the blossom comes out. Should that be impossible, it must be suspended during the 3 or 4 days of blossom time, and then be carried to completion. When it is evident that the crop on a tree will exhaust it if allowed to mature, a portion of it must be sacrificed by pruning. The loss thus occasioned is more apparent than real. In very prolific seasons, much fruit is wasted for lack of labour, and the trees are unnecessarily overtaxed, and bear poorly for some time afterwards. Everything should be done to ensure regular and even crops. The cuttings should be trenched in as manure. No branch should be allowed to bear more than two or three crops before removal. Regular and systematic pruning is one of the first essentials to successful coffee culture; where plantations have been neglected on this score, they must be very gradually reduced to proper condition, by sawing out the cross branches, and opening up the centre of the trees, in the first year; and thinning out about half the remaining wood, in the second year.

Manuring.—It is commonly said that coffee is an unusually exhaustive crop; but the exhaustion of the soil consequent upon coffee culture is a result of the peculiar conditions under which it is prosecuted, rather than of the nature of the plant itself. Better than any amount of artificial manuring, is the retention of the naturally rich surface soil, by the effective prevention of wash. As a secondary adjunct, however, judicious manuring will be highly beneficial, and even necessary in almost all cases after the first year or two. It is impossible to lay down any hard and fast rule for manuring; the most that can be done is to indicate the essential elements of coffee soils, the best artificial substitutes, and the best method of applying these substitutes. The best coffee soils appear to contain about 15 per cent. of combined iron, and alumina: the iron, if as red oxide, may amount to 20 or even 30 per cent., being a good absorbent of fertilizing constituents; but the alumina should not exceed 10 per cent. Lime is an essential, which must be supplied if wanting; this is too often overlooked, in the anxiety to furnish stimulants. The percentage of organic matter may be too high; it should represent about 0·2 to 0·3 per cent. of nitrogen. The best average manure for supplying nitrogen and potash is well-rotted dung; but its frequent application should be accompanied by a little lime, unless the soil is already very rich in that constituent; without the presence of lime, the shrubs will not receive the full benefit of the nitrogenous principles, but its use in a tropical climate must be governed by caution. Thoroughly fermented coffee pulp is a useful manure; but it is only half as valuable as dung, and costs more to apply. It should be kept covered as it is produced, and is best mixed with fermenting dung, failing which, it should be well limed. Alone, it is of small benefit; but forms a good vehicle for concentrated fertilizers. Almost all soils require a constant renewal of phosphoric acid and lime, which are not supplied by dung alone. These constituents are best furnished in the form of bones (steamed and ground), or concentrated superphosphate (containing 40–45 per cent. soluble phosphate of lime). Nitrogenous manures alone are too stimulating, and help to produce premature exhaustion, therefore bones may with great advantage be added to dung. Composts of pulp and cake are useful nitrogenous manures; but they must be accompanied by phosphates and lime. Potash seldom requires to be directly applied; but is advantageous after attacks of leaf disease. Magnesia seems to be a necessary constituent (from 0·5 to 2·0 per cent.) of all good coffee soils; when wanting, dolomite may be applied. The great object of manuring is to supply all the constituents required, and in an available form. For coffee, the nitrogen is better applied in an insoluble form (as in dung, fish-manure, or cake), than in a soluble form (as in guano, sulphate of ammonia, or nitrate of soda). Phosphates are best conveyed in bones, when a lasting effect is required; but high class superphosphates are preferable for immediate effect, as in cases of leaf disease. In tropical climates, all manures are best applied frequently and in small quantities. Regular manuring after each crop would doubtless be most generally economical and advantageous. The quantity must depend on local conditions, but should always be extra liberal after a full harvest. Artificial manures should be put out only in damp weather; dung may be applied at any time. The lime must never be in a caustic state; its best forms are gas lime and gypsum.

The manner of applying manures is not the same in all cases. No manure should be put more than 1 ft. below the surface of the ground, nor less than 18 in. from the stem of the coffee bush. On flat land, where there is no danger of wash, the manure may be spread over the surface, and hoed in to a depth of 9–12 in., or a square hole may be cut between each four shrubs, and the manure buried in it. On slopes, it is usual to dig a hole above each bush. For bulky manures, it may be 2 ft. long, 1½ ft. wide, and 1 ft. deep; for concentrated manures, its dimensions will be reduced. The holes should be filled up with any prunings or other vegetable matter at hand, and covered down firmly with the loose top soil; the new earth from the hole should be spread around the stem of the neighbouring tree to protect its roots.

Ordinary manuring is sometimes supplemented by other methods of improving the soil. One of these is to loosen it, by driving a long bar or a manure fork deeply into the ground, and then prizing up the earth, without turning it over. A second operation is that known as "mulching," or "ground thatching," which consists in covering the ground under the bushes with a layer, 6–9 in. thick, of hard long grass. The effect of this in cold, wet soils, is to keep the ground warm, and to throw off excessive moisture; in hot, dry situations, it is equally useful to retain moisture. In any case, weeds are kept down, and wash is quite prevented. When rotten, the grass may be hoed or dug in as manure. This thatching has been found a perfect cure for black bug. A third operation is called "trenching," or "waterholing." The trenches are made across the slope, and may be either open or closed. In the former case, holes, 3–4 ft. long, 12–15 in. broad, and 15–18 in. deep, are cut between each four trees; the soil taken from them is spread over the roots of the trees, while the holes are left open to act as catch-drains, and as receptacles for wash, weeds, prunings, and other vegetable matters, being emptied twice a year, and their contents spread around the roots of the shrubs. Closed trenches are ditches cut across the entire length of the coffee rows, 2 ft. wide and deep, and filled with any vegetable rubbish at hand; they are then covered with earth, and well trodden down, while the remaining soil is spread under the trees. The benefit of trenching is greatest in stiff soils. The refuse matter in the trenches should be limed, to kill grubs and other vermin for which it will form a nursery.

Diseases and enemies.—Besides peculiar conditions of climate, aspect, drainage, shade, shelter, &c., already alluded to, particular attention must be paid to the prevention or cure of certain maladies to which the coffee shrub is specially liable. The number of these insectiform and fungoid pests is considerable; but the only ones of sufficient importance to merit description are leaf-blight, fly, borer, bug, and canker.

1. Leaf-blight.—The leaf-blight of Ceylon and Southern India was first noticed in the former country about 1869, and in India two years later; by 1875, it had devastated whole districts, and since then it has been found in Sumatra and Java. Its existence at a distance from the Indian Ocean has not yet been proved, though there is some suspicion that an allied disease is indigenous to Western Africa. It is a fungus, known as *Hemileia Vastatrix*, and allied to the moulds. It is present in some form or other all the year round, and first attacks the under side of the leaves, causing spots or blotches, at first yellow, but subsequently turning black. These blotches are covered with a pale orange-coloured dust or powder, which easily rubs off; they gradually increase in size, until at last they have spread over the leaves, which then drop off, leaving the trees unable to produce crop, or to bring to maturity that which may have already been produced.

In districts affected by the south-west monsoon, during December to February, the fungus generally exists as an external parasite, in the form of long filamentous threads, covering every part of the bark and leaves, but so minute as to be invisible to the naked eye. The disease was made the subject of an official inquiry, by Daniel Morris, of the Peradineya Botanic Gardens, from whose report it appears that a successful mode of treatment has been found. Of the many materials experimented with, one only is invariably effective, viz. a mixture of best quality flowers of sulphur with caustic lime, in the proportions of 1 part (by weight or measure) of the former with three parts of the latter—1 : 2 gives much better results at increased cost—and thoroughly incorporating them before use. When small areas only are to be treated, sulphur blowers may be used for applying the powder; but it can be as effectively spread by hand, taking care that it is thrown upwards into the tree, and that the stem and branches become well coated. Sufficient will generally fall to the ground to disinfect the vegetable matter lying there; but under large and leafy bushes, a few extra handfuls may be sprinkled. This will especially apply when "mulching," or open trenching, is carried on. When once the *mycelium*, or vegetative part of the fungus, has penetrated the tissues of the leaves, no remedy can be used which will not also destroy the leaf. The only opportunity for combating the disease is while it is in the invisible filamentous state, on the exterior of the bark and leaves. At this time (December to February), each tree should be treated with about 5 oz. of the mixture, not omitting to disinfect the ground and whatever encumbers it. It has been observed that the treatment produces marked beneficial effects upon the trees in other ways; their appearance becomes more vigorous and healthy, the foliage improves in texture and colour, the wood matures and bears earlier, the blossom sets better, and the crop is heavier. The measure is preventive only. The disease being infectious, and the spores of the fungus easily distributed by wind, every precaution should be taken to eradicate it from abandoned coffee patches, and stray wild trees. Such had better be burnt, and the ground occupied by other produce. The cost per acre of the treatment is estimated as follows:—Flowers of sulphur, 1 cwt., R. 10; coral lime, 3 cwt., R. 5·25; hand spreading, R. 1·25; total, R. 16·50. In hardly any case would it exceed R. 18–20 an acre, without transport.

A disease known as "leaf-rot," rather prevalent in Mysore, is distinguished from the above, and is referred to a fungus named *Pellicularia Koleroga*, by Dr. M. C. Cooke. It appears about July, when the leaves of affected shrubs become covered with slimy, gelatinous matter, turn black, and drop off; clusters of berries also rot and fall. There is every probability that the sulphur and lime treatment would be effective in this case also. The shed leaves and fruit should be collected and burned.

Fly.—This disease has been known for many years in Dominica and Brazil; it has also spread to Venezuela, the Antilles, Porto Rico, Martinique, Trinidad, and all down the Atlantic coast of

South America. It is caused by the larvæ of a moth, scarcely $\frac{1}{6}$ in. long, named *Cemiostoma coffeellum*. The colour of the insect is dull-white or pale-grey, with a bar of black across the posterior end when quiet; its motions are very active, and it readily takes alarm. The female is either provided with an ovipositor of sufficient strength to pierce the cuticle of the leaf, beneath which the egg is deposited, or it deposits the egg in some irregularity on the surface of the leaf, leaving the future caterpillar to find its own way into the tissue. In either case, a caterpillar develops from the egg, and feeds on the cell tissue of the leaf, in all directions, between the two cuticles. The insect prefers young and delicate leaves, and is most active about the commencement of the wet season, when, doubtless, the majority of the eggs are deposited. It is dormant during the wet season—say from March to May. Of the varieties of coffee met with in Dominica, the mocha is most subject to the attacks of this moth, its leaves being the most delicate. Stronger leaved varieties, when fairly healthy, are scarcely attacked; but when existing under unfavourable conditions, such as to induce flaccidity of texture, they are sometimes much affected. The disease manifests itself by the appearance of large discoloured blotches on the leaves, causing their decay and fall. It has been stated that, by picking the leaves at such a time as to take the greatest number of the larvæ when about two weeks old, it would be easy to destroy the pest, as the size of the blotches would then easily distinguish the diseased foliage. The insect is very susceptible to the effects of wood smoke, and may easily be driven off or destroyed by the smoke of ordinary wood or grass fires. At present it does not exist in the West Indies to such an extent as to injuriously affect the fruitfulness of the trees, and is markedly less numerous where insectivorous birds abound.

Borer.—This pest, formerly known as the "worm" and "coffee-fly," is most troublesome in Southern India, especially in Coorg and the Wynaad, where, in 1865–6, it destroyed whole estates. Beetles with similar boring habits infest the coffee bushes on the West Coast of Africa, and in Zanzibar, and are occasionally troublesome in Jamaica. The Indian borer has been identified as the *Xylotrechus quadrupes*. In its complete stage, the insect appears as a winged beetle; it is $\frac{1}{2}$ to $\frac{3}{4}$ in. in length; rather finer in shape than a wasp; with a hard, shiny coat; in colour, red and black, or, in other cases, yellow and black, in alternate transverse lines. It bores a passage into the stem of the coffee-tree, usually at some few inches above the ground. This passage, at first horizontal, soon takes an upward spiral direction, and proceeds until a safe retreat is found, in which the larva may be deposited. The tree soon droops, and dies down to the point at which the entry has been effected, and where it can be easily broken off by a sharp pull at the upper part. The only course is to break off the tree in this manner, and then to burn the stem, with the larva secreted in its centre. Young shoots will proceed from the stump (if the perforation has not begun too near the roots), and one of these may be trained to succeed the original stem. There is a growing impression that the borer can be kept out of estates in hot, dry situations only by providing shade, and perhaps irrigation. Its ravages have always been worst on weedy plantations and new clearings.

Bug.—The coffee tree is attacked by various species of *Coccidæ* in most countries, where they are known by different names. Ceylon has been, perhaps, the worst sufferer in this respect; but careful cultivation has greatly reduced the evil. There are two distinct species of bug found in Ceylon, and called respectively "black," or "scaly," and "white," or "mealy." The former, *Lecanium coffeæ*, is a minute insect, which attaches itself to the tenderest shoots of the plant; the females have the appearance of small scollop shells, of a brown colour, and adhere to the leaf or twig in the same manner as the scollop shell to a rock. Each of these contains several hundred eggs undergoing incubation; and in a short time, the whole of the green wood of the tree will become covered with the young insects, and coated with a black soot-like powder, which renders the tree easily discernible at a distance. The bug will soon spread over whole estates, entirely checking the growth of the trees; the fresh young shoots are always first attacked, and such wood as is allowed to mature produces hardly any crop. The berries, moreover, are, in their earliest stage, destroyed by these insects, which cut them off at the stalk. The measures recommended for checking this scourge are to dust the bushes with a mixture of pounded saltpetre and quicklime, in equal parts; or to brush or sponge the affected parts with a mixture of soft-soap, tar, tobacco, and spirits of turpentine, in about equal quantities. A coolie, with a bucket and a piece of rag, can perform the office effectually. This species affects elevated (above 3000 ft.), cold, damp, close localities, where it is found in all stages of development all the year round, the propagation being continuous. It generally makes its first appearance under the shelter of a large rock, near a belt of forest, or at the bottom of a nullah.

White bug is a distinct species of insect, known as *Pseudococcus Adonidum*. It is small, flat, oval, about $\frac{1}{16}$ in. long, covered with a white down or fur, and having parallel ridges running across its back from side to side, like the wood-louse, though on a much smaller scale. It is found in various stages of development all the year round, and takes up its quarters on the roots of the trees to about 1 ft. beneath the surface, at the axils of the leaves, and among the stalks of the crop clusters, which it cuts off wholesale, either during the blossom stage, or just after the young berries have been formed; in the latter case, its operations may easily be recognized, by the large quantities of young green berries with which the ground beneath the trees will be strewn. It is also easily discovered by a white, flour-like excretion which it deposits around the axil nooks where it has made its abode. The prescriptions above recommended for black bug will be here found equally efficacious. In either case, probably, a decoction of common tobacco might be sufficient, while much more easily prepared. The white bug has a decided preference for hot, dry situations, and generally disappears in the wet season; too often, however, only to return as soon as the blossom has set.

Canker.—A disease which has created great havoc in Natal, and which causes an annual loss of about 1 per cent. of the trees in Jamaica, is "canker" or "bark disease." The first symptom is the withering of a tertiary or secondary branch, when it will be found that the bark under the primary branches is decayed and blue mouldy; the blue mould gradually extends downwards over the whole stem; a tree once attacked never recovers, but dies in a few months. All soils and situations seem liable to the disease, the trees beginning to suffer when about six years old. Though the mould is the proximate cause of death, the ultimate cause is evidently due to some unfavourable external condition. The opinions of experienced persons as to what this may be are various; it is attributed to neglect of cultivation, to unsuitability of climate, and to want of depth of subsoil. All may be partially right; but the last seems most probable, and is the reason given for it in Jamaica.

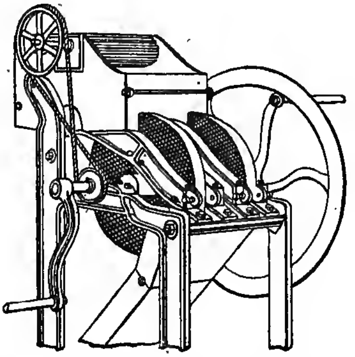
Rot, Grubs, Rats, Squirrels, &c.—"Rot," or the blackening and withering of the young leaves and shoots, is due to wet and cold, and may be cured by good drainage and mulching. Grubs of a large yellow kind destroy the tap-roots of the plants; cattle manure is a fertile source of them, and should be well limed. Rats, squirrels, grasshoppers, ants and spiders collectively do considerable mischief, and should be exterminated whenever possible. In Java, a fungus attacks the stems, giving them a white appearance, and producing death in all the parts above. In Venezuela, occurs a minute fungus named *Depazea maculosa*, which causes the so-called "iron-stain," circular or elliptical blotches of an ochreish-yellow colour. The same appears to be in Jamaica also.

Harvesting.—The clusters of buds which duly make their appearance are, at first, little, dark-green spikes; as they grow, they become straw-coloured, then under the influence of a few showers, almost white, and finally burst into snowy blossoms. After a day or two, the flowers turn brown and fade away, the more gradually, the better. While the bloom is out, rainfall is unwelcome; but after it has "set," a shower is beneficial. The pistils of the flowers soon assume the form of berries, gradually growing, and changing their colour from dark-green to light-yellow, which finally deepens to red. As soon as a sprinkling of red berries is seen, picking should begin; it will continue as long as any berries ripen, say 1 to 3 months. The berries, or rather cherries, must not be picked until fully ripe, as indicated by a deep purplish-crimson colour. As the crop rarely or never ripens all at once, two or three pickings are required, the second being the principal one, while the others are rather gleanings. Each mature cherry should be picked separately off its stalk, and never stripped off; the cherries as picked are dropped into a small bag—say 18 in. square—suspended from the neck; these bags are emptied into 1½ or 2 bushel sacks placed at intervals on the paths. If allowed to get over ripe, in wet weather, the cherries are liable to burst and drop the beans, or to fall off bodily; on clean ground, much may be recovered. In hot weather, the cherries are more likely to dry up and hold on to the trees. In order to convey the cherries to the curing houses, a great saving is effected, in long distances, by running them with water down galvanized iron spouting, made in 8 ft. lengths, laid with even gradients and curves, and duly secured. The cherries are despatched from cisterns, to which the due proportion of water is admitted; provision is made for collecting and utilizing the latter at the works.

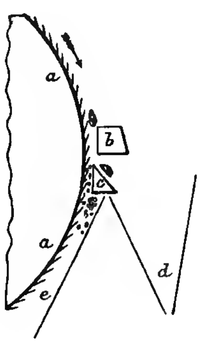
PREPARATION.—The preparation of the coffee necessitates the erection of extensive buildings and machinery; for these no specific plan can be given, because much depends upon the size and situation of the estate, and much upon the kind and degree of preparation contemplated. The site chosen for the works should be as near the centre of the plantation as is compatible with securing a patch of open airy ground, to which a good stream of water can be brought. The first requisite building is the "pulping house," comprising three floors—the cherry loft, the pulping platform, and the cisterns. Whenever possible, it should be built against a shallow cliff or embankment, so that the cherry-coffee may be delivered into the loft without being borne upstairs. The cherry loft is usually immediately over the pulping platform.

Pulping.—The operation known as "pulping" consists in liberating the coffee beans from the pulp in which they are enveloped. With ripe cherries, this is most easily and effectively accomplished immediately after picking, and efforts are usually made to complete the pulping of a day's picking during the same evening; if over ripe and shrivelled, but still comparatively moist inside, the cherries should first be soaked in water for a few hours. A number of machines have been invented for this purpose, the object in all cases being to pulp rapidly, thoroughly, and without injury to the bean; if the inner skin of the bean be broken, the latter is wasted. The most simple form of pulping machine is the "disc pulper," in which the separation of the bean and the pulp is effected by means of rotating discs, covered with a thin sheet of copper, whose surface has been "knebbed," or raised into rows of oval knobs, by the application of a blind punch. Pulpers of this class, being portable and cheap, are often used in the opening of distant estates, and commonly in India and Java. The "single" form is very light; driven by three coolies, it will pulp 20–25 bush. cherry an hour. The "double" form, shown in Fig. 500, has two discs, and is furnished with a feeding roller inside the hopper. It requires four to six coolies to pulp 40 bush. an hour; but driven by power, it will do 70–80 bush. The discs are placed between "cushions" of smooth iron, set at such a distance that the cherries cannot pass without being bruised; the cushions rest on a movable bed of iron, set so that no bean can pass downwards. When the disc revolves, the cherries are driven forward, and squeezed; the corrugations then catch the skins, and drag them between the disc and bed. These small pulpers have an advantage over the larger ones, in that each can be set to suit the size of a portion of the crop—which always varies; and with a number of machines, there is less likelihood of complete stoppage in case of an accident. One disc pulper to every 30–40 acres—say three to 100 acres: two to be set alike, and one for smaller cherries—should be ample.

500.



501.



The "cylinder pulper" is an older invention than the preceding, and has been subjected to numerous modifications. The principle is illustrated in Fig. 501; *a* is a cylinder of various diameter, revolving in the direction of the arrow. The cherries and water are guided between the cylinder and a piece of iron, called a "chop," *b*, set at such a distance that the smallest cherry is bruised while the largest bean is not damaged. The teeth of the cylinder catch in the pulp and drag it within the second chop *c*, which is made sharp at the top and is set so that while admitting the pulp it rejects the beans, which fall into the trough *d*; the pulp passes into the trough *e*. The cylinder is furnished with a toothed surface, by means of a sheet of copper pierced with a number of partial perforations, so as to resemble a magnified grater. Sometimes the punching is effected in such a manner as to produce three-cornered points, the apex of the triangle being at the top; in other cases a "half-moon" punch is used, and this is said to reduce the percentage of pricked beans. In any case, it is essential that the teeth shall be equally raised. Care must be taken to retain a bold working edge on the lower chop, as when it becomes worn and rounded, small and dry beans are liable to be caught and broken.

A very handy form of cylinder pulper is seen in Fig. 502. The pulping parts consist of an iron cylinder *a*, 24 in. by 15 in., covered with punched copper, and a pair of iron chops set to the breast of the cylinder. Below the cylinder, is a sieve *b*, provided with circular motion, for separating the clean pulped beans or parchment from the pulp and imperfectly pulped cherry. The parchment is carried by a spout to the cistern; the unpulped cherry is returned to the hopper *c*, and again passed through. Worked by six coolies, it will pulp 30–40 bush. cherry an hour; by power, 50–60 bush.

502.

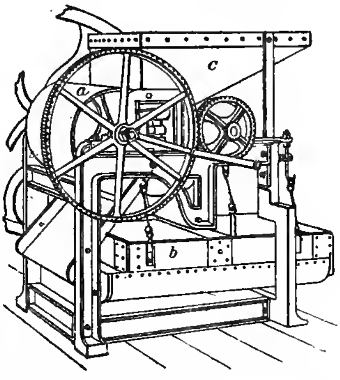
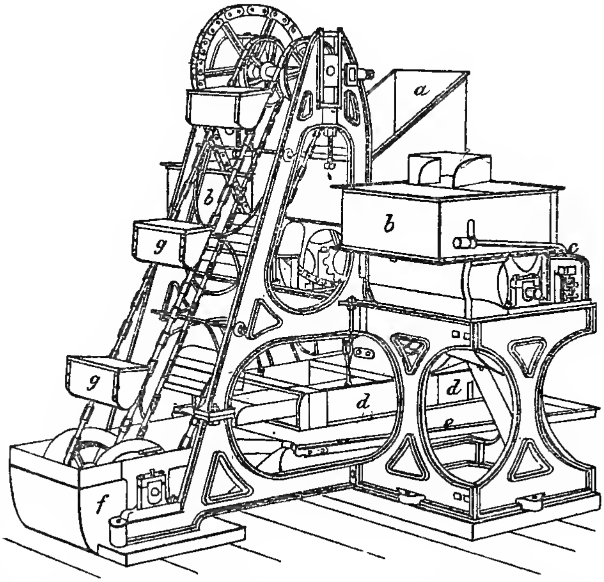


Fig. 503 represents a "gearless" pulper. It has two pulping cylinders, two pairs of chops, hopper and feed-boxes of galvanized iron, a large sieve with circular motion, and a set of elevator buckets. It easily pulps 100 bush. cherry an hour, and can be made to do 150–160 bush.; for effective speed, it requires a 16 ft. water-wheel, or a 3 h.-p. engine. The cherry is dropped into the central hopper *a*, whence it passes laterally into the two side hoppers *b*; from these, it drops on to the sides of the cylinders, and the pulping is effected at the chops under *c*. The pulp is floated away. The beans, together with some pulp and unpulped cherry, fall into a sieve *d*, through which the beans pass nearly clean, and are carried by spouts *e* to the cisterns. The pulp and unpulped cherry are delivered into a well *f*, whence they are returned, by the elevator *g*, to *a*, to be again passed through with fresh cherry.

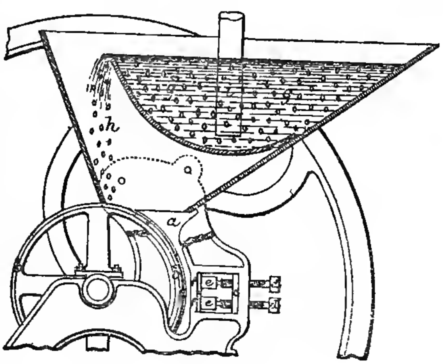
503.



The use of chops is now often superseded by a breast. This arrangement is shown in Fig. 504. The breast *a* is pushed by hand against the barrel *b*, and adjusted by the nut *c* and the screws *d*, which bear on the ends *e* of the breast by means of wooden wedges *f*; it is thus kept tightly in its place, as close as possible to the barrel without being in actual contact. The part *g* of the hopper *h* forms a water-box, to prevent stones from entering the machine. The cherry descends from the loft, through a trap-door, into the perpendicular spout *i*, reaching nearly to the bottom of the water-box. A continual influx of water carries the cherries gradually over the lip of the box into the hopper; the supply thus depends upon the rate at which the water is fed. When purchasing pulpers, care should be taken to obtain clear directions for setting them up, such as are issued by the makers, Walker Bros., Lime Street Square; and J. Gordon and Co., 8, New Broad Street.

There are three points which need attention in all pulpers—(1) regular feeding; (2) exact adjustment of the pulping parts; (3) suitable sieves. The first condition is best ensured by the arrangement shown in Fig. 504; the second will depend in a great measure, upon keeping the parts quite clean, and watching their wear; the third consists in providing a circular mesh of such a size as to stop the smallest cherry, while admitting the largest parchment bean. It is common to have sieves with two meshes, the smaller part being at the back, where the coffee comes down with force, the larger at the front, where it merely passes forward. This latter part should permit the largest beans to pass. In some seasons, there will be but little saccharine matter between the pulp and the parchment, so that they will adhere so strongly as to render pulping a difficulty. Instead of reducing the grade of the pulper, it is much better to leave it at the full size for ripe cherry, and to pass the coffee through several times, the pulp gradually becoming separated without damage to the bean.

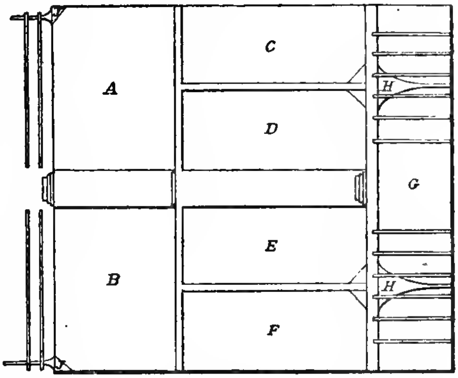
504.



The pulpers above described comprise those most commonly in use; a few others demand passing notice. The "bevel-gear" pulper is made with three pulping cylinders, or with two cylinders and a crusher. The office of the latter is to squeeze the cherries with sufficient force to effect the separation of the beans and the pulp of the larger cherries, while rendering the smaller ones more easily acted on by the pulper; it consists of a cylinder covered with overlapping steel plates, and does not get rid of the pulp, but sends everything forward into a sieve, whence all, except the proportion of pulped beans, is passed to the pulpers. It works well, but is somewhat complicated. The "double pulper and crusher" has two pulping cylinders and a fluted crushing roller, which latter is sometimes replaced by a third pulping cylinder. The "spur-gear" is cheaper than the gearless, or the bevel-gear, and will pulp 90–120 bush. an hour. "Butler's" consisted of two cylinders covered with grooved metal, revolving inversely; it worked well with uniform coffee.

Fermenting.—The "parchment" coffee, as it comes from the pulpers, is next submitted to a fermentation process, to remove the saccharine matter, without which the beans would not dry. This operation is performed in a series of tanks whose capacity will vary with the size of the estate, and which may be arranged as shown in Fig. 505. The pulpers are placed on a platform G, above the tanks, and in such a position that the pulped coffee can be run by water into the tanks, which must also be so situated that the coffee will always advance by the aid of running water, and may finally be conveniently conveyed to the drying ground, while the water and refuse run off. The amount of cistern accommodation necessary for an estate may be based on the allowance of 1 cub. ft. for each bushel of cherry picked in one day. The tanks are seldom less than three in number—two receiving cisterns, each large enough for the greatest possible daily pick, and a third for washing the parchment, nearly as large, superficially, as the other two combined. In the figure, A B are the washing tanks, 12 ft. 6 in. by 17 ft. 2 in. by 2 ft. deep, separated by a causeway 3½ ft. wide; C D E F, the fermenting tanks, each 8 ft. by 18 ft. 9 in. by 2½ ft. deep. These tanks are usually of brickwork, lined with cement or asphalt; but wood is much better, because less cold. They all have a slight incline, to assist the drainage. The receiving tanks are provided at the lowest corner with a good-sized outlet fitted with a plug, and with a movable sieve of perforated zinc or woven wire, fine enough to keep back the coffee when draining off the water, but not so fine as to choke with the saccharine scum. The receiving cisterns are used alternately. All the coffee pulped in one day is allowed to remain in the receiving cistern until a slight fermentation has set in; this occurs in twelve to eighteen hours in mild weather, but in cold weather it may take thirty to forty hours, or even more. There are two ways of conducting the fermentation—the dry, and the wet. The former consists in allowing the pulped berries to lie without water, the bottom of the tank being perforated, so as to drain off the liquid; by the latter, the tank remains full of water. The dry system is the better, as long as care is taken to turn the mass, so that the fermentation shall be equal throughout; the presence of water equalizes the fermentation, but retards it, and slightly injures the quality of the coffee. When the fermentation is not sufficiently prolonged, the beans will assume a yellowish colour—called "blanketty"—and will be difficult to dry, and liable to absorb moisture. When properly fermented, the separation of the saccharine matters is easily effected in the washing tanks, to which the beans and a good supply of water are admitted. The washing cistern is provided with a sluice door J at the lowest corner. This door commonly measures 6 in. wide by 3 in. deep. The coffee is constantly agitated by a wooden scraper or rake, by which the light coffee and refuse matters float, and may be skimmed off. The dirty water flows off through a tail-cistern, provided with a grating to catch the skins and any stray parchment. The sound berries are placed in draining boxes to remove the excess of moisture, and are then transferred to the drying ground, with the least possible delay. Should the climate be uncertain, it will be necessary to provide for the emergency of a succession of wet days, when drying cannot be proceeded with. Parchment coffee may be kept undried for a fortnight, without injury, by placing it in a cistern exposed to a continuous flow of cold water.

505.



Drying.—The berries to be dried are spread out on a flat surface exposed to the heat of the sun. The material forming the drying ground, or "barbecue," varies greatly. Very commonly, the ground is levelled, and then covered with a kind of concrete. Sometimes asphalt is laid down; but, besides being expensive, it is not sure to withstand the heat, and such surfaces are liable to crack and give way, if not very carefully drained. A very good plan is to lay down coir matting, on ground which has simply been made smooth and hard; the advantages of this plan are its cheapness, the ease with which extra ground can be requisitioned in case of need, and the use of the matting as a temporary covering in the event of a shower. Modifications of this method are to stretch coir or gunny cloth across wooden frames, or across trays with or without wheels. Shed accommodation must always be provided ready for the reception of the coffee at any moment. The beans must be constantly turned over, either by light rakes or by coolies' feet. The drying must be rendered equable, and must not proceed so rapidly as to crack the parchment before the bean is quite dry; for this reason, the coffee should not be exposed too long to a strong sun for the first day or so. During the drying, it is gathered in each day while the sun is still hot, and will then continue to dry under cover. Every care must be taken to prevent heating, which may happen by prolonged drying in mild weather; rather than permit this, the coffee should be returned to a tank, and kept washed with running water. If artificial drying can be effected, so much the better. An easy means of applying artificial heat is by passing an iron pipe, open at both ends, through a fire outside the store and below the level of the floor, continuing it into the store just beneath the floor. The heated air, passing upwards through the coffee, will carry off much of the damp. Revolving drying machines are also in the market. One of the best of these is Davey and Paxman's, originally intended for drying corn. It consists of cylinders, into which steam enters, and agitators arranged so that the coffee is impelled forwards, and caught up and rained down as the cylinder revolves. The central cylinder works in a steam jacket, outside which is a light casing of sheet iron, perforated at one end, so that air may be drawn through by a fan, to assist in the drying and to carry off the liberated moisture. This machine obviates the necessity for re-spreading the coffee on the barbecues before hulling. Three days' thorough sunning usually suffices to render the coffee quite dry and brittle, in which condition it is known as "parchment." As a rule, it is sent to port in this state, its further curing being left to the shippers; for not only is considerable expenditure on buildings and machinery necessary for the purpose, but the experience gained in manipulating various parcels of coffee will enable those who make the subject a special study to bring the sample up to the best standard of appearance and keeping properties. Coffee is said to retain its colour better, if allowed to remain for several weeks in the parchment; and its quality is said to continue to improve for months, and even years, the process being known as "curing." As, however, protracted curing causes great subsequent difficulty in removing the silver skin, coffee is never kept in the parchment longer than is compulsory.

Stores.—Though there is no necessity for curing the coffee, and it may be hulled at once, if desired, the exigencies of climate render a properly constructed store one of the greatest desiderata. The characteristic of the store must be dryness combined with security, hence galvanized iron forms the best material. It is generally of two storeys; the lower floor is sometimes boarded or asphalted, but the upper is always so made as to admit of free circulation of air through the coffee placed on it. This object may be attained by laying wire gauze, or coir matting, over reepers about 1 in. apart. Abundant ventilation must be provided. It will be necessary to watch for any signs of heating; and immediately on their appearance, the coffee must be turned over thoroughly.

An improved form of store is that built on the Clerichew principle. The floor of the upper storey, constructed as in the former case, rests on joists running lengthwise of the building. A ceiling is provided for the lower storey, by tacking to the joists, cloth which has been well soaked in boiled rice-water and whitewash, to render it air-tight; continuous air passages are thus made beneath the floor. About 10 ft. of one end of the lower apartment is partitioned off, and its sides are made as nearly as possible air-tight. It has no ceiling other than the floor above, so that the passages all open into it. In an opening in the wall of this chamber, a pair of large revolving fans are placed. Their rapid revolution draws a continuous current of air from the inside, and therefore through the coffee itself. In this way, dried parchment can be kept in perfect condition, without any turning over. By using heated air on the same principle, coffee may be housed while still only partially dry, and yet not suffer fermentation.

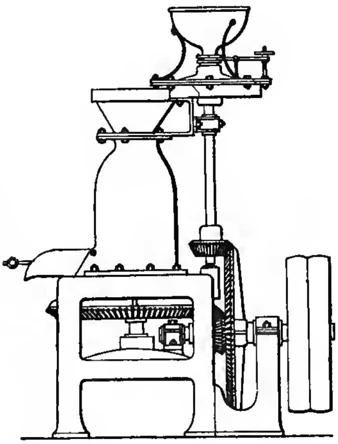
Hulling, or Peeling.—This operation consists in the removal of the "parchment" and the "silver-skin." The beans must be again exposed to the sun, for a period which it is difficult to define. Some say that they should be dried till they resist the pressure of the thumb-nail; but there is really no infallible test, as no two samples are exactly alike. It needs much experience to prevent loss of weight by over-drying, or of colour by under-drying. They peel best while still warm. A variety of hullers have been tried; but preference is commonly given to the old-fashioned edge-runner mill, composed of a circular trough with two large wheels revolving in it, and suspended about 2 in. from the bottom. The trough is one-half to two-thirds filled with beans, which remain until the grinding action of the revolving wheels has separated their skins, when they are let out by a lateral aperture. A trough 15 ft. in diameter should turn out 12 cwt. market coffee an hour; 4½ bush. good parchment coffee should give 1 cwt. clean coffee. The appearance of the coffee immediately after hulling is very light-coloured; but it soon assumes a horn-green tint, which it will retain unless exposed to damp, when it becomes dingy or mottled grey, and is classed as "country damaged."

An apparatus for peeling and polishing parchment coffee, combined with one for hulling dry cherry coffee, is shown in Fig. 506. The two parts may be disengaged and worked separately. An improved machine by which coffee of all grades may be hulled, scoured, and cleaned, and different kinds and grades of coffee may be mixed, and turned out with uniform appearance, has been patented by Patrick McAuliffe, of New York. Its operation is continuous, and it is said to create no dust.

Winnowing.—The peeled coffee, as it comes from the huller in company with the detached skins, is submitted to the influence of a fan, whose force must be so adjusted that it will effectually remove the skins without carrying off any coffee.

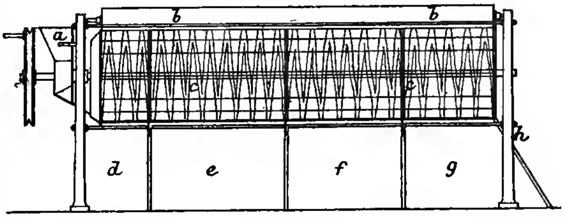
Sizing.—When the coffee has been cleaned from the skins, it is necessary to separate it into various sizes for market, chiefly with the object of rendering the subsequent roasting process more equable in its effect. Formerly, the sizing was performed by hand garbling or picking; but it is now the custom to employ a "separator," as shown in Fig. 507. It consists of an inclined, revolving, cylindrical sieve *c*, formed of perforated sheet iron, or steel wires, and divided into sections of different meshes. The coffee is fed in at the hopper *a*, which is furnished with a regulator and an internal worm, for the purpose of distributing it equally, while a revolving brush *b* prevents the meshes being choked. Sand and dust pass through the first section, and fall into the space *d*, small and broken beans are delivered at *e*, sound coffee escapes into *f*, the best and largest beans are caught at *g*, and the pea-berry rolls freely out at the end *h*. Another form of separator, known as Penney's, of Lincoln, is made adjustable, so that the gauges can be modified to suit the variations to which the crop is liable in different seasons. It is often fitted with a fan. By the use of these separators or sizers, the labour of garbling is reduced to merely picking out any stray foreign substances and unsound beans; the broken beans, or "triage," must also be separated by hand from the dust.

506.



Other Methods of Preparation.—There are times when it is impossible to pulp the coffee; the pulpers may get out of repair, or the weather may be so untoward that the cherry does not ripen sufficiently, or becomes too dry for pulping. In these cases, the cherry must first be fermented; the best way to do this is to place it in one of the tanks, or, if the quantity is too small to nearly fill a tank, in an old box or cask, and cover it with sacks or grass, or both. Here it is left until it acquires a good warmth. When the cherry, on squeezing, is no longer slippery, it may be taken out and spread in the sun to dry. For two or three nights, it need not be housed, nor will rain hurt it. When dry, it may be stored for curing, like parchment coffee, but must not be mixed with it. To ferment the cherry by leaving it in a heap on the ground is a bad plan, for two reasons: first, because when fermented it becomes very wet, and collects dirt, which, in the after treatment, will affect the colour of the coffee; second, because in a heap, the fermentation cannot be equal throughout the sample. Pulping is performed whenever possible, as the increased trouble entailed by the other process is not compensated for by the alleged improvement of the flavour, and no better price is got in the market.

507.



The native coffee of the East Indies is dried in the cherry; the dried pulp is then removed by pounding in common paddy-pounders, and the refuse is winnowed away in native baskets. Besides being tedious, ineffective, and expensive, the process gives a large proportion of damaged beans, and does not secure a regularity of colour.

Packing and Shipment.—As soon as the coffee has been sized and garbled, it is ready for the market. It is best packed in air-tight casks, made from wood which is not likely to taint the coffee in any way. Bags are sometimes used, double, but are inferior to casks. In shipping coffee, great care is required to prevent its coming into contact with other merchandise which may communicate to it a flavour or odour. Vessels carrying coffee should have perforated ventilating tubes from the bottom of the hold, passing through the cargo, and allowing the escape of the steam and gases generated during transit. Without this, the beans will be discoloured, and classed as "country damaged," an accident which cannot be covered by insurance. In well-ventilated ships, coffee loses about $\frac{1}{2}$ per cent. in weight, but gains in quality; under bad ventilation, there will be a gain of $\frac{1}{2}$ per cent. in weight, but a loss of colour, and consequent depreciation in value.

Market Varieties and Values.—The following list is intended to show the comparative prices (in shillings per cwt.) of the principal brands of coffee brought into the home market in 1878 and

1879:—*Jamaica*—good mid. to fine, 99–110, 103–126; low mid., 84–98, 92–102; fine ord. 60½–83. 71½–90; good ord., 58–60, 68–71; ord. and triage, 50–56, 63–7. *Ceylon* (Native)—bold, 66–72, 75–80; good and fine ord. 63–4, 70–4; small and ord., 50–61, 62–9; (Plantation)—fine, 102½–112, 109–17; fine mid., 100–2, 106–8½; good mid. 96½–9½, 103–5½; mid. 93–6, 100–2½; fine ord. to low mid., 82–92½, 84–99½; mixed and triage, 62–81, 68–83. *Other East India*—fine and sup., 106½–15, 110–28; good to fine, 101½–5, 107–9½; mid. to good mid., 92–101, 100–6½; fine ord. to low mid., 77–91½, 84–99; ord., 70–6½, 72–82; Native, 68–72. *Mocha*—fine yellow, 102–10; mid. to good, 93–100, 96–100; ungarbled, 80–2. *Java*—yellow, 77–94, 90–100; pale and mixed, 63–76½, 75–89. *Manilla*—54–65, 62–76. *Singapore*—50–64, 58–75. *African*—50–3, 52–7. *Rio* and *Santos*—washed, 77–97, 83–101; fine ord. and sup., 56–70, 64–80; good ord., 54–5, 61–3; ord., 45–53, 48–60. *La Guayra*—62–90, 76–97. *Costa Rica*—fine, 91–100, 92–100; mid., 84–90, 86–91; ord. to fine ord., 68–83½, 66–85. *Guatemala*—68–83, 70–85; mid. to fine, 84–97, 86–98. *New Granada*—70–98, 80–107. *Porto Rico*—75–100, 86–102. Also, occasionally, *San Domingo*—60–75. *Mexican*—65–84. *Savanilla*—plantation, 80–105; native, 62–78.

The commercial value of coffee depends upon the form, size, colour, smell, flavour, age, and uniformity of the beans; and on the presence or absence of stones, stems, and other foreign matters. The source is only partially valuable as an index of quality. Form is not a sure guide as to source, as it varies in the same sample; there are, however, three typical forms:—Mocha, small rounded (pea-berry); pointed Bourbon, medium sized, elongated, and pointed; and Martinique, large and flattened. Brazil, Martinique and Java coffees are of fairly regular size; but those of San Domingo and Mocha are very irregular. As a rule, medium sized beans have the best flavour. Colour depends entirely upon local peculiarities of growth and preparation; generally speaking, the coffees of the Old World are inclined to yellow, those of the New, to green. Weight decreases by keeping. Odour is a distinctive test, but requires long experience:—green Mocha resembles tea; Martinique and Jamaica, pure and pleasant; Porto Rico, less agreeable; Brazil, strong, varying in Rio and Santos; Java and Sumatra, sharp; Manilla, very pronounced. Flavour is another good test:—Mocha is best; Martinique, very agreeable; Guadaloupe and Porto Rico, less so; Padang, inferior to Java; Sumatra, slightly bitter. As to impurities:—San Domingo is usually very dirty; Ceylon, East India, Rio, Santos, Martinique, and Java, generally well prepared and clean. The nutritive or stimulating value of the sample depends upon the percentage of cafeine, which can only be ascertained by analysis.

Imports and Duties.—The imports of coffee into the United Kingdom were, in 1874, 1,405,900 cwt.; 1875, 1,590,000; 1876, 1,362,600; 1877, 1,608,000; 1878, 1,270,000. The supply of 1878 was contributed as follows:—Ceylon, 506,000 cwt.; Brazil, 201,000; Madras, 157,000; Central America, 156,000; British West Indies, 57,000; United States, 26,000; San Domingo, 26,000; New Granada, 16,000; Bombay and Scinde, 14,000; Straits Settlements, 14,000; Belgium, 14,000; Aden, 13,000; West Coast of Africa (foreign), 10,000; Cape of Good Hope, 9000; France, 9000; Germany, 9000; Asiatic Turkey, 5000; British Honduras, 5000; Venezuela, 5000; Portugal, 4000; Philippines, 3000; Spanish West Indies, 3000; Mexico, 1000; Holland, 1000; Bengal and Burmah, 700; Other Countries, 4000. The duties are:—on raw coffee, 14*s.* a cwt.; on kiln-dried, roasted or ground, 2*d.* a lb.

The receipts (stated in cwts.) at the principal European entrepôts during the first 11 months of the years 1876–7–8 respectively, were:—Hamburg, 1,508,000, 1,546,000, 1,482,000; Holland, 902,000, 1,509,000, 1,292,000; Havre, 710,000, 580,000, 823,000; Antwerp, 537,000, 479,000, 577,000; Trieste, 251,000, 225,000, 247,000. The imports (in cwts.) at Hamburg in the years 1874–78 were:—from Santos, 408,000, 379,000, 379,000, 440,000, 471,000; Rio, 274,000, 396,000, 395,000, 429,000, 320,000; La Guayra and Curaçao, 130,000, 175,000, 213,000, 183,000, 218,000; San Domingo, 85,000, 120,000, 115,000, 112,000, 82,000; Maracaibo and Costa Rica, 63,000, 36,000, 82,000, 82,000, 95,000; East Indies, 67,000, 54,000, 56,000, 80,000, 93,000; Other Countries, 313,000, 456,000, 323,000, 354,000, 316,000. In France, a duty of 156 fr. the 100 kilos. (about 65*s.* 5*d.* a cwt.) is charged on coffee imported directly, and an additional 20 fr. when it comes through a European entrepôt. The imports (in quintals of nearly 2 cwt.) at Trieste, in 1877–78, were:—from Brazil, 54,000, 74,000; Ceylon, 42,000, 41,000; Java, 9000, 12,000; Mocha, 3850, 4210; Malabar, 6000, 4000: San Domingo, 3430, 1690; La Guayra, 50, 1410; all others, 5000, 4000.

The imports into the Atlantic States of America were, in 1877, 152,327 tons; in 1878, 147,030 tons. Of the whole imports into the United States, in 1878, New York received 68·74 per cent.; this was contributed (in millions of lb.) as follows:—Brazil, 148; Maracaibo, 25; Java and Sumatra, 16; Hayti, 16; La Guayra and Porto Cabello, 9; Costa Rica and New Granada, 5; Mexico, Africa, &c., 3; Europe (excluding Holland), 3; Jamaica, 1; Holland, 0·6; Singapore, 0·3; Bolivar City, 0·2; Curaçao, 0·07; Ceylon, 0·05; Porto Rico, 0·02; Cuba, 0·03; Manilla, —; Macassar, —. The imports (in millions of lb.) at San Francisco, in 1876–7–8 respectively, were:—from Central America, 8·5, 15, 14; Manilla, 12, 1, 0·6; Java, 1, 0·4, 0·5; Hawaii, 0·1, 0·15, 0·1; Rio. 0·1, 0·25, 0·4; Ceylon, 0·045, —, —; Tahiti, 0·005, 0·015, —; Mocha, 0·005, 0·002, —; Mexico, 0·002, 0·002, 0·008; Peru, —, 0·003, —; Chili, —, —, 0·0005. In America, there is no duty on coffee imported in berry.

Consumption and Prospects.—The following figures, taken from the latest official returns, show the total consumption (in millions of lb.) of coffee in the chief countries where it is used, and the estimated consumption per head of the population; the figures in brackets indicate the estimated per capita consumption in 1873:—United States, 310 : 6·5 (7·6); German Empire 218½ : 5·0 (——); France, 120 : 3·25 (2·73); Holland, 70 : 18·0 (21·0); Belgium, 50 : 10·0 (13·48); Austro-Hungary, 36¼ : 1·0 (2·13); United Kingdom 34¾ : 1·0 (1·0); Italy, 28 : 1·0 (1·0); Sweden, 25 : 5·0 (6·11); Switzerland, 18 : 6·0 (7·0); Norway, 13½ : 7·0 (9·8); Russia 10⅓ : 0·15 (0·19); Denmark, 9 : 4·5 (13·89); Greece, 1¾ : 1·0 (1·42). From this, it would seem that the consumption of coffee does not increase at the same rate as the population, at least in the non-producing countries. In the East, on the other hand, it is said to be daily gaining favour with the natives. The comparatively trifling consumption in the United Kingdom may probably be ascribed to three causes:—the competition experienced from cocoa, and good cheap tea; the comparative ease with which these are prepared; and the extent to which coffee is adulterated. The spread of the coffee-house movement, and education of the people in the preparation of the beverage, should effect a revival. Meantime there is abundant scope in foreign markets; and if the Ceylon planters will only make a real and combined effort to stamp out the leaf disease, they may reap a double benefit, while Brazil, their great rival, is struggling against a disturbed labour market.

Adulterants and Substitutes.—Scarcely any dietetic article is so persistently adulterated. Its sophistication by means of chicory (see Chicory) seems to be a recognized custom. Recently, a substitute for chicory has been introduced, under the name of "mochara," which is said to consist simply of ripe figs, roasted and pulverized. The preparation is stated to have been for some time in use on the Continent; but its introduction to English markets was, till now, rendered impossible by Customs restrictions. It is sold at about half the price of coffee. Another illustration of the modern craze for replacing every genuine article by an inferior substitute is to be found in the announcement of a company to work Henley's patent for making coffee out of dates! In New Zealand, the berries of *Coprosma Baueriana* have been proposed as a coffee substitute. The seeds of *Cassia occidentalis* have been imported into Liverpool from the River Gambia, under the name of "negro coffee."

Coffee-leaves.—A decoction made from the leaves of the coffee shrub has long been used in the Eastern Archipelago, and has more recently been introduced to the coolies in Southern India. A few years since, it attracted considerable notice, and was recommended as a new article of import, to become a cheap substitute for tea. There seems to be no doubt that coffee-leaves contain the principle caffeine in sufficient abundance to make a valuable beverage, but the presence of an unpleasant senna-like odour would militate greatly against its popularity. As regards price, it is said that coffee-leaves could be prepared (like tea) and shipped at 2*d.* a lb., as against teas at 6*d.* to 10*d.* There exists, however, the difficulty that depriving the tree of its foliage damages the crop of berries, and injures the tree itself; on berry-producing trees, therefore, only the leaves obtained in the ordinary pruning operations would be available, and these would seem to yield so small a supply as not to be worth the cost of collection. Growing the shrubs for leaf alone would be a very questionable undertaking; but there appears to be no valid reason why, in the event of the berry crop failing, a portion at least of the leaves might not be gathered and prepared, if any means can be found for removing the objectionable odour. It has been urged that the product would chiefly be employed to adulterate tea; but, even if such were the case, it is manifestly better than many of the adulterants now in common use, and it is very doubtful whether the supply or the price would meet the requirements of the case.

Local details of Culture and Production.—The chief details of the local variations from the general modes of cultivation and preparation described above, together with special remarks on the peculiarities of soil and climate, and the latest available returns of the production, of the principal coffee-growing countries, are as follow:—

Arabia.—The culture of coffee in Arabia is almost confined to the district of Yemen, and is seen to greatest perfection in the Wady Nejran and the neighbourhood of Mecca. It is generally grown on terraces, up to an altitude of 3000 ft. on the slopes of the hills; but some is cultivated on lower ground, surrounded by large shade trees. The soil is kept moist by irrigation. The harvest is gathered at three periods of the year, the principal being May. Cloths are spread under the trees, which latter are shaken, that the ripe fruit may drop. The cherries are then collected, and exposed on mats to dry in the sun. A heavy roller is afterwards passed over them to break the envelopes, and the parchment is winnowed away with a fan. They are further dried before being stored. The pulp is thus shrivelled up, and constitutes about 20 per cent. of the mass of prepared coffee. This method is peculiar to Arabia, and the produce is known by a distinct name—Kishr,—a decoction of which is the common beverage of the Arabs. The coffee is said to be improved by this way of curing; but the plan is possible only in a very dry climate. Most of the Arabian coffee is pea-berry. The high reputation it long held in European markets is not to be ascribed to superior cultivation or improved stock, but to the fact that the coffee was first shipped to India, and thence by round-about ways to Europe, so that it was generally two to three years old when it reached its destination;—it has already been remarked how much coffee improves by keeping. Nowadays, genuine "Mocha," or Yemen, coffee is never seen westward of Constantinople; two-thirds of the total yield is consumed in Arabia, Syria, and Egypt, and the remainder in Turkey and Armenia. Even in Arabia itself, the bales undergo so much sifting and picking *en route*, that the quality deteriorates perceptibly as one leaves the centre of production. At the port of shipment, it is systematically adulterated or replaced by Abyssinian and other growths. The modern "Mocha" of the English market is principally contributed by the East Indies, and in a minor degree by South American States.

Australia.—The mountain ranges on the northern coast of Australia, from Moreton Bay to Torres Straits, and other parts, are recommended for coffee cultivation. In Queensland, the plant has long been successfully grown; but it has not yet become an article of export, and the plantations have recently suffered much from disease. Though it thrives well in the neighbourhood of Brisbane, Cardwell and the northern districts, especially the sheltered ridges of the Herbert and Endeavour rivers, offer the most favourable conditions. *C. Liberica* is doing well.

Bolivia.—Coffee of several varieties is grown throughout the whole of the Yungas district, and the best produce is reckoned not inferior to "Mocha." That cultivated in the plains yields the larger berries, but of inferior flavour; that on the hills gives smaller fruit, but of improved quality. Very superior coffee grows at El Chaco; but it does not appear to be largely cultivated, owing, doubtless, to the greater profit yielded by coca.

Borneo.—Coffee has been tried here in the gardens of the Europeans, and thrives remarkably well, producing a fine and well-flavoured berry. The Malays say that it is grown by the Dyaks of the Pontianak River, for the use of that settlement; but its cultivation on an extensive and systematic scale has not been encouraged, the Government probably not wishing to create a competition with Java, which so largely produces this berry. The hills on the mainland, opposite Labuh-an, would be well adapted for the cultivation, since here coffee might be grown without the trouble and expense of raising trees amongst the plantations, to protect the bushes from the sun, as is done in Java. On the lowlands, Liberian coffee has been introduced, and is doing well.

Bourbon.—The coffee grown on this island once enjoyed a European reputation, and was the mainstay of local prosperity; but hurricanes, the decay of the trees used for shade, and the preference now given to sugar cultivation, have caused a great decline in the production of coffee. In 1817, the crop exceeded 7,250,000 lb., but in 1875, only 467,500 lb. were shipped. The land under cultivation with coffee is but about 5000 acres. Five varieties of the coffee shrub are distinguished by the natives, viz.:—1. Mocha, the first introduced into the island, superior to all others, easy to grow, but requiring shade trees for shelter; 2. Leroy, the Sierra Leone species, a hardy kind, growing readily without shade, and having a seed of inferior quality, pointed at one end; 3. Myrtle, a Mocha variety, especially remarkable for longevity, and abundant crops; 4. Aden, with small, regular berries, and a peculiar aroma, cultivated in very small quantities; 5. Marron, an indigenous variety, common in the forests of the elevated interior, with a curious pointed berry, of so strong and bitter flavour that it cannot be used alone.

Brazil.—Brazil produces about as much coffee as all the remainder of the world. In 1874, it was calculated that nearly 1½ million acres were under coffee, and that the trees numbered about 530 million. The provinces where the culture is mainly followed are Rio de Janeiro, Sao Paulo, and Bahia; the ports are Rio, Santos, Pernambuco, and Bahia. More recently, the industry has assumed considerable proportions in Minas Geraes and in Ceara, notably in the hills of Maranguape, Aratana, Batunte, Ararife, Machada, and Uraburotama. The total exports, besides a very large home consumption, in 1878, were about 500 million lb.

Coffee flourishes in most parts of Brazil, even where exposed to cold; but in the latter case, its fruitfulness diminishes, and becomes too irregular to repay for cultivation. The ground is prepared by clearing and burning, or leaving the felled timber to rot, which it does in a year or two. The young plants are usually procured from old plantations, and are put out at two years. Corn and mandioca are grown between the rows till the fourth year, when the trees are about 6 ft. high, and bear the maiden crop. At six years, they bear fully, the crop reaching 1½ lb. a tree, on poor land; 3 lb., on medium land; and 4½ lb., on superior land. An acre contains about 350 trees. The duration of an estate, even under the best circumstances, very seldom exceeds thirty years; and where the soil is light, eight to ten years is the common limit. Five to 10 per cent. of the trees are annually destroyed by fungoid pests; and planters have now to contend against a rising labour market, and want of hands. Owing to carelessness, little more than half the crop is really harvested. Foreign cultivators adopt the usual pulping and other machinery for the preparation of the coffee; but the Brazilians generally follow another plan:—The cherry coffee is spread on *terreiros*, large, smooth concrete pavements, or on bamboo frames, to dry in the sun. The berries become black and crisp; at this stage, they are rubbed, to remove the pulp, and are then washed. The pea-berries are carefully separated, to be employed in the adulteration of Mocha coffee. Much of the remainder is sent into Europe under the name of Java, Ceylon, Martinique, and St. Domingo. It is also said that in Italy, Santos and Rio growths, especially the former, are largely imported for admixture with the more expensive Porto Rico. In France, it is becoming a formidable rival to Malabar, Java, and St. Domingo. From its strong flavour, due probably to the mode of preparation, Brazilian coffee improves more than any other by keeping.

Cayenne.—Coffee was at one time an important staple of this country, the variety grown being Mocha, for the cultivation of which the country is especially adapted; it is now chiefly grown as a shade tree for cocoa, annatto, and other crops, though a few Government plantations are maintained. The average production is scarcely 100,000 lb. a year; the shipments, in 1875, were but 752 lb. The product is not, however, quite lost; although temporarily abandoned, the trees continue to thrive in a wild state, and may be reclaimed hereafter. They attain a height of about 15–16 ft., with a trunk 30 in. round at a few feet from the ground; they are rich in foliage, but do not flower; they also appear to be safe from the ravages of insects.

Celebes.—The Minahassa district produces a very superior coffee; the kernels, instead of being opaque, and having a tinge of bronze, are translucent, and of a greenish-blue colour. The best are those which have these characters, and, at the same time, are very hard; this coffee commands a much higher price than that of Java, and is superior to any raised in the Archipelago, unless it may be some that comes from the highlands in the interior of Sumatra. The general character of the produce, however, is not good, too little care being bestowed upon its preparation. The crop is subject to some variation, but the average yield of the Government gardens is never less than 5,000,000 lb. The whole number of trees belonging to the Government is over 6 million; but a large proportion of these are young, and therefore bear little or no fruit. Several private individuals also own large plantations. The trees are found to thrive best above an elevation of 1000 ft. In some districts, the produce amounts to 2–4 lb. a tree, while in others it is only ½–¾ lb. It is packed in bags on the plantations, and is transported from the small storehouses in the interior to the large ones at Menado, where it is put on board vessels either directly for foreign ports, or to be taken to Macassar, and thence be reshipped to Europe.

Ceylon.—This island is now by far the most important coffee producer of all the British possessions, occupying the rank once held by the West Indies. In 1877, it was estimated that the capital invested in Ceylon coffee culture was nearly 14,000,000*l.*, and a notable increase has taken place since. The hill region, covering an area of about 4000 square miles, is somewhat circular in form, and its most elevated parts rise to 8280 ft. above the level of the sea. Systematic coffee cultivation is almost exclusively confined to those hills, although irregular native garden plantations are found everywhere in the south-western portion of the island, even close to the sea beach. The favourite and most fruitful elevation is between 3000 and 4500 ft.; but, in a few exceptional cases, estates descend almost to the foot of the hills, whilst others are situated at 5500 ft., and even higher. Native gardens, sometimes bearing good crops, may be met with along the coast actually at sea-level. In these cases, however, the plants will invariably be found growing under the shade of suitable trees, without which protection all chance of their thriving permanently would be out of the question. These native gardens are, moreover, limited in extent, and are generally richly manured, and often well-watered during the dry season. These conclusions are borne out in those districts where coffee cultivation has been attempted below 1000 ft. elevation, abandoned properties on every side bearing evidence that humidity and rainfall have been insufficient to neutralize the high temperature. In the neighbourhood of Kandy, there are properties which, even at 1800 ft., seem to owe their present existence chiefly to shade and irrigation. In fact, the climate which is most favourable for coffee, is that in which an Englishman will find little to complain of, except occasional malaria.

There are now some forty districts in which the cultivation is carried on, containing in all about 1400 properties, of which over 1200 are in course of cultivation; these have a total area of about 300,000 acres. The average crop per acre of land in bearing has ranged, during the twenty years from 1856 to 1875, from 5·07 cwt. an acre (in 1868), to 2·75 cwt. (in 1874)—the general average for the twenty years being rather under 4·25 cwt. an acre. In 1856, the production, taking the average of two years (a good and a bad season), was 5 cwt. an acre; in 1877, this had dwindled down to 3·43 cwt. At the average yield of twenty years ago, the island should, in 1877, have exported 1,120,000 cwt. of plantation coffee, whereas it fell short by 30 per cent. This reduced production per acre is greatly due to disease, but also to inefficient transport accommodation. With these remedied, the standard of 4 cwt. an acre all round could doubtless be maintained. The native cultivation of coffee has usually been calculated to extend over 50,000 acres; but it varies very much, according to the character of the season, the prices of produce, and the cheapness of money.

The most suitable soil is that which grows soft timber, and is dark chocolate-coloured, mixed with small stones, and dotted with granite boulders. As the strongest and most continuous wind comes from the south-west, it will be evident that this aspect is the worst that can be chosen; neither would it be wise to select one directly opposite, this being exposed for some months of the year to the north-east monsoon. A bleak and exposed aspect is one of those evils that can neither be mitigated nor remedied. The monsoons, blowing incessantly for three or four months together, are assailants which coffee bushes cannot withstand. Northerly or easterly facings are perhaps the best, not being directly exposed to violent wind for any lengthened period; the latter also gets the benefit of the morning sun. The season for beginning agricultural operations is October, or the early part of November, while the buildings should be finished by the middle of January. Felling is usually commenced in October–November, and the felled timber is left for fully six or eight weeks to dry. The best time for firing is 1st–15th of February, when the prevalent dry weather and not too violent north-east wind are favourable. Pitting should begin as soon as possible after the land has been cleared, say in January or February, and may be continued up to the end of June, or until the rainy season sets in. This wet season, extending more or less through June, July, and August, is the only safe time for putting out the plants. Abundant supplies of plants of all sizes are generally to be found growing wild in the forest, in the vicinity of old estates. These, having grown up in the shade, are generally lanky and straggling, and consequently require, before being planted out in the estate, to be "stumped"; they are then very independent, and usually come on well. Where wild plants are not to be had, others can frequently be got from native gardens at a trifling rate per thousand. When plants in sufficient number are obtainable in either of these ways, a nursery is but little required; but in case the planter should not find his wants thus supplied, it will be advisable to begin making a nursery. The nursery is usually made in May-June, and should yield plants fit for putting out at the same time in the following year. The best time to obtain seed is the end of October, when a few bushels of fresh berries of the new crop can be obtained from neighbouring estates. Over the planted seeds, a layer of rotten leaves may be spread two inches thick, the bed being then well watered at least once every three days, if the weather be dry, until germination takes place. In about six weeks, the seeds will begin to force their way above ground, and to send a root downwards, when the layer of decayed leaves may be gently and carefully removed. If it is intended to put out plants that have grown for three years in the nursery, Hull recommends their being cut down to stumps in the beds in the December or January before the planting season; they will then throw out suckers, which, by July, will be 9–10 in. high. When these plants are put out, a couple of the most promising suckers may be selected, the rest being pulled off. These two (being those nearest the roots) may then grow together for a month, after which the weaker of the two is taken off, the other being left to develop into the tree. By this plan he was able, in one case, to pick a maiden crop of 2–3 cwt. an acre off plants that had been hardly eighteen months in the ground. Once the rains commence, the sooner the plants are in their places the better. Early planting is most desirable, as upon it a maiden crop may often depend. When the climate is hot, it will be necessary to erect a "pandall," or awning, to protect the young plants from the sun during the dry months. The shade must, however, be removed on the approach of the rainy season, otherwise the drip will prove injurious to the plants, which, moreover, will be strengthened by such sun and air as they are likely to get at this time of year. Staking should be performed by the middle of May, before the commencement of the south-west monsoon. The blossom generally bursts forth in March, under the influence of the showers which usually fall in that month. About October, every preparation ought to be complete for gathering in the crop. The berries begin to ripen in October or early November, and continue to come on until the middle or end of January. In some low-lying districts, however, the crop ripens more rapidly, and all must be got in within about a month or six weeks. The labourers employed on the plantations are largely drawn from Southern India, chiefly from the districts of Madura, Tinnevelly, Tanjore, and Trichinopoly, though Mysore furnishes a considerable contingent. These Coolies are brought over by *Kanganies*, or native "gangers," who receive advances from the estate managers, to enable them to furnish funds for preliminary expenses, to each Cooly who enrols himself. The usual time for their arrival in Ceylon is between May and October; and for their return home, after the harvest. Local labour is also available for carpenter's and similar work.

The advantage of providing coffee with shade trees, at any elevation less than 2000 ft., is gradually being appreciated, and, in 1877, it was estimated that about 3000 acres of plantation coffee were growing under shade. It is evident, however, from experience gained at Hantane, Nilambie and Matale, that success depends much upon the kind of tree, and that the natural forest will seldom do, the coffee not prospering, and the falling trees doing much damage in some cases. In Dumbara, cocoa has been planted among the coffee, profiting by the shade of the latter for some years, and then expanding sufficiently to return the favour. It is said that under this shade some of the worst weeds do not flourish; but, remembering how very necessary is shade to cocoa itself at all stages of its growth, it is difficult to see what ultimate good can arise. Cocoa and coffee do not prosper on the same ground elsewhere, e.g. Central America, West Indies, Natal. In Lower

Matale, coffee growing under coco-nut palms is doing well up to the age of six years, and the coco-nuts are flourishing. More worthy of encouragement is the growth of shade-giving timber trees, especially subsoil feeders. Perhaps the best adapted for this purpose in Ceylon is the native jack (*Artocarpus integrifolia*), which attains a large size, and resembles, and belongs to the same family as, the bread-fruit tree. Its presence seems to be actually beneficial to the coffee-plant, it is a subsoil feeder, it produces a fruit much valued as food by the natives, its timber is valuable for cabinet-making and building purposes, and it flourishes best precisely in those situations where its shade is most required. As it will not bear transplanting, a few seeds must be placed, a couple of inches below the surface, in each spot where a tree is required to grow, the strongest sapling being retained. The Loquat tree is planted along the roadsides on many estates, and coffee appears to thrive well under it; it yields a useful fruit, but its timber is not apparently of much value. The castor-oil plant, which grows 6–10 ft. high in a year, bearing a crop in the first year, might perhaps be found useful in some cases, as it requires little care in cultivation; but it cannot be strongly recommended for growth with coffee, being apparently a surface-feeder. Plantains or bananas, as planted for shade in St. Domingo, will not injure the coffee; perhaps, for the first few years, till the jacks have had time to grow, they might be useful. Trees for shade should not be so near each other as to prevent a free circulation of air, nor entirely to exclude the sun's rays. They may, however, in hot situations, be grown tolerably close at first, it being easy to thin them out afterwards. In order to make the trees throw out wide leafy heads, they should be trained to single stems till 10–12 ft. high, all lateral branches being kept off. This will also tend to produce large straight timber.

Estimates.—In the following estimates for the purchase of 300 A. forest land, and 200 A. grass land, bringing 200 of the former into cultivation and full bearing, the price of the former is calculated at 10*l.* an acre, the latter at 4*l.*, and labour at 9*d.* a day, including Kanganies' wages:—

First year: 1st October to 30th September following:—Land, 3800*l.*; felling, burning, and clearing 50 A. at 45*s.*, 112*l.* 10*s.*; tools, 35*l.*; coolie lines, 80*l.*; conductor's house, &c., 50*l.*; temporary bungalow, 50*l.*; nursery for second year's extension (100,000 plants), 37*l.* 10*s.*; roads, 34*l.* 10*s.*; lining out 50 A. at 5*s.*, 12*l.* 10*s.*; holing 50 A. at 5 ft. × 6 ft. = 1452 holes per A. at 25 for 9*d.*, 108*l.* 15*s.*; filling in, at 120 holes for 9*d.*, 22*l.* 13*s.* 9*d.*; 75,000 plants at 10*s.* per 1000, 37*l.* 10*s.*; planting 72,600, at 200 for 9*d.*, 13*l.* 12*s.* 3*d.*; cleaning up and weeding 50 A. at 10*s.*, 25*l.*; superintendent, 120*l.*; allowances, 12*l.*; conductor, 45*l.* 12*s.*; contingencies, 50*l.*; = total, 4647*l.* 3*s.*

Second year (cultivation, 50 A., and extension, 50 A.):—weeding, 50*l.*; supplying vacancies 10*l.* 8*s.* 6*d.*; repairing buildings, 20*l.*; roads and trenching, 15*l.*; replanting nursery, 20*l.*; additional lines, 50*l.*; tools, 25*l.*; felling, clearing, lining, holing, filling in, and planting, as before, 270*l.* 1*s.*; roads, 1 mile, 12*l.*; cleaning and weeding, as before, 25*l.*; superintendent, 182*l.*; horse, 40*l.*; conductor, 51*l.* 12*s.*; contingencies, 50*l.*; = total, 821*l.* 1*s.* 6*d.*

Third year (cultivation, 100 A., and extension, 50 A.):—weeding, 100*l.*; supplying vacancies, 15*l.* 13*s.*; repairing buildings, 30*l.*; roads and trenching, 22*l.* 10*s.*; replanting and manuring nurseries, 25*l.*; topping and handling 50 A., at 7*s.* 6*d.*, 18*l.* 15*s.*; additional lines, 50*l.*; tools, 25*l.*; felling, &c., 50 A., as before, 270*l.* 1*s.*; roads, 1 mile, 12*l.*; cleaning and weeding, 25*l.*; pulping house, machinery, and store, 400*l.*; picking 850 boxes (125 cwt.) cherry, at 7*d.* a box, 24*l.* 15*s.*; curing, at 1*s.* a cwt., 6*l.* 5*s.*; carriage, at 1*s.* a bush. parchment, 31*l.* 5*s.*; superintendent, 262*l.*; conductor, 57*l.* 12*s*; contingencies, 50*l.*; = total, 1425*l.* 16*s.*

Fourth year (cultivation, 150 A., and extension, 50 A.):—weeding, 150*l.*; filling up vacancies, 19*l.* 10*s.* 3*d.*; repairing buildings, 40*l.*; roads and trenching, 33*l.* 15*s.*; partially replanting nursery, 12*l.* 10*s.*; topping and handling 50 A., 18*l.* 15*s.*; pruning 50 A., at 15*s.*, 37*l.* 10*s.*; completing store, &c., 400*l.*; picking 2850 boxes (425 cwt.) cherry, 83*l.* 2*s.* 6*d.*; curing, 21*l.* 5*s.*; carriage, 106*l.* 5*s.*; additional coolie lines, 50*l.*; tools, 25*l.*; felling, &c., as before, 270*l.* 1*s.*; roads, 12*l.*: cleaning and weeding, 25*l.*; permanent cattle sheds, 100*l.*; cattle, 75 head, at 3*l.*, 225*l.*; keepers, &c. (6 men), 53*l.* 12*s.*; superintendent, 312*l.*; conductor, 63*l.* 12*s.*; contingencies, 50*l.*; = total, 2108*l.* 17*s.* 9*d.*

Fifth year (cultivation, 200 A.):—weeding, 200*l.*; filling up vacancies, 23*l.* 9*s.* 6*d.*; repairing buildings, 50*l.*; trenching and roads, 42*l.* 10*s.*; nurseries, 12*l.* 10*s.*; topping and handling 50 A., 18*l.* 15*s.*; pruning and handling 100 A., 75*l.*; manuring 40 A., at 5*l.*, 200*l.*; picking 4850 boxes (725 cwt.) cherry, 141*l.* 9*s.*; curing, 36*l.* 5*s.*; carriage, 181*l.* 5*s.*; permanent bungalow, 500*l.*; stock (25 head), 75*l.*; keep of ditto, 53*l.* 12*s.*; superintendent, 362*l.*; conductor, 69*l.* 12*s.*; contingencies, 50*l.*; = total, 2091*l.* 7*s.* 6*d.*

Sixth year:—weeding, 250*l.*; filling up vacancies, 25*l.*; keeping up buildings, 50*l.*; trenching and roads, 40*l.*; nurseries, 12*l.* 10*s.*; pruning and handling 150 A. at 1*l.*, 150*l.*; ditto, 50 at 15*s.*, 37*l.* 10*s.*; manuring 40 A., at 6*l.*, 240*l.*; picking 6850 boxes (1025 cwt.) cherry, 199*l.* 6*s.* 6*d.*; curing, 51*l.* 5*s.*; carriage, 257*l.* 10*s.*; stock, 150*l.*; management, 431*l.* 12*s.*; contingencies, 50*l.*; = total, 1944*l.* 13*s.* 6*d.*

Seventh year:—weeding, supplying vacancies, maintenance of buildings and roads, trenching, nurseries, and manure, as before, 617*l.* 10*s.*; pruning, at 1*l.* an A., 200*l.*; picking, curing, and despatching 1200 cwt. crop, 593*l.* 6*s.* 8*d.*; stock, management, and contingencies, 613*l.* 12*s.*; = total, 2024*l.* 8*s.* 8*d.*

The balance sheet will then stand as under:—

	£	s.	d.		£	s.	d.
1st year:—To expenses ..	4647	3	0	By balance	4647	3	0
2nd year:— „ balance.. ..	4647	3	0				
„ expenses ..	821	1	6	„ „	5468	4	6
	5468	4	6		5468	4	6
3rd year:—To balance.. ..	5468	4	6	By 125 cwt. crop, at 90*s.* net	562	10	0
„ expenses ..	1425	16	0	„ balance	6331	10	6
	6894	0	6		6894	0	.6
4th year:—To balance.. ..	6331	10	6	By 425 cwt. crop, at 90*s.* ..	1912	10	0
„ expenses ..	2108	17	0	„ balance	6527	17	6
	8440	7	6		8440	7	6
5th year:—To balance.. ..	6527	17	6	By 725 cwt. crop, at 90*s.* ..	3262	10	0
„ expenses ..	2091	7	6	„ balance	5356	15	0
	8619	5	0		8619	5	0
6th year:—To balance.. ..	5356	15	0	By 1025 cwt. crop, at 90*s.* ..	4612	10	0
„ expenses ..	1944	13	6	„ balance	2688	18	6
	7301	8	6		7301	8	6
7th year:—To balance.. ..	2688	18	6	By 1200 cwt. crop, at 90*s.*..	5400	0	0
„ expenses ..	2024	8	8				
„ balance.. ..	686	12	10				
	5400	0	0		5400	0	0
Subsequent years:—expenses	2000	0	0	By 1200 cwt. crop, at 90*s.*..	5400	0	0

The yield of the crop is based on a first harvest of 2½ cwt. an acre, followed annually afterwards by one of 6 cwt. an acre; these figures are now manifestly too high. As to the longevity of coffee estates, there appears to be no necessary limit to the life of the plant in its natural state, and, under suitable conditions of climate, soil, and culture, it may live indefinitely. In native gardens in Ceylon, there are many trees far above half a century old, and several of the earliest European plantations still thrive and yield at upwards of forty years of age. The price of land has risen considerably since the introduction of Liberian coffee; low-lying plots that ten years since were not worth 4 R. an acre, now sell at 20*l.* No export duty is levied in Ceylon. The exports were, in 1874, plantation, 635,938 cwt., native, 97,020; 1875, 813,401 and 115,205; 1876, 586,580 and 80,585; 1877, 896,534 and 82,281.

Colombia.—According to Consul Mallet, the department of Chiriqui, in the interior of Colombia, offers a fine field for coffee culture. Planting has already been introduced, but only in a small way as yet. The fine lands lying along the slopes of the mountain ranges are said to be admirably adapted for the purpose. Land costs nothing, the climate is favourable, transport and labour are efficient and cheap. In other departments of the state, coffee culture is of old standing, the produce, especially from Ocama and Ambalima, being of excellent quality; it is, however, limited in quantity, and chiefly consumed in the country.

Costa Rica.—Coffee raised on the highlands of Costa Rica and Nicaragua is said to be unsurpassed in strength, and to possess an aromatic flavour unknown to the best Eastern growths; that grown at medium elevations is of good quality, and though without the plump form and bluish tint of the upland produce, it compares favourably with Javan or Moluccan coffee. The cultivation suffers much from want of labour. The quantities exported in the years 1875–8 respectively were about 23½ million, 10½ million, 24¼ million, and 18 million pounds. The principal consumers appear to be Great Britain, California, and France.

Ecuador.—Increasing attention is being given to coffee cultivation in Ecuador, and the produce is of good quality. The exports from Guayaquil during the years 1873–8 respectively were about 700,000; 1,000,000; 1,000,000; 800,000; 1,000,000; and 100,000 pounds. The crop of 1878 was completely spoilt by heavy rains; the yield was very inferior in quality, and so low in quantity as not to suffice for local needs.

Guatemala.—One of the principal coffee districts has suffered largely from Indian disturbances, exhaustion of the soil, and, perhaps, inadaptability of climate; but for every tree abandoned in this section, 100 have been planted in new and better lands. Probably there have been 2,000,000 new trees planted, consequently the crop of 1880–81 should exhibit a marked increase over that of any previous season. The Vera Paz or Coban district, which has its outlet on the Atlantic, viâ Yzabal and Belize, has been specially sought after by Germans and Americans, and is being industriously developed in its coffee-bearing qualities. The land and labour are cheaper than on the Pacific slope; but the yield per tree is very much less, being an average of 1 lb., while on the Pacific slope it reaches 3 lb., and even 5 lb. in some specially favoured localities. Nevertheless it is questionable which section will, in the end, produce the better results. Boddam-Whetham points out the existence of several disadvantages in the country, viz.;—the want of good roads, and the liability of losing most of the labourers at a moment's notice, in the event of their being required for military service; on some plantations too, water has to be conveyed in flumes from a distance. The advantages are that the climate is pleasant, as the plantations are situated between 2000 and 4500 ft. above the sea-level, and that hitherto there has been no disease, all the conditions for good crops being favourable. Coban coffee has a peculiar delicate flavour, and the fine plantations that are gradually arising, point to a prosperous future for this section of Vera Paz. The crop of 1878 was exported principally to the following countries:—California, about 7,500,000 lb.; England, 6,300,000; Germany, 2,800,000; France, 2,500,000; Belize (chiefly for England), 800,000; New York, 400,000; Belgium, 200,000; South America, 170,000. It was valued at 16 c. (100 c. = 4*s.*) a lb. at the port, but was barely worth 13 c. In the lower districts, the beans are dried by being spread on a *patio;* at higher altitudes, they are placed in shallow trays with perforated bottoms, and a current of warm, dry air is made to circulate through the building. The coffee is transported mostly on Indians' backs; a bag (100 lb.) is a load, and 18–24 miles constitute a day's journey, the pay for which is 9*d.*

Guiana.—Coffee culture in this colony seems to have been at its height in 1803, when nearly 10 million pounds were shipped. Since then, it has gradually declined, and, in 1874, the exports were but 40,000 lb.

Honduras.—The soil in favoured spots is very fertile, and in the gardens of Machaquila and Peten Sük, are coffee-trees yielding 7 and 8 lb. of berries. In the neighbourhood of the Belize River, Indian labour is available, and this side of the continent is much preferable to the Pacific slope, where much coffee is grown, on account of soil and climate, and more particularly as regards the effect of the sun, for it is more or less cloudy here throughout the year, affording the requisite shade to the plant. The lands here at 500–2000 ft. above sea-level, are better than the hills in the interior, if for no other reason on account of the facility of transport.

India.—Coffee cultivation in some parts of Southern India, has remarkably increased of late. The following concise statement from official sources shows the condition of the culture in the three provinces of Madras, Mysore, and Coorg, in the season 1876–7:—

Madras.—Under mature plants, 49,350 acres; under immature plants, 15,711 acres; total yield about 13¼ million pounds; average yield per acre of mature plants, 268 lb.

Mysore.—Under cultivation, 115,315 acres; total yield, about 6½ million pounds; yield varies from 1½ to 103 lb. per acre.

Coorg.—Under mature plants, 35,150 acres; under immature plants, 9000 acres; total yield, about 12 million pounds; average yield per acre of mature plants, 339 lb.

Large reserves fit for coffee-growing still exist in the Nilgiri Hills; but the Government is unwilling to encourage further deforestation. In the Wynaad district, there are reckoned to remain 200,000 acres of reserve suitable for coffee. The chief seats of the culture are the Wynaad, the Nilgiris, Mysore, Coorg, and the Shervaroy Hills. The Wynaad, officially divided into north, south, and south-east, is a district in the collectorate of Malabar, about 70 miles by 25. Its coffee is conveyed to the coast for curing and shipment, that from the northern division to Tellicherry and that from the south to Calicut, principally on pack bullocks. The Nilgiris are a spur of the Western Ghat range, running eastward, and form a bold and lofty group of mountains, containing the culminating elevation of this part of India, at upwards of 8000 ft. above the sea-level. The slopes adjacent to the approaches to Ootacamund are covered with coffee plantations on every side. Labour is not over abundant, the climate being found rather too cold and wet for the natives of the low countries; but many advantages of soil and climate render the district eminently suited for coffee cultivation. Some of the plantations are situated as high as 6000 ft. The port of shipment is Calicut, to which the crops are conveyed for a considerable distance by water. The Shervaroy Hills are situated in the centre of the Madras Presidency. Coffee cultivation has not made great progress so far, nor is the yield large. Possibly these hills are situated too far from the sea-coast, the climate being thus too dry; but by the judicious use of shade, such, for instance, as that of the jack-tree, this difficulty might be overcome. The district possesses great advantages in connection with labour supply and cheap transport, being tapped by the Madras and Beypoor Railway. In

Mysore, the principal districts where coffee culture is carried on are Munzerabad and Nugger. The slopes of the hills that rise on the plateau of Mysore are thickly clothed with plantations; and on the Bababuden range, there is hardly a spot fit for coffee raising left unoccupied. The produce fetches the highest price in the London market. The port of shipment is Mangalore. This district furnishes labour to Coorg and the Wynaad. The district of Coorg is some 60 miles in diameter, and its estates may be divided into three classes, each having peculiar advantages and drawbacks—the Mercara, the Ghat, and the Bamboo districts. The Mercara plateau varies in elevation from 3500 to 4000 ft., and is equally exposed to monsoon rains and dry easterly winds. It is well watered, the rainfall reaching 121 in., and being equally distributed throughout the year. Great precautions are needed against wash; shade is not usually required. The Ghat district was originally covered with thick forest, thus yielding a rich soil, whose fertility was increased by abundant humidity of climate. The estates have, however, been much injured by constant deforestation, by wash, and latterly by drought, and its attendant evils. The Bamboo district has an elevation of 3000–3300 ft., and an annual rainfall of about 65 in., gentle and seasonable. The ground is undulating, and the soil is very rich, not being exposed to wash. Shade is essential.

The seasons and operations in Southern India resemble in general those of Ceylon, but possess some peculiarities worth alluding to. There are distinct zones within which coffee will succeed; this is especially the case in Mysore, as has been admirably illustrated by Lewis Rice, in his exhaustive work on these regions. The raising of nursery plants is much more difficult on account of long drought and dry winds; abundance of water is, therefore, of vital importance. A northern aspect is best, being most moist during the dry season, and possessing the most uniform temperature: but it will be modified either eastwards or westwards according to the locality, so as to suit the prevailing wind. On the western slopes of the coast ranges, the south-west monsoon bursts with such force that coffee cannot withstand it; in that situation, therefore, an easterly tendency of aspect is imperative. Further inland, the drier and hotter climate will compel a westerly deviation, so as to catch as much as possible of the monsoon rains. In the western or wetter districts, shade is inadmissible; in the eastern or drier districts, it becomes a necessity. The plan of leaving individual trees when the forest is cleared, is an objectionable and obsolete way of securing shade. With the first rains after the burn, there springs up an abundance of saplings of the charcoal tree (*Sponia Wightii*). In two years, it forms an ample shade for the coffee plants; but as it grows older, the foliage becomes thin; the tree, moreover, is but short-lived, and its timber is soft and watery. While, therefore, it affords an excellent temporary shade, it must not be relied upon for permanent shade, but be replaced by other growths; being extremely light, its removal need not damage the coffee. It must be cut down while still living, as its death is said to kill the coffee under it. For permanent shade, preference seems to be given to the jack-tree, as in Ceylon; but the *Bauhinia*, *Poinciana regia*, mango, and others have their admirers. In Mysore, all coffee grown is subjected to an excise tax of 4 *annas* (6*d.*) a *maund* (25 lb.); in Coorg, there is no excise tax, but a land tax as follows;—for the first four years, *nil;* 5th–9th year, 1 *rupee* (2*s.*) an acre; thenceforth, 2 *rupees* an acre.

The following estimates (in rupees) for coffee cultivation in Southern India are based on the purchase of 300 A. of forest lands at 50 R., and 200 A. grass land at 25 R., bringing 200 A. of the former into full bearing; labour, 4 annas a day, exclusive of maistries' wages :—

First year:—Land, 20,000; tools, 350; felling and clearing, 50 A. at 20 R., 1000; coolie lines and bungalows, 1203; nursery containing say 1 lac of plants, for 2nd year's extension, 250; roads, to the estate and on the clearing, 230; lining out 50 A. at 3 R., 150; pitting, 50 A. at 5 ft. × 6 ft., say 1452 pits per acre at 4 as. for 20, 907; filling in pits, 151; plants, 75,000 at 7½ R. per 1000, 562; planting 50 A., 90; cleaning and weeding, till 30th Sept., 50 A. at 6 R., 300; superintendent, 1320; writer, 360; maistries, 10 per cent. on coolie labour, 417; contingencies, 500; = total, 27,790 R.

Second year (cultivation, 50 A., extension, 50 A.):—weeding, 900; filling up vacancies, 69; repairing buildings, 150; roads and trenching, 100; re-planting nursery, 133; additional lines, 350; tools, 250; felling, clearing, lining, pitting, filling, planting, cleaning up and weeding 50 A. at last year's rate, 2599; roads and trenching, 120; superintendent, 1800; horse, 400; writer, 420; maistries, 408; contingencies, 500; = total, 8199 R.

Third year (cultivation, 100 A., extension, 50 A.):—weeding, 1800; filling up vacancies, 10 per cent. on 50 A., 69; and 5 per cent. on 50 A., 34; repairing buildings, 225; trenching and repairing roads, 150; re-planting nursery, &c., 166; topping and handling 50 A., 125; additional coolie lines, tools, and roads, as before, 720; felling, &c., &c., 50 A., as before, 2599; pulping-house, store, and pulpers, 4000; gathering 1250 bushels cherry (say 125 cwt.), at 4 as., 312; curing at 8 as., per cwt., 62; despatching to coast, at 10 as. per bushel parchment, 390; superintendent, 2620; writer, 480; maistries, 559; contingencies, 500; = total 14,811 R.

Fourth year (cultivation, 150 A., extension, 50 A.):—weeding, 2700; filling up vacancies, 139; repairing buildings, 400; roads and trenching, 250; nursery, 100; topping, handling, and pruning, 425; additional coolie lines, tools, and roads, as before, 720; felling, &c., &c., 50 A., as before, 2599; completing store and pulping-house, 2000; gathering 4250 bushels cherry (say 425 cwt.), 1062; curing, 212; despatching to coast, 1328; superintendent, 3120; writer, 540; maistries, 789; cattle-shed, 1000; cattle (75 head), at 30 R., 2250; keepers, &c. (6 men), 432; contingencics, 500; = total, 20,566 R.

Fifth year (cultivation, 200 A.):—weeding, 3600; filling up vacancies, 173; repairing buildings, 500; roads and trenching, 400; nursery, 100; topping, handling, and pruning, 850; manuring 50 A. at 40 R., 2000; gathering 7250 bushels cherry (725 cwt.), 1812; curing, 362; despatching to coast, 2265; permanent bungalow, &c., 5000; cattle (25 head), 750; keepers (6 men), 432; superintendent, 3620; writer, 600; maistries, 981; contingencies, 500; = total, 23,945 R.

Sixth year:—weeding, 3600; filling up vacancies, 175; buildings, 500; roads and trenching, 500; nursery, 100; pruning and handling, 2000; manuring, 2500; gathering 10,250 bushels, 2563; curing and despatching, 3715; stock, 1200; superintendent and writer, 4220; maistries, 1000; contingencies, 500; = total, 22,573 R.

Seventh year:—cultivation, 9375; gathering, 12,000 bushels cherry (1200 cwt.), full crop, 3000; curing and despatching, 4350; stock, 1200; management, 5220; contingencies, 500; = total, 23,645 R.

The balance-sheet will then stand as under:—

1st year:—To expenses	R. 27,790	By balance	R. 27,790
2nd year:—To balance	27,790	By balance	35,989
„ „ „ expenses	8,199		
	35,989		35,989
3rd year:—To balance	35,989	By 125 cwt. crop, at 45 R. ..	5,625
„ „ „ expenses	14,811	By balance	45,175
	50,800		50,800
4th year:—To balance	45,175	By 425 cwt. crop, at 45 R. ..	19,125
„ „ „ expenses	20,566	By balance..	46,617
	65,742		65,742
5th year:—To balance	46,617	By 725 cwt. crop, at 45 R. ..	32,625
„ „ „ expenses	23,945	By balance	37,937
	70,562		70,562
6th year:—To balance	37,937	By 1025 cwt. crop, at 45 R. ..	46,125
„ „ „ expenses	22,573	By balance	14,386
	60,511		60,511
7th year:—To balance	14,386	By 1200 cwt. crop, at 45 R. ..	54,000
„ „ „ expenses	23,645		
„ „ „ balance	15,969		
	54,000		54,000
Subsequent years:—To expenses	23,645	By 1200 cwt. crop, at 45 R. ..	54,000

Among other Indian districts where coffee cultivation has been tried, it is reported from Chittagong that it yields 9, and even 12 cwt. an acre, and that thousands of acres of excellent land can be got near navigable rivers, and where manure and labour are abundant. The joint culture of coffee and tea is strongly recommended in this district, labour being available for each in its season. It has been tried, but with little success, in the neighbourhood of Darjeeling. It seems very doubtful whether occasional cold will not always be a bar to the general spread of coffee in N. India.

The quantities and values of the coffee exports from British India (excluding Ceylon), for the last five years of which statistics have been issued, were respectively:—1874, 40,815,040 lb.; value, 1,487,411*l.*; 1875, 34,925,072 lb.; value, 1,305,335*l.*; 1876, 41,662,432 lb.; value, 1,627,027*l.*; 1877, 33,874,768 lb.; value, 1,345,882*l.*; 1878, 33,300,624 lb.; value, 1,338,499*l.*

The drought of 1877–8 affected the coffee plantations, and would of itself sufficiently account for diminished exports, if the leaf disease and the borer did not help to keep down the yield. The average value per cwt. was a little higher than in 1876–77, having been just over 45 rupees as compared with 44·4. The United Kingdom and France are the two largest consumers of Indian coffee, although in both countries it is subject to excessively heavy duties. The Australian colonies consume large quantities of tea and coffee; but they take neither the one nor the other from India. Producers in India have hitherto found a ready market in Europe for their whole production, and have had no inducement to essay the opening of a trade with Australia. Nevertheless the trade would certainly become a source of considerable profit to India, and it would be well worth while to direct attention to the matter. The exhibitions at Sydney and Melbourne offer excellent opportunities for introducing these staples to the notice of the colonists.

Java.—Java is the second largest coffee-producing country, nine-tenths of the culture being in the hands of the Government, and effected by forced labour. Around the estates a fence is planted, about 12 ft. from the outer row of the plants, generally of the *jarak*, or castor-oil plant (*Palma Christi*), intermixed with the *dádap*, or the silk-cotton tree; and, in low situations, outside of this a ditch is dug, to carry off the water. These operations commence in August or September, and by the time the ground is in perfect readiness for planting, the heavy rains are nearly over. The plants are either raised from seed in nurseries, or the estates are supplied with "stumps" from wild or casual seedlings. Nursery plants are generally removed at six months, when they are about 12 in. high; their after growth is so rapid, that in nine months they attain to 2–3 ft. in height, and at twenty months are 6–8 ft. high, and capable of bearing ¾ lb. prepared coffee per tree. The trouble and expense of nurseries in so hot a climate are, however, very great, and the second plan is often adopted. In this case, the plants grow more slowly; but they become more lasting and hardy trees. The plantations are generally laid out in squares. The distance between the plants varies according to the fertility of the soil; in a soil not considered fertile, a distance of 6 ft. is preserved; but in a rich soil, where the plant grows more luxuriantly, 8 ft. × 4 ft. is the scale hitherto commonly used. Now, these distances are deemed too small, and new estates are being laid out at 10 ft. × 9 ft., and 9 ft. × 9 ft. At all altitudes below 2500 ft., shade seems necessary, especially during the early growth of the coffee-bushes. The tree almost universally employed for this purpose is the *dádap* (*Erythrina*), of which several varieties are abundant throughout the island, the *serap*, the *dóri*, and the *wáru;* the first is preferred as affording the greatest shade. It is propagated by cuttings; and in selecting them for the coffee plantations, care is had that they are taken from trees at least two or three years old, and that they are 3–4 ft. long, of which 1 ft. at least must be buried in the ground. After the *dádaps* are planted, holes are dug, 1½–2 ft. deep, for the reception of the coffee plants. It is a common saying that where the *dádap* flourishes, there also will coffee grow; but they are not always constant or necessary companions, for many gardens in high lands contain few *dádaps.* It is probable that in future these trees will be largely replaced by *Acacia Julibrissin* (*Albizzia Moluccana*), which grows very fast, and is superior for several reasons. Indigo is frequently planted among the young coffee, chiefly in order to keep down the weeds, but also to be used as manure. As the tree waxes, no attempt is made to train it, and it grows up with several stems as a native tree. It is pruned only when branches show signs of decay, or when the borer, which is very destructive, compels the planter to cut down the attacked stems. The weeds are dug up with mammoties, to a depth of 6 in., and piled in rows between the shade trees parallel to the lines of coffee. These weeds, among which is the alang-alang, and other fodder grasses, furnish valuable cattle food. When an estate shows signs of decay, the coffee trees are all cut down, the *dádap* trees being either felled or ringed near the roots, so that they may decay gradually and fall piecemeal to the ground; the process of replanting is then repeated in the same manner as before. Thus the land may be replanted several times, and so rich is it that the last garden will be better than the first. On the other hand, the climate is as a rule far too forcing for permanent culture. The average crop is very light; and after 12–14 years, the yield is so small as not to repay the cost of harvesting. On estates below 1000 ft., the trees bear earlier and produce more, but do not last beyond ten years; at altitudes of 3000–4000 ft., they may last 30–40 years. On many of the elevated plantations, the trees grow to a height of 30–40 ft., necessitating the use of ladders to gather the crop. Such trees are grown 25 ft. × by 25 ft. apart, on terraces 25 ft. wide, planted with grass at the edge, or all over, to prevent wash. These trees yield 6–7 lb. prepared coffee. The average produce of the Government plantations is reckoned, by Jagor, at only ½ lb. a tree; that of the few private estates at 1 lb. a tree; the difference is attributed to the ill effect of forced labour. The methods of cultivation adopted by the private planters vary considerably; in some instances, the trees are topped at 4–5 ft., and pruning is attempted, but the results are not satisfactory. The condition of the Government culture has remained stationary during the last forty years. The season affords what are termed three crops; the first is but small, the second is most abundant, and the third is rather a gleaning. Owing to the scarcity of water, the labourers convey the cherry coffee to their own homes, where they pulp and wash it with wooden pestles.

Attached to every principal village, near which there are coffee plantations of any extent, there is a drying-house, to which the pulped coffee is brought; it is there placed on hurdles, about 4 ft. from the floor, under which a slow wood fire is kept up during the night. The roof of the drying-house is opened at morning and evening to admit the air, and the berries are frequently stirred to prevent fermentation. As the direct heat of the sun is considered prejudicial, the roof of the house is closed during the day. This operation is repeated till the parchment is quite dry. The berries dried in this way are small, of a sea-green or greyish colour, and are supposed to acquire a peculiar flavour from the smoke, although it does not appear that any particular kind of wood is used for fuel. When dried in the sun, the bean becomes of a pale bleached colour, is larger, specifically lighter, and more insipid to the taste than the former. According to Jagor, a period of five to six weeks is required. The most common mode of freeing the bean from the parchment is to pound the berries, when dry, in a bag of buffalo hide, great care being taken not to bruise the beans. A mill of simple construction is sometimes used, but is not found to answer so well. The coffee beans are then put into bags or baskets, kept on raised platforms till the season of delivery, when they are carried down to the store-house, sometimes by men, but generally on the backs of buffaloes and mares, in strings of 1500–2000 at a time. In some instances, however, improved machinery has been erected for pulping and curing the coffee on the West Indian plan. The crop of 1878 was estimated to be 20 per cent. below the average, chiefly owing to the drought of 1877. The finer descriptions of Samarang (West Indian preparation), Buitenzorg (ordinary preparation), Government Preanger, and Government Padang, commanded high figures; nearly the whole of the two latter brands was bought up for the United States at very advanced figures. Further large importations of Liberian coffee seeds and plants took place during the year; but from the short period of its trial, no reliable opinion can yet be formed as to its suitability. These importations were effected from or through English houses, Ceylon growths being prohibited on account of the leaf disease. The exports of Java coffee, from 1st July, 1877, to 30th June, 1878, stated in *piculs* of 122 lb., were, to Holland, 1,096,372; France, 14,767; Port Said, for orders, 6943; Italy, 5775; Singapore, 5079; America, 3993; Australia, 1107; Channel, for orders, 102.

Liberia.—The Guinea Coast of Africa, and more especially the republic of Liberia, is remarkable among coffee producing countries, as the home of a peculiar species of coffee, formerly known as *C. microcarpa*, but now finally designated *C. Liberica*. It is distinguished from *C. Arabica* by much more robust habit; it attains a greater height, and both leaves and fruit are larger and less delicate; it also prefers low elevations. In its native country, this species grows as well near the sea (100 yds., or less distant), as thirty miles inland, and the wild plant is found even yet further towards the interior. The general temperature of the coast districts ranges between 22° and 31° (72° and 88° F.) in the shade, the maximum being 33° (91° F.) and the minimum 17° (62° F.); away from the sea, the temperatures decline 1°–2° F., principally owing to the rise of the land. The limits of elevation are from sea-level on the coast to 550 ft. inland. It is as much at home on flat land as on hill slopes, provided always that the land is drained.

Though the cultivation of this plant in its native soil was started by the late President Roberts, and is extending every year, attention has principally been paid to its acclimatization in other countries. In Ceylon and Southern India, some hundreds of acres are already planted with it, and the movement is still extending. A point greatly in favour of the plant is the low altitude at which it flourishes, thus permitting the utilization of land otherwise unproductive. At the elevations where *C. Arabica* is best cultivated, this species refuses to grow, and perhaps the highest successful plantation is at about 1500 ft., at which height it was found beneficial to leave some of the forest trees as shade; probably the planting of coco-nut trees would be better. The young plants require careful protection from wind and extreme heat; but soon become hardy. The size of the trees is such that an acre will not conveniently contain more than 450. At a greater elevation than 800 ft., difficulty is experienced in ripening the fruit. Planters are sanguine that a hybrid between the Arabian and Liberian species would flourish in the zone of 1000–3000 ft. The hope that the new species would be proof against leaf-disease has been somewhat disappointed; nevertheless, the trees are very much less affected than the common shrub. The trees appear also to demand less rain and to withstand greater heat. On the score of longevity, there appears to be little difference between the two kinds. They mature early, and bare heavily; one estate in Ceylon had trees yielding a ton an acre at 4 years old; and 7 cwt. an acre is said to be an average crop. The idea of its entirely replacing the longer known variety is fanciful, yet by cultivation and preparation much may be done to improve the inferior flavour and coarseness of the berry, which now prevent its being used alone.

The plant has been largely introduced into other of our Colonies, into Brazil, and by the Dutch into Java. In the West Indies it grows exceedingly well, and bids defiance to the blight (*Cemiostoma coffeellum*); it has a further advantage in this case that the ripened berries remain so long on the trees as to enable the crop to be gathered by few hands. It flourishes best on the "heavy bottom" lands, and in poor moist lands, and is recommended as particularly valuable for planting on cocoa estates. By grafting or inarching the Arabian species on stems of *Liberica*, an increased growth is obtained.

Madagascar.—Coffee grows well in most parts of Madagascar; in recent years, large plantations have been formed along the banks of the rivers on the eastern side of the island. These are chiefly managed by Creole traders, who employ slave labour. Coffee already promises to become a very important article of export.

Mexico.—Though Mexico scarcely figures in the coffee-producing countries, its capacity and adaptability have been tested by successful cultivation. The productive regions are found on the sea slope of the mountains: on the Pacific side, from Guatemala, for more than a thousand miles to the north, till reaching a line of occasional frost in the State of Sinaloa; and on the Gulf coast, from Yucatan into Tamaulipas, for more than a thousand miles. In addition, it flourishes in the valleys of the interior, wherever the table-land is depressed to the level of tropical and semi-tropical vegetation. The elevation above the sea, at which it is cultivated, varies from 4500 ft., and even higher, down to nearly sea-level in many localities on both coasts. The production need only be limited by the extent of land brought under cultivation. Mexico as a coffee-producing country has been tested by more than fifty years of experience. That coffee has not assumed the first place in exportation is to be attributed to the same causes which have retarded all development of the country. Hitherto, the production has been mostly consumed by the home demand, which is quite large, as coffee is in very general use by all classes; but during the past few years, the cultivation has increased, so that a small exportation has commenced. The statistics of the port of Vera Cruz indicate a steady development of the export, which ought in a few years to become considerable:—1871, 672,588 lb.; 1872, 1,912,020; 1873, 3,909,446; 1874, 4,204,446; 1875, 5,375,678.

The young plants are transplanted from the nurseries at twelve to eighteen months, to the fields, which are prepared in open forests, and on mountain sides affording shade. In open fields, a growing shade must be created, usually by planting bananas; but the best cultivators set out cinchona and valuable timber trees, as oak, walnut, &c. The second year after planting gives a very slight yield of coffee; the third year, about a half crop; and the fourth year (or when the plant is five years old), a full crop. The plants are set out usually about three yards apart each way, though often closer. The cultivation consists in keeping the fields clean, and ploughing: in certain localities, irrigation is necessary; the best planters prune carefully, keeping the height at 6–8 ft. The first flowering is sometimes as early as December; the second, in February; the third and most abundant, in March and April. The berries are dried by exposure to the sun, when they shrivel, and change to a black colour. They are then put into a mortar, and the beans are hulled or beaten out with a pestle, and are then separated from the parchment by the crude process of winnowing, though sometimes a fan-mill is used. So far, no disease of plant or berry has appeared; and although great drought may diminish the crop, it does not destroy it. The flower, when in full bloom, is sometimes broken off by severe winds; but this seldom diminishes the yield.

The trees continue bearing for twenty to twenty-five years. There are, however, trees sixty to seventy years old, which are yielding a fine crop. The average yield per tree is about 1½ lb., though with intelligent pruning and manuring, it may be increased to 3 lb. a tree. It is not uncommon to find trees yielding 5–7 lb., and in very exceptional cases, 25–50 lb. each. After the plants begin to bear a full crop, the annual cost of cultivation, up to sale in local market, is 6–7 cents. a pound. The above remarks refer especially to the region around Cordova, which is at present the greatest producer of the republic, and the most accessible to the American market; but several other localities are assuming some importance. One of these is the district of Soconusco, in the State of Chiapas, immediately upon the borders of the republic of Guatemala. Several foreigners and a number of resident proprietors have embarked in the cultivation. The special advantages presented here are cheapness of land and labour; the chief impediment is the fact that this district is disputed territory, claimed by both Mexico and Guatemala, and the tenure and protection of property are insecure. The valley of Uruapan, in the State of Michoacan, has great celebrity for its superior quality of coffee. But the most noted region is the State of Colima, on the Pacific coast; its product is so highly esteemed that it commands a fabulous price in the City of Mexico, and more distant places in the republic. The favourable report on sample lots sent to Europe in 1873 gave an impetus to the cultivation. Since that year, over one million plants have been set out, and are now beginning to bear: planting continues to increase, and coffee promises to become the principal article of export. The demand is so great that large lots fetch 27½ cents per pound at the plantation, mainly for consumption in the interior, a small portion only being shipped to Germany by resident German merchants, on private orders. Colima, and some other States, have passed liberal laws for the encouragement of coffee cultivation, offering premiums for the largest crop produced, and exempting coffee lands from all taxes.

Natal.—Coffee culture in this colony seems to be struggling against adverse conditions, notably the disastrous spread of the bark disease, for which no cure has been found. This is the more to be regretted as the quality of the beans is very fair, and the demand for the article is always growing. The causes of the disease do not seem to have yet been sufficiently investigated, and without this there is little good in making suggestions as to shade, manuring, pruning, &c., as remedies. The evidence in favour of partial shade in many localities is strong; for this purpose, local varieties of *Erythrina* might be used, as in Java, &c. One planter expresses himself very strongly on the subject of topping: he condemns the adoption of a universal standard of height, and recommends for the coast lands, a height of 6–8 ft.; and for the higher lands, ranging from Fields' Hill upwards, about 5 ft. Unlike Ceylon, elevation seems but little to affect the value of Natal estates; but river-beds, and low, damp places, being liable to frost, must be avoided. Too little attention, perhaps, has been given to irrigation in the dry season. The best months for making seed-beds are September or February: when the former is chosen, the seedlings should be ready for the nursery at the time of the autumn rains (March); when the latter, the spring rains (September–October). A safeguard against the young plants being scorched is found in large castor-oil leaves; they are cut with about 9 in. of stalk, and are stuck into the ground, between each plant and the sun, soon drooping, and forming sun-shades. The plants are said to begin bearing in eighteen months after transplanting, the yield gradually increasing till the 7th or 8th year, when they should give full crops. A fair average crop is put down at 1lb. a tree all round. Nearly all the crop is used in the colony or neighbouring republics, consequently the Customs returns only show a very small proportion of the annual yield; it is impossible, however, that the entire yield of the colony has ever exceeded 20,000 cwt. The exports were, in 1874, 680 cwt.; 1875, 363; 1876, 179; 1877, 91.

Nicaragua.—A few coffee estates exist; but the export is very trifling—some 400–500 lb. annually.

Pacific Islands.—Coffee has been successfully introduced into the Fiji and the Friendly Islands, and in the course of a few years it will probably form an important export. Trees raised from seed bear fruit in the fourth year. In the Sandwich Islands, the cultivation is also progressing, large plantations having been laid out with a view to supplying the markets of Sydney, California, and Chili. Almost the whole of the produce goes at present to the United States, the small remainder being taken by China and Germany. The total export, in 1878, was 127,963 lb.

Peru.—Coffee grows luxuriantly on the mountain slopes, the crops often being so heavy as to necessitate artificial supports for the branches. Nevertheless, the export from Mollendo, the second port of the republic, amounted only to about 140 cwt., in 1878.

Philippines, &c.—Coffee thrives remarkably in the Philippines, and the berry possesses a peculiar flavour which is highly esteemed on the Continent, so that though it is by no means well prepared or nice looking, the worst brands fetch a higher price than Java growth, and the value on the spot far exceeds the current rate of the London markets. There are two kinds of coffee, viz. "Manilla" and "Zamboanga." The former is grown in the islands of Batangas, Indan, Laguna, and Cavite; its price in place, in 1878, varied between 19½ dol. and 22 dol. (dol. = 4*s.* 2*d.*) a *picul* (139½ lb.); the beans are medium-sized, and pale-green in colour. The latter variety comes from Mindanáo, and the southern islands generally. The beans are larger than the "Manilla," but yellowish-white in colour, and flabby in texture; samples also always contain much rubbish; local prices, in 1878, fluctuated from 17½ to 21 dol. a *picul.* The exports of all kinds from Manilla were, in 1877, 3843 tons, value 245,980*l.*; and in 1878, 2306 tons, value 147,560*l.* The proportion sent to Great Britain, in the latter year, was only 160 tons, and to British Colonies, 242 tons; the remainder was taken by Continental Europe. Shipment is effected in bags of 150 lb., or in cases of 200–300 lb. In the islands of Cebu and Bohol, the natives have planted patches of coffee, and small parcels of "parchment" were offered in 1878. The quality is excellent, and the price stood at 14–16 dol. a *picul.* Small quantities, of inferior growth, from Yligan in Mindanáo were offered at 12–13 dol. a *picul.* In Timor, the Portuguese are extending the cultivation among the natives; the trees mature early, 1¼ cwt. of coffee being obtained from fifty trees in 4–5 years. In Amboyna, also, a number of trees have been planted.

Siam.—In the hilly districts of the East Coast of the Gulf of Siam, the cultivation is carried on to a limited extent. Some fine samples were shown at the Exhibition of 1862.

Straits Settlements.—After a fair trial, it seems that coffee planting in Penang has not been a success. During the first 12–18 months, the plants grow well, and are strong; but the effort of bearing fruit, under the influence of long-continued drought, weakens them so that they lose foliage and fall a prey to disease. Under shade, on the plains, they stand better; but the crop is very light, and often fails altogether. On the Great Hill, the plants bear better; but the plantations are restricted to narrow limits. Liberian plants have been introduced into Singapore and Sarawak, and promise well.

Sumatra.—Among the Eastern Archipelago, this island ranks next after Java in the quantity of its produce, the cultivation having been largely adopted by the natives. The quality of the berry varies much; the dark-yellow or brown are the best, the black are inferior. The annual crop may perhaps reach 20 million lb.

Surinam.—A century ago, this colony produced 7½ million kilo. of coffee; this enormous quantity has gradually dwindled down to insignificance:—In 1875, the production was 37,357 kilo.; the export, 644 kilo.; in 1876, the figures were 12,412, and 325; in 1867, 6179, and 159. In this last year, there was one estate planted with coffee and cocoa, and four with coffee and plantains.

United States.—The Department of Agriculture, at Washington, has recently issued a circular relative to the possibility of coffee culture in some of the States, and is led to believe that the conditions of climate and soil will be found suitable in Florida, Lower California, and part of Texas. It is stated, indeed, that in the two former is found an abundance of wild coffee. In California, seed obtained from Costa Rica has been planted, and the results hitherto are satisfactory.

Venezuela.—The annual production is about ½ million cwt., the best being grown in the cooler portion of the State. The crop is gathered in October; the cherries are spread on hurdles exposed to the sun, where they ferment for 14–20 days, and then dry. Pulping is performed by machinery, and the parchment is winnowed away. The average crop is generally placed at ½ lb. a tree, which in some localities is reduced to ¼ lb.

West Indies.—The decline of coffee culture in the British West Indies since the emancipation of the negroes almost amounts to abandonment. It is commonly attributed in great measure to the ravages of the blight already described; but it is evidently traceable rather to social influences and a faulty system of agriculture. Serious attempts are now being made to restore the industry to some of its former importance, so that a sketch of the principal conditions of successful culture may be opportunely given. The best soil is an open, dark-brown or reddish loam, 1–2 ft. thick, resting on finely disintegrated but undecomposed volcanic rock. Some of the finest ground exists on declivities which can be traversed only by planting the feet at the base of the coffee stems. On some hills of this character are now to be found trees 60–70 years old, which have been uprooted and have re-established themselves. In the face of this fact, the renovation of the existing abandoned plantations should be an easy matter. The trees should be relieved of the mass of bush, weeds, and "provisions" which now smothers them, and should undergo a judicious pruning, extended over three years if necessary. In this climate, shade and shelter are undoubtedly beneficial. On old, overgrown plantations, natural shade may be left when clearing, taking care to select trees of small foliage for the purpose. When laying out new estates, greater choice will be possible.

In many instances, cocoa has been planted amongst the coffee, probably with a view of getting crops of both from the same ground. It is quite possible to grow them profitably on the same field; but each must have its own sufficient space, and thus there is no gain; besides, their habits of growth are unsuited to the arrangement.

For the purpose of shelter, there is, perhaps, nothing better than the *pois-doux* tree, especially on inferior soils and in exposed situations; hedges of it planted as a break-weather are to be found on every abandoned estate. The pimento is equally suitable, but is of slower growth. Neither is of any value as a shade-giving tree. Of all indigenous plants, the *Moricypre* (*Byrsonina spicata*) appears to be the most suitable as a protection against both sun and wind; it is a small-leaved, fast-growing, medium-sized tree, and common everywhere. The distance from tree to tree will depend on the variety of coffee grown, and the character of soil and of situation; but it is indicated by the principle of each plant being so far from its neighbour, that when all have grown to their fullest size, they do not touch by about 1 ft. Thus the distance may vary from 4 to 8 ft., or even more. A very important factor in the sum of influences which have brought the culture to its present low ebb is to be found in the greatly diminished moisture of the climate occasioned by the wholesale destruction of the forests. This is especially the case with plantations on steep hillsides; and it remains to be seen what art can do to combat the difficulty.

Cuba.—In 1847, there were over 2000 coffee estates, yielding nearly 50 million lb. annually; in 1851, sugar and tobacco had so far replaced coffee that the production fell to 13 million lb.; and now Cuba imports coffee from Porto Rico.

Dominica.—From an annual production of over 2 million lb., Dominica has fallen to nil. The effects of the negro emancipation and the coffee blight were, perhaps, felt more severely here than in the other islands. The export tariff is 13½*d.* a cwt.

Grenada.—At one time, Grenada coffee was one of the only three brands known in the London markets; cocoa has now taken its place.

Guadaloupe.—A century ago, this French colony exported 7½ million lb. of coffee; in 1874, the exports were 625,200 lb. It nearly all goes to France as of Martinique growth. In 1873, there were 3588 *hectares* under coffee, yielding about 1000 lb. a *hectare* (= nearly 2½ acres).

Hayti.—Hayti has fallen from a production of 80 million lb. in 1789, to 54½ million in 1874, chiefly owing to disastrous hurricanes. The exports in 1878 were, to Italy, 83,000 lb.; Spain, 17,000; West Indies, 11,000; France, 3000; United States, 2000; Great Britain, 1400.

Jamaica.—This hilly island used to produce large crops of fine quality. The average annual shipment in 1805–7 was 28½ million lb.; this fell to 4 million in 1864; but increased to over 10 million in 1874. The export, in 1875, was 7,136,327 lb.; 1876, 8,707,552; 1877, 9,532,887. An export duty of 6*s.* a tierce is levied. Renewed efforts are being made to extend the cultivation, and what appear to be rather extravagant hopes are being based upon the introduction of Liberian coffee. Some plants of this variety, introduced in 1874, were placed in cinchona propagating houses, and then distributed to planters at all altitudes; those put out at the lower elevations attained the greatest success. In Jamaica, common coffee is cultivated at all heights, from the sea-level up to 5000 ft. The superior qualities, however, are only produced at heights ranging above 2000 ft., beneath which altitude the quality decreases in value as it approaches the level of the sea. As the peasantry, who are now the largest producers, almost exclusively cultivate their coffee below 2000 ft., the acquisition of a species adapted to the climate of the lowlands is a matter of great importance. A gradual diminution in the area of plantation coffee is taking place. The soil of the Port Royal Mountains, in which the best coffee is grown, is becoming more impoverished from year to year, and all the land adjacent to these plantations has been in a great measure exhausted by coffee cultivation, so that there is very little available land in their immediate proximity. These fields are confined to the southern slopes of the Blue Mountain range. The northern slopes, except near the sea, are covered with dense primeval forest, no attempts at cultivation having been made here, though these lands are the most valuable in Jamaica for coffee cultivation. It is important, however, to bear in mind that the conditions of humidity differ on the northern and on the southern slopes. On the latter side, the destruction of the forest has materially lessened the moisture, thus rendering the climate comparatively dry. The area of unoccupied land favourable for coffee, including forest on the eastern prolongation of the southern slopes, may be roughly estimated at 60,000-80,000 acres, nearly all of which belongs to government. The total area in the island now under coffee cultivation, much at unsuitable elevations, is 22,000 acres.

Martinique.—Here also coffee culture is declining, in spite of new lands being taken up. The acreage probably amounts to about 1400, the yield being reckoned at 500-1000 lb. a *hectare* (2½ acres); the total production in 1873 was 210,000 kilo.; it is mostly consumed in the island, France taking the little that is exported.

Porto Rico.—Coffee cultivation might be extended here on now unproductive land. Considerable quantities are grown in the province of Ponce, and minor quantities in Mayaguez, Arecibo, and Aguadilla. The quality is excellent, and though not well known in England, it is valued in Latin Europe. Shade is provided according to the needs of each plant. The beans are garbled for market, and those intended for the Mediterranean are polished in a mill, with the addition of a little colouring matter when necessary. The exports in *quintals* (of 101½ lb.) were, in 1874, 199,488; 1875, 256,485; 1876, 306,526; 1877, 137,140; 1878, 151,204. The destinations of the export of 1878, were: Spain, 16,771; Italy, 15,406; France, 5908; Great Britain and provinces, 5472; Germany, 4279; United States, 34; other countries (principally Cuba), 103,334.

Trinidad.—The coffee export reaches about 25,000 lb. yearly. There is said to be scarcely any part of the island where coffee culture may not be profitably undertaken; but the districts of Maracas, Aripo, and North Oroponche are regarded as possessing conditions not to be surpassed. The export duty is 11¼*d.* a cwt. The island possesses a fine Botanic Garden, in which are grown some ten varieties, or sub-varieties, of coffee. Some notes concerning their peculiarities may be of interest:—(1) Liberian coffee seems to be regarded as a means of reviving coffee culture in the Western Tropics. The plants thrive well in the ordinary red gravelly loam of the northern part of the island. From the nature of its growth, it must be planted widely, and topping is recommended at 7 ft. Prestoe advises an interval of 16 ft. between the trees, the space to be temporarily occupied by common creole coffee, which would benefit by the shade, and afford a quicker return; the latter are to be removed as soon as the Liberian plants require room, say at the 6th–7th year. (2) A narrow-leaved coffee received from Java seems well adapted for poor, rocky soils. It resists drought, is very prolific, and has a large bean; but it is slow of development. Its peculiar foliage enables it to withstand heat and drought, and renders it unliable to attack from insects and fungi. It should be planted at 6 ft.; its sturdy but stunted growth is said to obviate the necessity for topping and pruning. (3) Souffrière coffee has been so named from its occurrence on the Souffrière Hills of Dominica, where the plants remained uniformly fruitful and healthy, while surrounded by creole and Mocha trees all affected by blight and drought. The texture of the foliage makes it proof against insects; the natural habit of growth is trichotomous; and the bean is large. It seems suited for steep and barren hill-sides, and though less hardy than (2), it develops more quickly. (4) The Mocha variety is sub-divided into major and minor; the former attains a height of 7 ft.; the latter, formerly cultivated in the Maraval, St. Ann's, and Laventille valleys, does not exceed 4–5 ft., yields a smaller bean, and is less prolific. The northern hills and valleys of Trinidad might grow both sub-varieties, major in the low ground, and minor on the hills. Prestoe says that as a rule they would become most prolific under full exposure (presumably to the sun), after being established by the shade afforded by such crops as pigeon-peas, &c. Even such a scorching as to cause a partial shedding of the leaves he considers beneficial. (5) Bengal coffee differs from the others, in a very compact growth, small and long bean, and a preference for dense shade. Its peculiarly-shaped bean places it among second-class coffees as regards market price; but it is recommended for planting with cocoa, when this system of double cropping is practised.

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(See Beverages—Coffee).

CONDIMENTS.—See **SPICES.**

CORK. (Fr., *Liége*; Ger., *Kork.*)

The bark of trees consists, inwardly, of a parenchymatous or soft cellular tissue, and, outwardly, of a harder woody tubular tissue, the latter being generally the more abundant. If the growth of the parenchyma be prolonged and rapid, it will assume a more or less cork-like character, as in the case of some of the elms, the common oak, and many other trees. This peculiarity is developed to an exceptional degree in one species of oak, which has been named, from this circumstance, *Quercus suber*; it is the bark of this tree which constitutes the cork of commerce.

The tree is an evergreen, growing to a height of about 30 ft.; its acorns are edible, and resemble chestnuts in taste. It does not require a rich soil, but seems, on the contrary, to thrive best on poor and uncultivated ground. It is indigenous to the basin of the Mediterranean, and was introduced some years ago into the most temperate of the United States of America, for acclimatization. The principal cork-producing countries are:—

Portugal, especially the province of Alentejo. This cork is inferior to the French, but superior to the Italian, and is mostly shipped from Lisbon.

Spain, particularly Catalonia and Valencia.

Italy (Tuscany). A lighter and whiter variety than the Sardinian, and considered the second best imported to this country.

Sardinia produces a kind easily distinguished by its colour and weight, being pinkish-hued and heavier than the Tuscan or African sorts; said to be the best imported by us. In 1861, it was reported that the cork forests of Sardinia and Corsica had been in a great measure destroyed by improper working.

France, most abundantly in Languedoc, Provence, the environs of Bordeaux, and the Department of Var.

Africa, whose product is reckoned inferior to Tuscan. In Morocco, there are several cork forests, notably at El Araish. Algeria seems to be peculiarly favourable to the development of the cork oak, the climate having a uniformly high temperature, with profuse nightly dews, while the dry, warm, open hill sides are covered with a sufficiency of light soil. The cork thus becomes finer, more elastic, less porous, and more free from earthy particles than in Europe. The tree attains a larger growth here. The bark is usually dried in the sun; but if wetted during that operation, the drying is completed by artificial heat. There are over 2½ million acres of cork oak forest in this province, of which about 300,000 acres are utilized. It is said to be capable of producing as much cork as all the rest of the globe, if only the people could be kept to peaceful agricultural pursuits.

The tree attains to as great size in Britain as in Spain, and might be an object of cultivation in some of the warmest parts of these islands; but there is every probability that the wetness of the climate would seriously impede the operations of the cork harvest.

Portuguese acorns were planted, in 1859, in Wayne County, Mississippi, and all grew; the largest tree, eleven years later, measured 13 ft. in height. The trunk had attained a diameter of 11 in., and the cork bark was more than 1 in. thick. In 1872, the planting of cork trees was extended to Southern California.

From a correspondence which has taken place between the director of Kew Gardens and the Crown agents for the Colonies, on the subject of a supply of cork oak acorns to the Cape, it appears that the experience of sending them out to the Punjab proved that they lost their vitality very rapidly, and it became necessary to rely eventually upon a supply of young plants raised at Kew, and sent out in Wardian cases. Numerous cork oaks, however, already exist in the neighbourhood of Cape Town, and bear acorns freely, and it is believed that if these were systematically collected and sown, an adequate supply of young seedlings would very soon be procured.

In the humid district of Western Port, Australia, imported cork oaks grew 4 ft. in one year. Two other species of *Quercus* are found in Australia, viz. *Q. pseudo-suber*, and *Q. occidentalis:* the bark of the former is inferior for cork; but the latter, which is hardier than *Q. suber*, is said, by Professor von Mueller, to produce a very good cork bark.

Among the conditions necessary to successful cork-culture, climate and soil are foremost in importance. In the Mediterranean basin, the tree favours altitudes varying from 1600 to 3200 ft.; as regards latitude, it does not flourish beyond 45° N.; while the minimum average annual temperature must not be less than 13° (55° F.). The most generally suitable aspect is southerly. Slopes are always preferable to flat lands, as affording a more free circulation of air and admission of light. Considerable care should be shown in the selection of the soil. It is said that the tree in a wild state is found only on the older geological formations, as granite or clay-slate; and the experience of cultivators is that the best cork, and the most rapid growth, are produced on granitic, siliceous, and slaty (Silurian) soils, while the tree almost refuses to grow on calcareous soils. It requires abundant moisture combined with efficient drainage.

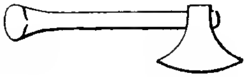
Planting is usually performed with seed. As a rule, large sweet acorns develop into trees of regular growth and yielding the finest cork; while small and bitter acorns produce trees of a coarse and inferior nature. The most approved method of planting appears to be the "furrow" or "belt" system, which consists in sowing the acorns at 20–40 in. apart in a furrow between two or more rows of grape-vines, placed at 5–7 ft. apart. The sowing and planting are conducted simultaneously, the vines affording the shelter which is so necessary to the cork tree during its early growth. The young cork trees are thinned out as required, so as to afford abundance of air and light to each.

French sivicultureists recommend an average of 110–120 trees a hectare (about 2½ acres), and calculate the production of cork at about 8 kilo. (say 18 lb.) a tree. The trees should be barked according as they arrive at maturity for the operation, rather than at fixed intervals independently of their condition. It is highly important to keep the forests cleared of the naturally-shed virgin cork, on account of the chances it offers of creating a conflagration.

The distinguishing feature of the cork oak is that parenchyma forms the mass of the bark. In the earliest stages of its growth, it is much less elastic than it ultimately becomes, owing to its containing, in the first instance, a large proportion of woody matter. The outer casing of the bark is formed during the first year's growth, and does not subsequently increase; but the parenchyma continues to grow, as long as the tree is alive. In consequence of this phenomenon, the pressure of the growing parenchyma beneath forces the outer shell to split and peel off in flakes. The substance thus shed under natural conditions is known as "virgin cork"; it is very coarse and of woody texture, its applications being, for these reasons, very limited. But the forcible removal of the cork bark, when performed in a judicious manner, is fortunately unattended with any evil consequence to the tree; on the contrary, the operation seems to hasten and assist the growth of the bark, improving its quality, at the same time that the tree waxes more vigorous, and attains greater longevity, trees which are regularly barked living to 150 years and upwards.

The age at which the first stripping may be attempted varies, with the locality, from fifteen to thirty years, the former being the most general. The yield much resembles the naturally-shed virgin cork, and is commonly included under the same term. Subsequently the barking is repeated at regular intervals of eight or ten years, the quality improving on each occasion. The second crop is, also, still too coarse for any but inferior uses. The cork harvest, as it may be called, takes place in the months of July and August, when the second sap flows plentifully. It is conducted in the following manner. An incision through the cork bark is first carried round the tree near the ground; then a similar cut, parallel to the first, is made just under the first branches; these are united by others of equal depth drawn longitudinally, and dividing the bark into broad planks. The instrument employed in the barking operations is a sort of axe, Fig. 508, the handle of which is flattened into a wedge-like shape at the extremity; in short, it is not unlike the axe used in this country for barking the common oak. After cutting, each plank is loosened from the tree by tapping it smartly, and, when thus isolated, its dislodgment is effected by inserting beneath it the wedge-shaped handle of the axe used in making the incisions. Occasionally the planks, after being cut out, are left to shed themselves, by the natural process resulting from the growth of the living bark beneath. The greatest care must be taken that the

508.



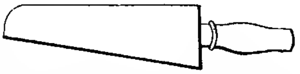
incisions do not penetrate to the inner bark, or the life of the tree would be destroyed. The thickness of the cork layer thus removed is seldom less than ¾ in. nor more than 3 in. According to the 23rd article of the laws regulating cork culture in France, the minimum thickness at which the bark may be removed is 0·023 metre (say 0·9 in.); on the other hand, no good can be gained by allowing it to exceed the ordinary thickness, as the extra amount would only cut to waste.

The freshly cut cork planks, or "tables," as they are called, have a natural transverse curve, corresponding with the shape of the tree from which they have been peeled. In order to flatten them, they are either heaped one upon another (with the concave side downwards) in deep trenches, plentifully moistened with water, and pressed beneath huge boulders; or, simply placed with the convex side towards a fire, and kept there till the heat has removed the warp. Previously to this operation, the variously sized "tables" will have been reduced as nearly as possible to uniform dimensions of about 3½ ft. long by 1½ ft. wide. The next step has for its object the closing of the pores of the cork, as non-porosity is the quality which chiefly determines the value of the article. The finest kind is compact and firm, without being hard, of even texture or grain, and slightly pink in colour. The most common method of filling up the cavities in crude cork is by placing the tables before an open fire, and heating them till the surfaces are partially charred or singed, the heating being conducted with great care, and the sides changed constantly. The objection to this process is that it causes the secretion of an empyreumatic oil, which is given off, and may be taken up by any liquid with which it comes in contact. An attempt was made to avoid this evil by using young cork, whose texture was already so close as not to require heating; but this was attended with little success, as the young cork was too thin for ordinary purposes, and could only be used by cementing several layers together. A much better plan, now often followed, is to boil the tables, scrape the surface, and then dry them in the sun. The pores are more effectually closed, and the sun-dried variety has none of the blackness of that dried by artificial heat. The "tables" are tied in bundles for transport to market.

Cork is not the only product of the cork oak. The inner bark of the tree contains about 12 per cent. of tannin, whose properties resemble those of catechu rather than the tannin of most other vegetable matters. It affords scarcely any of the light fawn-coloured deposit called "bloom," and it is doubted whether it is susceptible of conversion into gallic acid. It is not in favour with tanners, principally because it imparts a dark colour to leather on which it is used, and also because it yields no bloom. Its tannin is more easily extracted than that present in English oak bark, and, when used, it is generally mixed with the latter, or with valonea. Marseilles annually imports large quantities of it; in Italy, it is almost exclusively used in tanning sole leather; and, years ago, Ireland imported 8000 to 10,000 tons annually. It is only produced where the trees are most abundant, as its collection entails their destruction. (See Tannin.)

The uses of cork among ourselves are pretty generally known; but some of its applications where it is indigenous seem sufficiently curious. In Spain, beehives, kitchen pails, pillows, and window lights are made of it; in Portugal, it forms the roofing of houses, linings for garden walls, and fences for poultry yards; in Italy, images and crosses are carved out of it, footpaths are paved with it, and it is sometimes used in the buttresses of village churches; in Turkey, it forms cabins for the cork cutters, and coffins for the dead; in Morocco, it appears in the form of drinking vessels, plates, tubs, and house conduits; and in Algeria, shoes and wearing apparel, saddles and horse-shoes, armour and boats, landmarks and fortifications, furniture, stable-racks, and doorsteps, all consume their share. In England, its greatest and most important application is the manufacture of stoppers for bottles and other vessels, which are always known as "corks." Until recently, these corks were all cut from the "tables" by hand, and, though several machines have been invented for the purpose, many are still manufactured by manual labour. The workman sits at a bench, which has a ledge round it, to prevent the corks falling off. The knife (Fig. 509), which has a very thin and sharp blade about 6 in. long, tapering, and with a truncated end, is either placed edge uppermost in a notch on the bench, or is held in the hand. By a few dexterous circular cuts, the cork is turned out of the table, the size corresponding with the thickness of the latter. Wine-corks, &c. are cut across the grain; bungs are cut with it. The Duchy of Oldenburg, in Germany, employs probably more hands in the cork cutting industry than any other country in the world, the yearly product amounting far into millions. The work is performed at home by the whole family, after the fashion of the tenement-house cigar makers. Prices vary, but 5*s.* per diem is reckoned good wages; for the family to earn this sum, they must be skilled hands, and work hard for twelve hours. The spongy nature of cork necessitates that the edge of any instrument used to cut it should be brought into contact with it by a very drawing stroke, and the edge becomes dulled so quickly that it needs rubbing on a very fine-grained stone after every few strokes.

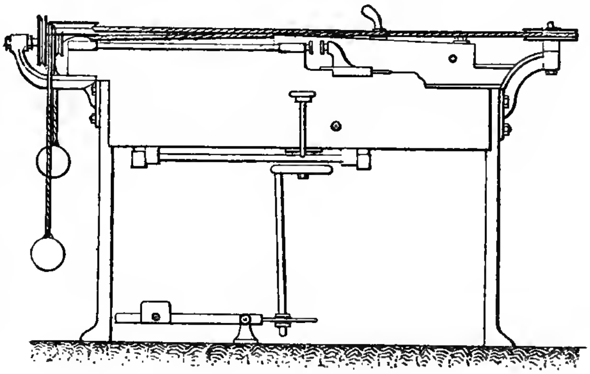
509.



The chief obstacles in the way of employing machinery for cork-cutting are the rapidity with which the edge of the cutter becomes dull, and the necessity for providing the means of adjusting the cutter so as to economize the cork, by making slight deviations from the cylindrical form where such are rendered desirable by the shape of the crude block, in order to entail the least possible waste.

The cork-cutting machine shown in Fig. 510 requires only one attendant, who works by hand, and releases the finished cork by a foot lever. It will cut corks or bungs either parallel or tapered, being provided with a second motion for taking off a second cut when required, and a stop pin for gauging the thickness of the cut and the diameter of the cork at once. It will make corks and bungs from ½ in. to 4 in. diameter, and from ½ in. to 3 in. long. The chucks are thirty-one in number, varying from ½ in. to 3½ in. diameter, the larger ones made of gun-metal, and the smaller of best wrought iron. The manipulation of the machine is easily learnt, and from 30 to 40 gross of corks can be turned out per day of ten hours.

510.



At the Vienna Exhibition, E. Boëthius, of Stockholm, showed an interesting set of cork-cutting machines, capable of being regulated to accommodate the cork, should it be too narrow or too faulty to yield a perfectly cylindrical cork. For cutting cork floats and other coarse work, hand-saws have been found to answer well, requiring less sharpening than knives. In these machines, however, knives are entirely employed, being kept sharpened by solid emery discs, revolving at high speed, arranged to maintain a razor-like edge on every blade. The work is divided into stages, a bottle-cork passing through four separate machines.

The first operation consists in cutting the "tables" into strips of adjusted width, according to the desired length of the manufactured cork; thence the strip is passed to a second machine, which trims down the thickness to correspond with the length. These are attended by a boy, and the cutters employed resemble toothless circular saws, kept as sharp as possible. Each of these machines provides material for five machines devoted to the third stage of the operation, by which the long strips are passed between a series of similar revolving cutters, and are delivered as corks in regard to their length, but square instead of round. The action here is self-regulated, and faults can be avoided as easily as by hand cutting. The fourth machine turns the square corks into cylindrical ones. The squares are put into a feeding hopper; two spindles approach in line, grip each cork between them, and turn it round against the edge of a stationary knife, by which the cork is perfected. The great point in these machines is the application of the emery wheel; and in all the stages, women and children can be employed as attendants. About 8–10 per cent. of the corks need a little hand trimming afterwards.

The following is an estimate of the cost of a factory with five cylindrical cutting-machines with accessories, to turn out about 20 million corks annually:—

Plant.

		£	s.	d.
1 Strip-cutting machine, say		112	0	0
1 Trimming „		112	0	0
5 Block-cutting „	at 90*l.*	450	0	0
5 Cylinder-cutting „	at 337*l.* 10*s.*	1687	0	0
1 Whetting „		56	0	0
1 Polishing „		28	0	0
1 Sorting „		84	0	0
1 Steam engine and boiler (four horse-power)		500	0	0
Plant for hand-cutting, sorting, &c.		337	0	0
		£3366	0	0

Working Expenses.

		£	s.	d.
Interest on capital at 16 per cent.		540	0	0
Fuel, 570 tons coal dust at 3*s.* 3*d.*, say		122	0	0
Oil for machinery, &c.		39	0	0
Knives, 20 circular at 11*s.* 3*d.*	£11 5 0			
„ 60 direct at 4*s.* 6*d.*	13 10 0			
„ 144 hand at 1*s.* 1½*d.*	8 2 0			
		33	0	0
Whetting, 3 lb. emery at 18*s.*	2 14 0			
„ 60 lb. tallow at 1*s.* 1½*d.*	3 7 6			
„ Wax	0 4 6			
		6	0	0

Labour.

	£	s.	d.
Engineer	84	0	0
Foreman	84	0	0
Cutting cork into strips, 20 million at about ½*d.* per 1000	67	0	0
Dressing ditto at ¼*d.* per 1000	38	0	0
Cutting into blocks, 13 million beer corks at 1¼*d.* per 1000	132	0	0
„ „ 3 million wine corks at 1⅓*d.* „	38	0	0
Cylindrically cutting 13 million beer corks at 1½*d.* „	161	0	0
„ „ 3 million wine corks at 1⅔*d.* „	44	0	0
Sharpening knives for cylindrical machines	38	0	0
Trimming 1,040,000 beer corks at 1*s.* 1½*d.* per 1000	58	0	0
„ 240,000 wine „ 2*s.* 3*d.* „	30	0	0
Hand cutting 3,750,000 beer corks at 2*s.* 3*d.* „	422	0	0
„ „ 250,000 wine „ 4*s.* 6*d.* „	64	0	0
Repairs	46	0	0
Contingencies	22	0	0
	£2064	0	0

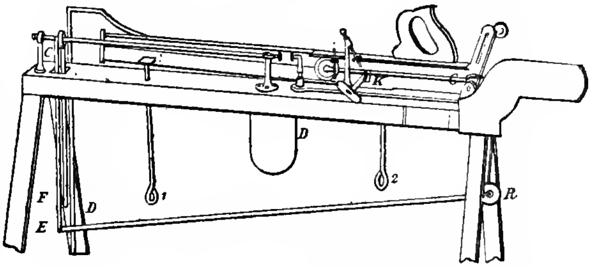
The cost for hand cutting is stated thus:—

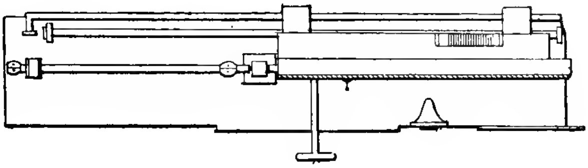
	£	s.	d.
Interest on capital required to furnish plant for a hand-cutting factory with 75 workmen, say 450*l.* at 16 per cent.	72	0	0
Fuel for warming	40	0	0
Knives, 60 dozen at 13*s.* 6*d.*, say	40	0	0
Tallow	2	0	0
Wages: three cutting strips at 67*l.* per annum, say	200	0	0
„ cutting 16,750,000 beer corks at 2*s.* 3*d.* per 1000	1884	0	0
„ „ 3,250,000 wine corks at 4*s.* 6*d.* „	730	0	0
Contingencies	64	0	0
	£3032	0	0

Perhaps the best cork-cutting machinery yet introduced is that devised by M. Powis Bale and Co., Saw-mill Engineers, 20, Budge Row, London, who have kindly furnished the following information and figures descriptive of their specialities. Figs. 511 and 512 represent a hand-power machine for cutting corks and bungs. The cork is cut into cylinders, by means of a plain steel knife, about 18–24 in. long, moving horizontally, and kept constantly sharpened by two small revolving emery discs bearing upon the cutting edge. The squares of cork to be rounded are held between spring centres, and, as the knife is pushed forwards, they receive a rotary motion by means of a lever and belt. One cork is rounded at each stroke of the knife, and is released from the spring centre by the elbow of the operator. The knife is fitted on an adjustable slide, to suit the various sizes of corks, so that a minimum of waste is produced. Suitable chucks are provided for cutting corks and bungs of various sizes up to 3 in. diameter. In working the machine, the following points should be attended to;—To give greater power to the spring R, which stretches the strap C, the lever is raised from E to F by the chain fixed at the end of the strap; to diminish the power of R, the operation is reversed. The rack K is advanced or drawn back, according to the size of the cork squares. The knife must be well adjusted to the squares, and the emery wheels must bear evenly on the cutting edge. The emery wheels are set in or out by loosening the screws under the bracket. To make tapered corks, the screw on the bracket R is loosened, and the set-screws 1 and 2 are turned from right to left, in order to cant the bracket carrying the knife to the required angle; the screw of the bracket is again tightened up, after ascertaining that the bracket rests securely on the set-screws. To vary the size of cylindrical corks, the set-screws are raised or lowered. The complete machine costs only sixteen guineas; by it, a lad can turn out 50–70 gross a day. It is said to be already in extensive use.

An equally ingenious machine made by the same firm is one for cutting cork into sheets, for lining helmets, hats, soles, &c., for which purpose they are sometimes required to be as thin as paper. The apparatus which performs this very delicate operation consists of a circular revolving steel knife, ground sharp at its periphery; the cork, having first been cut to the desired shape, is fixed in a movable chuck-plate, arranged to revolve by hand, and fitted with an extremely delicate feed-motion, for bringing the cork to the knife, or *vice versâ.*

511.

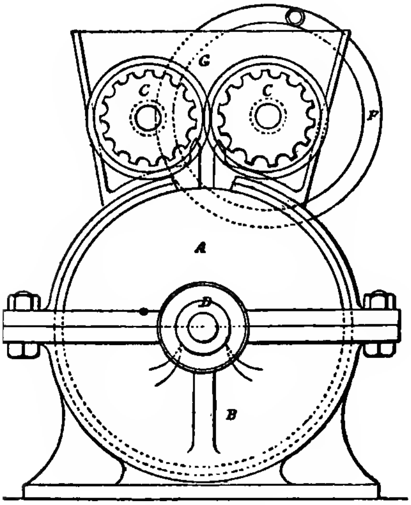




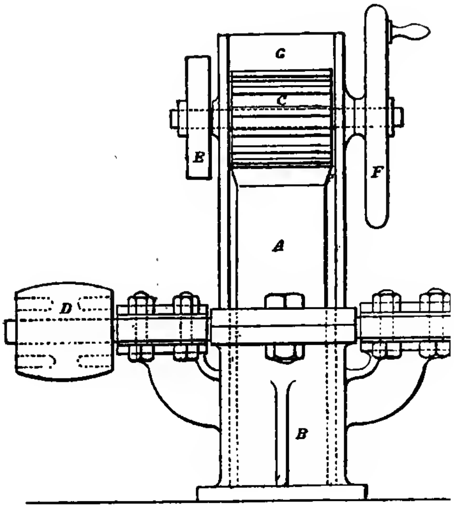
512.

Figs. 513 and 514 represent respectively a side elevation and an end view of a machine made by M. Powis Bale and Co., for the disintegration of cork waste. The main body of the mill is made of cast iron, and is divided into halves. In the centre of the mill is a cast-steel disc, serrated at its periphery after the manner of a file, and mounted on a steel spindle, which revolves in suitable bearings of phosphor-bronze. The interior of the mill, in which the serrated disc revolves, is fitted with a cast-steel periphery, and the slightest possible clearance is given to the revolving disc. The waste cork to be disintegrated is placed in a hopper, and forced in a solid mass through a narrow opening, and against the revolving disc, which operates upon it with the action of a file. When the powder attains the required degree of fineness, it is allowed to pass through adjustable screens or sieves, placed either in the bottom periphery, or in the sides of the mill.

513.



514.



The references indicate:—A, top half of mill; B, bottom half; C, fluted rollers for feeding in the cork waste, worked either by hand or by steam; D, driving pulley; E, pulley used when feeding by steam; F, hand wheel for feeding by hand; G, feeding hopper. The machine is said to disintegrate about 10 tons of cork before the file-plate needs sharpening, which operation is performed by a bevelled revolving emery wheel.

Further remarks on the disintegration of cork for the purpose of floor-cloth manufacture will be found under Floor-cloth.

The principal application of cork is for stoppering bottles, after being turned by the machinery just described; but it is also largely consumed in making life-boats and belts; in thin sections, for shoe-soles and hat-linings; for models and artificial limbs; and it is burnt to produce Spanish black. In France, it has been successfully applied as an insulator for boilers, tubes, &c., and for preserving the metal. Cork dust may be used in the toilette, as a substitute for rice and wood powders. Horse-collars stuffed with cork have been proved very superior, the substance being light, elastic, and a non-conductor of heat. "Virgin" cork is now largely employed in all kinds of rustic work. The produce of the second harvest is much used for making fishing floats, being too coarse for better purposes. The waste from cork cutting, which generally amounts to a third, is applied to filling cushions and horse-collars; as a stuffing for mattresses, it is the best substance in the world, being light and damp-proof, and forming a raft in case of floods or accidents at sea. It forms an admirable lining for ice-houses; and is largely consumed in the manufacture of cork carpets, kamptulicon, and linoleum (see Floor-cloth.) In cork factories, it is often utilized as fuel. A novel application of waste cork in France is for the manufacture of paste-board: the ground cork is thoroughly incorporated with paper pulp, by means of mixing machines and heavy hollinder presses; the water is then expressed, and the material is dried.

It is certain that the culture and use of cork were familiar to the ancient Greeks and Romans, though it was not then so largely employed as a stopper. In this shape, it appears to have been generally introduced towards the end of the sixteenth century, since which time the industry has not ceased to grow in importance. Its most important seats are San Felice de Guixois, Palafurgell, Palajos, Darnius, and Junquera. The province of Gironde produces annually about 12,500 tons of cork, and imports an additional 3000 tons, all of which is made into bottle corks, the manufacture employing about 8000 persons. In the United States, there are about sixty cork manufactories, cutting corks to the value of about 450,000*l.* annually. The large cork works at Stockholm employs five cylindrical cutting-machines, with their complement of preparatory appliances, consuming about 16,000 bales of cork, and turning out about 20 million corks yearly, with the assistance of manual labour to the amount of ten women and children; for dealing with the waste cuttings, an additional fifteen persons are employed, and, for sorting the corks, a further thirteen; but this latter number will be reduced by the introduction of a machine for sorting them according to size, leaving only the qualities to be separated by hand. The total number of employés is 45, representing the work of 150 when cutting by hand.

America, in 1877, was still importing cork bark at the rate of 120,000*l.* a year. France imported 75,736 cwt. of crude cork in 1865. Italy consumes most of her production at home; in 1875, the exports were about 575 cwt., valued at 663*l.*, and, in 1876, 982 cwt., valued at 1103*l.* Portugal is the largest exporter; in 1876, the figures reached 14,542 tons of rough cork, value 115,110*l.*, and 925 tons of manufactured cork, value 32,888*l.* The imports of cork into the United Kingdom, in 1878, were as follows:—

(*a*) Unmanufactured:

	Tons.	£
From Portugal	6,264	178,344
„ Algeria	362	10,094
„ Spain	199	6,136
„ France	93	4,106
„ other countries	99	2,187
	7,017	£200,867

(*b*) Manufactured:

	Lb.	£
From France	2,729,149	216,465
„ Portugal	2,383,837	163,372
„ Spain	476,910	34,620
„ other countries	48,749	3,590
	5,638,645	£418,047

The exports for the same year were:—

(*a*) Unmanufactured:

	Tons.	£
To Germany	431	15,736
„ Denmark	286	11,521
„ Russia	159	5,479
„ Sweden	141	5,655
„ Norway	129	5,312
„ Australia	51	1,952
„ other countries	102	3,475
	1,299	£49,130

(*b*) Manufactured:

	Lb.	£
To Australia	281,403	19,740
„ Germany	71,918	5,446
„ Sweden	46,988	3,925
„ British India	33,677	2,781
„ other countries	83,300	5,605
	517,286	£37,497

The values of the annual imports for the four preceding years respectively were:—

	1874.	1875.	1876.	1877.
Unmanufactured	£175,758	£195,109	£197,515	£203,541
Manufactured	390,882	396,078	489,539	491,603

(See Floor-cloth; Tannin.)

COTTON MANUFACTURES. (Fr., *Filature de Coton*; Ger., *Baumwollenmanufactur.*)

Cotton manufacturing, in its broadest sense, may be defined as the sum of the processes necessary to transform cotton—the seed down of *Gossypeum herbaceum*, and kindred plants (see Fibrous Substances—Cotton)—into yarn and cloth. The art is very ancient, having been practised in Eastern Countries from time immemorial. In those lands, the methods pursued have undergone little change since their first adoption. The marvellous perfection and beauty attained in the manufacture of Eastern textiles is the result of patient and persistent labour, continued through numberless generations, and which has led to the development of exquisite skill in the manipulation of simple instruments. This form of the art is, however, rapidly declining before the vigorous competition of the modern system, which in England has sprung up, and been almost perfected, during the last hundred years. The excellence of the latter is demonstrated by the fact that it has been adopted in almost every country of Europe, and in America. Of late years, it has even gained a footing in India, the original home of the cotton industry, and there its remarkable development has threatened the existence of its primitive rival. It is to the environments, conditions, and processes of successful manufacture by this system—which may most properly be called the English system—that the reader's attention will be exclusively directed.

This object will be most readily attained by selecting for description the method of manufacturing pursued in Lancashire, because this county is the birth-place of the system, and here it has received its highest development. The causes that have contributed to this result are manifold; but only those of a permanent character need be briefly noticed.

In Lancashire, all the conditions requisite for fitting it to become the seat of a prosperous manufacture of this particular exotic fibre are to be found. One of the chief of these is a humid atmosphere, which the district derives from its geographical position, lying directly in the track of prevailing westerly winds that come laden with moisture from the sea, tempering the severity of winter, moderating the heat of summer, and supplying perennial rains. These fall upon a geological formation composed of impervious rocks and clays, covered with only a thin layer of vegetable mould and are here retained, forming a subterranean reservoir, whence there arises a constant and great evaporation, that ensures the requisite humidity of the atmosphere—with few exceptions—the year round. The cotton industry is entirely—or very nearly so—located upon the Coal-measures, which form the mountainous portions of Lancashire and the adjacent counties; and the chief towns in which it is carried on are situated upon the hill-sides, almost within the cloud-track, or in the moist valleys under the shadows of the hills. The consequence is that the atmosphere, except during the rare occurrences of dry east winds or keen frosts, is sufficiently humid to preserve the pliability, and even to increase the strength, of the cotton fibre, during all the processes of manufacture. This feature contributes greatly to the success of the Lancashire cotton industry.

Another natural advantage enjoyed by Lancashire, is the hilly character of a great portion of its surface, which favours the formation of numerous streams. These in early days furnished the motive power for turning the jennies, water-frames, and mules, when they had grown beyond manual and animal power, and before the perfection of the steam engine; and though the latter generally superseded the earlier motors, abundant water was still essential for condensing purposes. As the trade has grown, the streams have been supplemented by canals and reservoirs, by means of which large manufacturing towns have been brought into existence in places where they could not otherwise have flourished.

On the adoption of steam as a motive power, the mineral riches of the district further assured the localization of the industry, which, even at that early time, gave promise of future affluence. Among the natural facilities of the district, too, must be included ready access to the sea, through the port of Liverpool, and thereby to the world. Nor would it be just to omit mention of the mechanical ingenuity and inventive talent of its operatives, and the readiness with which its capitalists encourage likely projects, tending to perfect the mechanism of the industry.

Technically considered, cotton manufacturing may be divided into two great branches—"spinning" and "weaving." The former includes all processes from the first handling of the raw material on its arrival in this country, until the product becomes a commercial article in the form of "yarn"; the second embraces every operation necessary to transform this into "cloth." Very frequently, both branches are united in one establishment; but there exists a strong and growing tendency to separate them. A proper conception of the causes underlying this movement is very important. They will be explained under the headings to which they respectively belong.

THE RAW MATERIAL.—A few remarks at this point upon the nomenclature, countries of production, varieties, characteristics, and mechanical structure, of the raw material of the cotton industry, will obviate the necessity of much repetition in subsequent stages, and enable the reader to comprehend more readily the different points as they come successively under notice.

The cottons of commerce are generally distinguished by geographical names, borrowed from the countries in which the article is produced. The scientific designations conferred by botanists are unknown in the trade. The prevailing system of nomenclature is unsatisfactory, because it gives rise to arbitrary distinctions; but custom and experience have obviated most of the practical difficulties, and any attempt to effect a change would probably be quite futile.

The chief contributors to the European supply are, in the order of their importance, as follows:—The United States, India, Egypt, Brazil, and Peru; as well as numerous other places of less note. Besides the cottons indigenous to most of these countries, nearly all produce different varieties, generally grown from seed of the most popular kinds cultivated in the United States. The following are those usually quoted in the Liverpool Cotton Brokers' Circular; to them are appended brief descriptions of their important characteristics:—

Country of Growth.	Variety.	Length of Staple.			Mean Diameter of Fibre.	DESCRIPTION.
		Max.	Min.	Mean.		
		in.	in.	in.	in.	
America	Sea Islands.. ..	1·80	1·60	1·70	$\frac{1}{1562}$	A fine, silky, regular cotton of several varieties, American being best.
	Florida ditto ..	1·85	1·30	1·58	,,	
	Upland	1·20	1·00	1·10	$\frac{1}{1290}$	Soft, and rather short in staple; usually clean, and best adapted for weft.
	Mobile	1·20	·90	1·05	,,	
	.. ..	1·20	·90	1·05	,,	
	Texas	1·00	·70	·85	,,	Firmer in staple than the above; but contains more leaf, and is less bright in appearance.
	.. .. ..	·95	·70	·82	,,	
	Orleans	1·20	·100	1·10	,,	The best and most regular of all the American cottons. Some lots are very white, but leafy; others of a creamy tone, but clean.
Brazil ..	Pernams	1·50	1·20	1·35	$\frac{1}{1265}$	Pernams to Maranhams are Brazilian cottons; and, as a rule, are harsh in staple, and give a wiry feel to yarns into whose composition they enter.
	"	1·40	1·10	1·25	,,	
	"	1·30	·90	1·10	,,	
	Ceara Aracati, &c.	1·30	1·00	1·20	..	
	Paraiba	1·30	1·10	1·20	..	
	Santos	..	..	..	..	
	Bahia	..	..	..	..	
	Aracaju, &c. ..	..	..	..	..	
	Maceio	1·30	1·10	1·20	..	
	Maranhams.. ..	1·30	1·00	1·15	..	
		1·30	·90	1·10	..	

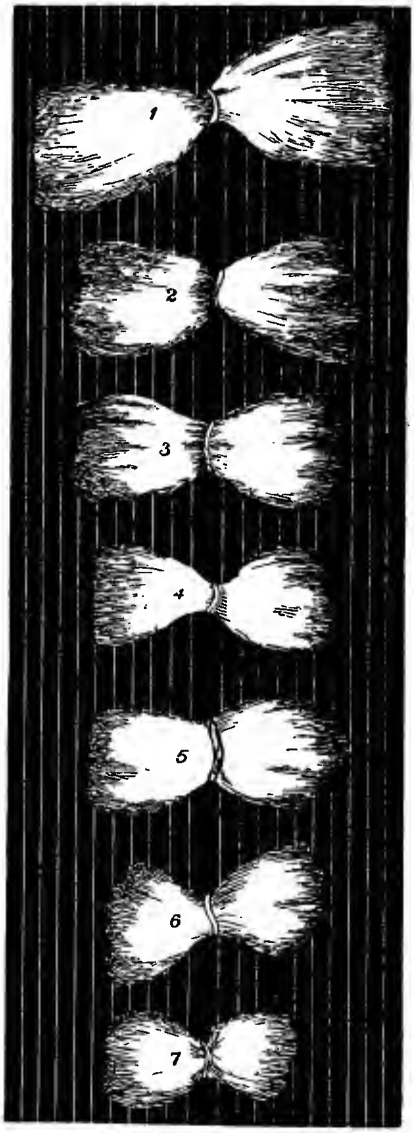
Country of Growth.	Variety.	Length of Staple.			Mean Diameter of Fibre.	DESCRIPTION.
		Max.	Min.	Mean.		
		in.	in.	in.	in.	
Egypt ..	Egyptian	1·60	1·40	1·50	$\frac{1}{1526}$	Brown Egyptian is soft and silky, whilst the white is usually hard and harsh.
	Gallini	1·50	1·20	1·35	..	
	,, brown ..	..	..	..	..	
	,, white ..	..	..	..	..	
	Smyrna	..	..	..	..	Harsh in staple, and characterized by its irregularly twisted fibres.
	Greek, &c.	..	..	..	..	
	Fiji : Sea Island	1·90	1·25	1·70	..	Very irregular in staple.
	Tahiti : ,,	..	..	..	..	
	West Indian ..	1·60	1·30	1·45	..	Fair in staple, but cannot be relied upon through successive seasons for uniformity of colour.
		1·40	1·20	1·30	..	
		1·30	1·10	1·20	..	
	Haytian	..	..	..	..	
	Laguayran ..	..	..	..	..	
	,, Sea Island	..	..	..	..	Exotic.
	Peruvian	..	..	..	..	Hard and soft varieties. The soft assimilates with Orleans; the hard is best mixed with Brazilian.
	,, Soft Staple	..	..	..	..	
	,, Sea Island	..	..	..	..	Exotic.
	African	..	..	..	..	Harsh-stapled cotton, not of a bright colour.
India ..	Surat	1·20	1·00	1·10	$\frac{1}{1185}$	The various classes under this head are fair working cottons; but the fibre is not so uniformly twisted as in Americans.
		1·20	·80	1·00	,,	
	Bengal	1·30	1·00	1·15	$\frac{1}{1309}$	From Sea Island and Egyptian seed.
	Rangoon	..	..	..	$\frac{1}{1185}$	Low in character; contains a large quantity of round and flat fibres.
	Madras	..	..	..	,,	

Cotton is valued according to the degree in which it possesses the special characteristics that best adapt it to the use for which it is intended. As its uses are multifarious, the raw material is classified in groups according to the probable wants of different consumers. The qualities chiefly considered in classifying cotton are length of staple, fineness, strength, smoothness, colour, and cleanliness. American varieties are classed in four qualities: good ordinary, low middling, middling, and good middling; South American, three: middling fair, fair, and good fair; Egyptian, two: fair, and good fair; East Indian, three: fair, good fair, and good. Standard samples of these classes are preserved for reference, in case of dispute, in the offices of the Liverpool Cotton Brokers' Association; and it is customary amongst brokers to form a set of the classes in which they deal, and, after careful comparison with the standards, to preserve them for easy reference when required. As, however, the crop of each succeeding year differs in some important respect from its predecessor, these standard samples are subject to considerable modification. According to the relative abundance or scarcity, fulness or deficiency, of special characteristics, the different varieties are classed up or down, as the cases may require. Thus, within a limited range, there is a constant fluctuation of the standard. The accompanying diagram (Fig. 515) shows the lengths of the staple in several representative varieties: 1: Sea Island, mean length of staple, 1·65 in.; 2: Egyptian, 1·50 in.; 3: Pernambuco, 1·25 in.; 4: American, 1·10 in.; 5: Port Natal, 1·10 in.; 6: Indian, 0·90 in.; 7: Indian, 0·65 in.

It will be obvious, from what has already been stated, that considerable skill and discrimination are required in selecting the right qualities of cotton for any required description of yarn, as mistakes cannot be rectified after the cotton has entered the first stage of manufacture.

The mechanical structure of the cotton fibre is such that its perfect development has an important bearing upon its quality. As received in this country, mature or ripe cotton fibres, when placed under the microscope, present the appearance of irregularly twisted ribbons with thick rounded edges. The thickest part is the root end or base—that which was attached to the seed. The diameter of the cylinder remains without material change, through probably three-fourths of the length, when it tapers off to a point. The accompanying illustrations admit of a comparison of the fibres of cotton at different stages of maturity. Fig. 516 exhibits a portion of mature fibre magnified; and Fig. 517, sections of the same. The latter show it to be a collapsed cylinder, the walls, as compared with the bore, being of considerable thickness. Fibres possessing these characteristics are longest and strongest, and are considered well developed. But amongst the perfect fibre, there is always more or less of unripe, imperfectly developed, or dead, fibre, according to the favourable or unfavourable conditions that have prevailed during the growth of the plant. The proportion of defective fibre naturally present is always largely increased by the practice, on the part of cotton growers, of collecting the immature pods on the cotton plant, after the latter has been killed by frost, or, from other causes, has ceased to grow. These are dried, and their lint is stripped from them, and added to the bulk. The appearance presented by the unripe fibre is greatly different, both longitudinally and in section, from that of the mature. In Fig. 518, the half-ripe fibre is shown longitudinally; and in Fig. 519, in section. The least ripe form in which cotton usually appears in commerce is depicted in Figs. 520 and 521. Though twisted almost as much as the perfect fibre, this last is thin, weak, and brittle; and, owing to the deficiency of cellulose, of which the walls of the mature fibre are composed, it is destitute of the corded edges seen in the latter. In sections, it appears like crooked bits of fine wire, showing little or no vestige of having been a hollow cylinder.

515.



When these defective fibres are found in great abundance, they seriously detract from the working quality of the bulk; and it is an important matter, in judging of cotton, to be able to distinguish them. This may be acquired by careful observation. In relation to these faulty fibres, the greatest circumspection needs to be exercised, in the seasons when the plant, with its load of bolls in all stages of growth, has been struck down by an early frost, for all the bolls are carefully gathered, and their contents abstracted, and mixed with the perfect lint.

The convolute form of the cotton fibre specially adapts it for its manifold uses. If it were cylindrical, like the fibres of flax and hemp, its shortness would prevent its holding together. But from their peculiar form, when twisted in the process of spinning, the fibres become firmly interlocked, by which means they may be made into a continuous thread, of considerable tenacity. When the finest varieties of cotton are employed, this thread is capable of remarkable attenuation. Lint gathered from the unopened or unripe pod, does not show these twistings in the fibre; hence it is incapable, when spun into yarn, of affording the same cohesive power, and produces defects wherever it occurs. The convolutions in the different varieties of American cottons are more regular, uniform, and numerous than in those of other descriptions, and fully account for their acknowledged superiority. The naked eye is incapable of distinguishing these twists; but the microscope shows them to amount to from one to three hundred an inch, and close examination would probably show even a wider range than this.

Many theories have been broached, and much ingenuity expended, in the attempt to explain the nature of this peculiarity of the cotton-fibre—the manner in which it is twisted upon its own axis. This point cannot be dilated upon here; but it may be permitted to put forward very briefly what appears to be a simple and natural explanation of the fact. It is known that fibres taken from unripe and unopened pods are invariably untwisted cylinders, tapering to a point at their extremity, which is closed. They have their root in, and receive all their nutrition from, the seed. Whilst in a growing state, the fluids of the plant circulate freely therein, conveying to every part the necessary amount of nutritive matter. When maturity is attained, this operation ceases: the juices are probably absorbed by the seed, and as they retire from the fibres, a vacuum is formed, first near the extremity, and subsequently along the length of each fibre, to its base at the junction with the seed. The pressure of the atmosphere, acting upon this vacuum where it is first formed, causes the tube to collapse and twist, from its apex downwards to its base. The seeds of each pod, ripening simultaneously, set up a commotion in the interior of the latter, by the general collapse of their fibres; and the consequent re-arrangement of these, in relation to each other, causes the pod to burst, when the desiccating action of the sun's rays expedites and completes the process. A further elucidation of this theory shews that it satisfactorily explains the whole phenomenon; and though perhaps of no great practical utility, it is not without interest, as it appears to have engaged the attention, and to have baffled the penetration, of previous writers on the subject.

516.

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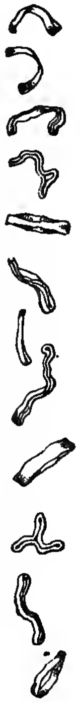
519.



521.

Mechanical Treatment of Cotton.—As a preliminary to a detailed description of the processes and machinery used in the various stages of the treatment of cotton, for the production of yarn, and afterwards of textiles, the subject will be rendered more easily intelligible by drawing up a scheme representative of the general procedure; this will also afford an opportunity of defining the principal technical terms used, and will remove any confusion arising from their occasional employment in wide, restricted, or otherwise varying senses.

Cotton Spinning.—This term, as previously indicated, is employed to describe in the aggregate all the operations involved in transforming raw cotton into yarn: that is, into a single twisted strand, or thread composed of cotton fibre. The word "spinning" has also a more limited signification, being used to denote, as will subsequently be seen, the concluding process of the series.

The manipulation, mechanical and otherwise, that cotton undergoes in being converted into yarn, from the state in which it is gathered from the plant, may be outlined as follows:—

1. "Ginning."—This is usually performed in the vicinity of the cotton plantation; the object being to remove the fibre from the seed of the plant, and partially to cleanse it from foreign matters.

2. "Packing" or "Baling."—After ginning, the lint is in a loose state, and unfit for convenient

transport to distant markets. hence it is necessary to compress it into less space, which is ordinarily performed by means of hydraulic presses. The package leaves the press in the well-known form technically called a "bale," in which state it passes through the markets into the hands of the spinners.

3. "Mixing."—Is the blending of different varieties of raw cotton, in order to secure economical production, uniform quality and colour, and an even thread, in any desired degree. Mixing is, in a measure, imperatively necessary, in order to neutralize the irregularities of growth, and imperfect classification, found more or less in all cottons. It is the first operation in a cotton mill.

4. "Willowing."—This is a process of opening and cleaning cotton, which, except in the Oldham district, is not much used in modern mills, and is retained chiefly for opening and cleansing low cottons, waste, &c.

5. "Opening."—In consequence of the heavy pressure to which cotton is subjected in packing, the fibres become strongly matted together; the opening process is to loosen them, and to remove a portion of the foreign substances present. It is the present equivalent of willowing.

6. "Scutching."—Has a twofold object: viz. the further extraction of impurities, and the formation of a "lap," which is a web or sheet of cotton formed in the machine, and wound upon a small roller. In this web, the fibres lie in all directions.

7. "Carding."—The foregoing processes have dealt with the cotton in bulk. In carding, the operation of opening is continued; but the material is treated in its individual fibres, which are taken from the lap, further cleansed, and laid in a position approximately parallel to each other, forming a thin film, which is afterwards condensed into a "sliver"—a round, soft, and untwisted strand of cotton.

8. "Combing."—Is used for the production of fine yarns, or those of very high quality. Its object is to obtain uniformity in the length of the fibres undergoing preparation; to accomplish this, all those shorter than the required standard are combed away, and rejected.

9. "Drawing."—In this operation, several slivers, the product of the carding process, are combined, and attenuated to the dimensions of one of the component parts; the objects are to render the new sliver more uniform in thickness, and to place the fibres more perfectly in parallel order.

10. "Slubbing."—Is a process by which a further combination of the slivers is effected, and the objects of drawing are more perfectly accomplished. The drawing or attenuation of the strand is now carried so far that it becomes necessary to twist it slightly, in order to preserve its cohesion, and rounded form.

11. "Intermediate" or "Second Slubbing."—Is in all respects a repetition of the above; necessary in cases where the most even and clean yarn is required. It is not ordinarily used in the production of low numbers.

12. "Roving."—This is a continuation of the preceding, its principal object being to still further attenuate the sliver. At this point, also, the latter receives additional twist, to enable it to bear the slight strain necessary to draw it from the "spool," without the formation of uneven places.

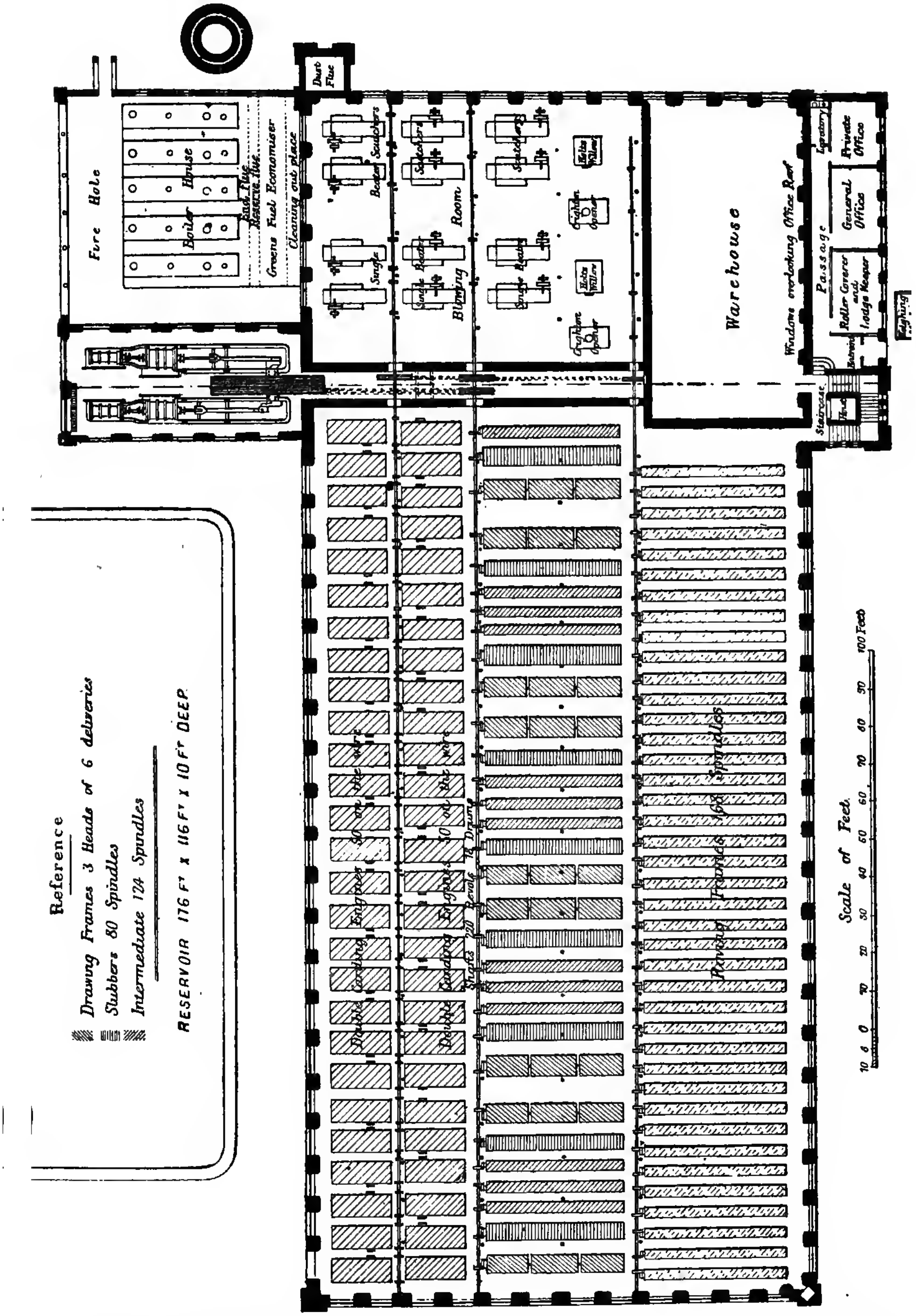
13. "Spinning."—The concluding process of the series. The sliver is here attenuated to the required fineness, and is given the twist by which the thread is completely formed.

14. "Doubling."—In this series, may be included the process of doubling, it being much more akin hereto than to manufacturing. It is a large and increasing business, often carried on in conjunction with spinning, but frequently found quite apart. It is a method of combining two or more threads to form a single cord; and is adopted in the production of many varieties of yarn, which are used for widely different purposes.

The above processes, and the machinery necessary thereto, will be described in the order given, excepting, however, the first two, which will be dealt with in treating of the production of the raw material (see Fibrous Substances). In performing this task, it is not intended to allude to obsolete methods and machines, unless such reference will tend to elucidate the principles on which the modern system is based. Even with this limitation, it will not be possible to make a general reader acquainted with every variety of machine that has met with, and still retains, a certain amount of favour.

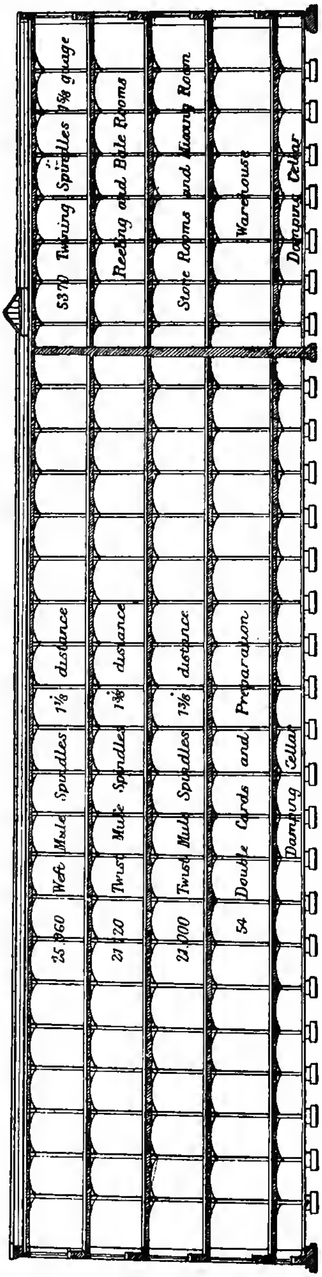
The Cotton Mill.—The considerations that influence the selection of a locality in which to erect a cotton mill are chiefly the following:—Firstly, proximity to an abundant store of cheap and good fuel; secondly, an unfailing supply of water, or means of preserving it; thirdly, easy and cheap means of access to the market, by road, water, or rail; and, fourthly, an area within which an experienced class of operatives can be obtained. There are several other minor points, but they need not be detailed. As many as possible of these conditions should be found in the locality selected, as all are highly important, and greatly conducive to success. The choice of site should be carefully considered. A valley, protected from dry winds, and open to moist ones, is of great advantage. The subsoil should be of stiff, impervious clay, such as will retain the moisture in a subterranean reservoir, the evaporation from which will be constantly moistening and softening the atmosphere—advantages that have been previously explained.

522.



The fittest materials for the structure will be dictated by the circumstances of the locality; but in the presence of the conditions prescribed above, brick will generally be found most suitable and economical. Should it be requisite to provide a reservoir for water, any clay excavated for this purpose, as well as from the foundation trenches, can be utilized for the manufacture of bricks. The methods of construction are various. The one formerly common—and, perhaps, even now cheapest in first cost—was a combination of brick or stone with timber. Another is the so-called "half fireproof" plan, in which that portion most liable to destruction by fire—until recently, considered to be that in which the preparatory machinery is worked—is constructed as far as possible without timber. But of late years, owing to the high speeds attained, the danger has extended to the mule-room. This experience has given rise to the most modern, and now generally approved, system, in which the whole structure is fireproof. There are several ways of attaining this end.

523.

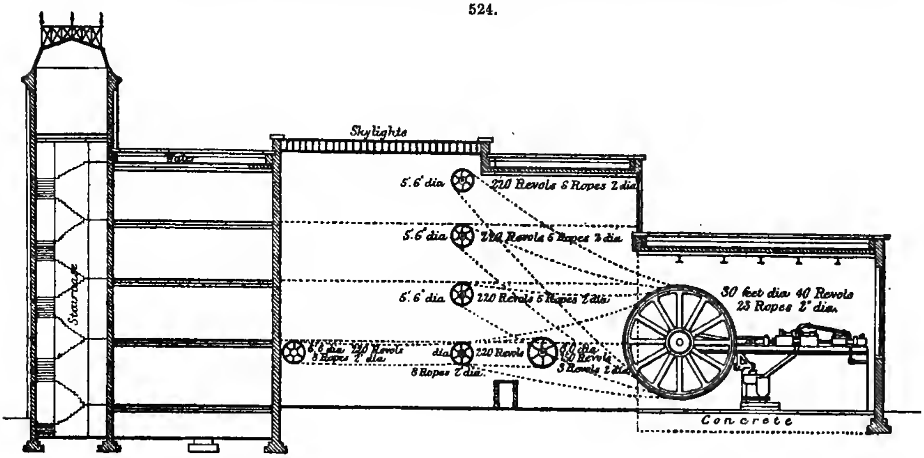


The mill shown in Figs. 522, 523, and 524, from drawings kindly furnished by A. H. Stott and Sons, mill architects, of Manchester and Oldham, is thoroughly representative of recent constructions, such as prevail in the great spinning districts of South Lancashire. The dimensions of the main portion of the structure would be about 295 ft. by 125 ft., accommodating 75,000 spindles, and the usual complement of machinery in connection. The foundations are of coarse rubble, on 1 ft. of mortar concrete. Those on which the columns immediately rest are of flag-stones. The walls are composed externally of pressed brick, and internally of common brick. The window-sashes are of wood, glazed in the lower part with rough plate, and in the upper with clear glass. The floors are supported upon cast-iron columns, in which brackets or arms are cast. To these are secured rolled iron beams, the object being to get two arches in place of one. Each pillar bracket is connected with the next by an arch beam, to form a complete continuation between the pillars and the direction of the bracket. The brick arches are 7 in. thick at the base, diminishing to 4½ in. at the crown; they are turned between the beams. Timber joists, 2½ in. deep, are then laid across the beams, and the space is afterwards filled up with concrete, composed of lime and furnace ashes. When this is thoroughly dry, the floors are laid with 1½-in. deal boards, nailed to the joists. Boarding is now generally preferred for all room floors, except the blowing-room. The floor of the cellar is composed of bricks, laid on puddled clay, with passages formed of cement concrete, or flag-stones. The roof of the mill is, in the first place, constructed in the same manner as the floor; but the concrete is laid level, and then covered with two coats of asphalt, each ½ in. thick. These are turned up the wall, 18 in. all round, and protected from the weather by a dwarf brick wall, built inside on the asphalt. Constructed thus, the roof forms a reservoir, containing 6–12 in. of water. The object of this is to render it thoroughly fireproof. In some cases, 12–18 in. of water is preserved, and arrangements are made for utilizing it at a moment's notice in the event of fire. When this plan is adopted, conduit pipes are laid to, and around, the interior of each room, and provided with the necessary taps. The staircase is composed of stone, with cast-iron risers.

The roof of the engine-house is fireproof, and supported on large rolled-iron girders; that of the boiler-house is of ordinary construction, provided with ventilators. The chimney rises to a height of 210 ft.; its diameter at the bottom is 17 ft. externally, and 8 ft. internally; at the summit, it is 9 ft. 10 in. externally, and 7 ft. 6 in. internally.

The arrangement of the mill is as follows:—The ground floor contains the blowing-room, carding-room, warehouse, offices, and entrance lodge. Over the carding-room, are three spinning-rooms, of equal dimensions. Above the blowing-room and warehouse, are situated the mixing-room for cotton, and store-rooms for sundries. Partially over the mixing-room is the bale-room, provided with a door opening on the end of the mill, and fitted with a self-acting hoist. Level with the bale-room is the reeling-room, and over these is a twining- or doubling-room. The boiler-house at the back of the mill contains five Lancashire boilers, 30 ft. long and 7 ft. diameter, each having two circular flues, 2 ft. 9 in. diameter at the firing end, tapering to 2 ft. 4 in. Behind the fire are inserted six Galloway tubes. The boilers are fed with water from the hot well of the engine. Behind each boiler, is fixed a fuel economizer, of ten pipes width: in all, 360 pipes. Passing through these, under the influence of the waste heat from the furnaces, the water attains a temperature of 138° (280° F.), before reaching the boilers. The latter are usually worked at a pressure of 90 lb.

524.



The engines are of the tandem type, with low-pressure cylinders in front, and high-pressure behind, on the same piston; the former are 40 in. diameter, the latter 21 in. The stroke is 6 ft. The air-pump is situated under the slides of the piston-rod, and is worked by a bell-crank motion; it has a stroke of 3 ft. The condenser stands by the side of the air-pump. The ordinary vertical type of the latter is still the most popular amongst practical men. The fly-wheel is 30 ft. in diameter; its periphery is 5 ft. 6 in. broad, and is grooved for the reception of 23 ropes. The grooves are V-shaped, and of such a depth that the ropes do not touch the bottom. The ropes are of hemp or cotton, and are made in different ways. In the centre of, and extending around the periphery, are cast a set of cogs, for barring it round; these can also be used for moving it by a small bar-and-ratchet arrangement.

Power is transmitted directly from the engine to each compartment of the mill, by means of the above-mentioned ropes, which are received by a grooved drum, fitted upon shafts that extend throughout the length of the mill. In the carding-room, the central shaft, driven from the engine, is turned by five ropes, and makes 220 revolutions a minute. Two other shafts, one on each side, run parallel with the former, and are driven from it, by ropes, at the same speed. The shaft nearest the rear of the mill supplies the motive power to the carding-engines; the middle shaft, to the drawing-frames, slubbing-frames, and intermediates; whilst the one farthest from the engine drives the roving-frames, the willows, and the openers. In the spinning-rooms, the shaft driven by the engine extends throughout the entire length, and makes 220 rev. a minute. In the top room, a shaft is carried over the warehouse part, and drives the twining-jennies. The bale-room, which receives the raw cotton, as it is hauled in from the mill yard by means of the automatic hoist, is provided with openings in the floor, bound with cast-iron frames, having covers of the same material. Similar provision is made in the mixing-room, for passing the raw material to the blowing-room. At the corner of this room nearest to the chimney, is a dust-flue, for carrying away the dirt and sand separated from the cotton by the willows, openers, and scutchers.

The machinery is arranged with a view to rendering the processes consecutive, and to incurring the least possible cost for handling the cotton as it passes through. For a mill of the dimensions indicated, 2 willows and 2 openers are required to serve 12 single-beater scutchers. These provide laps for 54 double carding-engines, 50 in. on the wire. Sufficient sliver is produced from these to supply 9 drawing-frames of 3 heads of 6 deliveries each; which, in their turn, serve 9 slubbing-frames, of 80 spindles each; whilst the latter give full employment to 12–13 intermediates of 124 spindles each, the production of these being taken by 40 roving-frames, of 168 spindles each. In a mill spinning 32's warp yarn and wefts to correspond, the above-named preparatory machinery suffices to supply the complement of spindles, about 70,000. Twining, or doubling, is a subsequent process.

Mixing.—The raw material received into the bale-room is examined by drawing samples from different parts of each bale, and is classified accordingly. This step is necessitated by the fact that the quality of cotton gathered at different periods of the picking season is subject to material variation. Errors of classification and warehousing may produce a better or worse quality than the purchaser intended, or mistakes may be made in purchasing, from unfamiliarity with the needs of the establishment. These are sources of error to be guarded against. When the quality and magnitude of the mixing have been decided on, the classified stock is drawn upon; the coverings are stripped from the bales, and the contents are passed in succession through the apertures in the floor to the room below, and spread upon the floor, in layers occupying a fixed area. Sometimes this space is railed off from the room. The "mixing" will be composed of as many layers as there are bales, these being taken in that order which will best enable their qualities to contribute to the end in view. When the mixing is completed, it is usual to test the result, by taking a vertical section of the blend—raked from the face of the pile—, sufficiently large to manufacture into yarn; this is carefully examined, and compared with a standard yarn, or with that from the last mixing. Should it be deficient in strength, cleanliness, or colour, a sufficiency is added of the raw material possessing the requisite quality. Sometimes the testing is repeated, especially when the quality is intended to be high class, and it is desirable to run no risk of deterioration; in other cases, the blend can be made so near the requirement, that it is not considered necessary. In low qualities, and admixtures of waste, the testing process is sometimes neglected; but in a well regulated establishment, it should never be omitted.

The satisfactory condition of the blend having been ascertained, it is ready for use. When required, it is carefully and evenly drawn down from the sides of the pile, by means of a rake; this ensures a further intermixture of the qualities.

The component parts of the blend will necessarily differ according to the quality of yarn sought to be produced. Experience will enable cotton-spinners of average skill to prescribe mixings with great accuracy; but there is nothing like uniformity among them in this respect, many affecting to keep the particulars secret. The following Table, however, very kindly furnished by John Butterworth, of Shaw, near Oldham, one of the most scientific and skilful spinners in Lancashire, shows, in a general manner, the adaptability of certain cottons for spinning different numbers of yarn, and their suitability for admixture with each other:—

Best Sea Island	.. ..	120's upwards.
Best Egyptian, and Shortest Sea Island	.. ..	80's to 120's.
Peeler (American), and Soft Egyptian	.. ..	60's to 80's.
Orleans, Texas, and Soft Peruvian	These two classes are mixed together, as the abundance or scarcity of each class prevails; but it is found that rough and smooth staples do not incorporate well, and hence do not make the best yarn.	40's to 60's.
Pernams, Paraibas, Maranhams, Maceio, Rough Egyptian, and Rough Peruvian		40's to 50's.
Puerto Cabello (W. I.), Surinam, and Brazilian Peruvian	The lower classes of American are often mixed with these varieties. Georgia, Boweds, &c., mix best with Dhollerah, Broach, Oomrawuttee, &c.; but stronger kinds are often used.	30's to 40's.
La Guayran (W. I.), Ceara (B.), and Aracaju (B.)	The strong low classes of American are best adapted to mix with West Indian, Rough Brazilians, Smyrna, African, &c.	26's to 36's.
Dhollerah, Dharwar, Broach, Oomrawuttee		16's to 28's.
Smyrna, African, Persian	.. ..	10's to 16's.
Comptah, Bengal, Madras, Rangoon	.. ..	very low numbers.

Several varieties not named above would mix with one or other of the classes; but special adaptations must be left to the discretion of the spinner.

At this point, it may be well to explain the significance of the figures in the third column of the above Table. Yarns are always quoted by the pound, the price differing according to quality and fineness. The latter is indicated by numbers, from 1's (one's) upwards; the limit of fineness in the mercantile article is about 300's (three-hundred's). These numbers are arrived at in the following manner:—In the early days of the trade, when yarns could not be spun with the regularity that can be accomplished at present, uniformity was secured by reeling the yarn, and assorting the hanks according to weight. The circumference of the reel was 1½ yds., and the 80th revolution was indicated by a rap from a released spring, the length then wound being 120 yds., or 1 "lea." When 7 leas had been wound, they were tied together, forming 1 "hank," or 840 yds. The number of these hanks in 1 lb. indicates the fineness of the yarn, which is expressed thus — 4's, 12's, 20's, 32's, 40's, 60's, &c., &c., to 300's. From the lowest Nos., it is customary to rise 1 hank at a time, up to 10's; thence steps of 2 hanks are generally taken, up to

24's; then 4 hanks at a rise, up to 40's; after this, the gradation, though sometimes 5, is generally 10 at a step. Any Nos. between these would be special, and would require to be spun to order.

Cotton yarns are always bought and sold by avoirdupois weight; but, in ascertaining the counts or Nos., it is necessary to subdivide the pound into Troy grains, of which it contains 7000. The measure employed is as follows:—

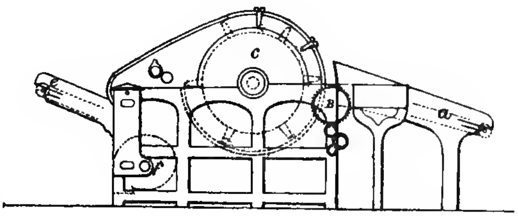
54 in. = 1 thread (or circumference of reel).
4320 „ = 80 „ = 1 lea.
30240 „ = 560 „ = 7 „ = 1 hank, or 840 yds.

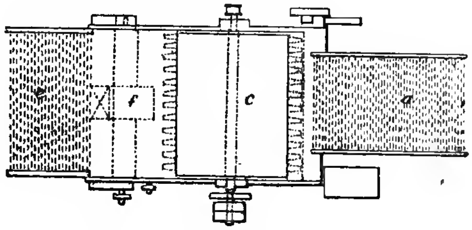
To ascertain the counts of a yarn, 7000 is divided by the weight (in grains) of one hank. It is customary, however, to take a proportionately less quantity, say 1, 2, or 3 leas, the dividend being 1000, 2000, or 3000 accordingly. The quotient is the number of hanks in 1 lb., hence the No. of the yarn.

Opening.—This process follows mixing. It is performed by the aid of various machines, according to the requirements or the preference of the spinner. The principal are the following:—The willow, the Crighton opener, the Porcupine, and Lord's opener.

The common, or Oldham, willow (Figs. 525 and 526) consists of a cylinder *c*, about 40 in. in diameter and 40 in. wide, mounted on a shaft, furnished with driving pulleys, and resting on bearings in the framework. Fitted on, and extending across, its periphery, are several rows of teeth, or blunt spikes. A semicircular casing, internally furnished with two or three rows of spikes similar to the above, covers the upper part of this cylinder. The lower portion is covered with a wire grid, in two parts, hinged together. The back section of this is fixed to the frame, whilst the front part is balanced by weights, suspended from cords or straps, passed over pulleys at each side, and attached to the end of the grid, which is free to move up and down in an opening in front of the machine. An exhaust fan *f* is placed behind the fixed part of the grid.

525.





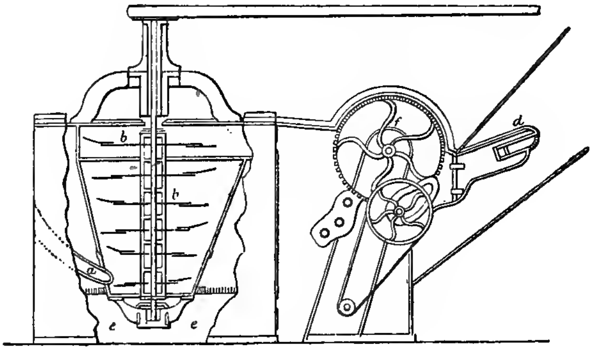
526.

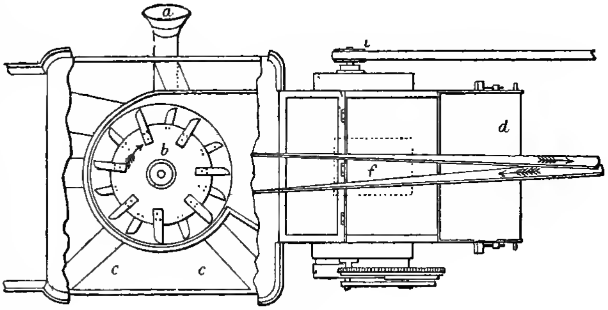
The operation is as follows:—The grid is let down, and a quantity of cotton is placed upon it. It is then raised, and the cotton is thus brought into contact with the spikes of the revolving cylinder, which dash it against the fixed spikes on the internal face of the casing, loosening its matted fibres, and freeing it from sand, dust, and other foreign matters, which fall through the grid into the cavity below, or are drawn away by the operation of the exhaust-fan, and discharged through a tube into the air. After the cotton has been subjected to the action of the machine for a few seconds, the grid is let down, and the cotton is thrown out. The process is then repeated with fresh material. This is the simplest form of the willow as it exists in use.

The willow, however, has lately undergone great improvements. It is sometimes made with an automatic motion, to let down the grid when the cotton has been in the machine for the proper length of time, which can be varied according to requirement. At other times it is made continuous, as seen in the figures, by placing a feed cloth *a* in front, and a lattice creeper *e* at the back, to carry away the cleansed cotton, which is then ready for delivery to the scutcher.

The second machine mentioned above, the Crighton opener, which is now in extensive use, is a modification of the cone willow. As will be seen from the accompanying illustrations, Figs. 527 and 528, in the interior of the framework, is fitted a conical grid, having its apex downwards, and resting on a cross-rail at a short distance from the bottom. On the top of the frame, stands a tripod, which forms a bearing for a vertical shaft, carrying driving pulleys, and descending through the centre of the grid to a foot-step in the cross-rail. Mounted on this shaft, are a number of discs *b*, smallest at the bottom and increasing in size as they approach the top. Fixed on these, are a series of thin steel blades, for beating the cotton. At the top of the grid, is an orifice conducting to the dust-cages. The space *c*, between the casing and the grid, forms a cavity for the reception of any foreign matter contained in the cotton. The machine is fed by means of the tube *a*, which may be introduced on any side away from the attachment. The latter includes the dust-cages, fan *f*, lattice-creeper *d*, and, below the dust-cages, a pair of small delivery-rollers, and an exhaust-fan. The cages are hollow cylindrical wire frames, with the wires set sufficiently close to prevent the entrance of the fibres of cotton, but wide enough to permit the dust to be drawn away by the current. Only the portion of the cage opposite the orifice is left open, the remainder being closed by an internal casing, which follows the contour of the cylinder.

527.





528.

The details of the process are:—The cotton is fed into the tube *a*, emerging into the lower portion of the conical grid, where it comes into contact with the beaters *b*, which strike it against the bars of the grid. This action loosens the mass of fibre, and permits any seed that may be in the lint, as well as sand, dust, &c., to fall through the grid into the dust-cavity *c*, and thence to the bottom *e*. The cotton remains subject to the action of the beaters, until it is opened sufficiently to admit of its being drawn upward, and carried away by the suction of the fan *f*, through the orifice. Following the direction of the arrow towards the dust-cage, it is taken on by the rollers, and passed to the lattice-creeper *d*, which discharges it upon the floor, or into a receptacle provided.

This machine has also been improved by the addition of an automatic feed or lattice apron, and a lap machine. By some, its action is regarded as being gentler, and less injurious to the cotton, than that of the willow, through its possessing no stationary teeth to intercept the progress of the fibre; also by its peculiar structure, which causes it to retain the cotton until thoroughly opened, but not longer, thus avoiding excessive beating.

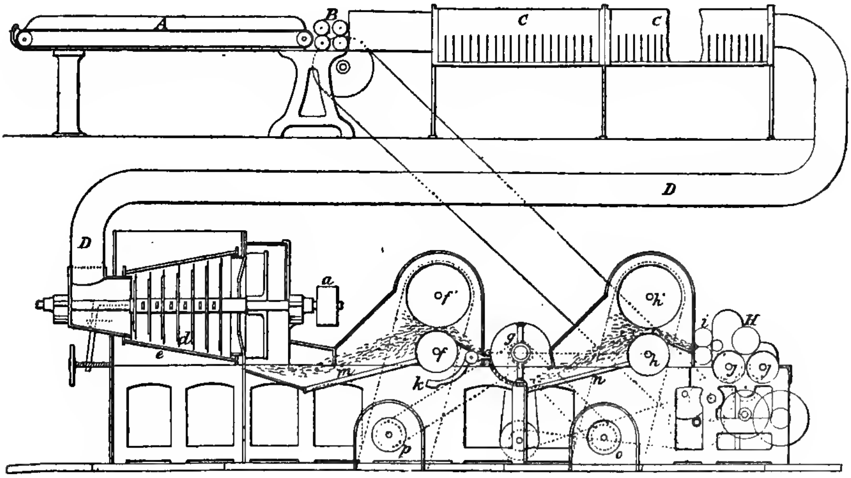
The "Porcupine" is another opener, whose chief difference from the willow as illustrated above lies in the possession of two cylinders for opening purposes, laid parallel to each other, the first of which has twelve rows of teeth, and the second four. It is fed and discharged by lattice-creepers, and exhausted by the usual appliances.

Lord's combined opener, scutcher, and lap-machine, is a remarkable illustration of the manner in which several processes may be concentrated in what is practically one machine. The inventors largely avail themselves of the pneumatic principle seen in each of the previously described openers, and use a current of air to bring the cotton from any moderate distance.

As will be seen from Fig. 529, which represents the feeding as taking place in the room above the machine, an endless lattice A, on which the cotton is evenly laid, delivers it to two pairs of rollers B, the second revolving more quickly than the first; these convey it to the tube, where it is instantly seized by the air current. During its aërial passage, sand, dirt, dust, small stones, and all heavy or dangerous substances accidentally present with the cotton, are dropped upon the bottom of the tube. In order to secure the abstraction of these, Messrs. Lord invented and patented their grated trunks. Intermediately between the feed table and the opener, several lengths of these tubes C are inserted. Seen in section, they are ⌂ shaped. Inside these, at short distances apart, plates of sheet iron are placed athwart, and slightly inclined against the direction of the current, and reaching about half-way to the crown of the tube. The spaces between these plates form cells for the reception of extraneous matter, which, dropping out of the cotton, is retained in them; it is removed daily through the bottom of the tube, which opens downwards, and is hinged for the purpose. These cells prove very efficient, as is shown by the quantity of dust that is taken out of those in the front, and its gradual diminution towards the last; and by the small amount of foreign matter thrown off in the opener and scutcher.

The opener consists of a horizontal shaft *a*, carrying a series of accurately balanced arms *d*, arranged radially on the shaft at several inches apart. These arms are of cast iron, with steel blades bolted firmly to their extremities. The length of these arms is, at the small end nearest the tube, about 18 in.; it increases gradually as the opposite side is approached, terminating with 28 in. When revolving, the arms describe the figure of a cone. A conical grid surrounds the beaters, constructed by the junction of two rings of unequal diameter by means of straight steel bars. This grid can be moved endwise upon the shaft, by means of the wheel beneath the tube, at the left extremity of the machine. The bars are fixed at the delivery end, but are capable of adjustment at the feed end, in order to increase or diminish the distance from the beater, according to the length of staple or quality of cotton that has to be treated. On the same shaft, at the delivery end of the beater, is a powerful disc fan, which, in conjunction with the other fan *p*, whose specific function is to exhaust the dust-cages *f f'*, and which is situated below them, draws the cotton from the extremity of the feed-pipe, through the beater, to the dust-cages; at this point, the cotton is received by two small rollers, that deliver it to the beater *g* of the scutcher, where it undergoes further opening and cleansing, by a process resembling the one it has just passed through, except as regards the form of the beater. The scutcher and lap attachment, which receives the cotton at this point, will be described in connection with the next machine.

529.



Scutching.—Scutching has a twofold object: to further cleanse the cotton, and to form a lap. If the raw material has not, in the previous stage, passed through an opener with a lap-forming attachment, it arrives at this point in bulk, and but partially cleansed and opened. Scutching is the first stage in the series of arrangements that produce the finished article. The lap is a continuous sheet of cotton, about 40 in. wide, which is formed into a roll of convenient length to suit the machinery. In it the fibres lie in all directions across each other, no attempt having yet been made to arrange them in parallel order.

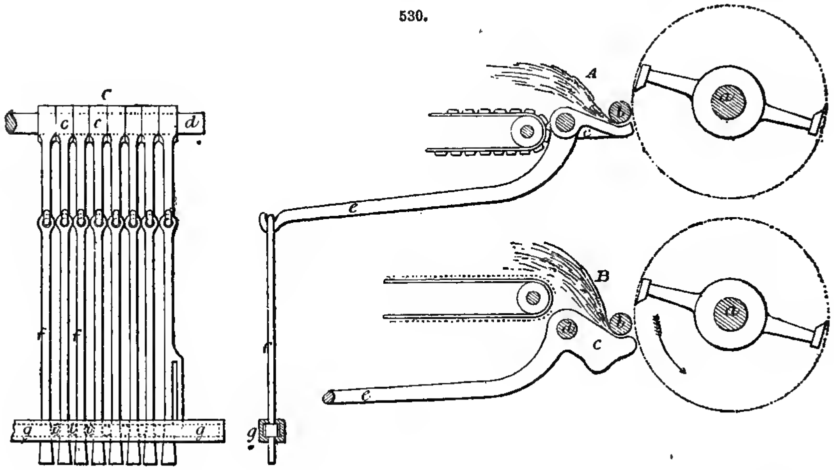
The scutcher has undergone many changes ere attaining its present comparative perfection. Amongst makers, the result is unanimity regarding the main features of the machine, tempered by differences on points of detail. The latter need not be brought fully before the reader: it will serve to describe one or two of the most popular and representative forms.

The Crighton scutcher is a well-known machine. It possesses a lattice-creeper, on which the cotton is evenly laid, in measured spaces, after being weighed. A pair of small fluted rollers take the cotton from the lattice, and pass it to a beater, having two blades encased in a cylinder; a quarter-section of the latter, from the fluted rollers to the bottom, is composed of a grid. The beater, having a speed of about 1000 revolutions a minute, strikes the cotton with great force from the rollers against this grid, causing leaves, motes, and other impurities, to fall through. Parallel with the bottom of the cylinder, is a passage, leading to the pair of dust-cages situated at the back. Along this, the cotton is drawn by the current induced by the exhaust-fans. The bottom of this passage is formed by a lattice, arranged with its surface open, for the reception of impurities that may have passed the first grids. This lattice moves over three rollers arranged thus—·.·, and, travelling in a direction opposite to that followed by the cotton, it carries away only substances of greater specific gravity than the fibres under treatment, and discharges them into the dust-cavity beneath the grid. The loose cotton is evenly distributed by the current over the wires of the dust-cages, as they slowly revolve. These wires, whilst holding the cotton, permit the extraction, through their interstices, of the fine particles of dust that may have come on the current of air along with the fibre,—hence their name. The perfect removal of sand or grit is of great importance, because were it to pass along with the cotton through subsequent processes, it would seriously damage the machinery. The cages join the cotton deposited upon them into one sheet, which is removed by a pair of small fluted rollers; these pass it to the compression-rollers, whence it escapes to the lap-roller; this, by means of a pair of large fluted rollers, revolving in the same direction, takes on the sheet of cotton until it has formed a thick roll, technically called a "lap."

From the first handling of cotton in the mill, the object is to obtain a clean, round, even thread of yarn. In order to secure this, it is necessary that the scutcher or first lap machine should be carefully fed, the cotton being spread evenly upon the lattice, so that it may pass through at a uniform rate. But it is not always possible to ensure this with hand labour, and mechanical appliances have in consequence been invented for the purpose.

The most popular, and reputedly the best, of these is the one introduced by Lords, and called the "lever-" or "piano-feed" motion, from its being in principle similar to, and in figure distantly like, the arrangement of the keys of a pianoforte. Fig. 530 will help to explain its details. Fig. A shows it in section: *a* represents the beater, the dotted line tracing the circle which its blades describe in their revolution. Instead of a pair of feed-rollers, as usual for delivering the cotton to the beater *a*, the bottom one is replaced by a series of levers *c*, extending across the frame, arranged as in Fig. C. In B, is shown a different form of the short end *c* of the lever, adapted for long-stapled cotton. By means of a hook at the extremity of the lever-arm *e*, the levers are attached to rods *f*, which increase in thickness at the end where they pass between two horizontal plates or bars *g*, laid parallel on the back and front of their pendant extremities. In the interstices, small bowls are introduced, shown by the dotted circles *i*. The rod *f*, on the right, is slotted for the reception of a connecting-rod attached to the levers, the second of which is connected with the strap-lever *p*, seen between the cone-drums in Fig. 531. A sector wheel, on the strap-lever *p*, gears into a similar one on the strap-lever p^1; *q*, *r* are cone-drums, and *s* is the strap by which motion is transmitted from one to the other.

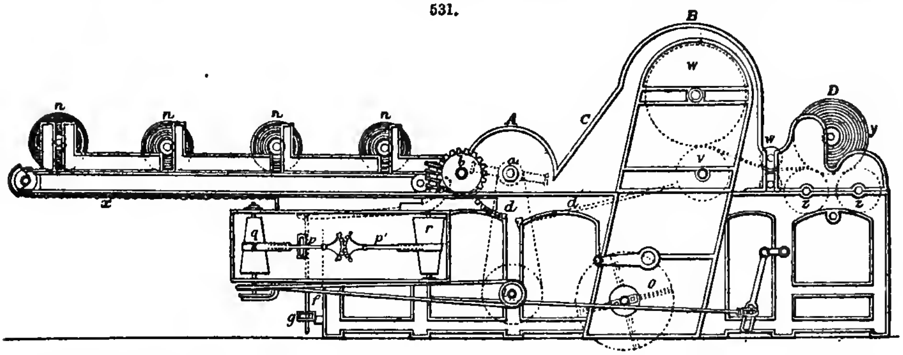
530.



The action of the different parts is as follows:—When the cotton is matted, or unevenly spread upon the lattice, causing a thick portion to go beneath the roller *b*, the short end of the lever *c* is pressed down, the long arm *e* is raised; this pulls up the rod *f*, the thick end of which, coming up between the bowls *i*, presses the rods in the only direction in which they can move—towards the slotted rod at the end, which, through the connecting-rod and levers above described, moves the strap *s* upon the cone-drums *q* and *r*, and regulates the speed according to requirement; the cone-drum *r* gives motion to the feed-roller *b*, through the worm on its shaft. This has proved to be a very efficient arrangement, and has been extensively adopted. It can be attached both to the first and second scutcher.

Lord's finisher lap machine, with the "piano" feed attachment, is illustrated in Fig. 531. The creel holds from four to six laps *n*, which, by means of the lattice *x*, revolving on the rollers at each extremity of the creel, deliver a three, four, or sixfold sheet of cotton to the feed-roller *b*; this, by means of the evener, or piano feed, just described, is made to deliver its burden to the beater *a*, at a uniform rate. The bottom of the beater case A contains a grid *d*, whilst a longitudinal grid *d*¹ extends to the dust-cages *v*. At C, the casing is usually glazed, or a doorway is formed, in order to permit inspection of the interior. Glazing is preferable, as a doorway interferes with the action of the exhaust draught. Next to the dust-cages, are the compression-rollers *w*, through which the cotton passes to the fluted rollers *z*, at the end of the frame, which, slowly revolving, wind it upon a roller, called the "lap-roller." When the lap *y* is completed, it is lifted from the frame, and laid aside, and the roller is withdrawn, and replaced to wind on another lap. The soft mass of cotton quickly closes up the space left by the withdrawal of the roller; and ordinarily, when the lap has to be skewered, for placing in the carding-engine, considerable difficulty and waste are the result. In order to obviate these drawbacks, a plan has been devised and patented by H. H. Clayton, manager of Kingston Mills, Hyde, which is thoroughly successful. In place of the solid lap-roller, the inventor substitutes a tube-roller, into which he inserts a long pin, having a flat head, of greater diameter than the roller. When the latter is withdrawn, the pin is left in the cavity, retained by the head, thus preserving the bore, maintaining the form, and facilitating the handling of the lap, whilst time and labour are economized, and all waste from the "stabbing" of the lap is prevented.

531.



The process through which the cotton passes is very similar to that in the compound opener previously described. The draught of the feed upon the laps in the creel is very slow, and stands in remarkable contrast to the action of the swiftly revolving beater. The exhaust-fans also revolve very rapidly, whilst the dust-cages move at a slow pace, in order to allow the draught to deposit a thick sheet of fibre upon the exposed portion of their surfaces.

The finisher lap machine is used for the purpose of completing the cleansing process, and obtaining a uniformly level lap, by doubling the laps from the scutcher. The idea which suggested the latter plan is to some extent erroneous. The assumed result would be achieved if it depended solely upon mechanical influences; but to these is closely allied a pneumatic force, which greatly modifies the process. The cotton, after passing the beater, is drawn by the current from the fans to the dust-cages; upon the exterior of these, it is accumulated, until the layer becomes impervious to the air, when the cotton ceases to be drawn to that spot, and is diverted to other portions of the cages, where the draught is still exerting its influence. An even delivery of the cotton may aid, but will not necessarily secure, the formation of an even lap, as the latter will quite as much depend upon the uniform strength of the current over the exposed surfaces of the cages. Should this vary appreciably in any portion, the lap will be thinner there than elsewhere. The pneumatic principle is dispensed with in all machines subsequent to the finisher lap machine.

Carding.—This is one of the most important processes in cotton-spinning. The object of those preceding it has been to cleanse the raw material from gross impurities, such as leaf, seed, sand, dust, and heavier objects, that may accidentally or otherwise be introduced. Carding is the final stage of cleansing. As far as the carding-engine is capable of accomplishing it, all short, tangled, and "neppy" fibre is removed in this operation. To make clean yarn, cotton should be selected free from immature seed, which the gin often fails to remove, owing to defective seeds being so small as to pass its blades, and get drawn in by the short and imperfectly developed fibre that covers them. Neither opening nor scutching abstracts them completely, and those that escape pass into the card, and are broken up. The particles are carried through the succeeding operations without being markedly visible, until the spinning is reached, when the twining brings them to the surface of the thread, where a great proportion are retained by the adhering fibres. In other respects, the cleansing function of the machine is very efficient.

In carding, the construction of the thread is commenced. Up to this point, there has been no effort to arrange the fibres in any given order. Here the attempt is first made to place them parallel. The thick sheet of cotton composing the lap is reduced to a thin cloud-like film, which is drawn through a cone tube, and condensed into a "sliver," a round, soft, and untwisted strand of cotton.

The carding-engine is the machine by which this is accomplished. Some difference of opinion exists amongst practical men as to the best principles of construction, and in consequence there are several forms of the machine. Good arguments can be adduced in favour of each, and probably the diverse opinions that exist originated in dealing with different classes of raw material, and getting various results.

To trace the development of the card would be interesting, but would need a volume for its elucidation. All that is necessary is to describe representative forms as now in use. Of these, there are three:—the roller, the Wellman, and the revolving flat card.

A section of the roller card, with a portion of the side, is shown in Fig. 532. Its chief parts are the following:—A, main cylinder or swift, which has a surface speed of about 1600 ft. a minute; the roller B is termed the "licker-in," from its function of taking the cotton from the feed-roller C, and delivering it to the swift. The small cylinder D is the doffer; E, the coiler; F, the can in which the sliver is coiled; and G, the lap, resting upon G′, the lap-roller. Arranged over the main cylinder, are a number of small rollers, *r* and *s*. The former are carding rollers or "workers"; the latter are "strippers" or "clearers." The cylinder, licker-in, doffer, workers, and clearers, have their surfaces covered with "cards," the fineness of which is varied according to the class of work to be performed.

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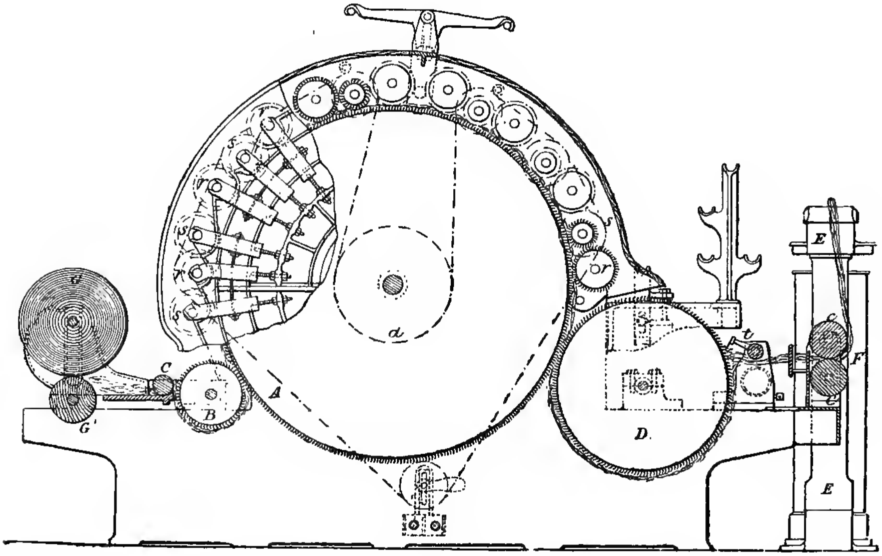

Cards are composed of small bits of wire, inserted at an angle, into a foundation of leather, cloth, or a composite material which includes a layer of indiarubber. They are usually made in the form termed "filleting"—a strip about 1½ in. wide, which is carefully wound in a spiral manner upon the cylinders and rollers. Sometimes they are made in what are termed "sheets." Fig. 533 shows the first card with which the cotton comes into contact, that clothing the "licker-in" roller. The card for this roller is purposely composed of strong wire, of short cut. The

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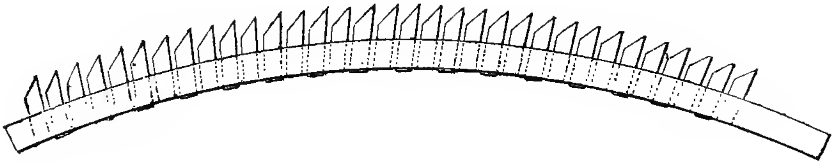

kind now generally employed is flattened, and cut diagonally at the required angle. It is extremely strong, and by its action, without injury to itself, will destroy any foreign matter that may be likely to come from the lap, and which, if it passed this point, would subsequently injure the fine clothing of the cylinder and rollers. This specimen shows the fineness required for use in the longer staples of cotton. Fig. 534 exhibits the card used for clothing the main cylinder, when fine cottons are used; its count or degree of fineness is 100's. No. 80's is used for low cottons, making coarse yarns; 90's, for general purposes; and 100's, for fine work. The clothing upon the doffer cylinder is nearly always 20 counts finer than that upon the main cylinder. The dirt-roller card, Fig. 535, is of a coarse wire openly set, so that it may readily receive into the interstices the motes, seed, leaf, or other description of refuse, lying upon the surface of the main cylinder. Its cut is similar in depth to that of the "licker-in" roller. The carding rollers, or "workers" and "clearers," are both covered with cards of the same fineness, or nearly so, as the main cylinder. The curved form of the illustrations shows the cards as when actually ready for work.

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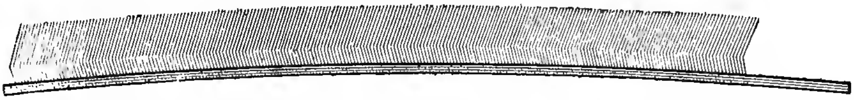

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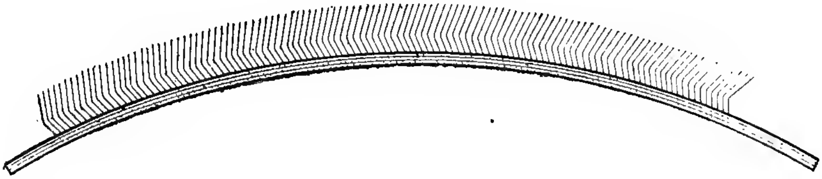

Good carding very greatly depends upon the careful adjustment of all the rollers to the surface of the cylinder, the cards of which, while set closely and evenly, should at no point touch each other. The rollers and clearers, in order to admit of this being done with the utmost nicety, are mounted upon two flexible "bends," very accurately turned, and fitted to the sides of the frame. The main cylinder, and all the rollers, are now usually composed of iron, which is less susceptible to the influence of damp or dry atmospheres than wood, the material formerly used. The bearings should be made of the most durable metal, and be kept carefully oiled. Every part should be set to work without oscillation, which, if permitted, soon renders good work impossible.

The process is as follows:—The machine having been supplied with the lap G, the end of which is passed under the feed-roller C, the lap-roller G′ slowly revolves, unrolling the web from the lap. The "licker-in" B, running at a surface speed of about 800 ft. a minute, strikes the cotton in a downward direction from the feed-roller, combing the fibres straight, and carrying them to the cylinder A, which, revolving at a surface rate of about 1600 ft. a minute, owing to its greater speed, and to the cards being bent in the direction of its motion—upward, strips all the cotton from the former, at that portion of its periphery nearest the licker-in. The cylinder carries the cotton forward to the first roller, which usually is a cleansing roller, and is technically called the "dirt-roller." Its surface speed is comparatively slow, only about 15 ft. a minute. Its function is to gather from the cotton all the remaining dirt, motes, seed, leaf, and neps, and to aid in combing the fibres straight. The dirt extracted is carried round, and stripped from the roller by the attendant; sometimes, however, a vibrating comb is attached for that purpose. The main cylinder carries the cotton onward to the rollers *r* and *s*, which successively assist in perfecting the cleansing and combing of the cotton. These rollers being set in opposition to the main cylinder, their contact surfaces move in the same direction, but at a greatly reduced speed. The cards are set on the stripper with the teeth inclined in the direction of the motion, whilst those on the workers are disposed in the reverse way, the teeth being thus in opposition to those of the main cylinder. The latter carries the cotton past the stripper to the worker *r*, the teeth of which exert a combing action, owing to its relatively slow movement of about 20 ft. a minute. That portion of the cotton, which is taken up by the teeth of the worker *r*, is carried round, until, coming into contact with the stripper *s*, it is taken by the latter, which moves at a surface velocity of 400 ft. a minute, and is itself stripped by the more swiftly revolving main cylinder. After passing the series of workers and strippers, the cotton is taken from the main cylinder by the doffing cylinder D, which has its teeth arranged in the opposite way, but moves only at the slow rate of about 60–70 ft. a minute in the same direction. The cotton is carried round its under side, until brought within reach of the doffer-comb *t*, fitted upon vibrating arms, and stretching across the face of the doffer, from which it strips the cotton in a thin film. Its movement is vertical, or nearly so; it strips the doffer in its descent, and clears itself when ascending. It makes 600–1000 strokes a minute according to requirement, being driven by balanced cranks. From the doffer-comb, the cotton is delivered in a thin sheet or film, which is condensed in its passage through a trumpet-shaped tube, and compression rollers *c*, whence it is carried over the pillar E, and, by an ingenious motion, is coiled in the can F, which stands upon a revolving plate. The cotton thus becomes a "sliver."

This form of carding-engine is probably most extensively in use, being best adapted for low and medium numbers of yarn. It is simple, easily set, and not liable to get out of order. The production exceeds that from flats, or the Wellman card, but the quality of the work is hardly equal. The cards should be put on both cylinders and rollers, closely, evenly, and with uniform tension. After being securely fastened, all should be evenly ground. The frame of the machine ought to be perfectly level, and placed on a floor free from vibration. The doffer, the taker-in, and the rollers, should be set exactly parallel with the cylinder, and be carefully adjusted as close as possible without touching.

Another system of carding is the one in which the rollers and strippers of the machine described above are dispensed with, the substitutes being a series of flats, extending from side to side of the machine, and covering the upper half of the cylinder. The under sides of these flats are covered with cards, and are so adjusted as to effect the same object as the above. This form of carding-engine has passed through numerous mutations and improvements, before its present stage of perfection was attained. Formerly the flats were stripped by hand, which required steady attention and skill on the part of the operative; qualities which were not always found in combination. As the difficulty of obtaining a supply of efficient men increased, attempts were made, with varying degrees of success, to accomplish the work by mechanical appliances. Amongst the most successful of these, was the method devised by George Wellman, an American, who invented the machine so widely known as the "Wellman card."

On its introduction into this country, it was taken in hand by Dobson and Barlow, machinists, further improved in numerous details, and adapted to work as either a first or "breaker," or as a finisher card. In the production of medium numbers of yarns, more carding is necessary than for lower counts. In many cases, the roller card is used as a "breaker"; in others, various adaptations compounded of the roller and the flat card are used, and sometimes modifications of the latter alone.

The finisher carding-engine on the Wellman principle, as made by Dobson and Barlow, is represented in the accompanying illustration, Fig. 536. In its main parts, it differs little from the preceding. The series of flats *f* are fitted upon adjustable brackets *g*, which are so arranged as to admit of each flat being set accurately parallel to the face of the cylinder. The lever or arm *h* moves backwards and forwards over the semicircle of flats *f*; on this arm, is fitted the flat-lifting and stripping apparatus, which has proved to be such an ingenious substitute for human attention. By

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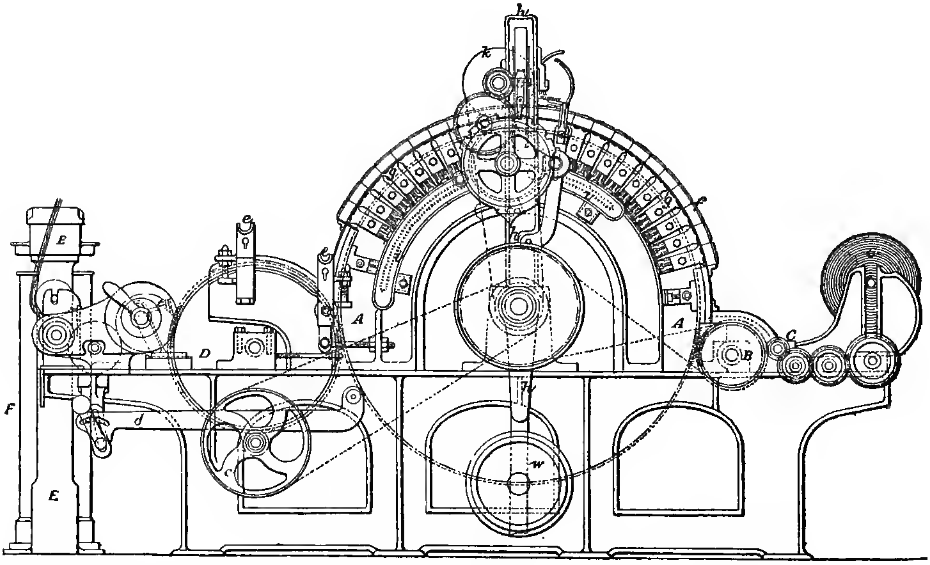

means of this arrangement, the flats are lifted from their respective brackets, and turned upward, and their face is exposed to the action of the stripper roller, which clears away the accumulated waste that has gathered thereon. Immediately this has been done, the mechanism restores it to its place; the arm resumes its movement, until it reaches the next flat that has to be stripped, when it again pauses, to allow the above performance to be repeated, and so continues until the whole of the flats are stripped, when the operations recommence. The order in which the flats are lifted varies, those nearest the lap needing to be stripped most often. The numbers of flats are so arranged that, whichever plan be adopted, each in proper order will come under the action of the stripper. The brackets *e* are for the reception of the grinding roller, for grinding the cylinder and doffer, without removing them from their positions.

The revolving flat card is another form of the same machine. In this machine, Fig. 537, the flats are arranged in the form of an endless lattice; the working flats rest upon a semicircular guide *n*, upon the tops of the sides of the frame, adjusted by means of the screws *p*. Those out of action are suspended upon carrier rollers *g*, over which they travel. The rate at which the lattice moves is very slow—about 1 in. a minute. In their course, each flat is subjected to the action of the stripping roller *k*, after which it passes on to take its place amongst the working flats.

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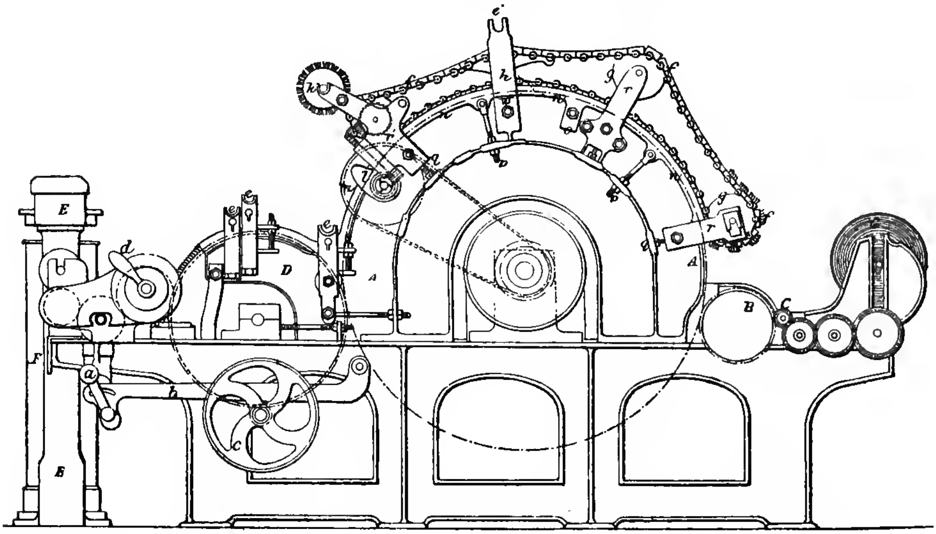

Besides these principal forms of the carding-engine, there are several modifications, wherein the distinctive features of the roller and the Wellman card are combined. These are called "combination" or "union" cards.

The most remarkable machine employed in the preparation of cotton for spinning is the combing machine used for long-stapled cottons, for fine yarns. It was invented by M. Heilmann, of Mulhausen, and first became extensively known to the public through being shown at the Exhibition in London in 1851. The patent was purchased by a company of Manchester spinners of fine yarns, for the sum of 30,000*l.* They for a time restricted its use to themselves, but subsequently permitted it to be supplied to the public, on payment of a royalty of 300*l.*, which brought its cost to 500*l.* This was reduced, as the patent neared its expiration. It was, however, virtually extended by the patenting of improvements which experience had suggested. It has since been extensively adopted, and, for making the best classes of yarns, is now regarded as indispensable. Another combing machine, invented by Imbs, has since been favourably received. In the Heilmann "comber" (Fig. 538), the lap *a* is placed upon the rollers *b*, which, by their revolution, unwind the fleece, and pass it down an inclined guide *c* to a pair of steel feed-rollers dd^1; the nether one is fluted, and the upper is covered with leather. These rollers have an intermittent motion, obtained through peculiar gearing, by which they are turned $\frac{1}{16}$–$\frac{1}{12}$ of a revolution at a time. They deliver the cotton to a nipper, which opens to allow its passage. This nipper is composed of two parts—the blade *e* and the cushion e^1, the latter being covered with leather. The nipper-blade receives motion from a cam, at the gearing end of the machine. The motion is transmitted through two levers, a connecting-rod e^3, and a shaft. The movement imparted to the blade is greater than is required to bring it into contact with the cushion plate, and the latter, being hung upon a pivot, and held forward by a spring, is pushed backward by the pressure of the blade, into a position which subjects the cotton to the action of the combing cylinder. A reverse movement then occurs, which permits the cushion plate and nipper-blade to advance with the cotton in their grip, to a point where, when the nipper-blade rises, the fibres are taken hold of by a detaching roller g^1, and a fluted segment on the combing cylinder f^1. The side of this cylinder opposite to the fluted segment carries a series of 17 combs f^2, graduated in fineness from 30 to 90 teeth in the inch. Between the fluted segment and the combs, is a plain space at each side, which affords time for making the required changes between the combs ceasing to act and the fluted segment coming into work, and *vice versâ*, the cylinder revolving continuously. The top comb is fitted above the cylinder; its purpose is to comb the ends of the fibres, and to prevent any being drawn forward, except those that have been combed and cleaned by the cylinder. The top comb has only a vertical movement, being lifted out of the way of the cylinder comb when the latter is passing beneath. The detaching roller g, with its leather-covered fellow g^1, and the accessory roller g^2, receive their motion from a cam, which is arranged to turn the roller g one-third of a revolution backward, then, reversing, two-thirds forward, when it stops until the cylinder-combs have prepared another length of fibre. The reverse movement is given to the roller g for the purpose of taking back the rear end of the previously combed fibres, so as to place them under, and attach them to, the fibres coming from the combs, to form them into a continuous sliver or riband, it being necessary to detach the fibres under operation from the remainder of the fleece as fed in, and also from the fibres already combed. The attachment having been made, the roller g reverses, and removes the next length of fibres out of the way of the cylinder combs. In order to properly catch the partially combed fibres, the top roller g^1 is made to move round the axis of the roller g, into contact with the fluted segment of the cylinder f^1, thus forming a revolving nipper. The top roller g^1 is brought into contact by the lever g^4 and its connections by means of a cam at the gearing end of the machine; it is in contact with the fluted segment only for a portion of the time that the roller g is making the partial revolution forward; but is always in contact with the roller g.

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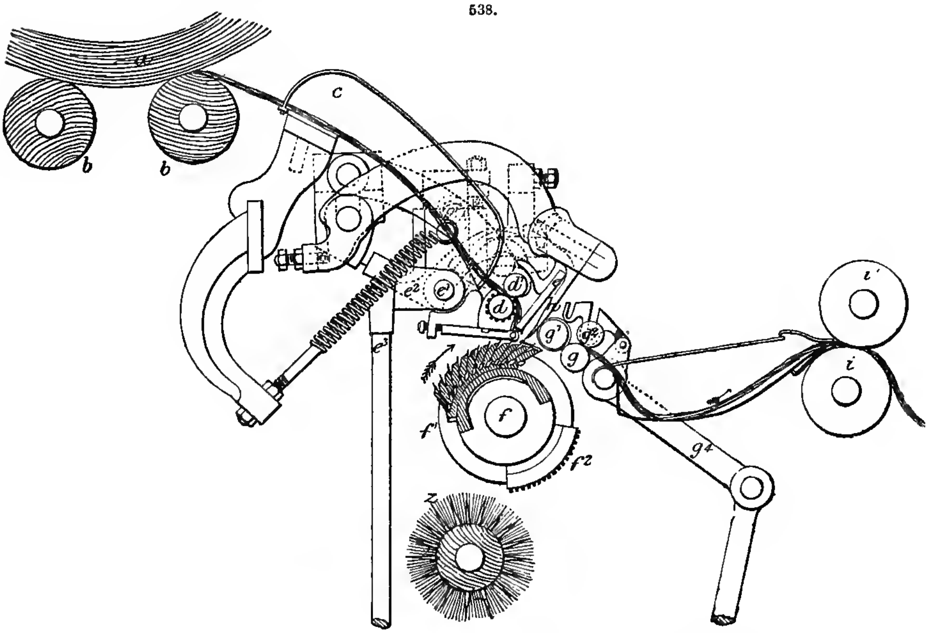


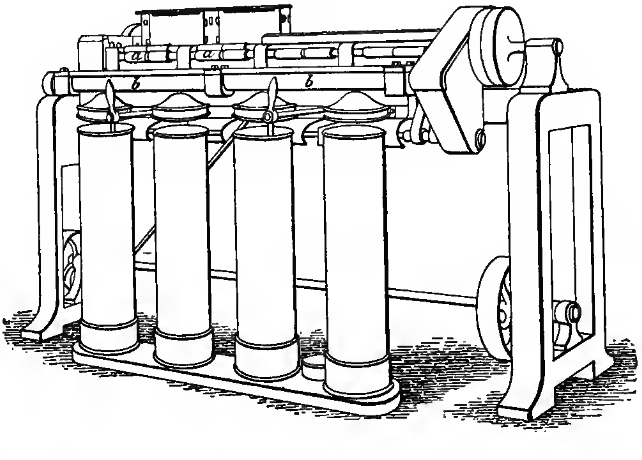
Combing being thus completed, the riband of cotton passes to the rollers $i\,i'$, and is drawn by them through a trumpet tube, which presses it together to form a round sliver. The slivers from the six heads are then united, passed through the drawing head at the end of the machine, and coiled into a can.

As the combing process has for its object not only the removal of dirt and neppy cotton, but also the separation of the short fibres contained therein, the disposal of these may be briefly described. When the roller g^1 and the fluted segment have got hold of the front ends of the half-combed fibres, the top comb falls a little in front of the part upon which the cylinder combs had previously operated. The roller g^1 and the fluted segment of the cylinder then draw the fibres forward, the top comb preventing anything coming forward, except the long fibres protruding through the teeth of the comb. The short fibres are thus left in the portion of the fleece from which the long ones have been drawn, and on the rollers $d\,d^1$ delivering a fresh length through the nipper $e\,e^1$, the combs on the cylinder f^1 pass through the projecting part of the fleece, and separate from it the neps, dirt, and all the fibres not long enough to be firmly held. They thus take the waste from the front ends of the fibre, and that which was left by the top comb. As the cylinder revolves, the waste is cleaned out by the action of the revolving brush z, which has a more rapid motion than the cylinder; the brush then throws the fibres upon a doffing cylinder, covered with card clothing, which is stripped by an oscillating comb, when it drops into a receptacle at the back of the machine. This short fibre and waste is subsequently used in spinning low and coarse qualities of yarn, in which cleanliness is not an important requisite.

Drawing.—One of the main purposes of each successive process in cotton spinning is to eliminate the defects and irregularities left by preceding operations. An intermittent or irregular supply of cotton to the lap machine produces variations in the weight of the laps, occasionally to the extent of 3–6 per cent. These, in the carding process, give correspondingly irregular slivers, and, if passed through the subsequent stages, would yield the most unsatisfactory results.

In order to obviate this, in the drawing process, 6–8 slivers from as many different cards are combined, and attenuated to the dimensions of one; six of these are again put up, and the operation is repeated; this takes place usually a third time, when the sliver is regarded as having been sufficiently drawn. The series of doublings stands thus—8 × 6 × 6 = 288, so that the irregularities existing at the commencement are reduced to an imperceptible amount.

539.



The machine by which this is accomplished is the drawing-frame, a front view of which is shown in Fig. 539. It is one of the simplest machines employed in cotton spinning. It is the first, however, in which is introduced the important principle of drawing or attenuating the material by means of rollers. Of these rollers, there are four pairs in this machine, arranged in parallel order behind each other. The front pair are visible at *a*. The two pairs at the rear are fluted; whilst in the two front pairs, it is only the bottom ones that are so constructed, the upper ones being covered with cloth or leather. These pairs of rollers revolve at different velocities, the speed increasing from the back to the front. By this action, the fibres are drawn into parallel order, the sliver is attenuated, and the unevenness of each, and the irregularities of the whole, are eliminated. The speed is graduated between the different pairs, in such a manner that the front or delivery rollers have a surface speed equal to about six times that of the taking-in rollers. Where eight slivers are drawn into one, it becomes correspondingly increased. The usual speeds of the rollers are in the following ratio:—Taking-in, 1·00; 2nd, 1·50; 3rd, 5·75; 4th, 6·00. These will differ as the draught is more or less, but the proportions will be maintained.

In the drawing-frame, the cans containing the slivers are arranged behind; the slivers are passed through holes in a horizontal plate, for the purpose of preventing their passing up in the form of loops, knots, or kinks. From here they go over a semicircular plate to a guide plate, in front of which the ordinary lever-stop motion is placed. This is a compound lever balanced in the middle. One end of this is spoon-shaped, and rises in front of the guide plate. The opposite projects beneath the semicircular plate, and has a loose bar, attached by a joint, pendant from its extremity. Beneath this bar is a notched shaft. The sliver, after passing the semicircular plate, is carried upon the spoon-shaped end of the lever; its weight and the draught upon it depresses it, so as to lift the pendant bar out of the way of the revolving notched shaft; thence, by means of the coiler, it is neatly deposited in the cans. When the sliver is finished, or breaks, the spoon end of the lever rises, the pendant bar at the opposite extremity is depressed, and stops the notched shaft, which, being driven by a catch box, its sliding portion is pushed aside, and stops the frame.

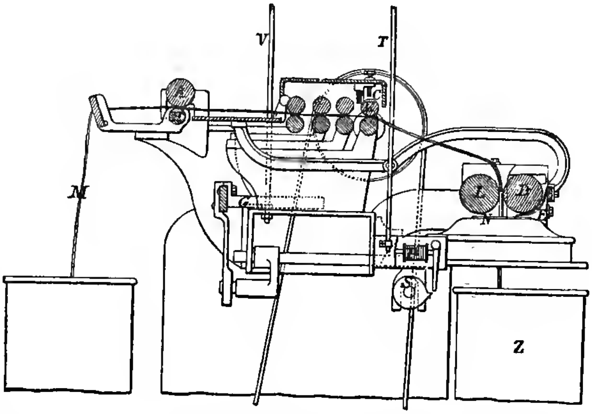
Until about 1840, much difficulty was experienced in making thoroughly even yarn, owing to the fact that efficient supervision could not be obtained from the operatives superintending the preparatory processes. It will be clear that when six, eight, or other numbers of slivers are drawn together into one, should one or more of these become exhausted or broken, and the draught of the remainder continue, the resulting sliver will be proportionately reduced in substance and strength. Wherever two or more threads are worked together to form one, this is liable to occur, and, when it happens, the commercial product is seriously depreciated in value. These defects were constantly pressed upon the notice of the trade, and led to many attempts at their removal; but success was not obtained until James Smith, of Deanston, invented the above-described stop motion, which partially remedied the evil. Since his day it has been considerably improved, but, at its best, has hitherto left much to be desired. It will be obvious, from the description, that its sensitiveness and constant action are dependent upon the presence of conditions which cannot always be assured. Many attempts to further improve it have been made, but without much success. It is, however, likely to be superseded by the electric stop motion, recently introduced by Howard and Bullough, of Accrington.

The inventors of this novel improvement, having regard to the fact that mechanical stop motions as ordinarily constructed are often either too cumbrous or complex to be sufficiently sensitive, or, if the latter be attained, are too fragile in their parts to be durable, sought to reduce these to a minimum, and, if possible, to increase the sensitivity. The idea of employing electricity for this purpose suggested itself, and the fact that cotton wool, in its ordinary condition of dryness, is a non-conductor, favoured the plan. After considerable effort, the invention was perfected; and, in practical application, it has been found to be all that could be desired.

To supply the electric current, the inventors employ a small magneto-electric machine, which is driven by a band or belt from the shafting that drives the machinery. It is very small, and the power needed is not more than would suffice to drive a small domestic sewing machine.

In Fig. 540 is seen a section of the chief working parts of the drawing-frame, with sufficient detail to show the application of the electric stop motion. The rods V and T convey electricity from the generating machine to the frame. The parts marked A, C, D, E, are connected with T, and H, K, L, N, with V. The drawing-frame requires to be stopped on any of the following occurrences:—on the breakage of the sliver M at any part, or on the exhaustion of the supply; on its lapping around the front rollers; and on the can Z becoming full. The insertion of the sliver between the rollers prevents electrical contact taking place. Should breakage occur, the slight space is instantly closed, the electric circuit is completed, and the small magnet P is endowed with power to attract the lever, which stops the revolving notched shaft S; this, by means of a catch box, as in the ordinary stop motion, moves the driving strap from the fast to the loose pulley. Should the sliver, or a part of it, begin to lap round either of the front rollers, the space between them is increased, the top roller K rising soon comes into contact with the screw C, which completes the electric circuit again, and stops the machine. When the can Z is filled, and the sliver would run to waste if not attended to, its accumulation lifts the tube wheel N, until it comes into contact with the point E, when electrical contact again takes place, and the machine is stopped. By means of another arrangement, the electrical circuit is broken when the machine stops, and the force is made available for the needs of other machinery.

540.



The introduction and utilization of this subtle agent in a realm of industry which is almost exclusively occupied by mechanical powers is quite new, and, in the cases of the drawing, slubbing, and intermediate roving-frames, to which it has been applied, has proved highly satisfactory. For the carding-engine, and the final roving-frame, to which it has also been applied, the inventors do not so strongly recommend it; but in neither of these cases is it so necessary, as the purposes to be answered, and the difficulties to be obviated, are not so important.

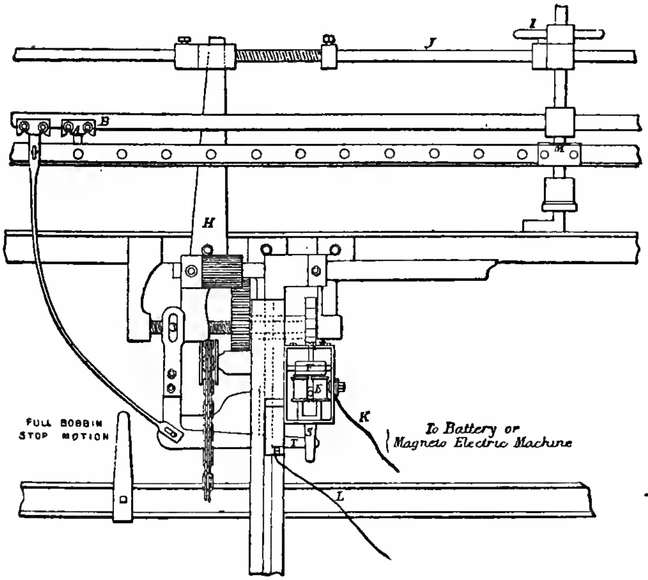
In the drawing process, the number of times the material should be doubled and drawn is chiefly dependent upon the class of cotton used. The object being to draw the fibres into parallel positions with regard to each other, drawing, carried beyond the point at which this is accomplished, is injurious and wasteful, weakening the fibre, and entailing loss. The varieties of cotton in which the fibre is soft and pliable, such as American qualities, brown Egyptian, and soft Peruvian, require less doubling than the harsh and intractable descriptions, such as Brazilians, &c. Much also in practice depends upon personal opinions. For the softer descriptions, when intended for yarns not exceeding 30's or 32's, putting it through two heads of eight ends each, thus doubling sixty-four times, will generally be found sufficient. In other mixings, or when higher numbers are spun, the employment of three heads of drawings is necessary; one of eight, and two of six ends each, being equal to 288 doublings. Sometimes eight ends are put through each head, when the number becomes 512.

Drawing-frames should never be placed in damp rooms, nor should the atmosphere of the room ever be allowed to become damp, as it tends to make the rollers "lick" the fibre, making a large percentage of waste. The opposite extreme of dryness should also be avoided, as it prevents the laying of the fibres parallel to each other, because they manifest a tendency to curl, which subverts the end in view.

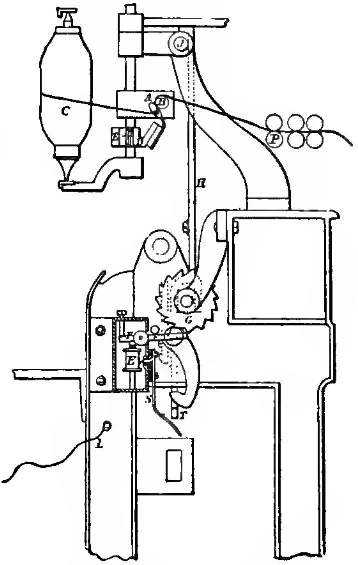
Slubbing.—As previously defined, slubbing is to further attenuate the sliver, and draw the fibres into more perfect parallel order. Instead, however, of 6–8 slivers being put up, only two are usually condensed into one. The machinery, in its first working parts, is similar to that of the drawing-frame; but, instead of the sliver—after this process called "slubbing"—being coiled in a can, it is wound upon a bobbin, or barrel, by means of the spindle and flyer; the slubbing-frame belonging to the series of bobbin and fly frames. It is generally constructed with about eighty spindles as a maximum number. These are of a size to fit them for the reception of bobbins 10–12 in. in height. The traverse is correspondingly large. In this frame, the cotton is first twisted, the attenuation of the sliver having proceeded so far, that, without this, its coherence would not be sufficient to pull the bobbin round when being drawn off in the subsequent process. As the strand of fibres has to be further attenuated, and much twist would prevent this, no more is put in than is necessary for the above-mentioned purpose. A better opportunity for describing the flyer, and the differential winding motion, will occur subsequently, so it need not be introduced at this point.

Intermediate, or Second Slubbing.—This is, in all essential respects, a repetition of the slubbing process, the machine containing, however, rather more spindles than the slubbing-frame, and its bobbins being smaller—8–9 in. In spinning Nos. below 20's, it is not usually employed. The accompanying diagrams illustrate the method of applying the electric stop motion to this important machine. In its operation, there are two occasions when the frame requires to be promptly stopped.

541.



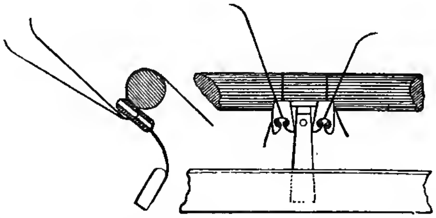
542.



Two "slubbings" are put up to form one thread, one of these may break, or the bobbin may become exhausted, and it is necessary that these occurrences should be detected immediately, otherwise the attenuation of the single thread, which would continue passing through, would cause a great amount of waste; or, if permitted to pass into the spinning-frame, it would seriously depreciate the quality of the yarn produced. Numerous attempts have been made to obviate the mischief by mechanical appliances, but without any satisfactory result, until the most perfect success was achieved by this invention.

As shown in Figs. 541 and 542, the bar on which the springs A are fixed is placed in connection with the positive pole of the battery or magneto-electric machine. The fluted roller B is in connection with the negative pole. The strands of cotton separate the spring and the roller; but when, through the breakage or exhaustion of one strand, they come into contact, the electric circuit is completed, and the magnet is charged, so as to attract downwards one end of the double lever F, the opposite end of which, rising into contact with a ratchet wheel, acts upon a clutch, and stops the machine through the medium of the usual appliances. The action of the working parts can be most clearly seen in Figs. 542 and 543, the latter being an enlarged view of the parts.

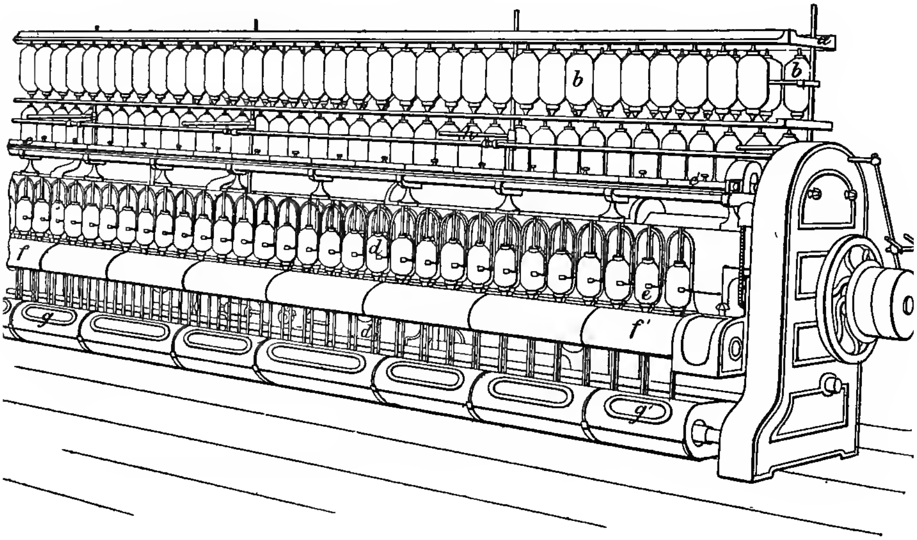
543.



Roving.—This is a continuation of the above, the object being the same, and the means by which it is accomplished, identical. The sizes of the spindles and bobbins are further diminished, whilst the number of the former is increased, ranging from 140 to 200; the lift of the bobbin is 5–7 in. Sometimes a second, or fine, roving-frame is used, where fine numbers are spun. It is often called a "jack" frame, and carries the fineness of the roving to 30–40 hanks.

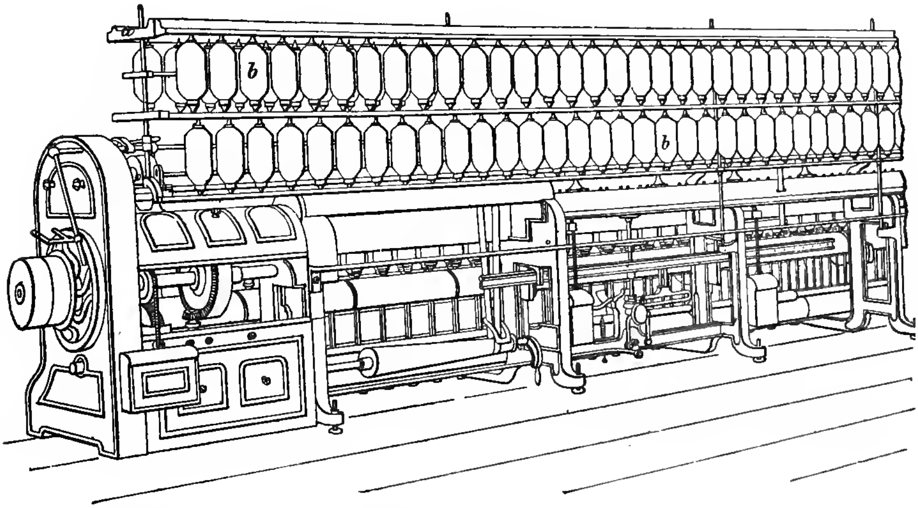
For purposes of illustration and description, the roving-frame may be taken as representative of the slubbing and intermediate frames. In principle they are the same, and differ only in details. All belong to the class of bobbin-and-fly frames. The roving-frame (Figs. 544, 545), unlike the slubbing-frame, which draws its supply of the raw material from the sliver cans, is provided with a creel similar to, but necessarily smaller in detail than, that of the intermediate frame.

544.



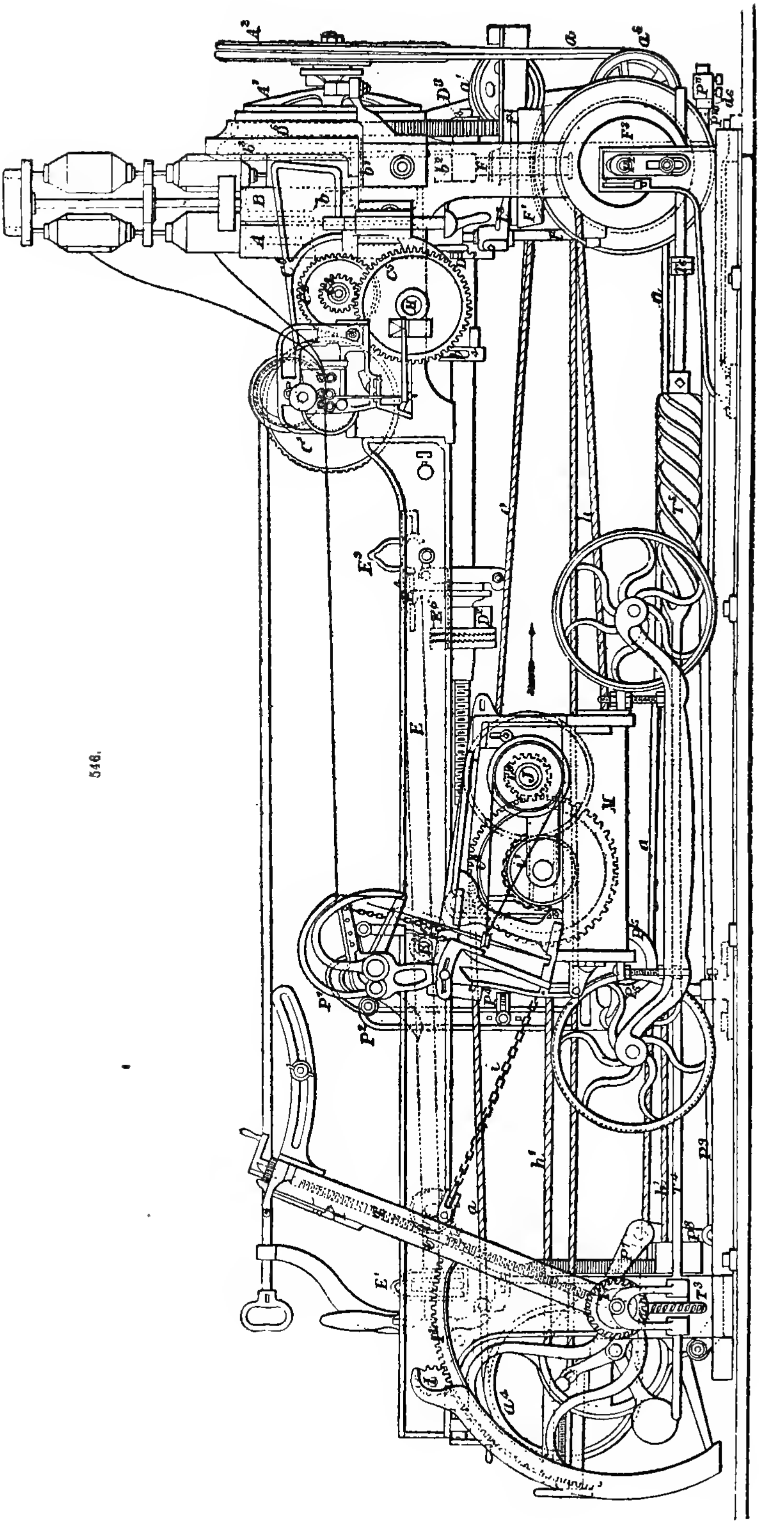
These creels contain the tubes or bobbins, holding the supply of the attenuated strand of cotton; the bobbins are arranged vertically, and held in a position to revolve easily, by lance-wood pegs, called "creel-pegs." In the slubbing-frame, are four pairs of drawing rollers; but in the roving-frame, only three pairs. The number of these rollers is sufficient to extend across the length of the frames from *c* to *c'*, and are laid horizontally, parallel to each other. The under one of each pair is fluted; the upper is plain, and covered with leather. The top rollers are generally made with loose bosses, the invention of the late Evan Leigh. Metallic plates, called "caps," cover the rollers, and serve to protect them from dust, and accidental injury. The rollers are mounted on a beam, called the "roller-beam," about midway between the creel and the spindles. The latter constitute a prominent portion of the machine, and are arranged in two rows, one behind the other, as seen at *d*. They are furnished with fliers, screwed upon the top; each of them possesses what is termed a "pressure-finger" *e*. The arms of the flier, to one of which this is attached, are tubular, and the pressure-finger is interchangeable. It is of great importance, in ensuring the perfect working and durability of the machine, that the flier should be nicely adjusted upon the spindle, and the arms be in equipoise. Two shafts extend throughout the length of the machine, under each of the series of plates marked *f f′* and *g g′*. The lower one carries the bevel wheels, that gear into smaller ones upon the spindles, by which the latter are driven. Similar gearing, upon the corresponding upper shaft, drives the bobbin at a slower speed, and in connection with a differential motion, arranged to accelerate or reduce the pace, as the diameter of the bobbin increases by the addition of successive layers of the strand of cotton, and according to the principle on which the machine may have been arranged :—viz. whether the flier runs faster than the bobbin, or the converse.

545.

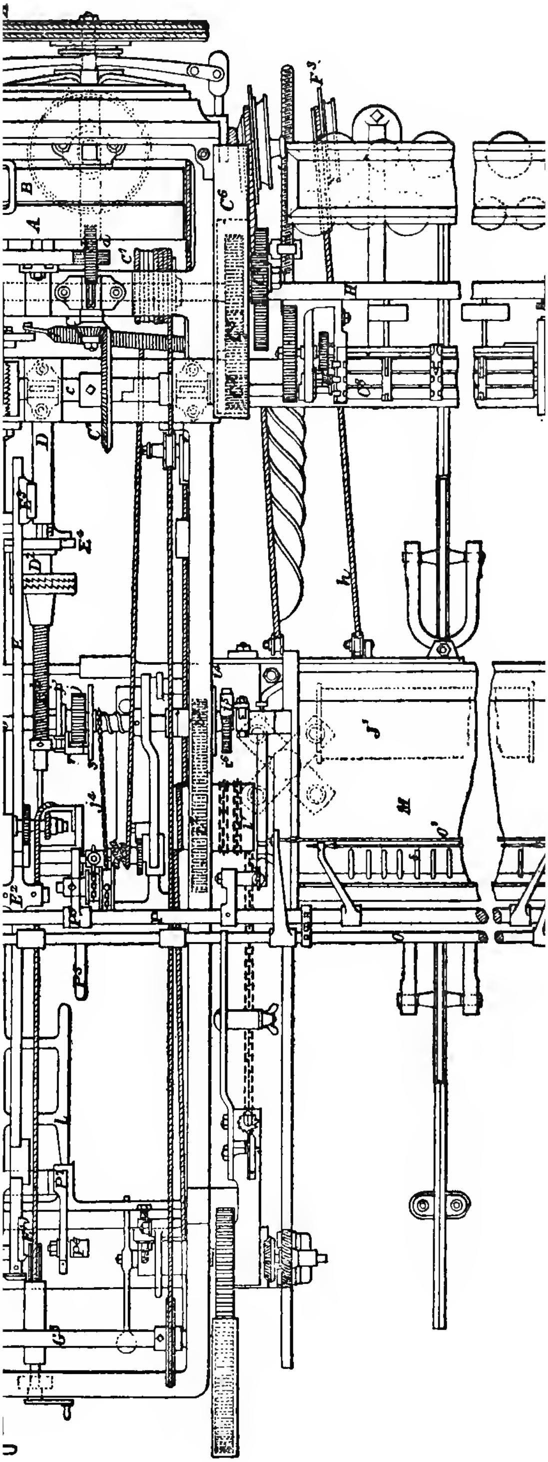


The formation of the raw material into a strand, and its attenuation, commenced in the carding engine, where the sliver coming from the card is usually about ¾ hanks to the pound; after its passage through the drawing, slubbing, intermediate, and roving frames, it may have become, according to requirement, 5, 7½, or 12 hanks. Should the jack frame be in use, it may be any number of hanks up to 40. The roving is now passed to the last machine of the series, in which the processes necessary to the construction of a thread from the raw material are completed. This is the mule, throstle, or its modification, the ring frame.

Spinning.—This is the chief process of the series; those previously described being subordinate and preparatory only. There are two methods in use: the older being that which Arkwright, if he did not invent, certainly rendered practicable, in his "water-frame," which, under subsequent modifications and improvements, has come to be called the "throstle-frame"; the second, the mule, invented by Samuel Crompton, in which the chief features of Hargreaves' "jenny" and Arkwright's water-frame are combined. In Hargreaves' machine, which was the first practically successful attempt to spin more than one thread at a time, a portion of roving was delivered from the frame, and attenuated by the draught of a receding carriage, containing the spindles, which, as they drew out the fibre, gave it the amount of twist necessary to constitute a thread. In all spinning machines, the twine imparted by the spindles naturally crowds into the thinnest portion of the strand, making it firm and hard, but leaving the thick parts almost unchanged. In this state, as the carriage receded still further, the thick parts of the thread were easily attenuated to the same degree as the other portion, and properly twisted, making a fairly uniform and even thread. This was a far more successful imitation of the operations of the hand spinner than was Arkwright's plan, invented subsequently; but it was not nearly so successful, owing to the roving having to be reduced entirely by the stretch of the receding carriage. The attenuation of the roving by the drawing rollers of Arkwright was much more easily accomplished, and admitted of the process of spinning being continuous; whilst in the latter, it was intermittent, stopping to wind upon the spindle each "draw" or length of yarn as it was spun, thus consuming nearly ⅓ of the time. The yarn was also insufficiently twisted for warp purposes, and was fit only for weft. That produced on the water-frame was firm and hard, and quickly began to displace the



546.


B
A
C6
d
C1
c
C7
D
E2
E4
D2
F3
H
C8
h
J1
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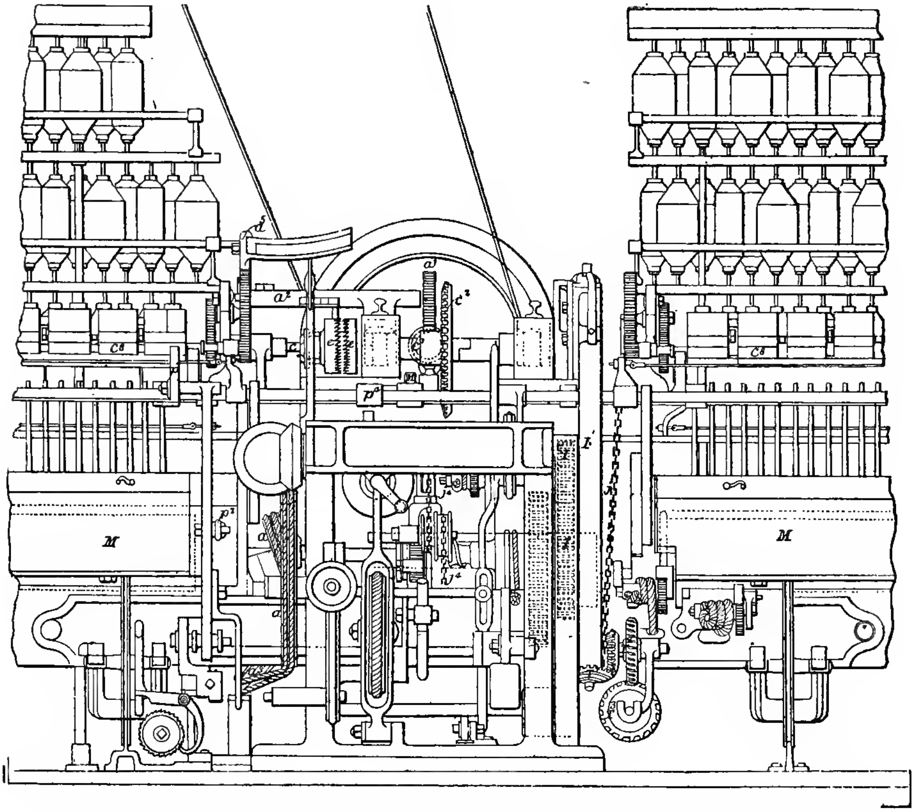
r
s
j4
L
O
P1
G3

linen warps at that time in use. It had, however, numerous defects, the chief of which was its irregularity in strength and evenness. The crude manner in which the preparatory processes were carried on at that time yielded a very irregular roving, from which the yarn had to be spun. Arkwright's machine possessed no means by which this could be eliminated, the drawing rollers reducing the thick and fine places only in equal proportion. The need of further improvement was therefore generally felt. Amongst the number who sought to accomplish this, was Samuel Crompton, who had been accustomed to spin weft on Hargreaves' jenny. Experience had made him acquainted with the merits and defects of both Hargreaves' and Arkwright's machines, and shown him that, to a great extent, they were complements of each other, and united would almost perfect the art of spinning. This he laboured for a long time to realize, and the fruit of his efforts was the mule, in which the distinctive features of the jenny and the water-frame are combined: the stretch of the yarn in the former, and the attenuation of the roving by means of rollers in the latter. The result of his success was quickly seen in the rapid multiplication of spindles chiefly on this principle. With subsequent improvements, the mule has become the most perfect and important machine in the series, and, as such, claims priority of notice.

Fig. 546 represents a side elevation of the mule headstock, with a transverse section of the carriage, shown as running in, and in the act of winding. The drawing-rollers and roller beam are also seen in section. In Fig. 547 is seen a corresponding plan of the mule, showing the headstock in the middle, and having spindles working on each side. Fig. 548 is a front view.

548.



The driving power is communicated to the machine through the horizontal first-motion shaft, on which are the fast and loose strap pulleys A B. When the carriage M has run in to the roller-beam, or drawing-rollers, the front of which series is seen at c^8, the driving strap is on the fast-pulley A, though a portion extends to the loose-pulley B. Motion is communicated to the drawing-rollers by the small change bevel-wheel C, driving the large bevel-wheel C^1, running loose on the horizontal shaft c, and connected with the front line of drawing-rollers. The spindles are also driven from the chief motor shaft by the double-grooved cord-pulley, or rim, A^2, on the extremity of the shaft, carrying the bevel-wheel C. From this pulley, an endless cord a passes downwards, beneath the guide-pulley a^1, thence to the oblique cord-pulley a^2, as seen in the carriage M, and to and around the tin roller a^3, keyed on the horizontal shaft J, which carries the tin cylinders J^1 used for driving the spindles. Thence it passes forward, and around the carrier-pulley a^4, fixed to the front of the frame, then along the floor to the guide-pulley a^5 at the back of the headstock, and thence to the rim-pulley A^2. Whilst these movements for the spindles and drawing-rollers are going on, the small spur-pinion C^2, keyed on the front roller *c*, drives the spur-carrier-wheel c^3, which drives the spur change-wheel c'', fixed on the boss of the smaller spur-wheel c^4; the last-named c^3 and c^4 run loose on studs, fixed to the movable weight-lever c^6, hinged on the front roller-shaft *c*, the spur-wheel c^4 gearing into the spur-wheel c^5, which is keyed on the shaft H, running the full length of the mule, and upon which are fixed three scroll-pulleys, one being seen at c^7, and one at each end of the shaft. These pulleys have a rope attached to and wound upon them, the other part being passed round the guide-pulleys, turned back, and attached to the carriage, for the purpose of traversing it outwards as the yarn is spun. When the carriage arrives at the extent of its stretch, i.e. is at the point of its traverse the furthest from the front drawing-rollers, the faller-shaft comes into contact with the incline E^1, fixed on one end of the beam-lever E, pressing it down, so that it turns on its fixed centre E^2. On the opposite end, is a similar incline E^3, also a stud E^4, on which hangs the pendant cam-plate, the back of which bears against the fixed bracket. At the lower end of this bar, is an oblong slot, through which the cam-shaft passes. This slot is of sufficient length to allow of the free vertical movement of the cam-plate. At each end of this slot, concentric with its centre, and projecting from the face of the cam-plate, are two circular inclines, one of which is seen at E^5, commencing its rise, and terminating diametrically opposite, being half a revolution. One end of a steel pin abuts against the top of this incline, and passing in a horizontal direction through the catch-box D^2, presses with its opposite end against the other half of the catch-box, holding it out of gear until acted upon. This half of the catch-box slides freely upon a key, fixed on the cam-shaft. A spiral spring E^6, one end of which presses against its boss, and the other against a stop-hoop, which is adjustable to regulate the tension of the spring E^6, is fixed with a set-screw to the shaft. This shaft next passes through the tubular cam-shaft D, to the back of the headstock, where it has the wheel D^3 keyed upon it. When the end of the beam-lever E is pressed down, so that it turns on its fixed centre E^2, moving its opposite end upwards, it carries the pendant cam-plate, with its circular incline, away from the steel pin; the new position allows the steel spring E^6 to act upon the catch-box, putting it into gear with the catch-box D^2, which it carries round half a revolution, when the steel pin which is brought with it comes into contact with the second incline, puts it out of gear, and causes all motion to cease. The tubular cam-shaft D runs in bearings, one at each end, projected from the frame side, and supports the last-mentioned shaft. The catch-box D^2 is keyed on one end, to give it motion. The cam 4, which acts on the lever 6, is also fast. The lever 6, passing upwards, extends to the catch-box on the front roller *c*, and is carried by a stud in the frame, the centre of which is seen in the plan. The helical spring 7 is attached to this lever, and thereby holds the catch-box in gear. The partial revolution of the cam-shaft D is effected by the revolving bevel-wheel *b*, fixed on the boss of the loose-pulley B, on the first-motion shaft, which gears into another wheel b^1, keyed on the top of the upright shaft F, which passes down to the scroll-shaft. Another bevel-wheel on the same vertical shaft b^2 gears into the large backing-off bevel-wheel shown by dotted lines in the drawing, cast in one piece with the spur-wheel D^5, and which runs loose on the journal of the main driving-shaft, and gears into the spur-wheel D^3, on the end of the cam-shaft giving motion. When the carriage arrives at the boundary of its stretch, the first movement of the cam-shaft D, actuated in the manner explained, is to throw out of gear the catch-box on the front roller-shaft, thus stopping the motion of the drawing-rollers and carriage. This is accomplished by the cams 4 and 5; the cam 4, coming round, presses against the projection on the lower end of the forked lever 6, working in the ring-groove in the projecting boss of the catch-box on the front roller-shaft. The cam 5 presses down one end of a beam-lever, the centre of which is seen at the opposite end, lifting the vertical bar, the top of which bears against the lower surface of the movable weight-lever c^6, and disconnects the spur-wheel c^4 and the wheel c^5, thus stopping the carriage.

The next operation is stopping the motion of the spindles. This is effected by the worm *d* on the first-motion shaft, gearing with the worm-wheel d^1 on the end of a short shaft, which passes through the bracket d^2, fixed to the headstock; the opposite end of this shaft carries a cam d^3, which acts at the proper time upon the end of the catch d^4, hooking on the end of the bracket d^2. The opposite end of this catch is joined to the strap-lever d^5, which carries the fork to guide the strap. When the catch d^4 is hooked on the bracket d^2, it retains the strap on the fast-pulley A. As the shaft makes one revolution during each stretch of the carriage, the cam d^3 is so adjusted as to act at the proper time upon the catch d^4, liberating it from the bracket d^2, when a helical spring is made to act upon the strap-lever d^5, shifting the strap on to the loose-pulley B. The lower end of this lever hinges on a stud, fixed in the frame side, and, at this point, it branches off for a short distance, in a horizontal direction, towards the back of the frame, passing under a short projection from the backing-off lever d^6. This projection rests upon the branch of the strap-lever; its office is to prevent a shock when putting the backing-off cones into gear as the strap leaves the fast-pulley. The backing-off lever oscillates on a stud fixed in the frame. On the upward branch of the lever, is a loose stud d^7, which is secured to one end of a screwed rod, by means of two nuts, so as to be adjustable; the other end is attached, by means of a small stud, to one end of the horizontal lever d^8, the middle portion of which fits the ring-groove on the boss of the conical friction-pulley, by means of which the latter is brought into frictional contact with the internal cone of the backing-off wheel b^3, on the main driving-shaft, and is thus made to revolve in an opposite direction to the main driving-shaft, by the bevel-wheel, on the boss of the loose-pulley B, as before shown. Thus, when the friction-cones are brought into contact, combined with the motion of the pulley A^1 and the main driving-shaft, the change reverses the revolution of the spindles. As soon as the backing-off commences, the ratchet-wheel j, which is keyed fast on the tin roller-shaft, is carried round with it. On the boss of this wheel, a ring-groove is turned, which is clipped by a bent spring j^1, and the latter being carried round with it by frictional contact, its free end bears against the tail of a catch r, pressing it into gear with the ratchet-wheel j, which carries the last-named catch and its stud with it. This stud is fixed in the disc 3, which runs loose on the tin roller-shaft J. The boss of the disc is formed into a spiral groove, increasing in diameter as it approaches the flange. A chain j^4 is attached to this boss, and, winding round the spiral groove, passes horizontally towards the front of the carriage, partially round a flanged carrier-pulley, fixed on the top end of the lever p^5, then up to and over a short bent lever p^3, and is fixed on the faller-shaft p, being attached by means of a screw and wing nut, to adjust its length. This short lever pulls down the faller-wire to the apex of the cop. A lever p^1 is fixed on the faller, and, at its free end, is a stud, on which hangs the pendant bar p^2. By the time the faller-wire s has attained the level of the points of the cops in process of formation, the foot of the pendant bar is drawn upon the top of the slide, with its anti-friction bowl resting on the cop-shaper R. A stud is fixed in the pendant bar, on which is placed the adjustable rod p^4, the other end being attached to the upper extremity of a short lever, placed just within the carriage. The opposite end of this lever is connected with a short shaft, at the extremity of which is fixed another lever p^3, which passes downwards beneath the carriage. The free end of this lever is formed into a double or forked incline, sufficiently wide to fit the anti-friction pulley p^6, which runs loose on a stud, fixed into the end of the lever p^7. This fork presses down the friction-pulley, which carries with it the lever p^7, the lower end of which is secured to the end of a short shaft, passing through a bracket, fixed to the lower portion of the frame. On the opposite end of this shaft, is fixed the boss of the lever p^8, to which, at its lower extremity, is secured a stud; to this stud is attached one end of a long rod p^9, which passes to the back of the headstock. Near to its extremity, is a stop-hoop, against which one end of a helical spring p^{10} abuts, the opposite end pressing against the lower end of the backing-off lever d^6, where the rod passes freely through, compressing the spiral spring p^{10}. At its extremity, is fixed a second stop-hoop p^{11}, which is fixed on the rod with set screws, being adjustable. The office of this stop-hoop is to disconnect the backing-off cones.

The inward movement of the pendant bar stops the further progress of the faller-wire, and locks the faller to the shaper. The chain j^4, being still in tension, draws the chain-pulley inwards; acting upon the upper end of the lever p^5, and upon the lower end of the lever p^7, move the long rod p^9 and stop-hoop p^{11}, carrying with them the backing-off lever d^6, which puts out of contact the conical friction pulley, when the backing-off ceases. On the upright shaft F, at the back of the headstock, is a cone friction-pulley F^1, one half of which slides on a key, fixed in the shaft; on its boss is a ring-groove. The other half runs loose upon the shaft, and, keyed upon its boss, is a bevel-wheel, which gears into a similar wheel on the scroll-shaft F^2, which extends for some distance on each side of the headstock. Two scrolls are fixed on this shaft, one of which is shown at F^3. A stout rope h, made fast to the boss, is then wound round the scroll attached by its end to the carriage, and thus pulls it in. A second rope is attached to the other end of the scroll, and is wound round in an opposite direction, passing off at the under side, and along the floor to the front of the headstock, where it passes over a carrier-pulley, fixed to the frame, and then back to the front of the carriage to which it is attached. At the lower extremity of the lever p^5 is fixed a stud, carrying an anti-friction bowl, on which the lever l rests while the backing-off is in progress; the boss of this is attached to the shaft l^1, which passes along the floor to the back of the headstock. On this, is a second lever, having at its free end a fixed stud, on which is placed one end of a vertical rod l^2, which is attached to the forked lever l^3, the free end of which works in the ring-groove, on the boss of the loose half of the frictional cone-pulley F^1, holding it out of contact. When the lever p^5 drops down, taking with it the lever l, it allows its shaft to rock, which causes the lever at the back end of the shaft to fall, bringing the cone friction-pulleys into contact, which gives motion to the bevel-wheels and scroll-shaft, and "puts up," or draws in the carriage.

At the moment that the cone-friction is in gear, the mitre-wheel G on the back shaft H, gears into the mitre-wheel G^1 on the side shaft G^2. At the opposite extremity of the shaft, is a second pair of mitre-wheels, giving motion to the shaft G^3, on the other end of which is keyed the spur-pinion I, gearing into the spur quadrant-wheel I^1, which forms a portion of the radial arm I^1, oscillating on a stud fixed in the frame. A coarse-threaded screw T is mounted upon this arm, and on it is fitted a nut *t*, free to move up and down. To this nut, is attached a chain *i*, which, passing down, is wound upon the chain-drum i^1, and made fast. The chain-drum i^1 is cast in one piece with the spur-wheel i^2, and keyed on a short shaft, gearing into a spur-pinion i^3 on the boss of the disc i^4, which runs loose on the tin roller-shaft J. A stud is fixed in the disc, which bears a catch i^5, that takes hold of the teeth in the ratchet-wheel i^6, fixed on the tin roller-shaft J. A bent spring clips into the ring-groove, in the end of the journal i^7, and its free end rests on the small catch i^8, thus completing the connection between the quadrant and the tin roller, by means of which the yarn is wound upon the spindles.

When the backing-off is completed, and the faller-wire is down at the apex of the cop, the anti-friction bowl at the foot of the pendant bar p^2 is resting on the lower part of the short incline, at the front of the shaper R. As the carriage, on running in, commences to wind the yarn on the cop, the bowl ascends the incline, further depressing the faller-wire to the base of the upper cone. The action of the parts is to uncoil the chain from the winding barrel, which gives motion, through the spur and ratchet-wheels, to the tin rollers, and thence to the spindles. The quadrant moves round its centre ¼ rev., and gives less chain, which increases the speed of the spindles, as the threads approach the apex of the cone of the cops.

When the building of the cop commences, the above-mentioned nut stands at the bottom of the screw, at the centre of oscillation. On the extremity of this screw, is a bevel-wheel T^1, gearing into a similar wheel on the boss of a spiral wheel T^2, running on a fixed stud. This spiral wheel gears into a second spiral wheel T^3, on the shaft T^4; on the same shaft, is fixed the spiral roller T^5. At this point the bowl begins to descend the longer incline of the shaper, which allows the faller-wire gradually to rise, guiding the thread to the apex of the cone of the cop, as the spindle winds it on. For a short distance, at both ends of the shaft T^4, is cut a screw-thread, which passes through a fixed nut bearing the shaft up. As the latter turns round, the spiral roller is taken towards the back, which gives less motion to the nut in the radial arm; this continues till the bottom of the cop is completed, when the spiral roller passes out of range, and its action ceases.

By means of this arrangement, when the yarn becomes too tight in winding on, the counter-faller *o* is depressed; a lever under the carriage, which is attached to the counter-faller by a chain, is lowered until it comes into contact with the spiral roller, to which it gives motion; by this means, the screw in the radial arm is turned round, working the nut upwards, until the yarn is slackened so much as to permit the counter faller to rise, and to disengage the lever from the spiral grooves in the roller.

When the winding of the yarn upon the spindle is completed, and the carriage arrives at the drawing rollers, the fallers are disengaged by the pendant bar striking a fixed stop in the frame, pushing it outwards, and disengaging it from the slide, when the fallers rise by the action of their springs. When the carriage has been put up, and has arrived within a few inches of the roller beam, the faller-shaft comes into contact with the incline E^2, pressing down the end of the long beam lever E, and forcing the pendant bar, with its circular incline, away from the steel pin, which allows the catch-box D^2 to turn the cam-shaft ½ rev. when it puts the strap upon the fast-pulley, and all the other motions into their original positions, where they are ready to recommence spinning.

The operation of this complex arrangement of shafts, wheels, levers, pulleys, ropes and springs, may be briefly recapitulated as follows:—The creel having been supplied with bobbins containing rovings, the ends of the latter are passed through small guide-wires, and between the three pairs of drawing-rollers *c*. The function of the back pair—that first taking hold of the roving—is simply to draw the latter from the bobbin. The motion of the middle pair is slightly quicker than the first, but only sufficiently so to keep the roving uniformly tense, in order that when delivered to the next, or front pair, running much more quickly, the "drawing," or attenuation of the roving may be equal throughout. Connection is then established between the attenuated rovings and the spindles. When the latter are bare, as in a new mule, the spindle-driving motion is put into gear, and the attendants wind upon each spindle a short length of yarn from a cop held in the hand. This done, the drawing-roller motion is placed in gear, and the rollers soon present the attenuated roving in front, to which the threads on the spindles are then attached, by simply placing them in contact with the untwisted roving. The different parts of the machine are next simultaneously started, when the whole works in harmony together, the back rollers pulling the sliver from the bobbins, and passing it to the succeeding pairs, whose differential speeds attenuate it to the required degree of fineness. As it is delivered in front, the spindles, revolving at a rate of 6000–9000 rev. a minute, twist the hitherto loose fibres together, thus forming a thread. Whilst this is going on, the spindle-carriage is being drawn away from the rollers, at a pace very slightly exceeding the rate at which the roving is coming forth. This is called the "gain" of the carriage, its purpose being to eliminate all irregularities in the fineness of the thread. Should a thick place in the roving come through the rollers, it would resist the efforts of the spindle to twist it; and, if passed in this condition, it would seriously deteriorate the quality of the yarn, and impede subsequent operations. As, however, the twist, spreading itself over the level thread, gives firmness to this portion, the thick and untwisted part yields to the draught of the spindle, and, as it approaches the tenuity of the remainder, it receives the twist it had hitherto refused to take. The carriage, which is borne upon wheels, continues its outward progress, until it reaches the extremity of its traverse, which is 54 in. from the roller beam, when the revolution of the spindles ceases, the drawing rollers stop, and the backing-off commences. This process is the unwinding of the several turns of the yarn, extending from the top of the cop in process of formation to the summit of the spindle. As this proceeds, the faller-wire, which is placed over and guides the threads upon the cop, is depressed; the counter-faller at the same time rising, the slack unwound from the spindles is taken up, and the threads are prevented from running into snarls. When the backing-off is completed, the carriage commences to run inwards—that is towards the roller-beam—the spindles winding on the yarn at a uniform rate, but by means of a varying speed in their revolution, as the faller is guiding the thread upon the larger or smaller diameter of the cone of the cop. Immediately the winding is finished, the depressed faller rises, the counter-faller is put down, and the former actions recommence in the order described, and are repeated until the "set" is completed—that is, the cops on each spindle are perfectly formed. In modern mules, when the set is finished, a stop-motion paralyzes every action of the machine, rendering it necessary to "doff," or strip the spindles, and to commence anew. Doffing is performed by the attendants raising the cops partially up the spindles, whilst the carriage is out; then depressing the faller, so far as to guide the threads upon the bare spindle below. A few turns are wound on, to fix the threads to the spindles for a new set, and then the cops are removed, being collected into cans or baskets, and subsequently delivered to the warehouse. The remainder of the "draw" or "stretch," as the length of spun yarn is called when the carriage is out, is then wound upon the spindles by the carriage being run up to the roller beam. Work then commences anew.

The modern mule is one of the most perfect triumphs of mechanical skill. The processes described above are entirely automatic, the labour of the attendants being confined to superintending: supplying the creel with rovings, piecing the broken threads, doffing the completed sets, and cleansing and lubricating the whole. In order, however, that the best results may be secured from the machine, it is necessary that an intelligent supervision should be exercised over it by managers, and great care be displayed by the attendants, otherwise serious damage can easily be done, and can only be repaired at great cost and trouble. Imperfect adjustment of the spindles and rollers, or neglect to lubricate the spindle footsteps, bolsters, and roller-bearings, or the friction surfaces of the headstock, may soon cause the neglected parts to wear down, and cause more or less defective action in the parts, greater labour for the attendants, and an inferior product for the result.

One of the most important parts requiring attention is the setting of the drawing-rollers in all the machines where they occur. Should the top and bottom rollers of each pair not be set accurately parallel, a great deal of destructive action takes place. In one part, the fibre is overdrawn, strained, broken, or cut. On the opposite side, where the rollers are too close, it is underdrawn and nepped (rolled), the product from the different bosses varying also in counts. The fluted surfaces, and the leather covers, are also greatly injured, and soon wear out. Great skill and care have hitherto been required for setting the top drawing-rollers with the accuracy necessary to produce the best results, and these qualities are not always available. As tending to obviate these difficulties, we may draw attention to the recent invention of a roller adjusting gauge, by H. H. Clayton, of Hyde, whose name has already been mentioned in connection with an improved method of lap skewering. By the use of this gauge, rollers may be set with the greatest accuracy and speed by an unskilful person.

The automatic or self-acting mule is not used for numbers of yarns much above 60's or 70's. When these points are passed, it has been found advantageous to retain the hand mule, which admits of being tempered to exigencies more readily than its rigid mechanical competitor. In spinning fine numbers of yarns, a distinctly different principle is introduced. When the carriage is within a few inches of the end of its traverse, the drawing-rollers stop delivering the roving, whilst the carriage, continuing its traverse, stretches the thread the remainder of the distance. This is for the same purpose as the "gain" of the carriage mentioned in spinning the ordinary counts.

In spinning the finest counts, the ordinary hand mule itself has to give place to a still more sensitive form of the mule, called the "Box Organ." In this mule the arrangement of the parts is such as to compel the spinner to wait until all the vibration ceases, before making the different changes. This is requisite, as the least tremor has a tendency to break down the almost invisible threads. This machine is usually employed for numbers above 160's.

The throstle-frame, as used in cotton-spinning to-day, is a development of the "water-frame" of

Arkwright. The latter machine, at the time of its invention, was justly regarded as displaying remarkable ingenuity and merit. In it, the system of drawing or attenuating the roving by means of rollers was first made a practical success, and proved so superior to all other modes that, until the invention of the mule, by Crompton, the water-frame stood far above all competitors. After the expiry of Arkwright's patent, the existence of which temporarily prevented the mule coming into use, the latter kept it in check, but never altogether displaced it. The relative superiority, in point of solidity and firmness, of yarn spun upon the water-frame rendered it extremely suitable for warp purposes, and better than could be obtained from the mule. It maintained this position until quite a recent date; and even now, the best mule-spun yarn does no more than equal it. For producing some descriptions, it is yet esteemed superior to all other machines, and unless such exist in the ring-frame—itself an important modification of the throstle—it is held to be without a formidable rival.

The throstle-frame is one of the series of bobbin-and-fly frames; in fact, the parent of the whole. In appearance, it differs little from the roving frame, previously illustrated, except that in detail its parts are smaller, and its spindles are more numerous. The latter run at a velocity of 3000–5000 rev. a minute, and are driven from a central shaft, placed within, and extending throughout the length of the machine, and supplied with driving pulleys at one end of the frame. This shaft carries a long tin cylinder, from which motion is transmitted to the spindles, by means of endless cotton bands, running upon small wharves on the latter. Each spindle is supplied with a flannel, leather, or cloth washer. On the top of each spindle, is mounted a flier; and midway, is the bolster-rail. When ready for work, each spindle is supplied with a bobbin—a small short tube with a flange at each end. These flanges differ in shape, the top one being slightly convex on its upper surface, the bottom one being concave, causing the bobbin, as it were, to stand upon a ring, coincident in its dimension with the circumference of the flange which constitutes the base. It is constructed thus, in order to diminish the friction that would otherwise exist. The bobbin fits loosely upon the spindle, and rests upon the cloth washer. The spindle-bolster, in most frames, is made to traverse up and down a distance equal to the length of the tube of the bobbin, or the space between the heads. This is called its "lift." In some instances, there is an independent lifting rail. The "ends" or threads having been attached to the bobbins, and the machine having been started, the twist is put in the roving as it comes from the rollers by the revolution of the spindles, the thread passing through the top of the flier, and then around its leg to the bobbin. The latter, being only in slight contact with the spindle, has a constant tendency to fall behind it in speed, were it not pulled along by the attached thread. As, however, the latter is being delivered by the rollers, the bobbin is permitted to drop behind, so much as to take up the yarn as it is spun, winding it upon its barrel or tube. In order that the yarn shall be evenly distributed, the bolster or lifting rail carries the bobbin up and down the spindle, which causes the yarn to be wound in even layers.

"Doffing," which is the operation of removing the full bobbins, and supplying the spindles with another set, is performed by the attendant called a "minder"—always a female—and an assistant child of either sex, denominated a doffer. In an ordinary sized frame, this generally takes 4–5 minutes; and, as the bobbins are small, and doffing is a frequent operation, especially in spinning low Nos., it is obvious that a considerable amount of time is expended on that process, besides the cost of keeping a set of operatives to perform it. The latter amounts to 4*d.*–6*d.* a spindle per annum. In consequence of this, many attempts have been made to devise some method of superseding manual by mechanical doffing, one of which, invented by Bernhardt, a spinner of Radcliffe, near Manchester, is generally regarded as a practical success, though the first cost of its application has prevented its extensive adoption.

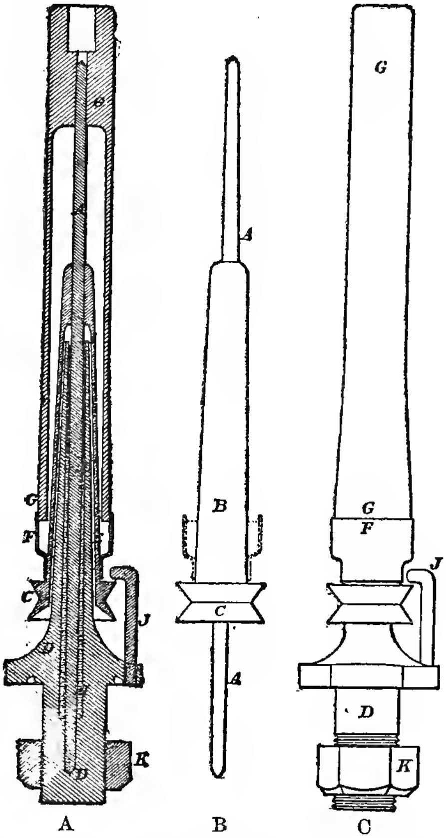
The throstle-frame has always possessed two great merits, those of being continuous in its operation, and of permitting the employment of female labour for its superintendence. These principles have led to numerous efforts to overcome its acknowledged defects, with the result that great improvements have been made from time to time. Amongst the earliest of these efforts must be ranked those of the late G. Bodmer, of Manchester. In patents taken out in 1838 and 1842, there are descriptions of a "bastard" spinning frame—a throstle-frame without fliers, and with mule spindles, on which cops were spun like those in the mule. This frame possessed what would now be called the ring and traveller, and, without much doubt, it forms the basis of the modern ring-frame, the origin of which is generally attributed to American inventors.

The throstle-frame, owing to its being available for the employment of female labour, was always the most popular spinning machine in the United States; and the experience gained by its extensive use stimulated invention, and led to its comparatively perfect development.

Whether the ring-frame was an English or American conception originally, it is undoubtedly the fact that it is in the latter country that it has been brought to such a degree of perfection as to render it a better machine than the throstle-frame, and also to endanger, for low and medium Nos., the supremacy hitherto enjoyed by the mule. In this country, during the last few years, it has attracted a great deal of attention, and been extensively adopted.

The ring-frame is a modified throstle, and preserves its chief features. It differs from the latter machine mainly in having the flier replaced by a ring, which is fitted in the traverse rail. From this it takes its name. This ring is grooved inside and out, or made with flanges, and is furnished with a small piece of flat steel wire bent in a form almost like the letter D, with the vertical line cut through, to permit its passage over the flange of the ring, when it clips into the groove. This is called the traveller. Its office is to constitute a drag upon the yarn, by means of which the latter is wound upon the bobbin. Its size and weight depend upon the counts of yarn required to be spun: coarse yarns demand the largest rings and heaviest travellers; and the finer yarns, the opposite. The capability of the frame extends from the lowest numbers to 50's or 60's; but it has not been found expedient as a rule to pass the first-named point.

549.

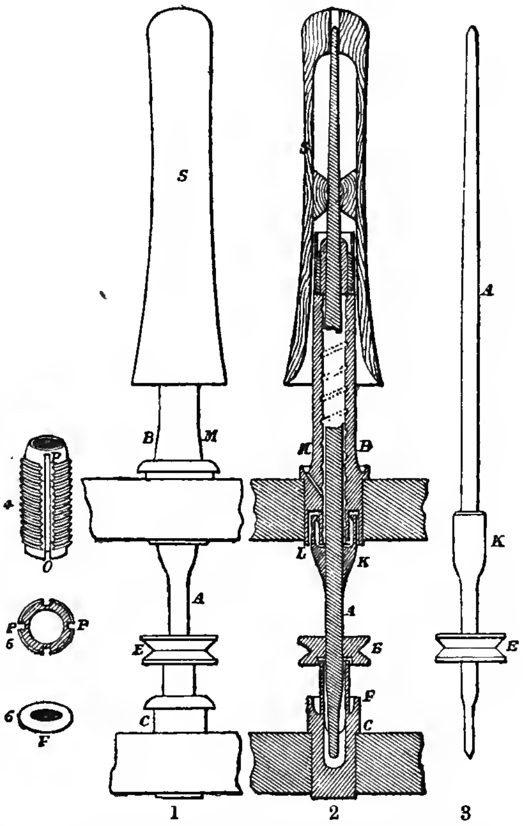


A B C

Owing to the high speed of the spindle—5000-9000 rev. a minute—that has been attained in the ring-frame, it has been found that the dimensions and construction of the spindle are points of vital importance. The frame alluded to above is furnished with what is known as the Rabbeth spindle. Of the three illustrations contained in Fig. 549, A represents a section of the spindle complete with bobbin; B, the spindle with its sleeve; C, spindle complete with bobbin. A brief description will suffice to render its construction easily comprehensible. The steel spindle A is furnished with a cast-iron sleeve B, which is firmly secured to it. This sleeve at its lower extremity has the wharve C cast upon it, for the reception of the driving band. A tubular bolster D is constructed to receive the lower part of the spindle. Literally it is a compound of bolster and footstep. The top of its tube is furnished with a German silver bush E, of which the dark lines indicate the section. This, when the spindle has been inserted, forms a cavity below, constituting an oil chamber or reservoir H. This effectually secures the perfect lubrication of the spindle foot, and of its frictional portion in the bush E at the top of the bolster D. The chamber carries sufficient oil to ensure perfect lubrication for several months, and experience demonstrates it to be efficient. The question arises at this point as to whether its lubricating properties may not become impaired or destroyed after being submitted for a lengthened period to the attrition of the revolving spindle; or whether some chemical action may not be induced which will essentially change its nature. In contact with brass in the bolster or footstep, after some time, oil becomes turbid, green, and slightly viscid. If this point has been decided favourably, as we are assured, this arrangement would appear to be unobjectionable. Should the oil work up and over the top of the bolster, the bobbin and yarn are still quite free from risk of contact, the oil falling down inside the sleeve B, and passing out beneath the wharve upon the exterior surface of the bolster. By means of the sleeve B and the bush E, the oil is securely protected from contamination by loose fibres, dust, or atmospheric influences. Upon the top of the wharve C, a brass cup F is securely fixed, for the reception of the foot of the bobbin G, which, however, has its chief bearing at the bushed part near the top of the spindle. The brass cup assists to steady the bobbin, and preserve the balance of the spindle; but its principal function is to facilitate doffing. In removing the full bobbin, the thread between the bobbin and the traveller coils itself in an open spiral upon the sleeve of the spindle. The empty bobbin, being placed upon the spindle, pushes the thread downwards into the cup, where it is firmly held by the contact of the two surfaces. After each operation of doffing, the threads are thus secured without loss of time, simply by the process of supplying the frame with a fresh set of bobbins. The bottom of the bobbin being within the cup, and the thread from the traveller passing over its edge, it is just in the proper position for recommencing spinning. The bolster is secured in position by means of the nut K. The wire J is for the purpose of retaining the spindle in the bolster during the doffing operation, or when taking the bobbin off for other reasons.

Another of the most successful ring-frame spindles is represented in Fig. 550. It is known in this country as the Booth-Sawyer spindle. Like the Rabbeth, it is of American origin. In the illustration, 1 represents the outline of the spindle mounted with bobbin; 2 is a vertical section of the same; 3, the bare spindle. As will be seen from the third sketch, the spindle is very simple, carrying only the wharve E, and a cup forming an oil chamber K. The bolster has a tube B, which is spirally grooved inside. Its basement is constructed in the form of a tube L, which receives the oil-cup K on the spindle. The bush 4, composed of bronze, is fitted into the top of the bolster-tube, and constitutes the bearing. The footstep C is furnished with an oil chamber F, and a tube extends to the wharve. In the bolster, lubrication is effected at M, when the oil poured into the cup flows through the hole into the bolster-tube, until it meets the revolving spindle, which carries it along the spiral groove to the bronze bush, where it comes into contact with the bearing surfaces between which it is forced by the pressure of the stream ascending from below. As this is constantly going on, the oil would be liable to pass over the top, flow away, and be wasted; but against this, provision is made by vertical grooves being cut into the sides of the bush, as seen at 4, and in the section of this at 5, the bush being inserted a little below the top of the bolster-tube, the oil which overflows passes down the vertical groove P in the bush, and at O re-enters the bolster-tube, there to be used over again. This is continuous, so that the spindle is kept perfectly lubricated, and no oil is wasted. When the spindle is at rest, the oil flows down the spiral groove into the spindle cup K, where it remains until work is resumed. Both oil chambers are supplied with covers, to prevent the entrance of loose fibre, dust, &c. Experience has proved this to be an efficient and economical method of lubricating the spindle, which, owing to the high speeds attained, is an absolute necessity if the machine is to be preserved for any length of time in working order. The bobbin for the Booth-Sawyer spindle is designed to secure lightness, firmness, and steadiness on the spindle. It possesses a wide bore, which extends almost to the top, where it is reduced so as to fit the spindle point only. In the centre of its length, it is bushed, at which point the second bearing is formed. Thus being firmly held at two points upon the taper spindle, it is quite free from vibration.

550.



There is a tendency in the "traveller" to collect fibre upon itself, which seriously injures the quality of the yarn, by increasing the strain upon it beyond the point it is calculated to bear. Many ingenious attempts have been made to overcome this difficulty, and several plans now in use are more or less efficient.

The ring-frame appears to have a great future before it; and since its introduction a few years ago, it has greatly risen in public estimation. At the moment of writing, we are informed that the largest firm of cotton machinists in this country have not a single order in hand for the ordinary throstle-frame, whilst they have several for the ring-frame. Every maker of cotton machinery in England has turned his attention to it; and many have sought to improve upon its present condition. As ordinarily used in America, and as introduced into this country, there are several drawbacks against its general adoption. The necessity of employing a bobbin, upon which to wind the yarn, would seriously interfere with the trade in yarn as at present conducted. The small quantity of yarn that can be put upon the bobbin, the weight of the latter in proportion to the yarn, and the cost of its transit to and fro between the spinning mill and the weaving shed, would form important items of expense, and do much to neutralize all its advantages. A very great proportion of the yarn spun in this country is produced for sale in that form, and is manufactured elsewhere. This is not the case in America; hence the same difficulty has not been experienced there. Another obstacle to its adoption is the fact that it has not yet been adapted to produce weft yarns, or filling, in the best forms. For some time, filling has been spun upon the ring-frame in America; but where this is the case, bobbins have been employed, and these have not been capable of reduction below a point which required the use of a large shuttle in the loom, or the re-winding of the yarn upon pirns, both of which courses are extremely objectionable.

The ingenuity of English machinists has therefore been directed towards the removal of these difficulties, and to the modification of the frame so as to fit it for incorporation with the existing system. The attempts made have been partially successful. Several makers have been able to dispense with the bobbin, and have spun cops upon paper or metallic tubes. This may be regarded as a partial success, but it will hardly be perfect until these can be abolished altogether. "Pin" cops, otherwise "pirn" cops, for the shuttle have also been successfully produced from machines constructed by Samuel Brooks, of Manchester, and John Tatham, of Rochdale. The machines upon which this has been done only require perfecting in a few points of detail before they become commercial successes; and this may be confidently expected in a very short time.

The adoption of the ring-frame is greatly to be desired, from the fact that it will preserve a large amount of capital invested in mills erected 25–40 years ago, but which, owing to recent improvements in the construction of the mule, are unable to compete with mills furnished with the most modern plant. These, however, could be easily adapted to the ring-frame: in fact, without alteration even are nearly as suitable as new erections would be. On this ground, it is to be hoped that success may attend the efforts being made to improve it.

Reeling.—This is one of several subsidiary processes carried on in connection with spinning, according to the character of the business transacted. It is used in the preparation of yarns for export, and also when the yarn as such has to undergo the further processes of bleaching, printing, or dyeing. For the former purpose, it is "straight" reeled, and made up into "short" bundles; for the latter, "cross" reeling is preferred, and the yarn is made up into "long" bundles.

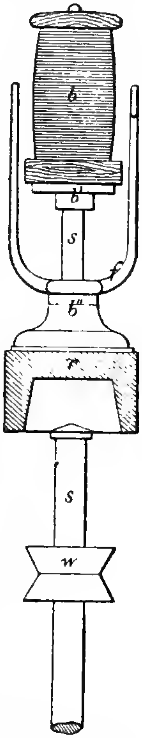
Where throstles or ring spinning frames are used, reeling, or "ball-warping," is a necessity, when the yarn is sold from the mill, as the transit of the bobbins backwards and forwards entails expense and loss, which it is usually sought to avoid. Warping will be explained under the next division.

Doubling.—This is a process in the course of manufacture, and is generally carried on in connection with spinning, though it often forms a separate and independent business. In it, two threads are twined together to form one. The throstle machine is most usually employed for the purpose. It is in all respects the same as the spinning-frame, except in being deprived of the drawing-rollers, which are replaced by a single pair of rollers of larger diameter. There are two processes of doubling, called "wet," and "dry." In the former, this pair of rollers are covered with brass, to prevent oxidation. After it leaves the cop or bobbin, the yarn is passed through zinc troughs filled with water. Inconvenience arises from the use of these troughs, through their liability to become receptacles for loose fibre, dust, &c., which is agitated when the water is renewed, and fouls the yarn, or necessitates the stoppage of the frame during its subsidence. This may be avoided, and all the troughs in a frame may be fed at one operation from a supply pipe at the end, by connecting the troughs together by means of little inverted U-shaped syphon pipes. This will prevent damage to the yarn, and loss of time. After passing the troughs, the yarn goes between the pair of rollers to the flier on the spindle, which gives it the requisite twist, and delivers it to the bobbin; this, lagging slightly behind the spindle in its revolution, winds up the thread.

In the doubling-throstle, especially where fine numbers are doubled, several serious disadvantages are encountered. One of these is in the fact that after doffing it is necessary to oil the spindles, in order to make the bobbin slip more freely than it otherwise would, so as not to break the fine threads in process. The consequence is that many bobbins soon become saturated with oil, the dry porous wood readily absorbing it, whereby the weight of the bobbin is greatly increased, and the drag is rendered unequal as compared with others that have not absorbed oil. This produces irregularity in the yarn. A greater evil is the large number of bobbins that are rendered useless. The saturated bobbins also stain the yarn wound upon them, by which its value is depreciated 3*d.*–6*d.* a lb. Often when a frame has been replenished with bobbins it is found that several will not slip; and the threads, after breaking and being pieced several times, are thereby rendered unfit for their purpose. They are then taken and stripped with a knife: yarn worth 1–5*s.* a lb. being thus reduced to waste, worth only 4–6*d.* a lb. In numerous other ways, yarn is stained by the saturated bobbins, and thereby greatly depreciated in value. A great quantity of oil is also consumed in the lubrication of the spindles, and a heavy loss is sustained weekly by the necessity of throwing out as unfit for use a great number of saturated bobbins.

The losses thus arising have led to many attempts to devise a remedy, though, until quite recently, without much success. An invention just perfected and patented by Taylor and Ramsden, of Bolton, has, however, accomplished the end sought. The arrangement is illustrated in Fig. 551. The spindle is reduced in length, and slightly tapered towards the top. The flier *f* is removed from the summit of the spindle—the position it occupies in the ordinary throstle —inverted, and relegated to the place formerly occupied by the bobbin *b*. Instead of being made fast, as before, it has a boss *b''* fixed to it, and is left loose upon the spindle, resting upon the bolster-rail *r*, with only the ordinary leather washer intervening. Midway on the spindles, is placed a braid *b'*, uniform in height. These braids have a rib cast upon and across their upper surface. The bobbin *b* being put upon the spindle, descends to the braid, the rib upon the latter fitting into a groove in its base. It is there held with sufficient firmness to prevent slipping. It will thus be seen that with the inversion of their relative positions, their functions are also exchanged: the drag being obtained from the flier, instead of the bobbin, as before. Fig. 551 exhibits the application of Taylor and Ramsden's invention to existing spindles. In the construction of new machines, it would be further modified, as seen in Fig. 552. This represents the most perfect form it has yet attained. The important changes effected will be best seen by contrasting the following particulars of the old and new forms:—length, 16 in. : 11 in.; weight, 14½ oz. : 5 oz.; length of traverse, 2 in.: 1¼ in.; weight of flier, 3 oz. : 1½ oz.; diameter of bobbin across top, 1½ in. : 2 in. The new form easily attains a speed of 7000 rev. a minute, whilst maintaining good results. The braid *b'* is dispensed with.

551.



The advantages of this arrangement are obvious, and will commend themselves to everyone practically acquainted with the matter. The bobbin is placed quite away from contact with oil, and revolves with the spindle. There are consequently no bobbins saturated, and no oil-stained yarn. The fliers not being to take off, doffing can be performed by the minder, a spindle at a time, without stopping the frame. This increases production and diminishes expense, dispensing with doffers' wages. The space between the arms of the flier is also increased. Bobbins can be used until they break, and the introduction of larger flanges greatly increases their capacity, and reduces the number of knots made by piecing the yarn in the winding room. There is no waste from snarled yarn at the spindle top, as in the old arrangement. In wet doubling, the fliers soon become rusty, and comparatively rough, which, owing to the thread having to pass several times round the arm, causes it to be frayed and roughened. In the new arrangement, this is obviated, the surface of the yarn is more glossy and free from fibre, enabling a better thread to be made from a standard quality of cotton, or the standard to be lowered, whilst the quality is maintained.

In a large establishment, say of 65,000–70,000 spindles, the economy resulting from this invention has been estimated at 1500*l.* per annum, and may safely be put at a considerably higher figure.

The ring-frame has also been very successfully adapted to doubling, and the yarn from it occupies a position intermediate in its characteristics between the productions of the throstle-frame and the twiner.

The last-named machine, the twiner, is an adaptation of the mule for doubling purposes, and the characteristics of the yarn from it are that it is less firm and hard than that from either of the above-mentioned machines.

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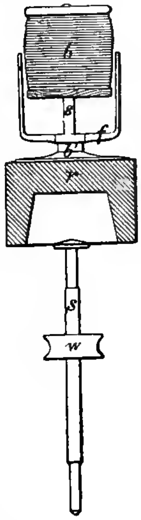


Gasing.—This is a process in which yarn is passed through a jet flame, in order to burn from the surface of the yarn the ends of the fibres that have not been thoroughly incorporated in the thread in the course of spinning. The yarn subjected to this process is usually doubled, and is used in the lace trade, and when polished for mixing with silk goods; in this connection, it usually forms the back of what are termed silk-faced textures. The gasing machine is like almost all others, nearly automatic. The yarn is wound from one bobbin to another, and, in its passage, goes through the flame. When the thread breaks, or the supply is finished, the gas jet automatically drops out of its position, until the connection is again made. In stopping the machine, the same thing occurs. Every care is taken to reduce breakages of the yarn to a minimum, as knots are a serious drawback to the value of this description of yarn. An essential quality of a good machine is that the pace of the thread should be capable of the nicest adjustment, so that it may never be under-singed nor burnt. The driving in order to secure this object should also be thoroughly uniform. There are several machines in the market, differing somewhat in details, but they call for no further description.

Polishing.—This is another of the subordinate processes employed in special branches of the cotton industry. In this, the hank of yarn is placed over two rollers of a machine, the distance between which is gradually increased, thus stretching the yarn to its full extent, whilst a sizing of beeswax and other materials is applied thereto. This imparts to the thread a beautiful gloss, and when the yarn is dyed in bright colours, the effect is exceedingly rich. Polished yarn is mostly used for silk mixtures.

Cotton Weaving or Manufacturing.—As technically understood, manufacturing forms the second great division of the processes usually grouped under that term, when used in its most extended signification. In the restricted sense in which it has to be considered, it includes all the processes necessary to transform yarns, after they leave the spinner, into the various descriptions of cotton cloths. These processes are five in number, and may be briefly defined as follows:—

1. "Winding."—This is the operation of transferring yarn from the cop or hank, to bobbins, to prepare it for the next stage.
2. "Warping."—In this stage, a given number of bobbins, generally 300–500, are placed in a creel, and the threads are wound thence in parallel order upon a large beam, to a length of 3000–5000 yds. This is the plan pursued where the sizing machine is used. Where the old system of ball sizing is retained, the method is different.
3. "Sizing."—This consists in immersing the yarn in a fluid composition, containing water, flour, starch, and other materials; the object is to solidify and strengthen the threads, to enable them to withstand the friction and strain incident to the subsequent process of weaving. There are three methods of doing this, which will be described in their place.
4. "Drawing- or twisting-in the warp."—This is simply furnishing the warp with the necessary healds, or harness, to make it ready for the loom.
5. "Weaving."—This is the art of interlacing threads, in such a manner as to make a web or texture. It is subdivided into branches; plain, twill, figure, and leno weaving. All these arise from the order in which the threads of the warp are opened to receive the weft, or filling, which composes the cross threads of the texture.

In primitive times, the art of weaving was of the simplest character. The weaver spun a single thread, and wound it into a ball; then stuck two or three sticks into the ground, and passed the thread around them a sufficient number of times to give the breadth and length required for the warp; next he interlaced a second thread by the simple process of darning, pressing the latter as closely together as he desired by the aid of his fingers. For a long time, very little progress appears to have been made. Some of the ancient nations, such as Egypt, Persia, Assyria, and Greece, attained great skill in the textile art, though the instruments they possessed showed little advance upon the above. India for many centuries possessed an almost world-wide reputation for the variety, beauty, and fineness of its textures; all these were manufactured by the simplest tools, the thread being spun by the distaff and spindle, or the single thread wheel, and the shuttle being passed through the open warp from hand to hand.

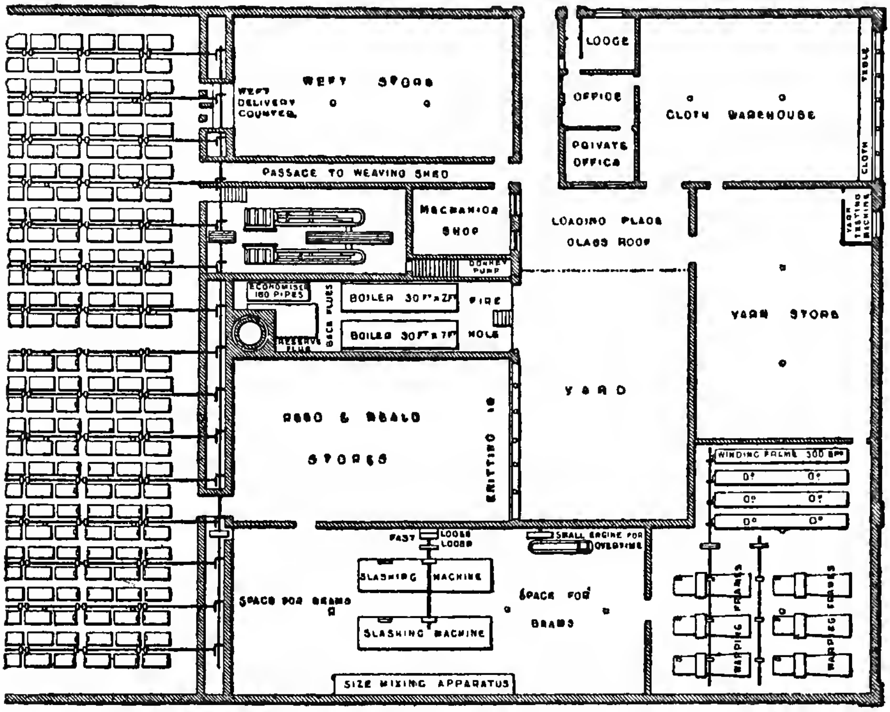
It is, however, to Lancashire that the world owes the impetus given to invention in the textile arts. Nearly all the great improvements have originated and been perfected within the boundaries of the county, and within a few miles of each other. The first great step was made by the elder Kay, of Bury, by the invention of the picking-stick, and the attachment of boxes to each end of the slay or lathe of the loom, for the reception of the shuttle, in place of the hand of the operative. This so greatly increased the productive power of the weaver, that cotton weft yarns—the warps were of linen—became exceedingly scarce, and advanced so much in price, that the spinners enjoyed a period of great prosperity. The weavers were often compelled to wander from cottage to cottage for several days in order to collect a sufficiency of weft to supply them for the remainder of the week.

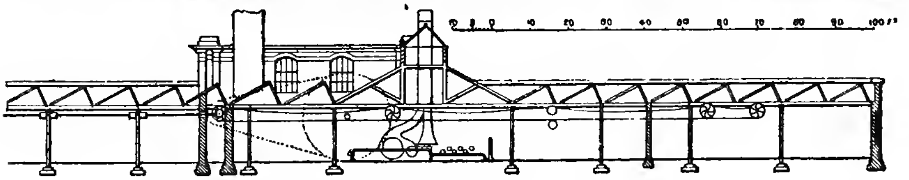
This state of matters stimulated invention very greatly, and, in many secluded corners, "conjurers," as the people then called inventors, were working to devise remedies for the scarcity of yarn which so many felt. Jas. Hargreaves, of Oswaldtwistle, near Blackburn, was the first to accomplish on his "jenny," the feat of spinning more than one thread at a time. The treatment he met with need be only cursorily alluded to here. The rapid manner in which the new invention spread in East Lancashire was not regarded with complacency. Mobs broke the jennies wherever they could find them, and compelled Hargreaves to fly for safety, which he found in Nottingham. Arkwright, thus warned, when he had made his water-frame a practical success, migrated in the same direction. Crompton closely followed these men with his combination of the jenny and the water-frame, which received the name of the "mule." The details of the two inventions last-named were wrought out almost upon the same spot, Bolton, and not long apart.

The invention of the jenny, the water-frame, and the mule, soon yielded an abundance of yarns, and the question arose as to how to work them up. Mechanical production suggested a mechanical power of consumption: hence the power-loom. A clergyman named Cartwright appears to have been the first to broach this idea, and to attempt its realization. After spending several years, and a considerable fortune, in the attempt, he only succeeded in achieving a very limited degree of success. But the idea was not destined to be lost: others were assiduously labouring to attain the same end. Horrocks, of Stockport, and Miller, of Glasgow, soon succeeded better; Bulloughs, of Blackburn, and a host of minor inventors, have contributed to bring the loom to its present degree of perfection. To no one, however, can be given exclusive merit; each man's improvement forms a complement to preceding inventions, and the earliest require the latest to perfect them. The system as now existing has been developed from the experience and labours of many. It is not yet perfect; frequent contributions are being made, and more are needed.

The Weaving-Shed.—The remarks made concerning the selection of a site for a spinning-mill, apply with equal force to that for a manufacturing establishment. To secure freedom from vibration, and a cool and soft atmosphere, the weaving-shed is always by preference placed on a ground floor. The preparation may be conducted in a building of two or three stories, should it be desirable to economize the ground space. The site should always be chosen so as to permit the windows of the roof of the weaving-shed to run in a direction from east to west, in order to present the glazed portion to the north, the light from this point being the greatest, most steady, and best adapted for manufacturing purposes. This point secured, regard must be had to the arrangement of the looms, which ought to run at right angles to the bays of the roof, in order that the slay, or lathe, may not cast shadows upon the warp in the process of weaving, and thereby interfere with the ability of the weaver to perceive the occurrence of breakages, or flaws of other descriptions.

553.





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Figs. 553 and 554 show plan and section of a well-arranged weaving-mill, from designs by the architects who furnished those for the spinning-mill. It will be seen that the general arrangement is such as to avoid the necessity of the material going over the same ground twice, which would increase the cost of handling. Assuming that the supply of yarn is purchased, it is brought into the establishment in large skips or baskets, holding 300–400 lb., and is warehoused in the yarn store.

From here, it is delivered to the winders; next, upon bobbins, to the warpers, and thence upon beams to the sizers. After undergoing the sizing process, it is delivered upon loom beams, to the "drawing-in-" or "looming-room" for the drawers or twisters to finish it for the loom. Hence, furnished with healds, it passes to the weaving-shed, in which, so far as the manufacture is concerned, it is completed. It is only in very rare instances in this country that bleaching, dyeing, or printing is carried on in the same establishment. Weft yarns, not requiring any treatment in passing from the spinner to the weaver, when received, are warehoused in the weft store, whence they are delivered in small cans or baskets over the counter to the weavers in the loom shed. When the cloth is woven, it is cut into certain lengths, called "pieces," and sometimes collected from the weavers by a labourer, carried into the warehouse, and entered to each weaver's credit. In other cases, the weavers perform this duty themselves. The cloth is next examined, made into bundles, and despatched to the agent or merchant in Manchester.

The above plan is designed to represent a mill of about 700 looms, and the complementary machinery, working medium numbers of yarns. It contains four winding frames, of 300 spindles each; six warping frames; two sizing machines, and 700–750 looms. The motive power is supplied by two tubular boilers, 30 ft. in length by 7 ft. diameter, which are supplied with a Green's Economizer of 160 pipes; and two horizontal engines, driving a large fly-wheel, grooved for the reception of ropes, by which power is transmitted to the main driving-shaft, which is walled off from the shed, in order to secure cleanliness, and to partially deaden the noise produced by the gearing. From the main shaft, and connected with it by bevelled gearing, a line of light shafting runs parallel with and between each two rows of looms, set back to back, which are driven from it. In the changes inevitable in the conduct of a large business, such as is implied by a mill like the one described, it sometimes occurs that orders for lightly picked goods will be received, in working which, the looms will overrun the preparatory department, which would cause inconvenience, loss of time, and diminished production. In order to avoid this result, a small engine is provided for overtime working of the preparatory department—especially the sizing machines,—without running the shafting and gearing of the other portion. The steam left in the boilers—and which would otherwise condense during the night—is generally sufficient for this purpose, and is thus utilized. A mechanics' shop for making repairs completes the equipment of the establishment.

Winding.—The first machine in the complement is the winding frame, of which a view is given in Fig. 555. It is one of the simplest machines in the series necessary for manufacturing; and its parts require only brief description. A skewer rail *a* extends throughout the length of the frame; *b* is the knee-board, covered with flannel, to cleanse the yarn from leaves, motes, and impurities. The next part is the traverse-rail, carrying the brushes *c*, the dark line running below representing a steel or glass rod. The box *d* is provided for the operative to pile the yarn upon, in a position convenient to the hand. The spindle *e*, carrying the bobbin *f*, is connected between the wharve *i*

555.