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Vol. 3

Part II



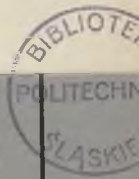
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NOVEMBER 1936



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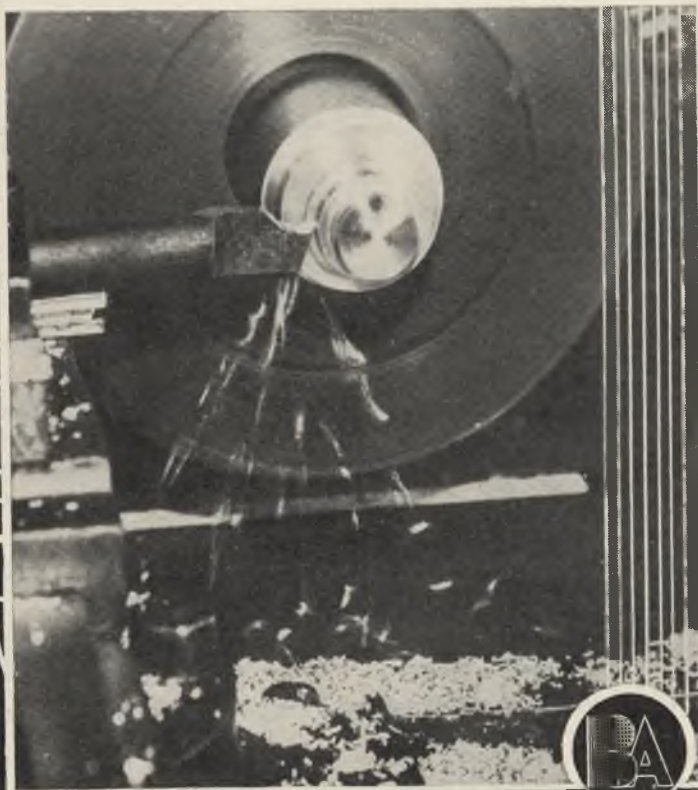
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Mineral Industry. Issues since 1932 (incl.).

Foundry Trade Journal. Volumes 1-25.

Journal of the Electroplaters' and Depositors' Technical Society.
Volume 1.

Journal of the Iron and Steel Institute. Volumes 1-15.

Journal of the Russian Physico-Chemical Society. (Chemical Part.)
1930, Volume 62, Part 4.

Metallwirtschaft. Volumes 1-5.

Mitteilungen aus dem Kaiser-Wilhelm-Institut für Eisenforschung zu Düsseldorf. Volumes 1-10.

Proceedings of the Institute of British Foundrymen. 1916-17.
(Volume 10.)

Revue de Métallurgie. Volume 1.

Transactions of the American Electrochemical Society. Volumes 1-3
and Volume 11.

Transactions of the American Foundrymen's Association. Volumes
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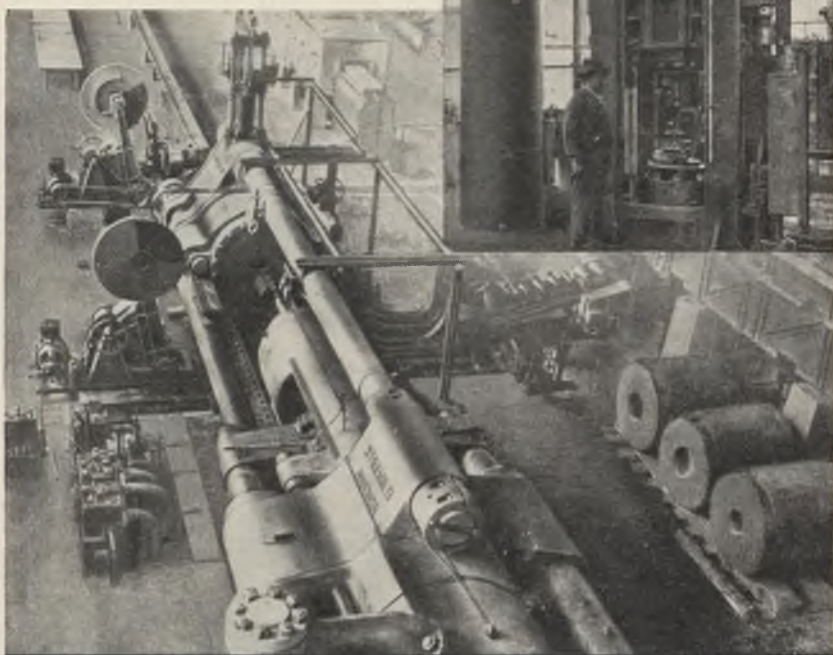
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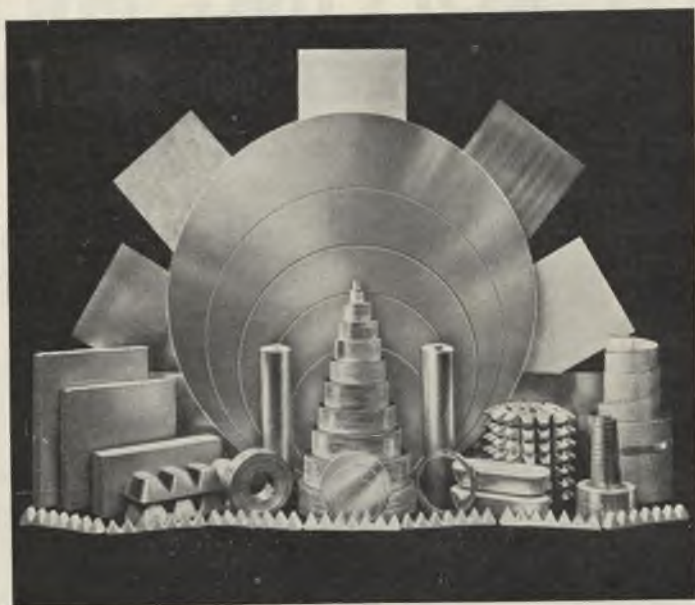
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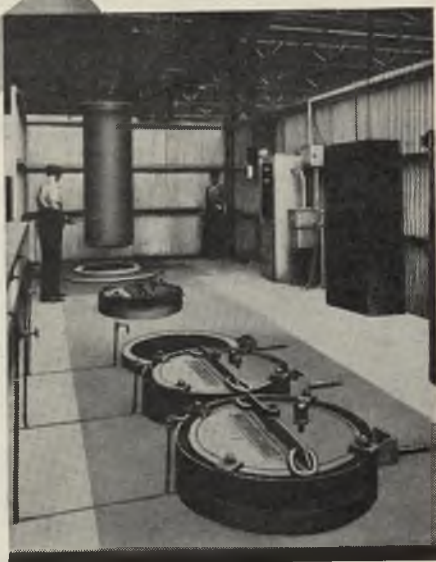
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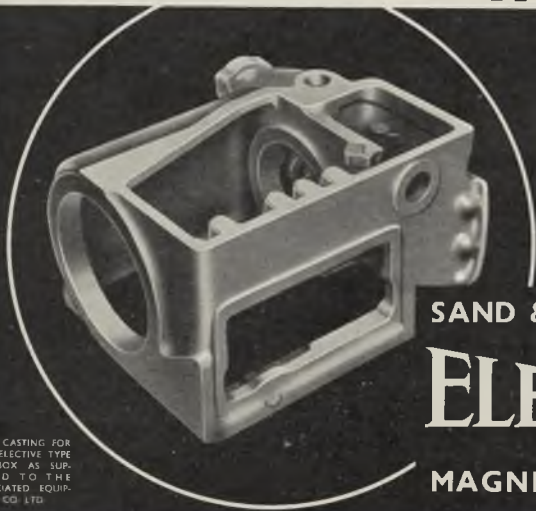
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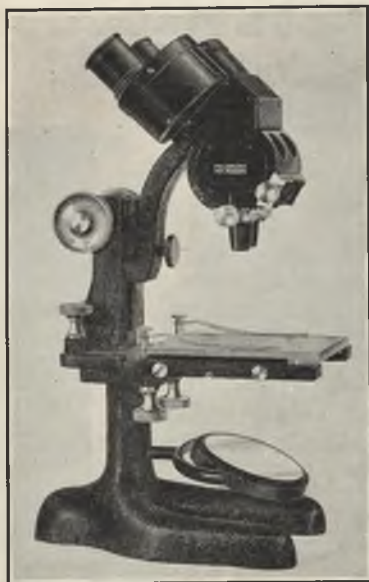
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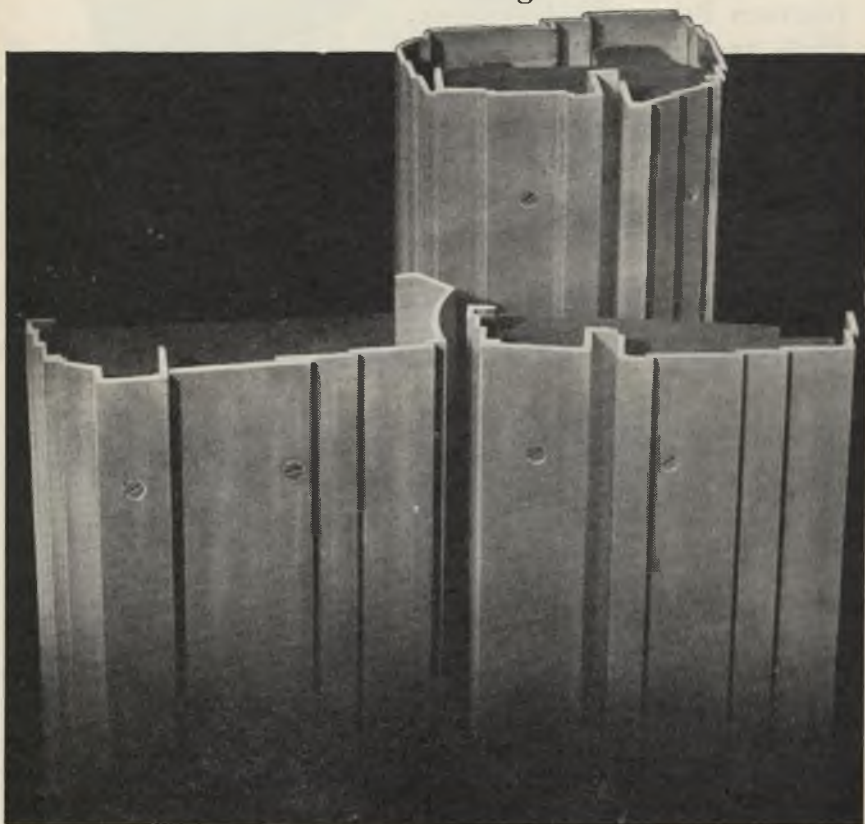
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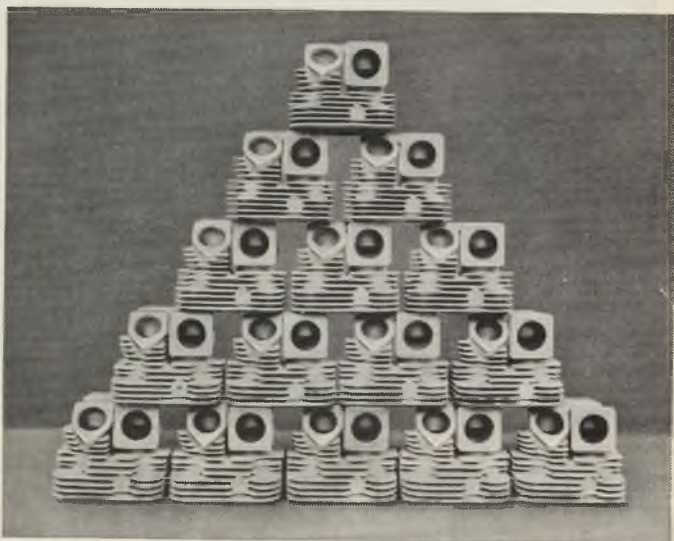
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The monthly issue of *Metallurgical Abstracts* may be cut up for card indexes, as members will receive early in 1937 the year's abstracts in bound form.



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INSTITUTE NEWS AND ANNOUNCEMENTS

Annual General Meeting and Dinner.

THE Twenty-Ninth Annual General Meeting will be held on March 10 and 11, 1937, in the Hall of the Institution of Mechanical Engineers, Storey's Gate, London, S.W.1, beginning at 10 a.m. on each day. The Annual Dinner will take place on March 10 at the Trocadero Restaurant.

Autumn Meeting, 1937.

The Council received at its last meeting, through Professor J. H. Andrew, D.Sc., an invitation to the Institute to hold its twenty-ninth Autumn Meeting at Sheffield in September, 1937. The invitation was warmly accepted. The last Sheffield meeting of the Institute took place in 1919.

List of Members.

A new edition of the List of Members is expected to be ready for issue about the end of November. Members who desire to receive a copy should send a post-card to the Secretary.

Membership Additions.

The following were elected on October 29, 1936:

As Members.

BARKER, Stuart Netherwood, Southampton.
BILLINGHURST, Philip Edward, Salisbury, S. Rhodesia.
BLACK, Arthur, Southampton.
DAY, William Arthur Jefferies, Pretoria, S. Africa.
EDENS, Leonard, Dipl.-Ing., Berlin-Spandau, Germany.
FARR, Harry, Cardiff, S. Wales.
HOLLINGS, Arthur Sidney, Birmingham.
HORLEY, Robert Eustace, Southampton.
KEMPF, Louis W., M.S., Cleveland, Ohio, U.S.A.
LAVES, Fritz, Dr.-phil., Göttingen, Germany.
LORENTZ, Marjorie Geraldine, B.A., Bridgeville, Pa., U.S.A.
MACDONALD, James, London.
MESSNER, Martin C., Katowice, Poland.

PULLEN, Alfred Norman Douglas, Grappenhall, Cheshire.

ROGLIN, E. C., North Canton, O., U.S.A.

TATTERSALL, Cecil Owen, B.Sc., A.R.C.Sc., Cawnpore, India.

WHITE, Edwin Hillier Maurice, Birmingham.

YATES, Donald, B.E., Port Pirie, S. Australia.

As a Student Member.

KING, George Rowland, Hounslow, Middlesex.

PERSONAL NOTES

The Editor requests that his attention be directed to items of interest to members that might be included under the "Personal Notes" heading. All contributions for the December issue of the Monthly Journal should reach the Editor not later than November 24.

MR. N. W. AGEW, Met.Eng., has been awarded the degree of Dr.Chem. by the Academy of Sciences of U.S.S.R. (Moscow) for a thesis on "Physico-chemical Study of Inter-metallic Molecular Solid Solutions."

MR. H. S. DUNCAN, B.Sc., A.R.S.M., is on leave from the Federated Malay States, and correspondence may be forwarded to him at 23 Dryden Road North, Gateshead, Co. Durham.

MR. C. F. J. FRANCIS-CARTER, formerly Chief Chemist, Messrs. Morris Motors, Ltd. (Radiators Branch), Oxford, has been appointed Head of Research Department, Messrs. The Pyrene Company, Brentford, Middlesex.

SIR FRANCIS GOODENOUGH, C.B.E., will shortly sever his connection with the Institute—of which he has been a member since 1917—in view of his retirement. He has been Executive Chairman of the British Commercial Gas Association since 1911.

MR. N. M. HOPKIN, A.R.S.M., B.Sc., has recently been elected Associate of the Institute of Chemistry.

Local Sections News

MR. EDWARD SPURR has been appointed Chief Engineer to the London Laboratories of Sloane Square, where he is in charge of research work and general development work in relation to aircraft engines and aircraft structures.

Birth.

On August 19, 1936, a daughter was born to Mr. and Mrs. A. G. Robiette at Birmingham.

Obituary.

MR. S. CHOLEWINSKI died on September 26, 1936, after a long and painful illness. He was Director of the "Babbit" Aluminium Foundry, Warsaw, Poland, and had been a member of the Institute of Metals since 1933.

MR. C. W. MURRAY died in Southsea on August 19 at the age of 79 years. He was Superintendent Engineer and Manager of the Marine Department, Messrs. Babcock & Wilcox, Limited, from 1900 to 1930,

and was elected to membership of the Institute of Metals in 1914.

MR. A. R. STEWART died on August 6, 1936. He had been a member of the Institute since 1916.

The Engineering Institute of Canada.

Members of the Institute of Metals are cordially invited by the Engineering Institute of Canada to participate in the celebrations of its fiftieth anniversary at a semi-centennial meeting to be opened in Montreal on June 15, 1937.

It is the expressed desire of the Council of the Canadian Institute "that this occasion may be the means of bringing about a closer acquaintanceship between engineers of Great Britain and Canada." Special plans are being made for a group to travel together. Members interested should get into touch with the Secretary of the Institute of Metals.

LOCAL SECTIONS NEWS

MEETINGS IN NOVEMBER AND DECEMBER *

Birmingham Section.

Some Aspects of Industrial Hygiene. By Howard E. Collier, M.C., M.B., Ch.B.
(December 3.)

Metallurgical Problems in the Chemical Industry. By N. P. Inglis, D.Sc.
(December 15.)

London Section.

Supper-Dance. At Thames House, Millbank, S.W.1, at 7.30 p.m., on November 25.

Tickets, price 6s. 6d. each, can be obtained from any Committee member of the Section, or from the Institute Secretary.

Some Impressions of Industry in the U.S.S.R. By W. T. Griffiths, M.Sc.
(December 2.)

This will be a joint meeting with the London Branch of the Institute of British Foundrymen, who will be acting as hosts. The meeting will be held in the *Charing Cross Hotel* at 8 p.m.

Manchester Metallurgical Society.

Discussion on Microscopy. Opened by J. Dickson Hannah, M.Sc.Tech.
(November 18.)

* For places and times of meetings, where not given, the green folder programme already issued should be consulted.

Local Sections News

North-East Coast Section.

Refractory Materials. By J. W. Mellor, D.Sc. (November 27.)

The meeting is being held, by invitation of the Newcastle Branch of the Society of Chemical Industry, in the Chemistry Lecture Theatre at 7.30 p.m. The lecture is the Jubilee Memorial Lecture of the Society of Chemical Industry.

Scottish Section.

Metal Spraying by the Wire Process. By W. E. Ballard. (December 14.)

A brief historical survey of the process of metal spraying; a brief description of the three methods used in modern industry; description of the wire pistol; the structure of metal-sprayed coatings; the influence of the gases used; nozzle distance, &c.; metal spraying as a preventative of corrosion; the choice of metal coatings governed by the electrolytic theory of corrosion; the use of metals of super-purity; preparation of the surface to be metallized; building up by metal spraying; repairs of castings; a description of the industrial uses of the process; zinc coatings for prevention of atmospheric corrosion; aluminium coatings for steelwork food vessels and chemical plant; the aluminizing process for the prevention of high-temperature oxidation; the metallurgy of aluminizing; tin coatings by spraying for food vessels, &c.; nickel coatings for corrosive media.

The author hopes to show a film on metal spraying in addition to the slides.

Sheffield Section.

Wrought Nickel Silver Alloys. By Maurice Cook, M.Sc., Ph.D. (December 11.)

The classification of this group of alloys is discussed with particular reference to recent proposals, and consideration is given to the relationship between colour and composition. The melting and casting procedure is briefly dealt with, and attention is directed to the importance of casting temperature and deoxidation. The mechanical properties, constitution, stamping and machining properties of hot-working nickel silver alloys, or nickel brasses, in the form of extruded rods, are described. The results of a detailed study of the physical and mechanical properties of a series of alloys conforming to the suggested British Standards Institution specification, are given. These tests were carried out on strip produced by cold-rolling, and in addition to hardness and tensile tests, information is given regarding the annealing characteristics of the alloys, and such properties as electrical and thermal conductivities, coefficient of expansion, and density.

Swansea Section.

Display of Films of Metallurgical Interest. (December 8.)

The new Honorary Secretary and Treasurer of the Swansea Section is Mr. K. M. Spring.

International Chemical Congress.

The Transactions of the International Chemical Engineering Congress, held in London in June, 1936, will be published as early as possible next year, and are obtainable at the pre-publication price of £10, until January 31.

The Publishers, Messrs. Lund, Humphries and Co., Ltd., 12 Bedford Square, London, W.C.1, will send on application, full prospectus of the 121 papers which, with General Reports on Sections, and Discussions, and an account of the Congress, occupy Vols. I-IV. Vol. V contains the Author and Subject Index. Most of the Papers are in English; all are provided with French and German summaries.

MEETINGS OF OTHER SOCIETIES

WEDNESDAY, NOVEMBER 18.

ELECTRODEPOSITORS' TECHNICAL SOCIETY.—Dr. H. J. T. Ellingham: "Modern Views Regarding Electrolyte Solutions." (Northampton Polytechnic Institute, St. John Street, Clerkenwell, London, E.C.1, at 8.15 p.m.)

THURSDAY, NOVEMBER 19.

COMPANY OF ARMOURERS AND BRASIERS IN THE CITY OF LONDON.—Dr. J. L. Haughton: "The Equilibrium Diagram of Alloys; its Meaning, Construction, and Use." First of Three Lectures. (Royal School of Mines, Prince Consort Road, South Kensington, London, S.W.7, at 8 p.m.)

SATURDAY, NOVEMBER 21.

INSTITUTE OF BRITISH FOUNDRYMEN, SCOTTISH BRANCH, FALKIRK SECTION.—M. Russell: "Design, Patternmaking, and Moulding, and their Relationship to Producing Castings Competitively." (Temperance Café, Lint Riggs, Falkirk, at 6 p.m.)

THURSDAY, NOVEMBER 26.

COMPANY OF ARMOURERS AND BRASIERS IN THE CITY OF LONDON.—Dr. J. L. Haughton: "The Equilibrium Diagram of Alloys: its Meaning, Construction, and Use." Second of Three Lectures. (Royal School of Mines, Prince Consort Road, South Kensington, London, S.W.7, at 8 p.m.)

SATURDAY, NOVEMBER 28.

INSTITUTE OF BRITISH FOUNDRYMEN, EAST MIDLANDS BRANCH.—F. Dunleavy: "More Non-Ferrous Problems." (Loughborough College, at 6 p.m.)

TUESDAY, DECEMBER 1.

ELECTRODEPOSITORS' TECHNICAL SOCIETY.—W. H. Riley: "Modern Plating Shop Practice." (James Watt Memorial Institute, Gt. Charles Street, Birmingham, 3, at 7.30 p.m.)

THURSDAY, DECEMBER 3.

COMPANY OF ARMOURERS AND BRASIERS IN THE CITY OF LONDON.—Dr. J. L. Haughton: "The Equilibrium Diagram of Alloys; its Meaning, Construction, and Use." Third of Three Lectures. (Royal School of Mines, Prince Consort Road, South Kensington, London, S.W.7, at 8 p.m.)

INSTITUTE OF BRITISH FOUNDRYMEN, SHEFFIELD AND DISTRICT BRANCH.—Commander Trevor Glenny: "The Planning and Progress of Foundry Operations." (King's Head Hotel, Change Alley, Sheffield, at 7.30 p.m.)

INSTITUTION OF ELECTRICAL ENGINEERS.—P. Dunsheath: "Continuous Extrusion of Lead Cable-Sheaths." (The Institution, Savoy Place, Victoria Embankment, London, W.C.2, at 6 p.m.)

FRIDAY, DECEMBER 4.

INSTITUTE OF BRITISH FOUNDRYMEN, BIRMINGHAM, COVENTRY, AND WEST MIDLANDS BRANCH.—E. J. L. Howard: "Bronze Castings." (James Watt Memorial Institute, Gt. Charles Street, Birmingham, 3, at 7.30 p.m.)

SATURDAY, DECEMBER 5.

INSTITUTE OF BRITISH FOUNDRYMEN, EAST MIDLANDS BRANCH, LINCOLNSHIRE SECTION.—F. Dunleavy: "Non-Ferrous Problems." (Technical College, Monks Road, Lincoln, at 7 p.m.)

TUESDAY, DECEMBER 8.

INSTITUTION OF ELECTRICAL ENGINEERS, NORTH MIDLAND CENTRE.—P. Dunsheath: "Continuous Extrusion of Lead Cable-Sheath." (Hotel Metropole, King Street, Leeds, at 7 p.m.)

WEDNESDAY, DECEMBER 9.

INSTITUTE OF WELDING, SCOTTISH BRANCH.—J. Carpenter: "Electrode Manipulation." (Royal Philosophical Institute, 207 Bath Street, Glasgow, at 7.30 p.m.)

FRIDAY, DECEMBER 11.

INSTITUTE OF WELDING, MIDLANDS BRANCH.—T. E. B. Nixon: "The Behaviour of the Arc." (James Watt Memorial Institute, Gt. Charles Street, Birmingham, 3, at 7.15 p.m.)

SATURDAY, DECEMBER 12.

INSTITUTE OF BRITISH FOUNDRYMEN, EAST MIDLANDS BRANCH.—S. A. Horton: "Patterns and Their Relation to Moulding Problems." (Loughborough College, at 6 p.m.)

INSTITUTE OF BRITISH FOUNDRYMEN, SCOTTISH BRANCH.—W. H. Smith: "Mould and Core Drying." (Royal Technical College, Glasgow, at 4 p.m.)

WEDNESDAY, DECEMBER 16.

ELECTRODEPOSITORS' TECHNICAL SOCIETY.—E. A. Ollard: "Rectification of Acid Copper Solutions." (Northampton Polytechnic Institute, St. John Street, Clerkenwell, London, E.C.1, at 8.15 p.m.)

INSTITUTE OF WELDING, MANCHESTER AND DISTRICT BRANCH.—L. B. Wilson: "Developments in Resistance Welding." (Manchester College of Technology, at 7.30 p.m.)

ROYAL SOCIETY OF ARTS.—Sir William Brazg: "The Development of Crystal Analysis." (The Society, John Street, Adelphi, London, W.C.2, at 8.30 p.m.)

THURSDAY, DECEMBER 17.

LEEDS ASSOCIATION OF ENGINEERS.—T. E. B. Nixon: "Electric Welding Plants." Joint Meeting with Institute of Welding. (Griffin Hotel, Leeds, at 8 p.m.)

STRESS-STRAIN CHARACTERISTICS OF COPPER, SILVER, AND GOLD.*

By J. McKEOWN,† M.Sc., Ph.D., MEMBER, and
O. F. HUDSON,‡ A.R.C.S., D.Sc., MEMBER.

SYNOPSIS.

A study has been made of the stress-strain characteristics of gold and silver of a very high degree of purity, and also of two coppers, one oxygen-free but containing a small amount of silver (about 0.003 per cent.), the other containing 0.016 per cent. oxygen but free from silver, both having little more than traces of other impurities. Stress-strain curves were obtained to determine limit of proportionality, 0.01 per cent. proof stress, and Young's modulus. The materials were tested in the fully-softened condition, after slight tensile overstrain (less than 1 per cent.) and after definite larger amounts of tensile overstrain (5-15 per cent.), and after re-heating the overstrained specimens at different temperatures.

It is generally considered that copper in the fully-annealed condition has no elastic limit, and the present tests have shown, as was expected, that pure gold and pure silver, when fully annealed, also show no proportionality of stress to strain in any part of the stress-strain diagram.

The elastic properties induced by cold-working were retained in large measure in all three metals after re-heating for short periods at moderately elevated temperatures, when the amount of cold-working (tensile overstrain) had been small. Low-temperature annealing, as used in the tests described, did not, however, result in raising the limit of proportionality of pure gold and silver and of oxygen-free and oxygen-containing coppers, to the same extent as in other cases, e.g. other kinds of copper.^{1, 2} The tests have shown that, when any of the metals, fine gold, fine silver, oxygen-free and oxygen-containing coppers, has been subjected to a small tensile overstrain, the effect of this small overstrain is evident in the stress-strain characteristics, even after re-heating to relatively high temperatures.

The tests have shown that the value of Young's modulus (E) for this oxygen-free copper is decreased by a small (5 per cent.) tensile overstrain to 15.7×10^6 lb./in.² (mean value). Larger amounts of overstrain appear to result in a recovery in the value of E ; with 15 per cent. overstrain the value of E found being 17.6×10^6 lb./in.². This is in agreement with the results of Kawai's previous work.

Annealing of the overstrained copper tended to restore the value of E lowered by previous overstrain, and by suitable treatment a value of 18.2×10^6 lb./in.² was obtained. Similar effects of re-heating after overstrain were found in the cases of fine gold and of fine silver, although the raising of the modulus by heat-treatment was less marked than in the case of copper. Gold, which had a value of E of 10.3×10^6 lb./in.² when overstrained 5 per cent., gave 11.3×10^6 lb./in.² when re-heated for $\frac{1}{2}$ hr. at 300° C.

* Manuscript received June 27, 1936.

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‡ Research Superintendent, British Non-Ferrous Metals Research Association, London.

Note to Abstractors and Other Readers.—This paper will be published, in permanent form, in the *Journal of the Institute of Metals*, Vol. LX, 1937. Reference should accordingly be as follows: *J. Inst. Metals*, 1937, 60 (Advance copy).

McKeown and Hudson : Stress-Strain

SOME time ago the authors had the opportunity to carry out tensile tests on standard 0.564 in. test-pieces of fine gold and fine silver, the materials being very kindly lent for this purpose by Messrs. Johnson, Matthey and Co., Ltd., at the suggestion of Professor R. S. Hutton. The original object of the tests was to obtain full load-extension diagrams for these two metals when in a state of high purity and in the annealed condition. It was felt, however, that while the specimens were available it would be of interest to examine the stress-strain characteristics of gold and silver after overstrain and after overstrain followed by heat-treatment. Later the tests were extended to include copper, and for this purpose a sample of copper of high purity (oxygen-free) was kindly supplied by Messrs. Thos. Bolton & Sons, Ltd., who also supplied some otherwise exceptionally pure copper containing 0.016 per cent. oxygen.

I. PREVIOUS WORK.

The effect of cold-work alone and followed by heat-treatment on the elastic properties of metals has been the subject of numerous investigations, and only the more recent work is reviewed. In 1929 Hudson, Herbert, Ball, and Bucknall ¹ dealt at some length with the effect of heat-treatment on the hardness and on the elastic properties, particularly the limit of proportionality, of copper containing small percentages of various added elements. In 1931 Jones, Pfeil, and Griffiths ² dealt with the effect of heat-treatment on the elastic limit of nickel-copper alloys, while in 1932 the present authors ³ in a paper dealing with the effect on copper at low stresses of cold-work, heat-treatment, and composition referred particularly to the influence on the stress-strain characteristics of these variables.

All these investigations showed that cold-work produces in most materials a definite range of proportionality of stress to strain where none exists in the materials in the fully-annealed state, and that this range is generally increased by suitable low-temperature heat-treatment. These investigations were mainly confined to the determination of limit of proportionality and proof stress, the determination of Young's modulus being as a rule considered as a subsidiary matter.

On the other hand, W. Kuntze ⁴ in 1929 gave evidence to show that the value of Young's modulus was dependent on the previous history of the specimen tested. He concluded that cold-working decreased the value of the modulus while heat-treatment subsequent to cold-working increased it.

Batson and Hyde ¹⁰ state that if the limit of proportionality is

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exceeded the value of Young's modulus (E) for steel may be decreased, in some cases by as much as 20 per cent. Recovery, however, is effected by rest or immersion in boiling water. The same authors quote the results of tests made at the National Physical Laboratory to determine the effect of heat-treatment on the value of E . The maximum effect due to heat-treatment alone (4 per cent.), was found in the case of the 2.75 per cent. nickel, 0.25 per cent. carbon steel.

An example of cold-work followed by precipitation-hardening as effecting a change in the value of E is given by beryllium-copper.⁵ Fully-annealed (water-quenched) sheet containing 2 per cent. beryllium has a value of E of 15.2×10^6 lb./in.², for the same sheet rolled 6 Nos.* hard $E = 16.0 \times 10^6$ lb./in.² and heat-treated after rolling $E = 17.9 \times 10^6$ lb./in.². With 2.5 per cent. beryllium the sheet rolled 6 Nos. hard gave $E = 16.3 \times 10^6$ lb./in.², and when heat-treated $E = 19.0 \times 10^6$ lb./in.².

Kawai⁶ carried out an investigation on Armco iron, mild steel, nickel steel, copper, aluminium, and nickel to determine the effect produced on the modulus by cold-working with and without subsequent heat-treatment. He found that in iron and steel the modulus always decreases with cold-working and that in the other metals it decreases for a small degree of working, but increases for a large degree of working. The effect of annealing iron and steel subsequent to cold-working was to increase the modulus again; thus, in the case of mild steel drawn with 36 per cent. reduction annealing at 900° C. returned the modulus to the original value of the soft material.

In the case of copper, aluminium, and nickel, previously cold-worked, the modulus increased rapidly as the annealing temperature was increased, a maximum being reached at 300°, 200°, and 350° C., respectively, at which temperatures recrystallization began to become noticeable; from this point the modulus decreased up to about 650°, 500°, and 900° C., respectively, where it had returned to the initial value before cold-working.

In the 1911 May Lecture to the Institute of Metals, Beilby⁷ quoted the results of acoustical tests on the changes in elasticity due to annealing at various temperatures, the test being carried out on vibrating tongues of gold, silver, copper, and iron. The pitches of the hardened tongues were raised by annealing treatments, the increase being of the order of 5 per cent. by annealing at the crystallizing temperature. Since the frequency of vibration is proportional to the Young's modulus, it follows that the modulus was increased by the heat-treatments.

* 50 per cent. reduction.

II. EXPERIMENTAL.

A. *Materials.*

The gold, assayed by the makers, was 999.999 fine and the silver 1000.000 fine. In each case the metals were cast in $1\frac{1}{4}$ -in. diameter bars and then rolled to a diameter of 0.8 in. in steel rolls. The bars were then annealed for 10 minutes at 500° C., and standard British Standard 0.564-in. diameter specimens were machined from them. After the machining operation, the finished specimens were given another anneal for 10 minutes at 500° C.

The oxygen-free copper was of high purity, the oxygen content being less than 0.0005 per cent. A spectrographic analysis gave the following results :

	Per Cent.
Bismuth	less than 0.0001
Arsenic	„ „ 0.001 (if any)
Lead	0.001 (approx.)
Iron	0.005
Nickel	0.0005
Silver	0.003
Antimony	not detected (less than 0.002 if any)
Tin	„ „ (less than 0.005 if any)
Silicon	„ „

This material was supplied in the form of hard-drawn $\frac{7}{8}$ -in. diameter bar. It had been hot-rolled in the ordinary way to (nominal) $1\frac{5}{8}$ in. diameter from an imported, vertically cast, 250-lb. wire-bar of O.F.H.C. (non-guaranteed) quality, and drawn to $\frac{7}{8}$ in. diameter on a draw-bench, being given an intermediate annealing of approximately $\frac{1}{2}$ hr. at 650° C. at 1.0 in. diameter. Specimens were machined to the British Standard 0.564 in. size.

The oxygen-containing copper was supplied in the hard condition in the form of machined bar 7 mm. in diameter. It was made from copper of unusual purity, hot-rolled from an ordinary horizontally-cast 250 lb. wire-bar to $\frac{9}{16}$ in. diameter, annealed, pickled, cold-drawn on a block to No. 000 S.W.G. approximately, and finished on a draw-bench without intermediate annealing to $\frac{5}{16}$ in. diameter; it was finally machined to 7 mm. in diameter. Specimens having a diameter of 0.1784 in. (area $\frac{1}{10}$ sq. in.) on the 2-in. gauge-length were machined from the bar. This copper contained 0.016 per cent. oxygen, and in a careful spectrographic analysis the only other impurities detected were iron (0.001 per cent.) and lead (0.0002 per cent.). It should be borne in

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mind throughout the subsequent discussion of results that, whereas the oxygen-free copper contained about 0.003 per cent. silver, this specially pure copper, while containing a small amount of oxygen, was apparently entirely silver-free; several independent spectrographic and chemical analyses, carried out to detect silver, completely failed to do so.

B. Testing Methods.

Two different testing machines were used in this investigation, a 5-ton Avery lever machine and the 5-ton range of a 20-ton Amsler hydraulic machine. The Amsler machine was calibrated against standards before the tests were made, and a cross-check of the two machines was made using a standard steel specimen, elastic to loads greater than 5 tons, and an extensometer. The test showed that the calibration of the machines agreed to within less than 0.5 per cent.

The extensometer used in the determination of the elastic properties of the materials was a Lamb's roller extensometer designed for a gauge-length of 2 in. The scale distance used was such that 1 cm. on the scale represented a strain of 1×10^{-4} on the specimen. The scale was graduated in mm., and a reading could be estimated to 0.2 mm. with an accuracy of at least ± 0.2 mm., *i.e.* the strain was estimated to $\pm 2 \times 10^{-6}$. With such a high sensitivity as this, it is important, of course, that temperature variations should be very small. The tests were made in a basement laboratory where temperature was constant to $\pm 1^\circ$ C. during the period of the test. In addition, the specimen and extensometer were left for at least 1 hr. after being assembled in the testing machine, to allow them to attain a steady temperature before any testing was proceeded with.

For accurate testing of elastic properties the greatest care is necessary to ensure axial loading of the specimen, and this was secured by using grips of the Robertson type. These grips were made on the lathe that was used to produce the copper specimens.

All the determinations of elastic properties were made on the Avery machine, on which the load could be read directly to 0.01 ton and by vernier to 0.001 ton. In most of the tests on gold and silver, the load was increased in increments of 0.025 ton, and this increment could be read to ± 0.001 ton. Thus, for an increment of stress on the specimen of 0.100 ton/in.², the probable error was ± 0.004 ton/in.². Taking a mean value of E for gold and silver as 10.5×10^6 lb./in.², then the strain corresponding to ± 0.004 ton/in.² = $\pm \frac{0.004 \times 2240}{10.5 \times 10^6} = \pm 0.85 \times 10^{-6}$, a measurement approximately half the sensitivity of the strain measure-

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ment. It follows from this that the measurement of stress was about twice as sensitive as the measurement of strain. Attempts were made to increase the sensitivity of strain measurements by reading the scale to ± 0.1 mm., but it was considered after experience of this that the increase in sensitivity was not fully justified in all cases, and it was decided to adhere to the former method where the strain was measured to a sensitivity of $\pm 2 \times 10^{-6}$.

Where the value of Young's modulus is calculated from a stress-strain curve showing a very low limit of proportionality of stress to strain, the sensitivity of strain measurement becomes important. As an example, take the case of a specimen having a limit of proportionality of 0.4 ton/in.² and a modulus of 10.0×10^6 lb./in.². The calculated strain at 0.4 ton/in.² is 90×10^{-6} , and this may be read as 92 or 88×10^{-6} . The former value would give $E = 9.74 \times 10^6$, while the latter would give $E = 10.18 \times 10^6$ lb./in.², *i.e.* a total variation of 0.44×10^6 on a mean value of $10 \times 10^6 = 4.4$ per cent. On this account the values of E given in this paper and derived from specimens having a limit of proportionality of only about 0.4 ton/in.² and a value of E of the order of 10×10^6 lb./in.² may be in error by about $\pm 2\frac{1}{4}$ per cent. When the limit of proportionality is 1 ton/in.², on the other hand the value of E will vary only by ± 1 per cent., and as the limit of proportionality increases the probable error in E will decrease.

C. Annealing.

Annealings at temperatures of 500° C. and over were carried out in an electric muffle furnace, and heat-treatments at 250° – 400° C. in an electric tubular furnace in air. Heat-treatment at 200° C. was given in an oil-bath.

D. Stress-Strain Curves.

The stress-strain curves were plotted to a strain scale such that 1 mm. on the paper represented a strain of 2×10^{-6} on the specimen. From the straight-line portions of the curves, the limit of proportionality and Young's modulus were determined. The proof stress was determined by drawing, parallel to the elastic line, a line distant from it 1×10^{-4} strain or 0.01 per cent. and noting the stress at which it cut the stress-strain curve.

In a number of cases the early part of the stress-strain curve consisted of two straight-line portions having different slopes. The first part up to a stress of about 0.3 ton/in.² was followed by a much longer straight length on which the experimental points lay very well. In such cases the limit of proportionality and E were determined from the

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second straight-line portion and the first part was ignored. The reason for this peculiar form of stress-strain relationship, present in some cases and absent in others, is not known, but it is interesting to compare the finding with that of Chalmers⁸ on lead specimens using an interference extensometer by which strain was read to 10^{-7} . Chalmers obtained from lead specimens a new type of closed stress-strain loop. The early part of the loading line was curved, and that was followed by a straight portion which was found to persist up to the elastic limit. If the elastic limit was not exceeded, the unloading line was an exact reproduction of the loading line starting with a curve and continuing on a straight line. It may be mentioned that in the loops obtained by Chalmers the straight lines were parallel.

In practically every case in the present work, the return line from the maximum stress down to the initial stress was determined, the rate of unloading being the same as the rate of loading. Except for the case of the severely worked materials, which had been overstrained during the test by only a small amount, the return line was curved for all of its length (see typical stress-strain curves in Figs. 1 and 2). This resulted in the permanent set being less than the apparent inelastic extension at the maximum load. In all three materials, and particularly in the silver, the limit of restitution or elastic limit was much greater than the limit of proportionality, in some cases it was observed to be greater by as much as 100 per cent.

A study was made of the effect of rate of stressing in the case of the fully-annealed materials by increasing the stress in equal increments each 10 minutes and taking readings of the scale at 1 minute, 5 minutes, and 10 minutes after each stress was applied. The creep occurring at the higher stresses was clearly shown by the curves obtained. The curves were plotted in such a way that the creep occurring during the period 1-10 minutes at any stress was eliminated from the strain reading for 1 minute after stressing at the next higher stress and similarly for 5 minutes. This enabled curves to be obtained on the one specimen as if it had been subjected to three separate tests simultaneously—in which the stress was increased at 1-, 5-, and 10-minute intervals, respectively. It is, of course, possible that the curves obtained in this way for the 1- and 5-minute intervals are affected slightly by the strain-hardening due to the small amount of creep occurring during the 10-minute interval. A very interesting feature of the curves obtained was that the return lines, while curved, were parallel for the three rates of stressing. This appears to indicate that the curvature of the unloading line is not a time effect; in other words, is not a phenomenon connected with negative creep.

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E. Load-Extension Diagrams to Fracture.

Most of these tests were made at a slow rate on the 5-ton range of the 20-ton Amsler machine. In a test on the Avery machine the gauge-length, 2 in., was marked on the specimen using small centre punch marks, and the machine was operated at its lowest speed. Dividers were set to 2.05 in., and when the gauge-length had extended to this amount the load was read off the beam and the time noted. The dividers were now set to 2.10 in., and the load corresponding to this gauge-length noted as before. This process was continued until just past the maximum load. It should be noted that the pulling of the specimen was continuous, not a series of steps, movement of the poise on the beam being stopped only for the short time necessary to read the load.

In the case of the tests on the Amsler machine, the gauge-length was measured by dividers at intervals of time, and the corresponding loads noted.

In each case the rate of testing (given in the tables) was calculated by dividing the final extension per in. of original gauge-length at fracture by the time taken for the test.

III. RESULTS OF THE TESTS.

The results of the tests are given in Tables I-XVII, and typical stress-strain curves obtained are illustrated in Figs. 1 and 2.

A. Gold.

(1) *Annealed (as received) material (Table I).*—None of the specimens gave a limit of proportionality, but from the figures given in Table I for strain at maximum stress applied in the test and for permanent strain it would appear that there was some variation in initial condition of the specimens, although they were received in a nominally fully-annealed condition.

(2) *Effect of overstrain on the annealed material (Table II).*—The overstrain in these tests was produced by pulling the specimens in the testing machine until the gauge-length had increased by the desired amount. The effect of 5 per cent. overstrain was to give the material a definite limit of proportionality of 1.3 ton/in.² and a 0.01 per cent. proof stress of 3.6 tons/in.², the value of Young's modulus being 10.3×10^6 lb./in.².

(3) *Effect of heat-treatment after 5 per cent. overstrain (Table II).*—The effect of heat-treatment following 5 per cent. overstrain is set out in Table II, from which it is seen that annealing at 200° and 300° C.

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reduced the limit of proportionality and the proof stress but increased the modulus.

(4) *Effect of speed of testing on ultimate tensile strength and elongation of annealed specimens.*—The results of these tests are given in Table III, where it is seen that reducing the speed of testing causes a reduction in ultimate tensile strength.

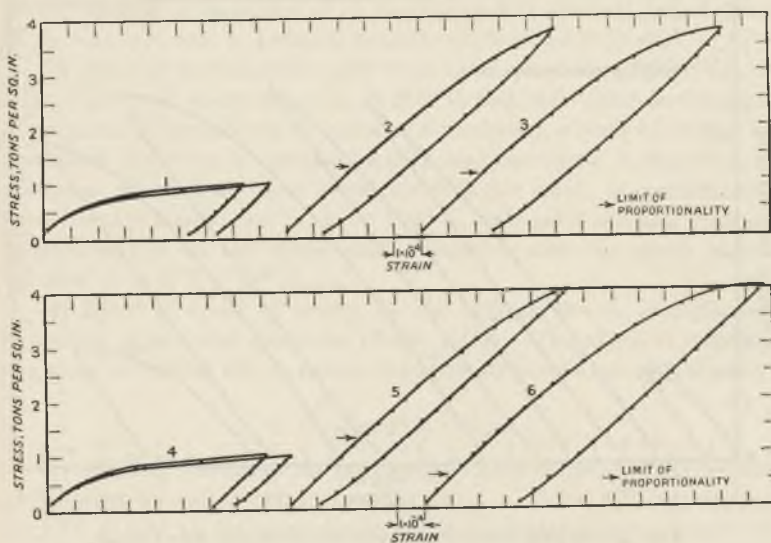


FIG. 1.—Typical Stress-Strain Curves for Silver and Gold.

- Curve 1. Silver specimen No. 3, annealed (as received). Curves for 0.1 and 0.01 ton/in.²/minute rates of stressing.
- Curve 2. Silver specimen No. 3, annealed (as received) + 5 per cent. tensile overstrain.
- Curve 3. Silver specimen No. 3, annealed (as received) + 5 per cent. tensile overstrain + $\frac{1}{2}$ hr. at 350° C.
- Curve 4. Gold specimen No. 4, annealed (as received). Curves for 0.1 and 0.01 ton/in.²/minute rates of stressing.
- Curve 5. Gold specimen No. 4, annealed (as received) + 5 per cent. tensile overstrain.
- Curve 6. Gold specimen No. 5, annealed (as received) + 5 per cent. tensile overstrain + $\frac{1}{2}$ hr. at 300° C.

(5) *Effect of overstrain and heat-treatment on the ultimate tensile strength and elongation (Table IV).*—The effect of 5 per cent. tensile overstrain was to increase the ultimate tensile strength slightly and to reduce the elongation slightly. The effect of 5 per cent. overstrain followed by treatment for $\frac{1}{2}$ hr. at 200° C. was to give a further increase in the ultimate tensile strength, the effect on the elongation being very slight.

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B. Silver.

(1) *Annealed (as received) material (Table V).*—Extensometer tests made on “as received” specimens showed some variation. Two of the specimens gave a possible small limit of proportionality, while the other four gave no proportionality of stress to strain. As in the case

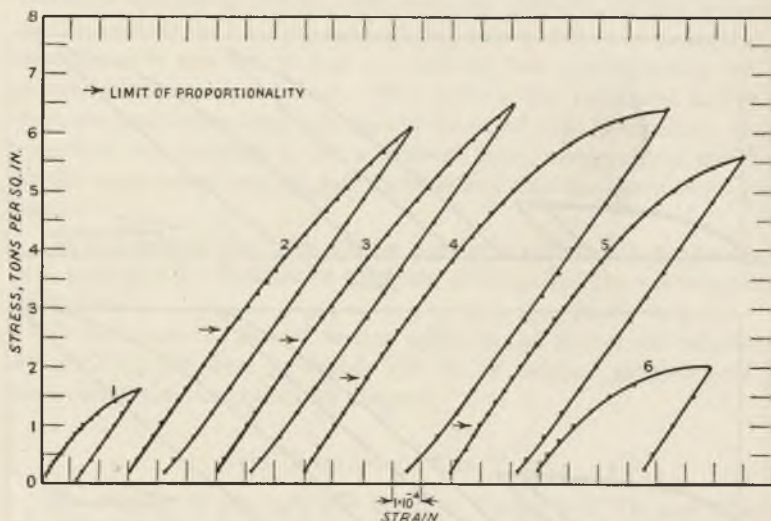


FIG. 2.—Typical Stress-Strain Curves for Oxygen-Free Copper.

- Curve 1. Hard-rolled and annealed 1 hr. at 500° C. (Specimen No. 15.)
Curve 2. Hard-rolled, annealed 1 hr. at 500° C. + 5 per cent. tensile overstrain. (Specimen No. 1.)
Curve 3. Hard-rolled, annealed 1 hr. at 500° C. + 5 per cent. tensile overstrain + 1 hr. at 200° C. (Specimen No. 3.)
Curve 4. Hard-rolled, annealed 1 hr. at 500° C. + 5 per cent. tensile overstrain + 1 hr. at 400° C. (Specimen No. 5.)
Curve 5. Hard-rolled, annealed 1 hr. at 500° C. + 5 per cent. tensile overstrain + 1 hr. at 500° C. (Specimen No. 6.)
Curve 6. Hard-rolled, annealed 1 hr. at 500° C. + 15 per cent. tensile overstrain + 1 hr. at 500° C. (Specimen No. 13.)

of the gold specimens, the greatest differences between the specimens were shown by the strain at 1 ton/in.² and the permanent set. From the results of the tests it would appear that the final heat-treatment of 10 minutes at 500° C. given by the makers did not produce material in the fully-annealed condition, this treatment being insufficient completely to remove all effect of the slight overstrain, which may have occurred in machining. To investigate this matter further, specimen No. 2 was given two further treatments, first 1 hr. at 500° C., and

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secondly 1 hr. at 700° C. The first treatment failed to remove the small limit of proportionality induced by the overstrain produced in the initial testing, while the second treatment appeared to produce full annealing.

(2) *Effect of overstrain on the annealed (as received) material (Table VI).*—The effect of 5 per cent. overstrain was to give the material a limit of proportionality of the order of $1\frac{1}{2}$ tons/in.², a 0·01 per cent. proof stress of $3\frac{1}{2}$ tons/in.², and a Young's modulus of $10\cdot1 \times 10^6$ lb./in.².

(3) *Effect of heat-treatment after 5 per cent. overstrain (Table VII).*—After 5 per cent. overstrain $\frac{1}{2}$ hr. at 200° C. had little effect on the limit of proportionality and left the value of E unaltered, while $\frac{1}{2}$ hr. at 350° C. decreased the limit of proportionality and increased E slightly. A specimen which had been overstrained 5 per cent. in tension and subsequently heated for 1 hr. at 700° C. still gave a small limit of proportionality on the stress-strain diagram, with the much higher value of $E = 11\cdot3 \times 10^6$ lb./in.².

(4) *Effect of speed of testing on the ultimate tensile strength and elongation of annealed specimens (Table VIII).*—The effect of reducing the speed of testing was to reduce the ultimate tensile strength slightly.

C. Oxygen-Free Copper.

(1) *Effect of annealing the (as received) hard material.*—The results of different annealing treatments are given in Table IX. Annealing for 1 hr. at 500° C., although giving material which would be considered as fully annealed, did not completely remove all traces of elasticity, and it was possible to determine the value of Young's modulus after this treatment. Annealing the material for $\frac{1}{2}$ hr. at 650° C. did not appear to produce any further annealing effect. The effect of a treatment of 1 hr. at 200° C. was to increase the limit of proportionality and the proof stress of the "as received" material. It may be noted that the effect of the higher temperatures of annealing was to produce a decrease in the value of the modulus.

(2) *Effect of overstrain on the annealed material.*—The annealed material was that which had received 1 hr. at 500° C., and the results of the overstrain tests are shown in Table X. The effect of 5 per cent. overstrain was to give the material a definite limit of proportionality of the order of 2·5 tons/in.² and a proof stress of the order of 5·5–6 tons/in.². An overstrain of 10 per cent. gave a slightly lower limit of proportionality but a high proof stress of the order of 8 tons/in.². An overstrain of 15 per cent. gave a limit of proportionality of 2 tons/in.² and a proof stress of about 8·4 tons/in.², a value higher than that of the original hard material. The effect of overstrain on Young's modulus

may be noted : the original material in the hard condition had a value of E of 18.3×10^6 lb./in.², while for the annealed material, overstrained 5 per cent., E was 15.7×10^6 lb./in.². Overstrain of 10 and 15 per cent. gave values of E of 16.5×10^6 lb./in.² and 17.5×10^6 lb./in.², respectively. The value for the fully-annealed material could not be directly determined, but from the evidence given by specimens 15 and 16 in Table IX, it is of the order of 17.5 to 18×10^6 lb./in.². The results seem to point to the conclusion that a small amount of overstrain produces a considerable decrease in the value of Young's modulus, while a larger overstrain gives a value which is higher than that produced by the small overstrain but lower than that of the annealed material. This, it should be noted, is in complete agreement with the results of Kawai,⁶ who showed that for copper with increasing amounts of cold-work produced by stretching, the value of E at first decreased, reached a minimum at approximately 5 per cent. elongation and then increased again.

(3) *Effect of heat-treatment after overstrain.*—The effect of heat-treatment after overstrain is shown in Table XI. The effect after 5 per cent. overstrain may be summarized as follows :

- (a) *Limit of proportionality.*—Treatments for 1 hr. at various temperatures up to 500° C. produced at first a slight increase, followed by a gradual decrease of the limit with increasing temperature of treatment. Treatment for 1 hr. at 500° C. left a limit of about 1.0 ton/in.².
- (b) *Proof stress.*—The changes in proof stress corresponded with the changes in the limit of proportionality.
- (c) *Young's modulus.*—Treatments for 1 hr. at 100°, 200°, and 300° C. produced little effect on the modulus, but such effect as there was appeared to indicate a definite small increase; while treatments for 1 hr. at 400° and 500° C. produced a further and decided increase.

The effects of treatments for 1 hr. at various temperatures up to 500° C. after 15 per cent. overstrain was to decrease gradually the limit of proportionality, the last treatment removing all traces of proportionality of stress to strain. The value of Young's modulus was again increased by increasing temperature of treatment.

(4) *Load-extension diagrams to fracture.*—The results of the tests on the copper specimens are given in Table XIII, and typical curves of stress and extension are shown for this material (and also for the gold and silver) in Fig. 3. It should be noted that, in accordance with usual practice, in these curves the stress in each case is the load divided by the area of cross-section of the specimen at the commencement of the

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test, in other words the "nominal stress." Attention may be directed to the tendency for slight increase of the ultimate tensile strength by low-temperature annealing after the 5 per cent. overstrain in the copper specimens.

The load-extension curves for the materials in the fully-annealed condition have been re-plotted as curves of true stress and strain, the

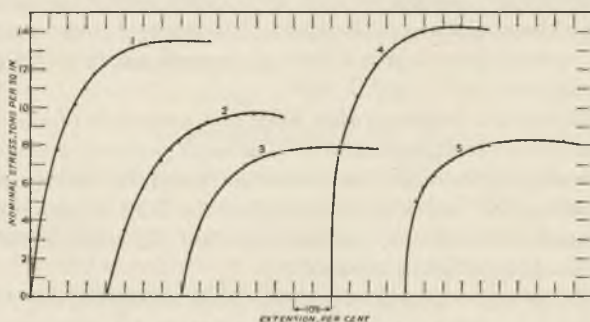


FIG. 3.—Typical Load-Extension Curves.

- Curve 1. Oxygen-free copper specimen. Hard rolled and annealed $\frac{1}{2}$ hr. at 650° C.
 Curve 2. Silver specimen. Annealed (as received).
 Curve 3. Gold specimen. Annealed (as received).
 Curve 4. Oxygen-free copper specimen. Hard rolled, annealed $\frac{1}{2}$ hr. at 650° C. + 5 per cent. tensile overstrain + 2 hrs. at 350° C.
 Curve 5. Gold specimen. Annealed (as received) + 5 per cent. tensile overstrain + $\frac{1}{2}$ hr. at 200° C.

cross-sectional area of the specimen at any extension being determined by assuming constant volume of the gauge-length portion of the specimen. Attempts have been made in the manner indicated by G. I. Taylor⁹ to determine suitable parabolas to fit these curves, but no true fits were obtained. The equations of the parabolas which fitted the curves best in the region of 0.1–0.2 strain were as follows, S being the stress in tons per sq. in. and s the strain.

Pure gold	.	.	$S = 19.1 \sqrt{s}$
Pure silver	.	.	$S = 19.4 \sqrt{s}$
Oxygen-free copper	.	.	$S = 33.6 \sqrt{s}$



D. High-Purity Silver-Free Copper Containing 0.016 Per Cent. Oxygen.

(1) *Effect of annealing the (as received) hard material (Table XIV).*—The effect of annealing the "as received" material at 500° or 600° C. was to remove completely all traces of proportionality of stress to strain. The effect of heat-treatment of the "as received" material

for 1 hr. at 200° C. was to reduce the limit of proportionality from about 2 to 1.27 tons/in.², the proof stress from 9 to 7 tons/in.², and to increase the modulus very slightly.

(2) *Effect of overstrain on annealed material (Table XV).*—The effect of 5 per cent. overstrain on the annealed material was to give it a limit of proportionality of 1 to 1.25 tons/in.² and a modulus of 16.6×10^6 lb./in.², compared with 19.9×10^6 lb./in.² in the original material in the hard state. The effect of 15 per cent. overstrain on the annealed material was to give a limit of proportionality of 1.4 tons/in.² and a modulus of 18.1×10^6 lb./in.².

(3) *Effect of heat-treatment after 5 per cent. overstrain (Table XVI).*—The effect of heat-treatment at 200° C. after 5 per cent. overstrain was to increase slightly the limit of proportionality and the Young's modulus. Treatments at 300° and 400° C. decreased the limit of proportionality and increased the modulus, treatment at 500° C. removing all traces of proportionality of stress to strain.

(4) *Effect of heat-treatment on ultimate tensile strength (Table XVII).*—The effect of overstraining the annealed material 5 per cent. was to increase the ultimate tensile strength slightly, and annealing treatments up to 400° C. did not reduce the value appreciably. 1 hr. at 500° C., however, caused a considerable reduction in ultimate tensile strength. The effect of 15 per cent. overstrain on the annealed material was to increase the ultimate tensile strength from 15 to 17.25 tons/in.².

A large number of specimens broke at or close to the gauge-mark, and consequently it is not possible to reach very definite conclusions as to the effect of overstrain and heat-treatment on the elongation.

IV. COMPARISON OF THE OXYGEN-FREE AND OXYGEN-CONTAINING COPPERS.

A. Elastic Properties.

In the annealed condition (up to 650° C.) the oxygen-free copper tended to retain some small range of proportionality of stress to strain, whereas the oxygen-containing copper showed no such range.

The effect of 5 per cent. overstrain in the case of the oxygen-free copper was to give it a limit of proportionality of the order of 2.5 tons/in.², whereas in the case of the oxygen-containing copper the limit was only of the order of 1 ton/in.². On the other hand, the Young's modulus was higher in the case of the oxygen-containing copper than the oxygen-free copper after this amount of overstrain. After 15 per cent. overstrain, the oxygen-free copper had a limit of proportionality of 2 tons/in.² and a modulus of 17.65×10^6 lb./in.², the corresponding

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figures for the oxygen-containing copper being 1.4 tons/in.² and 18.1×10^6 lb./in.².

In both coppers heat-treatment following overstrain produced a lowering in the limit of proportionality and an increase in the Young's modulus. In the case of the oxygen-free copper, however, treatment for 1 hr. at 500° C. following 5 per cent. overstrain produced a limit of proportionality of the order of 1 ton/in.², whereas similar treatment in the case of the oxygen-containing copper removed all traces of proportionality of stress to strain.

B. Ultimate Tensile Strength.

In the fully-annealed condition the ultimate tensile strength of the oxygen-containing copper was more than 1 ton/in.² higher than that of the oxygen-free copper, and throughout the various treatments this difference in the strength was approximately maintained. It may be noted that the reduction in area is greater for the oxygen-free than for the oxygen-containing copper.

The effect of oxygen in slightly increasing the ultimate tensile strength of copper is well known, but its effect on the elastic properties of the copper has not been very fully investigated. In the present work it is not clear, however, whether the superior elastic properties of the oxygen-free copper are due to the absence of oxygen alone or in part to the presence of the small amounts of other impurities, *e.g.* silver (0.003 per cent.).

V. THE EFFECT OF VERY SMALL AMOUNTS OF OVERSTRAIN.

The effect of a very small amount of overstrain on the stress-strain characteristics of the materials tested has been considered for the two cases :

- (1) When the specimen is re-tested without any intermediate treatment.
- (2) When the specimen is re-tested after treatment.

In the case of the oxygen-free copper the results of some tests are given in Table XII, and from these it will be seen that the application of a very small overstrain produced a considerable increase in the limit of proportionality. If such overstrain is now followed by a heat-treatment at 500° or 600° C., the limit of proportionality is reduced but is still higher than the original limit. The effect on the modulus is the reverse, the small overstrain producing a small, but apparently

definite, decrease of the value of E , which is more or less completely restored by the subsequent heat-treatment.

A specimen of gold in the "as received" annealed condition which had been slightly overstrained to the extent of 0.147 per cent., and then heat-treated for 10 minutes at 500° C., had a limit of proportionality of 0.4 ton/in.², the value of E being 10.7×10^6 lb./in.². A similar silver specimen which had been overstrained 0.0368 per cent. and heated for 1 hr. at 500° C. gave a limit of proportionality of 0.4 ton/in.² and a Young's modulus (E) of 10.7×10^6 lb./in.².

These results illustrate the importance of slight overstrains in their effect on the stress-strain characteristics and also the retention of some of the effects of the overstrain after treatment at comparatively high temperatures.

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APPENDIX.

TABLE I.—Gold. *Properties of Annealed (As Received) Material (Extensometer Tests).*

Specimen No.	Rate of Stressing, Tons/in. ² /minute.	Limit of Proportionality, Tons/in. ² .	Maximum Stress Applied, Tons/in. ² .	Strain × 10 ⁴ at Maximum Stress.	Permanent Strain, × 10 ⁴ .
1	0.6	nil	1.0	30.20	28.4
2	0.1	nil	0.8	22.40	20.80
6	0.1	nil	1.0	18.30	16.32
3	0.01	nil	0.8	16.30	14.70
4	0.01	nil	1.01	8.98	6.90
5	0.01	nil	1.0	26.14	24.10

TABLE II.—Gold. *Effect of Heat-Treatment after 5 per Cent. Overstrain (Extensometer Tests).*

Specimen No.	Heat-Treatment.	Limit of Proportionality, Tons/in. ² .	0.01% Proof Stress, Tons/in. ² .	Young's Modulus, Lb./in. ² ÷ 10 ⁶ .	Maximum Stress Applied, Tons/in. ² .	Strain × 10 ⁴ at Maximum Stress.	Permanent Strain, × 10 ⁴ .
4	...	1.30	3.60	10.3	4.03	10.36	1.12
6	½ hr. at 200° C.	0.75	2.65	10.7	3.365	9.02	1.40
5	½ hr. at 300° C.	0.60	2.85	11.3	4.045	12.60	3.40

TABLE III.—Gold. *Effect of Speed of Testing (Tests to Fracture).*

Specimen No.	Condition.	Rate of Pulling, In./in./minute.	Ultimate Tensile Strength, Tons/in. ² .	Elongation, on 2 in., Per Cent.	Reduction in Area, Per Cent.
1	Annealed as received	0.05	7.89	73	90
2	" " "	0.05	7.88	72.5	90
3	" " " + 10 minutes at 500° C.	0.009	7.56	68	92

TABLE IV.—Gold. *Effect of Overstrain and Heat-Treatment (Tests to Fracture) Rate of Pulling in all tests 0.05 in./in./minute.*

Specimen No.	Condition.	Ultimate Tensile Strength, Tons/in. ² .	Elongation, on 2 in., Per Cent.	Reduction in Area, Per Cent.
1	Annealed as received	7.89	73	90
4	" " " + 5 per cent. tensile overstrain	7.97	65	87
6	" " " + 5 per cent. tensile overstrain + ½ hr. at 200° C.	8.20	64.5	93.5

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TABLE V.—*Silver. Properties of Annealed (As Received) Material (Extensometer Tests).*

Specimen No.	Condition.	Rate of Stressing, Ton/in. ² /minute.	Limit of Proportionality, Tons/in. ² .	0.01% Proof Stress, Tons/in. ² .	Young's Modulus, Lb./in. ² ÷ 10 ⁶ .	Maximum Stress Applied, Tons/in. ² .	Strain × 10 ⁴ at Maximum Stress.	Permanent Strain, × 10 ⁴ .
1	Annealed as received	0.1	0.3	0.7	10.3	1.0	14.16	12.06
5	" " "	0.1	nil	---	---	1.0	11.50	9.40
6	" " "	0.1	0.3	0.65	11.1	1.0	22.02	19.90
2	Annealed as received	0.01	nil	---	---	1.0	5.76	3.68
3	" " "	0.01	nil	---	---	1.0	8.42	6.40
4	" " "	0.01	nil	---	---	1.0	5.28	3.30
2	1 hour at 500° C.	0.01	0.4	0.9	10.7	1.0	3.70	1.70
2	1 hour at 700° C.	0.01	nil	---	---	1.0	23.38	21.40

TABLE VI.—*Silver. Effect of 5 per Cent. Overstrain on Annealed Material (Extensometer Tests).*

Specimen No.	Limit of Proportionality, Tons/in. ² .	0.01% Proof Stress, Tons/in. ² .	Young's Modulus, Lb./in. ² ÷ 10 ⁶ .	Maximum Stress Applied, Tons/in. ² .	Strain × 10 ⁴ at Maximum Stress.	Permanent Strain, × 10 ⁴ .
2	1.90	3.70	10.1	3.76	9.12	0.80
3	1.30	3.30	10.1	3.76	10.00	1.34

TABLE VII.—*Silver. Effect of Heat-Treatment after 5 per Cent. Overstrain (Extensometer Tests).*

Specimen No.	Heat-Treatment.	Limit of Proportionality, Tons/in. ² .	0.01% Proof Stress, Tons/in. ² .	Young's Modulus, Lb./in. ² ÷ 10 ⁶ .	Maximum Stress Applied, Tons/in. ² .	Strain × 10 ⁴ at Maximum Stress.	Permanent Strain, × 10 ⁴ .
2	½ hr. at 200° C.	1.80	3.5	10.1	3.34	7.70	0.48
2	½ hr. at 350° C.	1.20	3.15	10.3	3.76	11.24	2.62
5	1 hr. at 700° C.	0.30	0.5	11.3	0.63	6.12	5.02

TABLE VIII.—*Silver. Effect of Speed of Testing (Tests to Fracture).*

Specimen No.	Condition.	Rate of Pulling, In./in./minute.	Ultimate Tensile Strength, Tons/in. ² .	Elongation on 2 in., Per Cent.	Reduction in Area, Per Cent.
1	Annealed as received	0.05	9.61	65	91.5
4	" " "	0.01	9.19	60	90
6	" " "	0.01	9.16	67.5	91

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TABLE IX.—*Oxygen-Free Copper. Effect of Annealing (Extensometer Tests).*

Specimen No.	Condition.	Limit of Proportional-ity, Tons/in. ² .	0.01% Proof Stress, Tons/in. ² .	Young's Modulus, Lb./in. ² × 10 ⁶ .	Maximum Stress Applied, Tons/in. ² .	Strain × 10 ⁴ at Maximum Stress.	Permanent Strain, × 10 ⁴ .
0	As received (hard)	2.2	8.1	18.3	8.0	10.4	0.62
14	" " + 1 hr. at 200° C.	3.4	9.0	18.7	9.2	11.78	0.55
0.2	" " + 1 hr. at 500° C. A.C.	0.6	1.4	15.3	2.0	7.80	5.26
0.3	" " + 1 hr. at 650° C. A.C.	0.6	1.3	15.7	2.0	7.40	5.00
7	" " + 1 hr. at 500° C. F.C.	0.6	1.4	16.4	2.0	6.85	4.58
15	" " + 1 hr. at 500° C. F.C.	0.36	1.5	17.3	1.6	3.36	1.20
16	" " + ½ hr. at 650° C. F.C.	0.37	1.48	17.9	1.625	3.40	1.40

A.C. = Air-cooled. F.C. = Furnace cooled.

TABLE X.—*Oxygen-Free Copper. Effect of Overstrain on Material Annealed 1 Hr. at 500° C.F.C. (Extensometer Tests).*

Specimen No.	Amount of Overstrain, Per Cent.	Limit of Proportional-ity, Tons/in. ² .	0.01% Proof Stress, Tons/in. ² .	Young's Modulus, Lb./in. ² × 10 ⁶ .	Maximum Stress Applied, Tons/in. ² .	Strain × 10 ⁴ at Maximum Stress.	Permanent Strain, × 10 ⁴ .
1	5	2.64	5.7	15.8	6.08	9.60	1.20
17	5	2.20	5.95	15.7	6.00	9.20	0.68
8	10	2.16	7.9	16.5	9.54	14.32	1.06
9	15	2.00	8.4	17.7	10.20	14.42	0.78

TABLE XI.—*Oxygen-Free Copper. Effect of Heat-Treatment after Overstrain (Extensometer Tests).*

Specimen No.	Amount of Overstrain, Per Cent.	Heat-Treatment.	Limit of Proportional-ity, Tons/in. ² .	0.01% Proof Stress, Tons/in. ² .	Young's Modulus, Lb./in. ² × 10 ⁶ .	Maximum Stress Applied, Tons/in. ² .	Strain × 10 ⁴ at Maximum Stress.	Permanent Strain, × 10 ⁴ .
...	5		2.42	5.8	15.7	...	...	...
2	5	1 hr. at 100° C.	2.62	6.1	16.2	6.84	10.76	1.44
3	5	1 hr. at 200° C.	2.44	5.7	16.2	6.49	10.12	1.16
4	5	1 hr. at 300° C.	1.80	5.2	16.5	6.04	9.94	1.76
5	5	1 hr. at 400° C.	1.80	5.1	17.3	6.42	12.42	3.58
6	5	1 hr. at 500° C.	1.00	4.7	17.8	5.62	10.00	2.22
24	5	1 hr. at 500° C.	0.73	4.2	18.2	5.36	12.32	4.42
9	15		2.00	8.4	17.7	10.20	14.42	0.78
12	15	1 hr. at 200° C.	1.88	8.5	17.7	9.36	13.04	0.64
18	15	1 hr. at 300° C.	1.55	7.2	17.9	8.82	12.32	0.56
19	15	1 hr. at 400° C.	0.88	6.2	18.5	8.76	12.46	0.70
13	15	1 hr. at 500° C.	nil	1.975	5.88	3.60

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TABLE XII.—Oxygen-Free Copper. Effect of Very Small Amounts of Overstrain (Extensometer Tests).

Specimen No.	Overstrain, Per Cent.	Treatment after Overstrain.	Limit of Proportionality, Tons/in. ² .	Young's Modulus, Lb./in. ² ÷ 10 ⁴ .	Permanent Set, Per Cent.
20	nil	nil	0.37	18.4	0.033
	0.033	nil	1.24	17.7	0.0358
	0.0358	1 hr. at 500° C.	0.62	18.3	0.0412
	0.0358 + 0.0412	nil	1.03	17.3	0.0452
	0.0358 + 0.0452	1 hr. at 600° C.	0.54	18.1	0.0420
	0.0358 + 0.0452 + 0.0420	nil	0.86	17.6	0.0468

TABLE XIII.—Oxygen-Free Copper. Effect of Overstrain and Heat-Treatment (Tests to Fracture).

(Rate of Pulling in all Tests 0.05 in./in./minute.)

Specimen No.	Condition.	Ultimate Tensile Strength, Tons/in. ² .	Elongation, on 2 in., Per Cent.	Reduction in Area, Per Cent.
---	As received	18.5	29	85.5
14	1 hr. at 200° C. F.C.	18.2	28.5	86
7	1 hr. at 500° C. F.C.	13.65	58	86
15	1 hr. at 500° C. F.C.	13.73	62	90
10	½ hr. at 650° C. F.C.	13.68	62	88.5
16	½ hr. at 650° C. F.C.	13.76	63	90
1	1 hr. at 500° C. F.C. + 5 per cent. overstrain	14.15	58	87
17	1 hr. at 500° C. F.C. + 5 per cent. overstrain	13.82	58.5	88
2	1 hr. at 500° C. F.C. + 5 per cent. overstrain + 1 hr. at 100° C.	14.47	58.5	88
3	1 hr. at 500° C. F.C. + 5 per cent. overstrain + 1 hr. at 200° C.	14.55	60	86.5
4	1 hr. at 500° C. F.C. + 5 per cent. overstrain + 1 hr. at 300° C.	14.40	59	85.5
5	1 hr. at 500° C. F.C. + 5 per cent. overstrain + 1 hr. at 400° C.	14.25	60.5	87.5
6	1 hr. at 500° C. F.C. + 5 per cent. overstrain + 1 hr. at 500° C.	14.48	63	87
22	1 hr. at 500° C. F.C. + 5 per cent. overstrain + 1 hr. at 500° C.	14.3	61	89
8	1 hr. at 500° C. F.C. + 10 per cent. overstrain	14.75	54	86
9	1 hr. at 500° C. F.C. + 15 per cent. overstrain	15.43	46	85.5
12	1 hr. at 500° C. F.C. + 15 per cent. overstrain + 1 hr. at 200° C.	15.72	49	88
18	1 hr. at 500° C. F.C. + 15 per cent. overstrain + 1 hr. at 300° C.	15.18	*	87.5
19	1 hr. at 500° C. F.C. + 15 per cent. overstrain + 1 hr. at 400° C.	14.80	48.5	88
13	1 hr. at 500° C. F.C. + 15 per cent. overstrain + 1 hr. at 500° C.	13.70	66.5	91

* Broke at gauge-mark.

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TABLE XIV.—Oxygen-Containing Copper of Very High Purity.
Effect of Annealing (Extensometer Tests).

Specimen No.	Condition.	Limit of Pro- portionality, Tons/in. ² .	0.01% Proof Stress, Tons/in. ² .	Young's Modulus, Lb./in. ² ÷ 10 ⁶ .	Maximum Stress Applied, Tons/in. ² .	Strain × 10 ⁴ at Maximum Stress.	Permanent Strain, × 10 ⁴ .
1	As received	1.97	9.2	19.9	12.5	15.84	0.96
10	" " + 1 hr. at 200° C.	1.27	6.9	20.4	9.07	10.92	0.41
2	" " + 1 hr. at 500° C. F.C.	nil	...	...	2.68	8.48	5.08
8	" " " " " "	nil	...	...	1.21	4.00	2.70
3	" " + 1 hr. at 600° C. F.C.	nil	...	...	2.98	5.17	1.50

TABLE XV.—Oxygen-Containing Copper. Effect of Overstrain on
Annealed Material (Extensometer Tests).

Specimen No.	Annealing Treatment.	Amount of Overstrain, Per Cent.	Limit of Pro- portionality, Tons/in. ² .	0.01% Proof Stress, Tons/in. ² .	Young's Modulus, Lb./in. ² ÷ 10 ⁶ .	Maximum Stress Applied, Tons/in. ² .	Strain × 10 ⁴ at Maximum Stress.	Permanent Strain, × 10 ⁴ .
7	1 hr. at 600° C. F.C.	5	1.0	...	16.6	2.46	3.30	0.18
9	" " " " " "	5	1.04	4.65	17.0	6.35	10.52	1.60
11	1 hr. at 500° C. " "	5	1.27	6.3	16.7	7.25	12.04	1.84
13	1 hr. at 500° C. " "	15	1.40	6.6	18.1	8.97	12.92	0.91

TABLE XVI.—Oxygen-Containing Copper. Effect of Heat-Treatment
after 5 per Cent. Overstrain (Extensometer Tests).

Specimen No.	Annealing Treatment.	Heat-Treatment.	Limit of Pro- portionality, Tons/in. ² .	0.01% Proof Stress, Tons/in. ² .	Young's Modulus, Lb./in. ² ÷ 10 ⁶ .	Maximum Stress Applied, Tons/in. ² .	Strain × 10 ⁴ at Maximum Stress.	Permanent Strain, × 10 ⁴ .
9	1 hr. at 600° C. F.C.		1.04	4.65	17.0	6.35	10.52	1.60
4	" " " " " "	1 hr. at 200° C.	1.25	4.46	17.6	6.0	9.46	1.20
5	" " " " " "	1 hr. at 300° C.	0.90	4.25	18.6	6.28	10.52	1.90
6	" " " " " "	1 hr. at 400° C.	0.36	1.61	18.4	2.15	4.96	2.30
7	" " " " " "	1 hr. at 500° C.	nil	...	...	2.46	3.30	0.18
12	" " " " " "	1 hr. at 300° C.	0.91	4.50	17.8	6.38	10.70	1.92

Stress-Strain Characteristics

TABLE XVII.—*Oxygen-Containing Copper. (Tests to Fracture.)*

(Rate of Pulling in all Tests 0.05 in./in./minute.)

Specimen No.	Condition.	Ultimate Tensile Strength, Ton/in. ² .	Elongation, on 2 in., Per Cent.	Reduction in Area, Per Cent.
1	As received (hard)	23.8	*	58.5
10	" " " + 1 hr. at 200° C.	23.6	9†	64.7
2	" " " + 1 hr. at 500° C. F.C.	15.0	50.5	83.6
8	" " " " " " " " "	15.0	43†	80.5
3	" " " " " " 600° C.	15.05	42.5	83.3
9	As received + 1 hr. at 600° C. F.C. + 5 per cent. overstrain	15.55	38†	77
4	As received + 1 hr. at 600° C. F.C. + 5 per cent. overstrain + 1 hr. at 200° C.	15.6	40.5	82.7
5	As received + 1 hr. at 600° C. F.C. + 5 per cent. overstrain + 1 hr. at 300° C.	15.5	41.0	79.8
6	As received + 1 hr. at 600° C. F.C. + 5 per cent. overstrain + 1 hr. at 400° C.	15.4	36.0	79.8
7	As received + 1 hr. at 600° C. F.C. + 5 per cent. overstrain + 1 hr. at 500° C.	13.8	43.5	79.2
11	As received + 1 hr. at 500° C. F.C. + 5 per cent. overstrain	15.75	*	77
12	As received + 1 hr. at 500° C. F.C. + 5 per cent. overstrain + 1 hr. at 300° C.	15.8	*	80
13	As received + 1 hr. at 500° C. F.C. + 15 per cent. overstrain	17.25	22	74.5

* Fractured at gauge-mark. † Fractured close to gauge-mark.
F.C.—Furnace cooled.

THE ESTIMATION OF GRAIN-SIZE IN THE REGION ABOVE 10^{-3} CM.*

By R. A. STEPHEN,† M.Sc., MEMBER, and R. J. BARNES,† Ph.D.

SYNOPSIS.

X-ray methods proposed for determining grain-sizes above 10^{-3} cm. are critically examined. It is shown that to be generally applied in practice any such method must use the same specimens as are used by the metallurgist for microscopic examination. This necessitates the use of back reflection photographs, except in the case of thin sheets.

A new method for determining a value for average grain-size solely from X-ray results is described.

An empirical method too is considered for determining average sizes from a graph. The graph is derived from plotting spots on a given (*hkl*) reflection against the grain-size of standard specimens.

INTRODUCTORY.

As the ordinary method of grain counting is tedious and cannot as a rule be applied non-destructively, the authors undertook an investigation into an alternative method of grain-size determination, particularly as the control of grain-size is becoming of more importance in metallurgical practice. Perusal of the literature showed that various claims in connection with X-ray diffraction methods have been put forward from time to time. These methods have not been applied in industry to any extent, and it was decided, therefore, to examine critically their practical or theoretical disadvantages; these are not always apparent from the opinions expressed in the papers themselves.

Czochalski took Laue photographs through thin specimens, and a qualitative idea of the grain-size was obtained by comparison with pictures of standard specimens. The Laue method cannot be applied generally, except in the case of thin sheet work. It is, too, a qualitative test, and investigation on the counting of spots shows that the method is very difficult to apply quantitatively. The Laue method cannot be regarded, therefore, as practicable for general use.

The diffraction lines in a powder photograph with a grain-size above 10^{-3} cm. become spotted, *i.e.* individual reflections can be sorted

* Manuscript received August 10, 1936.

† X-ray Service Laboratory, Philips Lamps, Limited, London.

Note to Abstractors and Other Readers.—This paper will be published, in permanent form, in the *Journal of the Institute of Metals*, Vol. LX, 1937. Reference should accordingly be as follows: *J. Inst. Metals*, 1937, 60 (Advance copy).

out. Glocker¹ published details in which the sizes of the spots were shown to be proportional to the grain-size, and this was elaborated by Clark and Zimmer.² This involves measuring the size of diffraction spots—a difficult task; in fact, it is more tedious than ordinary grain counting with the microscope. It also seems open to objection on the grounds that grains of equal size are not necessarily equally imperfect. This method, too, cannot be considered to be of great utility, except for noting variations of grain-size in the area examined.

Recently Shdanow³ has published a paper describing another method, which at first sight appears to be more promising. This is based on rather a different view-point; if a large number of crystals are arranged at random and are irradiated by monochromatic X-rays, a certain proportion will be in a position to reflect in accordance with the Bragg law. From the number of reflections, knowing the dimensions of the camera and pinhole system, it is possible to calculate the number of grains irradiated. Since the volume irradiated is known, the grain-size can be deduced. The authors again used thin slips, *i.e.* transmission pictures; it appears that this was done to arrive at an accurate knowledge of the volume irradiated. This method, although theoretically sound, must be rejected in practice on the grounds that transmission pictures necessitate thin slips, and as monochromatic radiation must be used, the exposures are long. The present authors have endeavoured to extend this treatment to reflection pictures.

Short references have been published by the National Physical Laboratory on X-ray methods of determining grain-size, which appear to rest on a similar argument, but in which reflection pictures are obtained. This, of course, is much better, for in practice much shorter exposures result, and the method is non-destructive. A paper dealing with this subject has not apparently been published.

The present authors have been studying this question for some time, and during this period these latter references have appeared. The reflection technique was considered. During the theoretical treatment many difficulties arose in arriving at a rigid formula to be applied quantitatively. To obtain a relation for relative grain-sizes at first appeared easy, but a closer examination showed that it is very difficult to derive a satisfactory relation between grain-size and the number of spots to be used as a basis for relative grain-size determination. A fairly simple method for determining the absolute grain-size of a specimen was evolved.

In Part I of this paper this new method for determining an absolute value for the mean grain-size by X-rays is described. The X-ray data for grain-sizes of samples of aluminium are compared with the microscopic measurements of grain-sizes of the same specimens.

Grain-Size in the Region above 10^{-3} cm.

In Part II the determination of relative grain-sizes is considered, and the difficulties in arriving at a rigid expression are discussed. The numbers of spots which can be counted on reflection photographs are plotted against the actual grain-sizes of samples, and a smooth curve obtained. Such a method once standardized can be applied in practice in a simple way, and seems to be less laborious than ordinary grain counting by the microscope. The same photographs, too, yield information on recrystallization, release from internal strain or directionality—information which cannot be obtained by ordinary metallurgical examination.

PART I.

Theoretical.

In this the derivation of the formula relating grain-size to the number of spots in a definite (hkl) line for a definite grain-size is given for a back reflection picture.

If a specimen consisting of a large number of small crystals orientated at random be irradiated by a fine pencil of monochromatic X-rays, then, in general, some of the crystals will be so oriented that they give a certain (hkl) reflection in accordance with the Bragg law. If the geometrical conditions are chosen correctly, there will, in general, be one spot on the photographic film corresponding to one grain,* and so the number of spots will determine the number of crystals in a position to give this particular (hkl) reflection. For certain experimental conditions one can calculate the probability that a single crystal will be in a position to give this (hkl) reflection. Combining this probability factor with the number of spots observed on the film for this reflection, it is possible to deduce the total number of grains irradiated. If, therefore, for the same set of experimental conditions the volume of the specimen irradiated is known, the grain-size can be determined.

The calculation of the factor F , expressing the probability of reflection, is for the usual way of taking powder photographs impossible. Shdanow³ determined this graphically, and took into account the size of the focus of the X-ray tube used and the usual haphazard geometry of the normal pinhole system. This author discussed the general case and mentioned the simplification which results from a long or narrow diaphragm, a method which the present authors use. The use of a long pinhole system whose dimensions and position with respect to the focus of the X-ray tube are such that it is completely filled with X-radiation, simplifies the mathematics and renders easy the calculation of F . Shdanow still utilized the transmission through a

* It is possible to get two spots from one grain if the divergency of the primary beam be large enough.

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thin specimen, a method which has been discarded by the present authors for the reasons previously given, *i.e.* long exposures and rarely applicable in practice.

In Fig. 1 *SS* is a pinhole system of diameter a placed in such a position with respect to the focus of the X-ray tube that it is completely filled with radiation. *CC* is the specimen with its plane face perpendicular to the incident rays at a distance D from the front of the diaphragm.

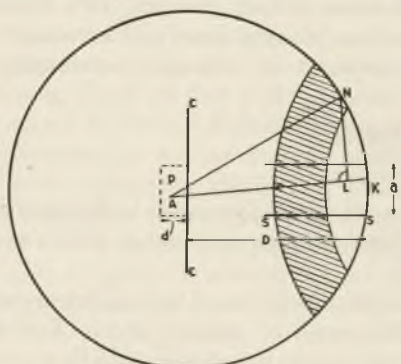


FIG. 1.

small compared with D the cone can be regarded as right-angled and constant whenever A may be in P . With A as centre, construct a reference sphere of radius D . Let AK be any one of the cone of rays incident at A , let AN be the normal to a set of planes in a crystal at A , and let NL be the normal from N to the ray AK . If angle $KAN = (90^\circ - \theta)$, where θ is the glancing angle of reflection, then a reflection will result, hence if N fall on a circle with $NL = D \sin(90^\circ - \theta)$ as radius, a reflection of the ray AK will occur. Similarly, for any other ray of the cone to be reflected N must lie on the appropriate circle. The envelope of these circles is a belt of area $2\pi D \sin(90^\circ - \theta)a$ around the sphere, so that the probability that this set of planes will reflect one of the rays of the cone is

$$F = \frac{\text{area of belt}}{\text{area of surface of sphere}} = \frac{2\pi D \sin(90^\circ - \theta)a}{4\pi D^2} = \frac{a \cos \theta}{2D}.$$

i.e.

* The actual estimation of d is not easy; it may be regarded, however, as that depth beyond which any grain gives a reflection so weak that it cannot be seen on the film by visual observation. This distance d depends on the grain-size, *i.e.* it is possible for a large grain at average depth d below the surface to give a just visible spot, whereas a small grain at average depth d would give a spot which would not be visible owing to its lesser intensity. For one particular grain-size and for a definite time of exposure, d can be regarded as a constant.

Grain-Size in the Region above 10^{-3} cm.

If there are N grains in P , then the probable number of reflections from a given plane from the grains in P is

$$\frac{N \cos \theta a}{2D}$$

Let Y be the number of spots for a given (hkl) reflection coming from the grains in zone P .

Then
$$Y = \frac{Nj \cos \theta a}{2D}$$

where j is the number of planes in the particular form.

i.e.
$$N = \frac{2DY}{ja \cos \theta}$$

If V is the volume of zone P the volume of 1 grain = $\frac{V}{N}$ and the mean length of the grain edge, G , is given by

$$G = 3 \sqrt{\frac{Vja \cos \theta}{2DY}} \dots \dots \dots (1)$$

In the foregoing we have dealt with the central zone P alone, which is easily amenable to mathematical analysis.

With the experimental conditions as depicted in Fig. 1 a limited part, Q , of the specimen lying outside P is irradiated by the more oblique rays passing through the diaphragm, and so Q will also produce spots corresponding to this (hkl) reflection. A little consideration will show that the pencil of rays incident at any point in Q not only varies the further remote the point is from P , but also is of such shape that the factor F expressing the probability of reflection cannot be rigidly calculated. Shdanow used a graphical method to determine F for this zone.

If now the diaphragm is long enough to come practically to the front surface of the specimen, the outer zone Q becomes very small and can be neglected. This is only the case either for a long diaphragm or if a circular "stop" of diameter a is placed concentric with the axis of the diaphragm so that only reflections from P are allowed to register on the film. In the experimental portion to follow the long diaphragm has been mainly used.

Considering expression (1), we find that it is required to know V . Now V is equal to $\frac{\pi a^2}{4} \times d$ (the effective depth). Unfortunately d is not constant, but varies with the grain-size. This introduces the difficulty in deriving a rigid mathematical formula applicable to reflection pictures for different grain-sizes.

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For one particular grain-size, however, and a constant exposure time and irradiation conditions, d is a constant. V can therefore be determined if d can be determined. The determination of d is approached by considering the relative intensities of the rays reflected by a small grain at a distance d below the surface of the specimen and of a similar grain on the specimen surface.

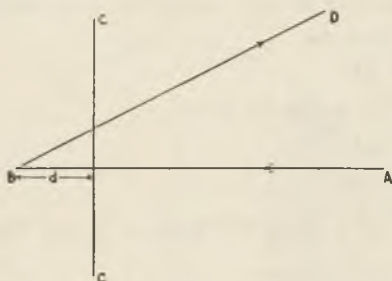


FIG. 2.

Referring to Fig. 2, AB is a ray incident on the specimen CC . Let B be a point distance d below the specimen surface, and let the reflected ray lie along BD .

If I_0 is the intensity of the incident ray, the intensity I_B at B will be given by

$$I_B = I_0 e^{-\mu d}$$

where μ is the linear absorption coefficient of the X-rays in the specimen.

Suppose a fraction, K (depending on the structure factor, &c.), is reflected by a grain at B , then the intensity at B of the reflected ray is

$$KI_0 e^{-\mu d}$$

This ray has to traverse a further distance BD , and since $BD = d/\cos(180 - 2\theta)$ the intensity on emerging from the specimen surface is

$$KI_0 e^{-\mu d} \left(1 + \frac{1}{\cos(180 - 2\theta)} \right)$$

The intensity of a ray reflected by a similar grain at the surface is KI_0 ,* and the intensities of other reflected beams lie between these two values.

Let the intensity ratio of the strongest and weakest reflected rays be r , then

$$r = e^{\mu d(1 - \sec 2\theta)}$$

i.e.
$$d = \frac{\log_e r}{\mu(1 - \sec 2\theta)}$$

Thus the volume of part P taken as a cylinder of height d radius $\frac{1}{2}a$ is given by

$$\frac{\pi a^2 \log_e r}{4\mu(1 - \sec 2\theta)}$$

and the mean length of the grain edge G is given by

$$G = 3\sqrt{\frac{\pi a^3 j \cos \theta \log_e r}{8DY \mu(1 - \sec 2\theta)}} \quad \dots \quad (2)$$

* We are here neglecting the absorption in the reflecting grain itself.

Grain-Size in the Region above 10^{-3} cm.

Considering this expression, all terms are known except r , the ratio of the intensities of the strongest and weakest spots. There must be a certain minimum blackening for one to see a spot on the film, and the blackening of the strongest spot will depend both on the exposure time and on the grain-size. It is not possible to obtain a measure of the blackening ratio by photometric means, and in any case this procedure can be ruled out from a practical point of view. If it were possible to know the exposure in advance, *i.e.* expose so that the strongest spot has a blackening about equal to unity, then an estimate of r , the intensity range, could be given. This possibility was borne in mind, but a much simpler way of surmounting the difficulty was devised.

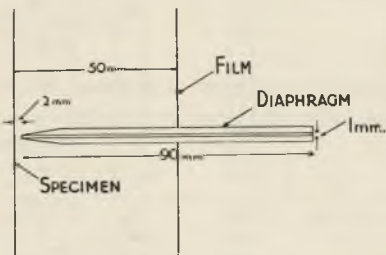


FIG. 3.

A photograph of the specimen was obtained by making the exposure time, t_1 , short so that the strongest reflections produces spots

of medium blackening B (less than unity). The photograph was repeated using the same part of the specimen with a longer exposure time, t_2 . The two photographs are compared side by side, and all spots in the second photograph, which have a blackening equal to or greater than B , must be produced by reflected beams with an intensity range r , where

$$r = \frac{t_2}{t_1} *$$

If Y_1 is the number of these spots in the second photograph, this is the value of Y , corresponding to r given by the ratio of the times of exposure, to insert in expression (2) for the determination of the absolute grain-size.

The taking of two photographs obviates the need for photometry and permits the evaluation of the actual grain-size using X-ray data alone.

Practical.

The grain-sizes of six specimens of aluminium have been determined by this double picture method. The essential arrangement and dimensions of the apparatus used are shown diagrammatically in Fig. 3. By tapering the end of the diaphragm as shown it can be brought very near the specimen surface without interfering with the required reflected beams. The (331) reflection, conveniently given by CoK_α radiation was observed. The two photographs were compared side

* This follows from the Schwarzschild law $S = F (it^p)$, where S is the blackening, i the intensity, and t the exposure time. p may be taken as unity for X-rays.

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by side on a viewing lantern, and the mean value of two or three of the blackest spots in the first photograph was taken as the value of B .

TABLE I.

Specimen No.	Photo No.	Exposure, Minutes.	$p = \frac{t_2}{t_1}$	r .	Grain-Size Calculated, Mm. $\times 10^{-3}$.	Grain-Size by Metallurgical Count, Mm. $\times 10^{-3}$.
P. 445	174	1 } 2½ }	2½	15	3.3 mean 3.1	2.8
	171	1 } 5 }					5	33	3.08
	174	1 } 20 }	20	72	2.9	
	172	1 } 2½ }					8	47	2.96
	174	20 } 5 }	4	24	3.24	
	173	20 } 5 }					4	24	3.24
	171	20 } 5 }	4	24	3.24	
	173	20 } 5 }					4	24	3.24
	172	20 } 5 }	4	24	3.24	
173	20 } 5 }	4				24
P. 732	168		2½ } 10 }	4	31			2.98 mean 2.95	3.35
	166	2½ } 20 }	8			50	2.92
	168	2½ } 5 }		4	32			2.95
	167	20 } 5 }	4			32	2.95
	169	5 } 20 }		4	32			2.95
	167	20 } 20 }	4			32	2.95
P. 431	162	1 } 10 }		10	20			4.08 mean 4.1	4.2
	163	1 } 30 }	30			30	4.07
	162	1 } 30 }		30	30			4.07
	164	30 } 30 }	30			30	4.07
P. 439	156	1 } 12 }		12	9			5.48 mean 5.2	6.35
	161	1 } 20 }	20			15	5.00
	260	1 } 40 }		40	20			4.8
	261	20 } 40 }	40			20	4.8
	260	1 } 40 }		40	20			4.8
	262	40 } 40 }	40			20	4.8
P. 427	216	10 } 2½ }		4	50	
	218	10 } 45 }	4.5			60
	215	45 } 10 }		9	102	
	216	45 } 5 }	9			102
	215	45 } 5 }		9	102	
	217	5 } 5 }	9			102
P. 554	221	10 } 2½ }		4	77	
	223	10 } 40 }	4			86
	220	10 } 40 }		8	130	
	221	10 } 5 }	8			130
	220	40 } 5 }		8	130	
	222	40 } 5 }	8			130
	222	5 } 5 }		8	130	

In the larger grain-sized samples in particular the α_1 and α_2 reflections cannot be differentiated, so that the total number was counted and halved to get the correct value for Y . Details of the results are given in Table I.

Grain-Size in the Region above 10^{-3} cm.

Possible Modifications of Method for Large Grain-Sizes or Highly Absorbing Substances.

Owing to the soft radiations used, *viz.* CuK_α or CoK_α , which are highly absorbed in metals, it was thought at first that the analysis could be treated as if only grains in the surface gave spots which could be counted.

Consider the expression which was obtained in section (1) for G the grain-size

$$G = 3\sqrt{\frac{\pi a^2 \cdot d j \alpha \cos \theta}{8DY}}$$

If d is smaller than G , one would be justified in treating the whole calculation as if only the grains in the surface give countable reflection spots, and then we should have, simply,

$$G = 2\sqrt{\frac{\pi a^3 \cdot j \cos \theta}{8DY}}$$

now

$$d = \sqrt{\frac{\log r}{\mu (1 - \sec 2\theta)}}$$

in which r is the relative intensity of the weakest and strongest observable spots. Judging from experimental results, r is of the order of 1 to 50, and is bound normally to exceed the ratio of 1 to 10.

Using these values of r , the values of d corresponding to the K_α radiations of Cu and Co for specimens of aluminium, copper, and iron have been calculated. These are given in Table II.

TABLE II.

Specimen.	$d \times 10^{-3}$ cm.	r .
<i>Radiation CuK_α.</i>		
Al	14.7	1-50
	8.6	1-10
Cu	3.97	1-50
	2.3	1-10
Fe	0.74	1-50
	0.4	1-10
<i>Radiation CoK_α.</i>		
Al	8.4	1-50
	5.0	1-10
Cu	2.7	1-50
	1.6	1-10
Fe	4.5	1-50
	2.6	1-10

Copper radiation is never used for examination of iron owing to the enhanced incoherent scatter, but cobalt is specially convenient.

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Both in the case of aluminium and iron, d for the usual 1-50 intensity ratio is of the order of 5×10^{-3} cm., which is very near the maximum grain-size which it is normally wished to count—it is clear, therefore, that in general for aluminium and iron, grains below the surface layer will give rise to countable spots, and therefore the volume formula must be applied.

PART II.

Determination of Grain-Size from an Empirical Chart.

It is necessary to take two photographs of the same region to determine the absolute value for the mean grain-size. The authors have endeavoured to find whether it was possible to develop a suitable method by which the grain-size can be determined from one picture alone; this would be a considerable advantage in practice. The total amount of X-radiation reflected by small grains is proportional to the volume of the grain. The length of a spot has been shown to be proportional to the grain-size, and the width of a reflected spot is a linear function of the grain-size and the divergency of the beam; it can be seen, therefore, that the intensity of a spot or the blackening of a spot varies approximately with the grain-size. The authors have tried using this as a method of grain-size determination, but there are many difficulties in the practical estimation of the intensities of the spots.

It is fairly easy, however, to derive an empirical relationship between the numbers of spots on photographs taken under standard conditions and the grain-sizes for a given series of specimens. By expressing this relationship in the form of a graph, the grain-size of an unknown specimen can then be read off, after observing the number of spots on a photograph taken under these standard conditions. For constant experimental conditions it is sufficient to realise that Y is some function of G the grain-size.

The graphs relating the total number of observable spots to the grain-size for the same series of aluminium specimens as used before is given in Fig. 4. The (331) reflection given by CoK_α radiation was observed. The source of X-rays was a "Metalix" apparatus for crystal analysis which gives a fairly constant output with a constant size of focal spot.

Curve (1) shows the number of spots plotted against the grain-size determined with the microscope, while in curve (2) they are plotted against the grain-size determined by X-rays. For grain-sizes larger than 5×10^{-3} cm. the method is not very sensitive, but in the useful region down to 10^{-3} cm. results to within 10 per cent. can be obtained.

Grain-Size in the Region above 10^3 cm.

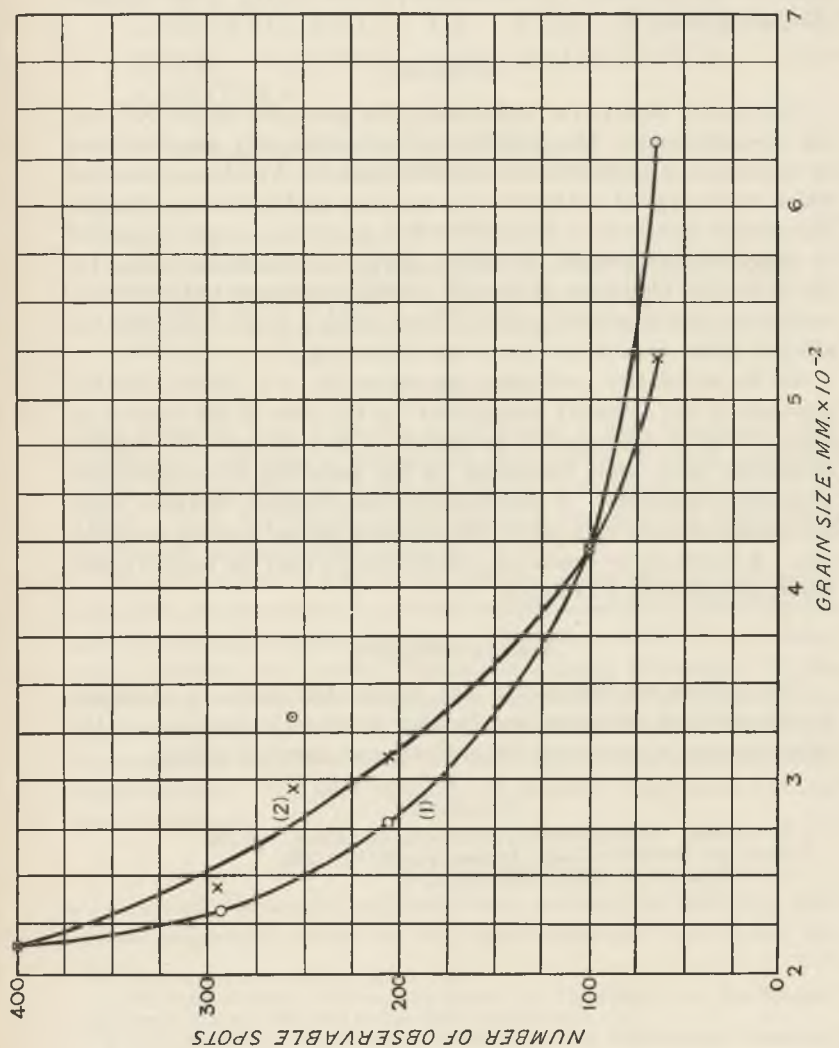


FIG. 4.

Estimation of Grain-Size

With regard to specimen P. 445, there appears to be some discrepancy between the results for grain-size determined by the two methods—judging from the curves it appears that the X-ray result is the more correct.

SUMMARY.

The use of X-rays for determining the grain-size above 10^{-3} cm. has been discussed. The reflection method is the only one which can be considered as practicable for ordinary work, for it is the only method which can be applied on the ordinary specimen used by the metallurgist. The method described by Shdanow on thin specimens cannot be applied to reflection photographs. It forms, however, a satisfactory basis for the theoretical treatment of another method developed by the present authors—a double-picture method from which a mean value for the absolute grain-sizes of specimens can be derived.

So far as relative grain-sizes are concerned, it is shown that the grain-size is not inversely proportional to the cube of the number of spots owing to the relative intensities of the strongest to weakest observable spots being dependent on the grain-size for constant experimental conditions. A smooth curve was obtained, however, when the number of spots on a given (hkl) line were plotted against the grain-size. A chart can be constructed which can be used for routine grain-size examination in this region.

ACKNOWLEDGMENT.

The authors are indebted to The British Aluminium Co., Limited, for the supply of specimens, and for their kindness in carrying out the determination of grain-sizes by ordinary metallurgical means.

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ALLOYS OF MAGNESIUM. PART V.—THE CONSTITUTION OF THE MAGNESIUM-RICH ALLOYS OF MAGNESIUM AND CERIUM.*

By J. L. HAUGHTON,† D.Sc., MEMBER OF COUNCIL, and
T. H. SCHOFIELD,‡ M.Sc., MEMBER.

SYNOPSIS.

The constitution of the magnesium-rich alloys of magnesium and cerium has been re-determined. The eutectic point is found to be at 21 per cent. cerium and 590° C. Magnesium dissolves about 1.6 per cent. cerium at the eutectic temperature and probably less than 0.15 per cent. at 337° C.

I. INTRODUCTION.

THIS report is Part V of the investigation of the constitution and mechanical properties of magnesium alloys which is being conducted at the National Physical Laboratory under the direction of Dr. C. H. Desch, F.R.S., for the Metallurgy Research Board of the Department of Scientific and Industrial Research.^{1, 2, 3, 4}

Recent research on magnesium alloys has shown that the mechanical properties of some alloys at elevated temperatures are improved by the addition of small amounts of cerium. The present work has been carried out to confirm and possibly supplement existing information on the constitution of the cerium-magnesium alloys and has been extended to alloys containing up to about 40 per cent. cerium in order to establish the composition of the eutectic and to confirm the existence of a peritectic reaction. The solid solubility of cerium in magnesium has also been determined.

II. PREVIOUS WORK.

Although Muthmann and Beck⁵ were probably the first to prepare cerium-magnesium alloys, the only systematic study carried out was

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Note to Abstractors and Other Readers.—This paper will be published, in permanent form, in the *Journal of the Institute of Metals*, Vol. LX, 1937. Reference should accordingly be as follows: *J. Inst. Metals*, 1937, 60 (Advance copy).

Haughton and Schofield: Alloys of Magnesium

that by Vogel,⁶ who investigated the constitution in some detail. Using fairly pure magnesium and cerium containing 6.5 per cent. of impurities, he found the eutectic point to be about 27 per cent. cerium and 585° C. No evidence of solid solubility was given.

III. PRESENT WORK.

Preparation of the Alloys.

The magnesium was supplied by British Maxium, Ltd., and contained as impurities: aluminium 0.018; iron 0.020; silicon 0.013 per cent.

The cerium, kindly given by La Société de Produits Chimiques des Terres Rares, contained 97.7 per cent. cerium and 1.25 per cent. iron.

The alloys were prepared by adding cerium in small quantities to molten magnesium under a flux in a stainless steel crucible. They were cast into smaller stainless iron crucibles of the type previously described;¹ the excess was cast into iron moulds, and a vertical slice cut from the ingots was used for chemical analysis; in some cases the remainder was used for the preparation of other alloys and for microscopical examination. The flux had the same composition as that employed previously, and a minimum quantity was used for each melt.

Thermal Analysis.

Heating and cooling curves of nine alloys were recorded. Because of the large difference in specific gravity between cerium and magnesium, it was deemed advisable to carry out the thermal analysis in the stirring apparatus designed by Payne.⁷

Most of the thermal curves were recorded on an inverse-rate recorder by means of manual signals depending on observations of a deflection potentiometer, but some were recorded automatically on the recorder by means of an automatic potentiometer⁸ actuated by a photoelectric cell.

Two heating and two cooling curves of each alloy were recorded, and as the temperature arrest of the liquidus taken from the first and second pair of curves agreed closely it was assumed that no appreciable change in composition had taken place during the taking of the curves. After the curves had been taken, the metal was remelted in the crucible and cast into an iron chill. In certain cases the ingots thus obtained were analyzed, and the cerium content was always less than that of the alloy before taking thermal curves. This discrepancy was probably due to losses caused by adding new flux when remelting the alloy from the thermal curve crucible. That considerable loss could be caused in this way was shown by the analysis of the flux from one of the rich cerium

Part V.—Magnesium-Rich Alloys

alloys which gave 18.5 per cent. cerium. Cooling curves of two alloys were taken down to 360° C., but no arrest points were observed below the eutectic temperature.

The results of the present work and of Vogel's work are embodied in Figs. 1 and 2, respectively.

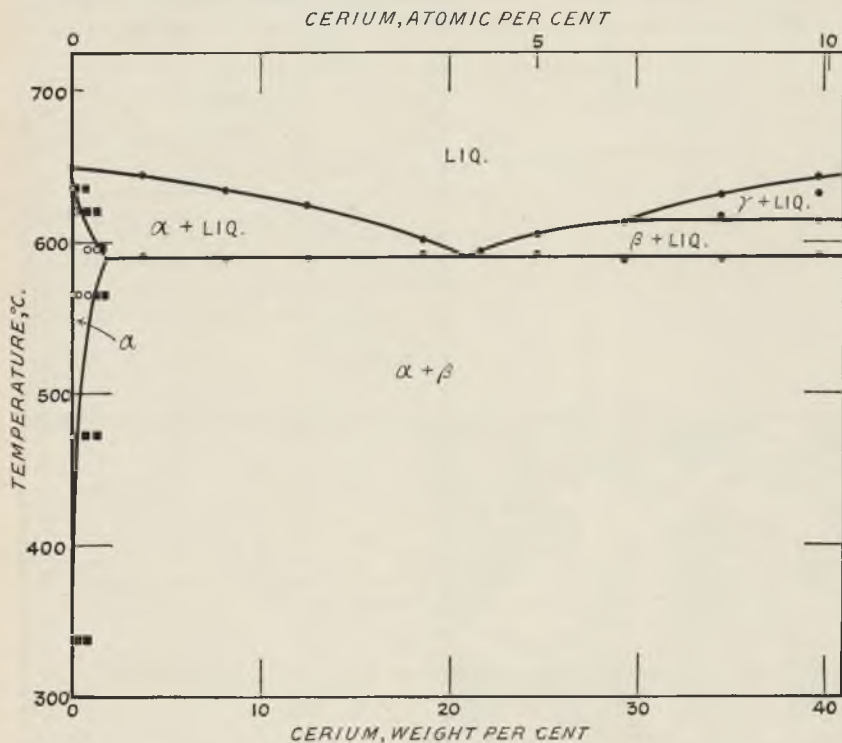


FIG. 1.

FIG. 1.—Equilibrium Diagram of the Cerium-Magnesium Alloys Containing up to 40 Per Cent. Cerium. (Haughton and Schofield.)

Microscopical Examination.

The specimens were rubbed down by hand on emery paper and polished on velvet with metal polish. Specimens of cerium content near and beyond the eutectic were brittle and were mounted in Bakelite before polishing.

The specimens were etched either in a 4 per cent. solution of nitric acid in alcohol or in a mixture of citric acid, nitric acid, and glycerine. All specimens used for the determination of the solidus and solid solubility were annealed in hydrogen contained in sealed tubes of

Haughton and Schofield: Alloys of Magnesium

Pyrex glass. Quenching was done by pushing the tube containing the specimens directly into cold water.

The Liquidus.

The liquidus differs in temperature and form from that plotted from Vogel's data; the former falls less steeply and is below the latter.

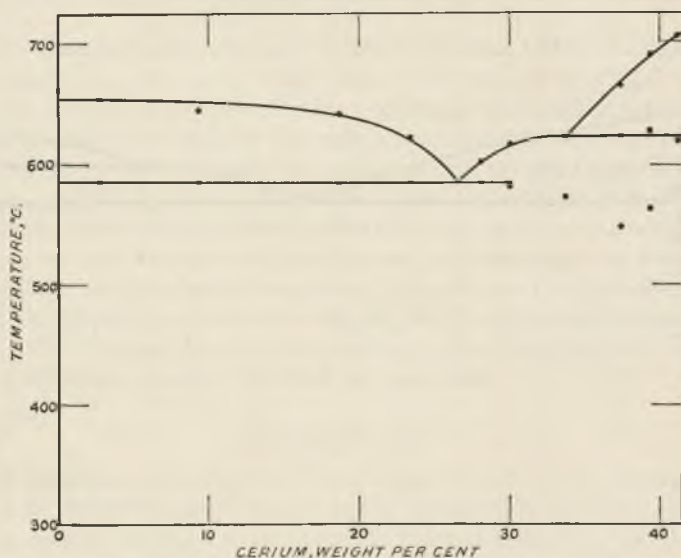


FIG. 2.

FIG. 2.—Equilibrium Diagram of the Cerium-Magnesium Alloys Containing up to 40 Per Cent. Cerium. (Vogel.)

It should be noted that the temperature of the melting point of magnesium given by Vogel is high ($661^{\circ}\text{C}.$).

The Peritectic Reaction.

The existence of a peritectic observed by Vogel has been confirmed by thermal analysis and by microscopical examination. The temperature of the peritectic reaction is about $614^{\circ}\text{C}.$

Figs. 3 and 4 (Plate I) show an alloy containing 39.7 per cent. cerium as cast and after annealing at $565^{\circ}\text{C}.$ for 6 hrs., respectively. The cooling curves of this alloy showed four definite arrests, one of which was close to the peritectic; no explanation is put forward for one arrest point which suggests increasing complexity of the system. Investigation

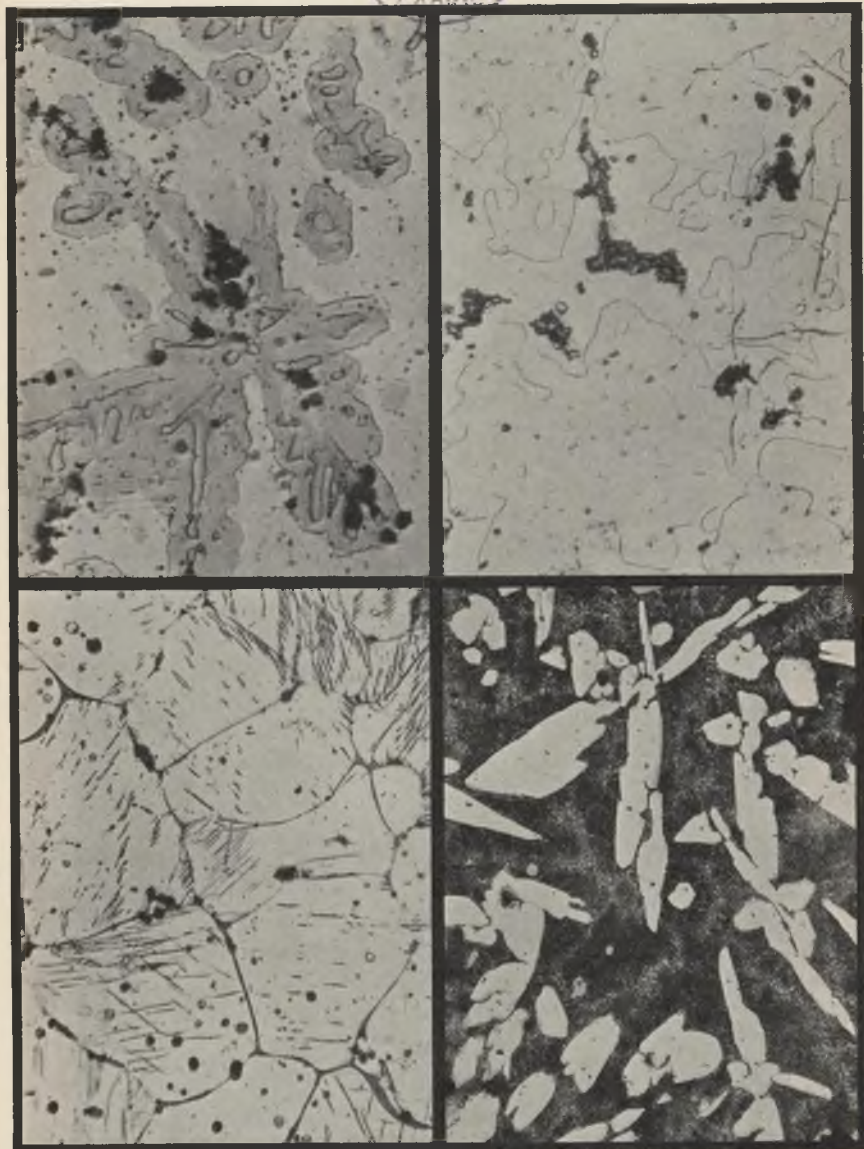


FIG. 3.—39.7% Cerium, As Cast. Etched in 4% Nitric Acid in Alcohol. $\times 500$.

FIG. 4.—39.7% Cerium, Annealed at 565°C . for 6 Hrs. and Quenched. Etched in 4% Nitric Acid in Alcohol. $\times 300$.

FIG. 5.—1.7% Cerium, Quenched from 595°C . Etched in Citric Acid, Nitric Acid, and Glycerine. $\times 150$.

FIG. 6.—24.7% Cerium, As Cast. Etched in Citric Acid, Nitric Acid, and Glycerine. $\times 150$.

7



8



FIG. 7.—18.6% Cerium, As Cast. Etched in Citric Acid, Nitric Acid, and Glycerine. $\times 150$.
FIG. 8.—21.6% Cerium, As Cast. Etched in Citric Acid, Nitric Acid, and Glycerine. $\times 150$.

Part V.—Magnesium-Rich Alloys

of the diagram beyond this point, however, lies outside the scope of the present work.

The Eutectic.

From thermal evidence, the eutectic point was found to be at 21 per cent. cerium and 590° C., compared with about 27 per cent. cerium and 585° C. from Vogel's data. Confirmation of this was obtained by microscopical evidence. Figs. 6 and 7 (Plates I and II) show the structure of alloys containing 24.7 and 18.6 per cent. cerium, respectively, and illustrate the primary separation on either side of the eutectic. Fig. 8 (Plate II) shows the structure of an alloy containing 21.6 per cent. cerium and shows that it contains a small amount of hypereutectic primary. It was possible to distinguish between the two primaries by etching in boiling water which stained the α primary brown but left the β primary unchanged. Photographs illustrating the etch are not reproduced because liquid exuding from the numerous holes in the specimen caused a tarnish film to spread over the surface and rapidly spoiled its appearance.

The Solidus.

The position of the sloping part of the solidus was determined from microscopical examination of alloys quenched after annealing at various temperatures. All alloys, both for the determination of the solidus and the solid solubility line, were first annealed at 565° C. for 6½ hrs. to render them homogeneous. Fig. 5 (Plate I) shows the structure of an alloy containing 1.7 per cent. cerium quenched from 595° C. The chilled liquid is readily visible.

The Solid Solubility Line.

The solid solubility of cerium in magnesium was determined microscopically. Specimens of suitable composition were annealed at 565°, 472°, and 337° C. for 12 hrs., 40 hrs., and 5 weeks, respectively. Although microscopical examination led to conclusive evidence of the amount of solubility at 565° C., some doubt exists as to the solubility at the lower temperature; this was due to the difficulty in identifying small amounts of a second phase in the presence of small amounts of impurity originating from the cerium.

Magnetic Properties.

It has been discovered that some of the cerium-magnesium alloys, and certainly those containing about 20-40 per cent. cerium, are magnetic in that they are feebly attracted by a strong permanent magnet. It seems improbable that the magnetism can be solely due to the iron in the cerium because the latter is not attracted by a magnet.

Alloys of Magnesium—Part V

IV. CONCLUSIONS.

The constitution of the magnesium-rich alloys of magnesium and cerium has been determined. The eutectic point is found to be at 21 per cent. cerium and 590° C., compared with about 27 per cent. and 585° C. observed by Vogel, who used much less pure metals than were employed in the present investigation. Vogel did not determine the solubility of cerium in magnesium, which is now shown to be about 1.6 per cent. at the eutectic temperature, and probably less than 0.15 per cent. at 337° C. The existence of the peritectic observed by Vogel has been confirmed, though at a slightly lower temperature (614° C.). Some of the alloys are found to be very feebly magnetic.

V. ACKNOWLEDGMENTS.

The authors wish to express their thanks to Dr. C. H. Desch, F.R.S., under whose supervision the work was carried out. They are also indebted to Messrs. P. Ward, B.Sc., and W. H. Withey, B.A., for carrying out the analyses of the alloys. They would also like to express their gratitude to the Société de Produits Chimiques des Terres Rares who have, on several occasions, supplied them, gratis, with both cerium and "mischmetall" for this work and for the work on mechanical properties referred to at the beginning of this paper.

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APPLICATIONS are invited for a WIGGIN POST-GRADUATE SCHOLARSHIP in the Department of Metallurgy. Candidates should have attained the standard of the B.Sc. degree with Honours. Applications will be entertained from graduates in Physics or Chemistry without special knowledge of Metallurgy. The value of the Scholarship is £80 per annum; it is tenable for 1 year, but may be renewed in certain circumstances for a further period. Applications, accompanied by the names of three references if possible, should be sent before November 30 to Professor D. Hanson, Dept. of Metallurgy, The University, Edgbaston, Birmingham.

APPOINTMENT VACANT.

A VACANCY occurs for a METALLURGIST to take charge of a Works Laboratory in the Midlands and be responsible for routine control and development. Experience of light alloys desirable and preferably some knowledge of foundry methods. Commencing salary £500 p.a. Apply Chief Metallurgist, British Aluminium Co., Ltd., Warrington.

METALLURGICAL ABSTRACTS

(GENERAL AND NON-FERROUS)

Volume 3

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Part 11

I.—PROPERTIES OF METALS

(Continued from pp. 385-389.)

***Researches with Pure Aluminium Wire of High Tenacity.** H. Röhrig and K. Schönherr (*Aluminium*, 1936, 18, (8), 374-375).—Specimens of aluminium wire containing iron 0.16 and silicon 0.10% and having a tensile strength of 28.8 kg./mm.² with an elongation of 0.2% were kept for various periods at 75°, 100°, and 130° C. and the tensile properties determined from time to time. At 75° C. the tensile strength decreased to 25.7 kg./mm.² in 16 days and to 25.5 kg./mm.² in 40 days, while the electrical conductivity increased by 1.4%. At 100° C. the strength decreased rapidly at first then much more slowly to 22.1 kg./mm.² after 30 days, and at 130° C. it had decreased to 20.2 kg./mm.² after less than 3 days. From these results it is concluded that the metal had been heated at too high a temperature during the early stages of rolling and then cooled quickly so that silicon was retained in supersaturated solid solution, thus giving rise to the unusually high tensile strength of the drawn wire.—A. R. P.

The Cold-Working of Metals and Its Influence on the Quality of Aluminium. — (*Z. Metallkunde*, 1936, 28, (8), 240-242).—Curves are given showing the change in tensile strength, hardness, and elongation of 99.7% aluminium with the degree of reduction by cold-rolling. The change in properties is more marked the thinner and the narrower is the starting sheet.—A. R. P.

***The Behaviour of Three Single Crystals of Aluminium in Fatigue under Complex Stresses.** H. L. Cox and W. J. Clenshaw (*Proc. Roy. Soc.*, 1935, [A], 149, (867), 312-326).—The development at the N.P.L. of a new type of combined flexural and torsional fatigue testing machine made it possible to carry out tests under alternating flexural stresses on single crystal specimens. Three single crystal specimens, all of the same orientation, were tested, one under alternating flexural, one under alternating torsional, and the other under a combination of alternating torsional and alternating flexural stresses. The distribution of slip bands on each specimen was entirely in accordance with that predicted from the calculated values of the shear stresses according to the resolved shear stress law, and the results thus afford evidence of the validity of this law in cases where the stress distribution is not simple. Measurements of the mean slip-band spacing were made and the relation between mean slip-band spacing and the value of the resolved stress was examined. The fracture of the specimens is shown to occur in the normal manner by the development of cracks formed on the site of the previous heavy slip, and the dependence of failure on the value of the resolved shear stress is demonstrated.—S. G.

***The Influence of Sodium and Calcium on Industrial Aluminium.** B. F. Grashchenko and V. Darovski (*Legkie Metalli (Light Metals)*, 1936, (1), 17-37).—[In Russian.] Alloys with up to 0.1% sodium were prepared from aluminium containing silicon 0.1-0.58 and iron 0.14-1.5%, the amount of sodium retained increasing with the percentage of impurities. Up to 0.04% sodium had scarcely any influence on the mechanical properties, but larger amounts slightly reduced the hardness without affecting the tensile strength, and produced severe intercrystalline corrosion. Under the microscope the sodium particles appeared as dark spots in the corrosion centres. The

* Denotes a paper describing the results of original research.

† Denotes a first-class critical review.

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sodium content was unaffected by annealing at 480° C., but could be reduced to 0.012% by repeated fusion. Up to 0.15% calcium only slightly affected the mechanical properties of aluminium at temperatures up to 480° C., provided that the silicon did not exceed 0.5%. With a lower silicon and higher calcium content the mechanical properties are somewhat improved, but the limiting overheating temperature is reduced, the effect being increased by iron. Calcium reduces the resistance of aluminium to corrosion. It is concluded that industrial aluminium should contain not more than 0.1% calcium, or not more than 0.08% if up to 0.04% sodium is also present.—D. N. S.

†**Properties and Alloys of Beryllium.** Louis L. Stott (*Metals Technology*, 1936, 3, (5), 17 pp.; and *A.I.M.M.E. Tech. Publ.* 738).—The physical properties of beryllium are described and tabulated. Beryllium-rich alloys have no commercial applications, but its alloys with copper, nickel, and iron, or with more complex alloys of these elements, have important applications and remarkable mechanical properties. Data for the mechanical properties (tensile strength, ductility, and hardness) are given for a number of alloys, together with the effects on the electrical conductivities of the copper-base alloys. The uses of the alloys are also briefly indicated.—W. H. R.

***Absolute Photoelectric Yield of Beryllium, Magnesium, and Sodium.** Marvin M. Mann and Lee A. DuBridge (*Phys. Rev.*, 1936, [ii], 50, (4), 398).—Abstract of a paper read before the American Physical Society.—S. G.

***The Electrical Resistance of Bismuth Single Crystals [Containing Lead, Tin, Antimony, or Tellurium].** Alfred B. Focke and John R. Hill (*Phys. Rev.*, 1936, [ii], 50, (2), 179–184).—Single-crystal rods of bismuth containing up to 0.81 atomic-% of lead, tin, antimony, or tellurium were prepared with the principal axis parallel and perpendicular to the axis of the rod, and the electrical resistances were measured at temperatures between -185° and $+100^{\circ}$ C. The addition of lead or tin to bismuth causes a marked increase in the electrical resistance; the increase is greater the larger the amounts of the impurity provided that recrystallization with the precipitation of a second constituent does not occur. The addition of tellurium usually causes a decrease in resistance until the point at which a second constituent is precipitated. The effect of antimony is complicated. These results are explained on the basis of the theory of H. Jones (*Met. Abs.*, 1935, 2, 681), and the approximate solubility limits of tin, lead, antimony, and tellurium in solid bismuth are estimated.—W. H. R.

Investigations on Bismuth Crystals. II.—Change of the Thermoelectric Power in Transverse Magnetic Fields. E. Grüneisen and J. Gielessen (*Ann. Physik*, 1936, [v], 27, (3), 243–255).—v. G.

***The Theory of the Galvomagnetic Effects in Bismuth.** H. Jones (*Proc. Roy. Soc.*, 1936, [A], 155, (886), 653–663).—Calculations are made of the change of resistance in a magnetic field and of the Hall coeffs. of bismuth single crystals. The estimate of the number of electrons overlapping the principal Brillouin zone for bismuth, previously given to account for the diamagnetic properties, is shown to lead to the very large galvomagnetic effects which are observed. Minute traces of impurity in bismuth are shown to have very great effect on the galvomagnetic properties, particularly at high magnetic field strengths. In this way the variation of the Hall coeff. with field strength is explained, and fair agreement is obtained between the calculated change of resistance at various fields and Kapitza's observations.—S. G.

Calcium. A. Schubert (*Russko-Germanskiy Vestnik Nauki i Tehniki (Deut.-russ. Z. Wiss. Tech.)*, 1936, (5), 3–7).—[In Russian.] A review.—N. A.

***The Sorption of Hydrogen and Deuterium by Copper and Palladium. I.—The Behaviour of Copper and Copper Oxides.** H. W. Melville and Eric K. Rideal (*Proc. Roy. Soc.*, 1935, [A], 153, (878), 77–88).—The following heterogeneous reactions of hydrogen and deuterium are investigated with these

results: CuO is reduced by atomic hydrogen and deuterium at 20° C. at the same velocity. This is in agreement with previous experiments showing that free atoms of hydrogen and deuterium react at identical velocities. CuO is more rapidly reduced by hydrogen than by deuterium at 156°–269° C. The difference in energy of activation is 0.4 k.cal. This is also in agreement with the observation that hydrogen reduces simple molecules on a metal (nickel) surface more quickly than deuterium. Hydrogen and deuterium are sorbed by and desorbed from copper at the same velocity at 71°–200° C., except that at higher temperatures hydrogen is sorbed slightly more quickly.—S. G.

***The Sorption of Hydrogen and Deuterium by Copper and Palladium. H.—The Sorption by Palladium and Diffusion Through Copper.** H. W. Melville and E. K. Rideal (*Proc. Roy. Soc.*, 1935, [A], 153, (878), 89–103).—Cf. preceding abstract. The diffusion of hydrogen and deuterium through palladium, copper, and nickel is investigated at 150°–350° C. and at pressures from 1 to 200 mm. For each metal hydrogen diffuses more quickly, the difference in energy of activation for diffusion being 0.8 for palladium, 0.6 for nickel, and 0.8 k.cal. for copper, respectively. The copper and nickel are supported on palladium. In copper it is shown by employing composite films Cu–Pd–Cu and Pd–Cu–Pd that the rate-determining step, and therefore the step responsible for the difference in the velocity of diffusion, is not due to any process connected with the gas–metal interface. With palladium measurements of the solubility of the two isotopes are also made, hydrogen being the most soluble. Combining these results with the diffusion measurements it is shown that the difference in velocities of diffusion is due partly to the greater solubility as well as to the greater mobility of hydrogen on palladium. Potential barriers are constructed from diffusion and solubility data, and it is shown that there exists a definite barrier for the penetration of hydrogen from the surface to the interior. The barrier has the same height for both hydrogen and deuterium and a mechanism for the transfer of gas is suggested.—S. G.

†**The Failure of Lead by Creep.** J. Neill Greenwood (*Proc. Australasian Inst. Min. Met.*, 1935, (100), 477–497).—From a critical review of recent work and from the results of experiments which are not yet completed, evidence is adduced to show that lead can fail by intercrystalline cracking by the application of a steady stress in air and that at operating stresses it is probable that this cracking is accompanied by less general distortion than occurs at 500 lb./in.² and that, therefore, the possibility of failure occurring is not a remote one even in the absence of vibration or corroding liquids. The rate of creep of lead at stresses below 500 lb./in.² is very considerably influenced by its previous thermal and mechanical treatment and by very slight changes in composition; thus even minute increases in the silver, zinc and, more especially, in the bismuth, antimony, and tellurium contents of commercial lead produce a considerable increase in the rate of creep, although a similar effect is obtained by removal of the ordinary impurities in lead.—A. R. P.

***On the Conduction of Heat by Some Metals at Low Temperatures [Lead, Copper, Tungsten].** H. Bremmer and W. J. de Haas (*Physica*, 1936, 3, (7), 672–686; and *Comm. K. Onnes Lab. Leiden*, No. 243a).—[In English.] The heat conductivity was determined for lead, copper, and tungsten. For lead an increase of the heat resistance is found at very low temperatures. This resistance is higher in the superconductive state than in the state in which superconductivity has been disturbed by means of a magnetic field. This is in complete agreement with the results for other pure superconductive metals. The so-called ideal resistance of copper is still decreasing at the lowest temperature at which the determinations have been carried out. It is proportional to T^2 . The ideal resistance of tungsten approaches a minimum value.—S. G.

***The Magnetization Curves of a Superconducting [Lead] Sphere and Ring.** D. Shoenberg (*Proc. Roy. Soc.*, 1936, [A], 155, (886), 712-726).—The (diamagnetic) magnetization curve of a superconducting pure lead sphere is measured by the Faraday method. The magnetization curves of a lead crystal sphere and an impure lead sphere are also measured, and the magnetization of an anchor ring of pure lead is described. The results are discussed in connection with the intermediate state recently proposed by Peierls.—S. G.

***Determination of the Heat Resistance of Mercury at the Temperatures Obtainable with Liquid Helium.** W. J. de Haas and H. Bremmer (*Physica*, 1936, 3, (7), 687-691; and *Comm. K. Onnes Lab. Leiden*, No. 243b).—[In English.] A new apparatus is described for the determination of the heat resistance of pure mercury. The measurements show that even this very pure substance has a minimum value for its heat resistance though this is found at a very low temperature (3.8° K.). Mercury shows a decrease of heat resistance when superconductivity is disturbed by means of a magnetic field, just as the other pure superconductive metals do.—S. G.

***The Relation Between Electron Field Emission and Contact Electromotive Force for Liquid Mercury.** Dan H. Moore (*Phys. Rev.*, 1936, [ii], 50, (4), 344-347).—The relation between the contact electromotive force and the impulsive potential necessary to initiate a vacuum spark has been studied for a liquid mercury cathode. For impure mercury no definite relation could be found, whilst for purified mercury the relation between the work-function and the breakdown field was only in qualitative, and not in quantitative agreement with theory.—W. H.-R.

Purification of Mercury. Biagio Pesce (*Annali chim. applicata*, 1936, 25, 654-657; *C. Abs.*, 1936, 30, 5844).—Two distillations, boiling with concentrated sodium hydroxide, and about 30 washings through a column of dilute nitric acid are recommended. The sp. gr. is checked with a special pycnometer to 0.0002 grm.—S. G.

***The Transition Between the Superconductive and the Normal State. I.—Magnetic Induction in Mercury.** K. Mendelsohn (*Proc. Roy. Soc.*, 1936, [A], 155, (886), 558-570).—The change of induction of long-shaped mercury specimens is investigated when passing from the normal to the superconductive state. Experiments at constant temperature and constant field were carried out separately. An arrangement is described which permits the temperature to be kept constant to less than 0.005° during the whole experiment. The change in induction from zero to its normal value when passing from the superconductive to the normal state is found to be discontinuous within the limits of accuracy. When passing from the normal to the superconductive state a more gradual change of induction is observed. This "hysteresis" is discussed with respect to a possible "supercooling" from the normal into the superconductive state. A change of induction in time with constant variables of state (temperature and magnetic field) is observed. This time effect cannot be explained by secondary causes, but seems to be a peculiarity of the transition between the superconductive and the normal state of the mechanism.—S. G.

***Hydrogenation by Adsorbed Hydrogen Atoms.** K. S. Ablezova and S. Z. Roginskii (*Doklady Akademii Nauk S.S.S.R.* (*Compt. rend. Acad. Sci. U.R.S.S.*), 1935, 1, (7/8), 490-492 (in Russian), 492-493 (in German); *C. Abs.*, 1935, 29, 6826).—Metal films that are completely incapable of catalyzing the combination of ethylene and hydrogen molecules will, when covered at -180° C. with a layer of adsorbed hydrogen atoms, effect the hydrogenation at or below room temperature. Further, if ethylene is added at liquid air temperatures to a fresh film of nickel saturated with atomic hydrogen, the ethylene remains adsorbed even on warming the film to room temperature, although in the absence of the layer of atomic hydrogen neither ethylene nor ethane is appreciably adsorbed by the nickel film at room temperature.—S. G.

***Magnetization of Nickel under Compressive Stresses and the Production of Magnetic Discontinuities [Barkhausen Effect in Nickel].** C. W. Heaps (*Phys. Rev.*, 1936, [ii], 50, (2), 176-179).—The magnetization of nickel bars under compression has been studied at stresses up to 10 kg./mm.². A strictly rectangular hysteresis loop cannot be obtained by compression alone, although an approximation to this shape can be obtained by using sufficiently high pressures. The Barkhausen effect is not much affected by compression alone. In an elastically bent wire, much smaller stresses produce large magnetic discontinuities, but a composite specimen consisting of a nickel bar fixed inside a nickel tube so that the bar is in compression and the tube in tension behaves similarly to unstressed material. The existence of contiguous compressed and stretched regions appears necessary for the appearance of the large discontinuities, and the way in which these discontinuities are produced is discussed.—W. H.-R.

***Reversible Change of Thermal Energy Accompanying Adiabatic Change of Magnetization in Nickel.** T. C. Hardy (*Phys. Rev.*, 1936, [ii], 50, (4), 395).—Abstract of a paper read before the American Physical Society. The experimental method devised by A. Townsend (*Met. Abs.*, 1935, 2, 139) has been so improved as to permit a study of the magneto-caloric effect in materials for which the total hysteretic energy increase is small in comparison with the reversible thermal energy changes which occur during a half cycle of magnetization. The specimen of nickel examined by H. was the same as that used by Townsend, except that it had been annealed at 1100° C. for 2 hrs. in hydrogen at atm. pressure and cooled to room temperature in 10 hrs. The hysteresis loss per half cycle is approx. 1200 ergs/cm.³. As the magnetization is decreased from near saturation to approx. the knee of the magnetization curve, the thermal energy decreases almost linearly with magnetizing field by the amount, 9000 ergs/cm.³. Below the knee of the curve, the magnetization decreases rapidly to zero and the thermal energy decreases by an additional 16,000 ergs/cm.³. On remagnetization the same process is reversed, except for the addition of the hysteresis heat, which appears in the region of most rapid variation of magnetization with field. Throughout the entire process the decrease of thermal energy is several times greater than the external work done by the specimen on the magnetizing currents.—S. G.

On the Effect of Tensile Stress on the Magnetization [of Nickel] above the Curie Point. Gertrud Scharff (*Ann. Physik*, 1936, [v], 25, (3), 223-232).—Tensile stresses have no effect on the Curie point of nickel.—v. G.

The Magnetic Behaviour of a Nickel Wire under Great Torsion. Richard Gans (*Ann. Physik*, 1936, [v], 25, (1), 77-91).—The observed magnetic effects of torsion on nickel are explained theoretically.—v. G.

***On the Mechanism of Displacement of Noble Metals from Solutions of Their Salts by Hydrogen under Pressure. I.—Displacement of Palladium from Solutions of Palladium Chloride.** V. V. Ipatiev and V. G. Tronev (*Dokladi Akademii Nauk S.S.S.R.* (*Compt. rend. Acad. Sci. U.R.S.S.*), 1935, 1, 622-624 (in Russian), 624-626 (in German)).—S. G.

***On the Mechanism of Displacement of Noble Metals from Solutions of Their Salts by Hydrogen under Pressure. II.—Displacement of Noble Metals from Solutions of H₂PtCl₆, H₂IrCl₆, Na₂IrCl₆, and Na₂RhCl₆.** V. V. Ipatiev and V. G. Tronev (*Dokladi Akademii Nauk S.S.S.R.* (*Compt. rend. Acad. Sci. U.R.S.S.*), 1935, 1, 627-629 (in Russian), 629-632 (in German)).—S. G.

***Normal Energy Distribution of Photoelectrons from Potassium Films as a Function of Temperature.** C. L. Henshaw (*Phys. Rev.*, 1936, [ii], 50, (4), 398).—Abstract of a paper read before the American Physical Society.—S. G.

***Transition Phenomena in the Condensation of Silver Vapour on Clean and Gas-Covered Tungsten.** Milo B. Sampson and Paul A. Anderson (*Phys. Rev.*, 1936, [ii], 50, (4), 385).—Abstract of a paper read before the American Physical

Society. In a tube which had been subjected to severe out-gassing, sealed from the pumps, and gettered with vaporized barium, duplicate tungsten filaments, dissimilar only with respect to the condition of their surfaces, were bombarded with gas-free silver vapour supplied by a molybdenum foil oven which could itself be thoroughly outgassed by flashing. One of the tungsten filaments was cleaned by flashing at 2800° K., while the other was allowed to retain the oxygen coating which persists after flashing at 1400° K. Permanent condensation of silver on the gas-covered filament occurred only after its temperature had been decreased to 900° K. and typical transition effects appeared. At the same vapour stream intensity permanent condensation on the clean tungsten occurred at 1220° K., approximately the temperature of the vaporizing oven, and none of the characteristic critical phenomena could be detected. It is probable that transition ("critical temperature") effects in the condensation of metal on metal as observed by Estermann, Cockcroft, and others are conditioned by the presence of surface films of gas and vapour and disappear when such films are removed.—S. G.

***Preparation of Silver Sheet. The Tensile Properties of Sheet of Commercial Silver Alloys in Relation to the Method of Manufacture.** H. Moser and E. Raub (*Mitt. Forschungsinst. Edelmetalle*, 1936, 10, (2/3), 19-26).—The effects of rolling, forging, and forging and rolling on the tensile properties of 835- and 925-fine silver sheet prepared from flat skillets and round bars are shown in tables and diagrams. In all cases considerable variations were observed in parallel tests so that general conclusions could not be drawn from the results. Usually, however, sheet of 835-fine silver prepared from flat skillets showed a higher tensile strength and yield point but a smaller elongation than that prepared from round bars; these differences tended to become smaller the greater the amount of work put into the metal. In the case of 925-fine silver, only the elongation behaved similarly, the tensile strength and yield point varying little with the method of preparing the sheet. Lower tensile properties were obtained by hot forging than by rolling, but rolling after forging removed these differences. Oxide films produced by intermediate anneals had no effect on the final properties of the sheet provided that they were not allowed to become too thick.—A. R. P.

***The Formation of Blister Silver.** Ernst Raub, Fritz Distel, and Alice Schall (*Z. Metallkunde*, 1936, 28, (9), 253-257).—The gases which cause blisters to form in annealed silver sheet have been analyzed after expelling them by fusion *in vacuo*. From a 10:90 copper-silver alloy melted in a graphite crucible in a coke fire the occluded gas consisted of sulphur dioxide 41-48, carbon dioxide 28-31, water 24-30, and nitrogen 0-6%; the corresponding figures for the same alloy melted in an oil-fired furnace were 62-68, 3-6, 29-30, and 0-2%, and in a gas-fired furnace 62-64, 19-20, 11-13, and 0-5%. From a 20:80 copper-silver alloy melted in a coke-fired furnace in such a way that the furnace gases were drawn over the surface and then cast through a luminous gas flame, the gas extracted contained carbon monoxide 45-8, hydrogen 27-2, methane 17-9, and carbon dioxide 9-1 vol.-%. The sulphur dioxide content is due to absorption of sulphur and oxygen from the furnace atmosphere and their interaction on solidification of the metal; the remaining gases are entrapped during casting. Thorough deoxidation of the molten metal with phosphorus or lithium removes the oxygen, and thus prevents formation of sulphur dioxide; at the same time both elements inhibit dissolution of hydrogen in the metal. In thoroughly deoxidized metal much of the sulphur is removed by volatilization as silver sulphide.—A. R. P.

***Micro-Plasticity in Crystals of Tin.** Bruce Chalmers (*Proc. Roy. Soc.*, 1936, [A], 156, (888), 427-443).—Experiments are described on the isothermal stress-strain-time relations of single crystals of tin of two grades of purity (99-987 and 99-996%), the stress being pure tension and the strain being measured to

10^{-7} cm./cm. on a length of 3 cm. Creep is found to occur under all stresses, its initial rate being proportional to stress for small stresses, and of the order of 3×10^{-9} cm./cm./minute per grm./mm.² (micro-creep), while above a fairly definite stress of the order of 120 grm./mm.² the rate of creep increases much more rapidly with stress (macro-creep). Micro-creep decreases with time in a roughly exponential manner, and macro-creep remains constant for a considerable time. The phenomena are considered from the point of view of the current theories concerning the mechanical strength of metallic crystals, and it is shown that micro-creep can be accounted for by an extension of G. I. Taylor's theory of fault propagation.—S. G.

***Continuous Measurement of Changes in the Electronic Work-Function During the Fusion of Tin.** Paul A. Anderson (*Phys. Rev.*, 1936, [ii], 50, (4), 386).—Abstract of a paper read before the American Physical Society. A slight modification of the method for measuring contact p.d. (*Met. Abs.*, 1935, 2, 368; this vol., p. 110) made possible continuous observation of progressive alterations in the work-function of a metal surface down to time intervals of a few seconds. Applied to study the change in work-function attending the transformation of γ -tin to liquid tin the method yields electron current-time curves which are similar to temperature-time fusion curves. The break in the current-time characteristic does not coincide with the disappearance of the solid phase but follows it after a measurable time interval. The shape of the curve beyond the break is finite, decreasing from a high positive value to zero as the temperature of the liquid tin is increased. If, as is unlikely, these effects are due to liberation of adsorbed gas the curves provide a means of following the desorption continuously. They may indicate a persistence of the regularly orientated lattice structure of solid tin beyond the melting point. The contact p.d. between γ -tin and liquid tin is found to be 0.17 v. The liquid tin has the lower work-function, in agreement with the photoelectric measurements of Goetz, which, uncorrected to the true thresholds at 0° K., yield the value 0.16 ev. for the difference between the work-functions.—S. G.

***Influence of Crystal Structure on Electron Emission from "218" Tungsten Wire.** W. B. Nottingham (*Phys. Rev.*, 1936, [ii], 50, (4), 398).—Abstract of a paper read before the American Physical Society. The thermionic emission from "218" tungsten wire has been shown by Johnson and Shockley (*Met. Abs.*, this vol., p. 196) to vary with crystallographic direction. Single crystals of this wire average 0.25–1.0 cm. in length and present 6 strips of strong emission separated by 6 strips of weak emission as the filament circumference is explored. The electron energy distribution as indicated by retarding potential measurements becomes ambiguous near "zero field" because the currents received are coming in effect from a cathode of inhomogeneous surface structure to a single collector. In the case of thoriated filaments it is thought that the actual surface exposed may be much more uniform than that found in "218" wire, thus accounting for the accurate reproducibility of the energy distribution curves. In contrast, the curves observed with different samples of "218" wire have not been in exact agreement with each other and have generally shown an apparent reflection effect larger than that for thoriated tungsten. If it be assumed that the work-function varies sinusoidally from a minimum to a maximum differing by 0.5 v., an approximate theory gives good agreement with experiment.—S. G.

***Cathode Ray Oscillography of Gas Adsorption Phenomena. I.—A Method for Measuring High-Velocity Approach to Certain Physical and Chemical Equilibria.** M. C. Johnson and F. A. Vick (*Proc. Roy. Soc.*, 1935, [A], 151, (873), 296–307).—The changes in electron emission from a solid surface are recorded by a cathode ray oscillograph and are used to study processes at a tungsten-oxygen interface.—S. G.

***Cathode Ray Oscillography of Gas Adsorption Phenomena. II.—Durations of an Adsorbed State of Oxygen on Tungsten.** M. C. Johnson and F. A. Vick (*Proc. Roy. Soc.*, 1935, [A], 151, (873), 296–316).—Cf. preceding abstract. The evaporation of a layer of oxygen atoms on tungsten was studied. The duration of the adsorbed state is 0.36 seconds at 2548° abs. and increases to 3.49 seconds at 2362° abs. The heat of evaporation of the oxygen layer is $147,000 \pm 3000$ cal./grm. atom. A numerical value of the τ_0 of Frenkel's theory is obtained. Ageing of the tungsten was found to increase the heat of evaporation of the oxygen, and certain contamination by added vapours was found to decrease it.—S. G.

***The Mobility of Sodium on Tungsten.** Richard Charles Leslie Bosworth (*Proc. Roy. Soc.*, 1935, [A], 150, (869), 58–76).—By depositing a small patch of sodium on the centre of a tungsten strip filament and traversing the strip from time to time with a well-defined spot of light, the photoelectric properties were used to measure the mobility of the sodium film. It was observed first of all that a clean strip absorbs sodium, a portion of which, however, reappears on the surface from which it evaporates when the strip is heated above 1300° K. There is a limit to the capacity of the strip to absorb sodium, and once that limit is reached any excess sodium is stable on the surface and, if deposited as the active patch, spreads or migrates over the surface at such a rate that the strip is approx. uniformly active after 1 or 2 hrs. at 300° K. or 5–10 seconds at 800° K. An activation energy of 0.25 v. is indicated for this migration, and within experimental error the same energy is associated with the absorption process, leading to the conclusion that this latter consists of migration down slip planes and intercrystalline cracks.—S. G.

***The Effect of Temperature, Degree of Thoriation, and Breakdown on Field Currents from Tungsten and Thoriated Tungsten.** A. J. Ahearn (*Phys. Rev.*, 1936, [ii], 50, (3), 238–253).—The field currents from thoriated tungsten with different degrees of thoriation have been studied. The measured currents are independent of temperature up to about 1040° K. At higher temperatures the results are accounted for completely by assuming that the observed current is due to the ordinary thermionic emission plus a field current independent of temperature. The characteristic field current curve is independent of the degree of thoriation of a thoriated tungsten filament. As the voltage is increased an electrical breakdown occurs which raises the field current by a factor which may be as high as 10^4 – 10^7 . With pure tungsten this breakdown does not change the thermionic activity of the cathode, but with thoriated tungsten the thermionic activity is increased. A. concludes that the electric field applied to the cathode surface, rather than the applied voltage, is the important factor in producing breakdowns.—W. H. R.

***Field Currents and Thermionic Currents from Thoriated Tungsten and Pure Tungsten.** A. J. Ahearn (*Phys. Rev.*, 1936, [ii], 50, (4), 398).—Abstract of a paper read before the American Physical Society.—S. G.

***The Photoelectric Properties of Zinc.** Charles F. DeVoe (*Phys. Rev.*, 1936, [ii], 50, (5), 481–485).—The long wave limit for zinc prepared by evaporation in a high vacuum varied between 2900 and 2930 Å. in a number of experiments; the corresponding work-function is 4.24 v. The effects of varying the pressure under which the distillation was carried out, and of foreign gases, were studied.

—W. H. R.

***Reflecting Power of Evaporated Metal Films in the Near and Far Ultra-Violet.** G. B. Sabino (*Phys. Rev.*, 1936, [ii], 50, (4), 396).—Abstract of a paper read before the American Physical Society. The reflecting powers of evaporated metal films from the visible to 450 Å. were determined for aluminium, antimony, beryllium, bismuth, cadmium, chromium, copper, gold, iron, lead, magnesium, manganese, molybdenum, nickel, palladium, platinum, silver, tellurium, tin, titanium, zinc, and zirconium. Photographic methods were

used. The accuracy of the work in the near ultra-violet was of the order of 3% and in the far ultra-violet not better than 5%.—S. G.

***The Polarimetric Determination of Optical Properties [of Films].** Richard Maury Emberson (*Phys. Rev.*, 1936, [ii], 50, (4), 396).—Abstract of a paper read before the American Physical Society. A study was made of the polarimetric method for determining the optical properties of a surface. The experimental work was carried out with a polarimeter designed and constructed in university shops. The equations used in the computations of results were based on theoretical work of T. C. Fry. It was found that certain instrumental errors profoundly affect the results. When the observed data were freed from these errors a decrease was noted in the variation of the computed optical constants of a surface with the angle of incidence at which the data were obtained. Studies were made of thin metal films deposited on glass. The results indicated that, while the computed film thicknesses were of the correct order of magnitude, they were not independent of the angle of incidence of observation; also, the computed thicknesses were always complex, with the imaginary part negative and about the same size as the real part.—S. G.

Comments on "Vapour Pressure Measurements of High Boiling Point Metals" by Baur and Brunner. Joseph Fischer. Emil Baur and Roland Brunner (*Helv. Phys. Acta*, 1935, 18, 1028–1030).—Cf. *Met. Abs.*, 1935, 2, 209. F. states that von Wartenberg's apparatus as used by B. and B. is not suitable for boiling point measurements. B. and B. reply.—S. G.

***Calculation of Various Physical Constants of Heterogeneous Substances. II.—Dielectric Constants and Conductivities of Polycrystals in the Non-Regular Systems [Antimony, Bismuth, Tin, Cadmium, Mercury].** D. A. G. Bruggeman (*Ann. Physik*, 1936, [v], 25, (7), 645–671).—The relations between the electrical conductivities of single crystals and of polycrystalline aggregates have been determined mathematically for the non-cubic metals antimony, bismuth, tin, cadmium, and mercury.—v. G.

Magnetic Investigations of the Plastic Deformation of Metallic Substances. H. J. Seemann (*Metallwirtschaft*, 1936, 15, (40), 931–936).—The present position of our knowledge of the influence of plastic deformation on the magnetic properties of non-ferromagnetic metals and alloys is reviewed.—v. G.

***New Determinations of Gyromagnetic Ratios for Ferromagnetic Substances.** S. J. Barnett (*Phys. Rev.*, 1936, [ii], 50, (4), 390).—Abstract of a paper read before the American Physical Society. See also *Met. Abs.*, 1934, 1, 226. New and extensive measurements were made on a number of substances including electrolytic iron, cold-rolled steel, nickel, Permalloy, Hopkinson's nickel-iron alloy, pure cobalt, cobalt alloyed with a few % of copper, cobalt alloyed with nickel (Bloch's alloy), and Preuss's iron-cobalt alloy. All the work was carried out by methods differing only slightly from those used by B. in the last work on rotation-by-magnetization. The values of the gyromagnetic ratio obtained range from about $1.02 \times m/e$ (nickel-iron) to about $1.10 \times m/e$ (pure cobalt), with mean errors in a number of cases of much less than 1%. Earlier values have been confirmed. No certain difference has been found between results obtained with the magnetizing coil fixed to the earth and magnetizing coil fixed to the vibrating body.—S. G.

Theory of Surface Ionization on Glowing Metals. A. I. Anselm (*Dokladi Akademii Nauk S.S.S.R. (Compt. rend. Acad. Sci. U.R.S.S.)*, 1934, 3, (5), 329–331 (in Russian), 332–334 (in German)).—Theoretical.—S. G.

***The Resistance and Thermoelectric Properties of the Transition Metals.** N. F. Mott (*Proc. Roy. Soc.*, 1936, [A], 156, (888), 368–382).—Explanations are given in terms of the quantum theory of metals of the following phenomena: the decrease in the temperature coeff. of resistance of palladium and platinum at high temperatures; the large negative thermoelectric power of palladium and platinum; the increase in the absolute magnitude of the thermoelectric

power of palladium when it is alloyed with copper, silver, gold, or hydrogen, and the sudden decrease for higher concentrations; the sudden change in the temperature coeff. of resistance of ferromagnetic metals at the Curie point; the behaviour of the thermoelectric power of nickel near the Curie temperature.

—S. G.

***Electromagnetic Equations of the Superconductor.** F. and H. London (*Proc. Roy. Soc.*, 1935, [A], 149, (866), 71–88).—S. G.

Magnetic Transition Curves of Superconductors. R. Peierls (*Proc. Roy. Soc.*, 1936, [A], 155, (886), 613–628).—Theoretical. Discusses the magnetic properties of a superconductor for that range of external field strength in which some lines of force are passing the body, but in which their density is less than outside.—S. G.

***The Thermodynamics of Magnetization.** E. A. Guggenheim (*Proc. Roy. Soc.*, 1936, [A], 155, (884), 70–101).—S. G.

Contact Potential, Energy of Emergence, and Thermoelectric Potential.—I. G. Mönch (*Erlanger Ber.*, 1934, 65, 191–201; *Chem. Zentr.*, 1935, 106, (II), 20; *C. Abs.*, 1936, 30, 5089).—This first paper of a series reviews the work of others on these properties of metals and semi-conductors and outlines problems the solution of which is to be undertaken experimentally.—S. G.

***The Relation Between Energy of Emergence and Contact Potential.—II.** G. Mönch (*Erlanger Ber.*, 1934, 65, 202–207; *Chem. Zentr.*, 1935, 106, (II), 20; *C. Abs.*, 1936, 30, 5089).—See also preceding abstract. The difference between the energy of emergence and that of the contact potential of tungsten and platinum was experimentally determined as follows: An electrically heated platinum sheet was sputtered with tungsten on one side. By means of a screen system, small currents of electrons (equal portions on each side) were made to impinge on each side as an anode. The current of electrons on each side was absorbed in relation to the accelerating potential. The value of the saturation currents gives the value of the energy of emergence; the distance between the breaks (beginning of saturation) of the two lines gives the difference in contact potential. Such measurements substantiated the theoretical requirement that the energy of emergence in volts, disregarding sign, is equal to the difference in contact potentials, for the case of tungsten–platinum.—S. G.

***The Relation of the Contact Potential to the Condition of Strain of a Metal Surface.** G. Mönch (*Erlanger Ber.*, 1934, 65, 211–214; *Chem. Zentr.*, 1935, 106, (II), 21; *C. Abs.*, 1936, 30, 5089).—Cf. preceding abstracts. Experiments were carried out to determine any change in the energy of emergence with change in the strain of the metal surface. The difference between the energy of emergence for the strained and unstrained surface was measured by the difference in the contact potentials. A nickel sheet 0.8 mm. thick can be bent in a vacuum to a cylinder of 4 cm. radius without exceeding the elastic limit. Surface expansion amounts to about 1%; volume expansion to about 0.3%. Current-voltage lines were plotted before and after the bending of the metal for a current of electrons flowing from a glowing cathode to the metal under investigation as anode. The shift in such lines along the potential axis then gives the change in contact potential. The experiments showed that with an expansion of 1% the change in energy of emergence was certainly less than 4×10^{-3} v.—S. G.

On the Application of the Dirac Matrix Method to the Theory of Metals. S. Shubin (*Dokladi Akademii Nauk S.S.S.R. (Rep. Acad. Sci. U.S.S.R.)*, 1935, 3, (1), 15–18 (in Russian); and *Compt. rend. Acad. Sci. U.R.S.S.*, 1935, [N.S.], 3, 15–18 (in German)).—Theoretical. The method is applied to the problem of electron gas under the influence of an alternating electric field.—N. A.

***The Interaction of Atoms and Molecules with Solid Surfaces. I.—The Activation of Adsorbed Atoms to Higher Vibrational States.** J. E. Lennard-Jones and C. Strachan (*Proc. Roy. Soc.*, 1935, [A], 150, (870), 442–455).—The

behaviour of an atom or molecule adsorbed on the surface of a solid is investigated by wave-mechanics. Formulæ are found for the mean interval between successive excitations from the state of lowest vibrational energy to various excited states and for the mean time during which the atom remains in an excited state. An application is suggested to the theory of the migration of atoms along surfaces.—S. G.

***The Interaction of Atoms and Molecules with Solid Surfaces. II.—The Evaporation of Adsorbed Atoms.** C. Strachan (*Proc. Roy. Soc.*, 1935, [A], 150, (870), 456–464).—Cf. preceding abstract. A formula is obtained for the probability of evaporation of an adsorbed atom or molecule from a solid surface. The theory is applied to the evaporation of H_2 , HD, and D_2 from a metal, and it is shown that over a wide range of temperature the average length of time spent by HD on copper is about 4–6 times that of H_2 , while the time spent by D_2 is about 20 times as great as that of H_2 .—S. G.

***The Interaction of Atoms and Molecules with Solid Surfaces. III.—The Condensation and Evaporation of Atoms and Molecules.** J. E. Lennard-Jones and A. F. Devonshire (*Proc. Roy. Soc.*, 1936, [A], 156, (887), 6–28).—Cf. preceding abstracts. A detailed theory of the evaporation and condensation of atoms and molecules at solid surfaces is worked out. Formulæ are found for the probability that an impinging particle will condense on to a solid surface and for the length of time that it will remain there. The theory thus provides explicit formulæ for the constants which occur in Langmuir's adsorption isotherm in terms of the physical properties of the solid and its surface field. The mechanism by which evaporation is supposed to take place is by the transfer of a quantum of the thermal energy of the solid to the adsorbed atom. As thermal quanta are as a rule small, the energy applies mainly to atoms and molecules held by weak forces such as van der Waals' forces. It is found that evaporation may, even at low temperatures, take place in two or more stages, an atom being first excited to a higher vibrational level and then, while in that excited state, receiving another quantum of energy sufficient to cause evaporation. To illustrate the effect of mass the probabilities of condensation and evaporation of H_2 , HD, and D_2 are evaluated in typical circumstances. The coeff. of condensation is found in many cases to be quite small and not equal to unity, as is frequently assumed.—S. G.

***The Interaction of Atoms and Molecules with Solid Surfaces. IV.—The Condensation and Evaporation of Atoms and Molecules.** J. E. Lennard-Jones and A. F. Devonshire (*Proc. Roy. Soc.*, 1936, [A], 156, (887), 29–36).—Cf. preceding abstracts. A theory of evaporation of atoms from a solid surface is worked out for a model in which an adsorbed atom can vibrate radially and laterally about its point of attachment, but cannot migrate. Evaporation is controlled by the rate at which thermal energy is communicated from solid to the adsorbed atom. The condition for detailed balancing between adsorbed and evaporated states gives an equation for the adsorption isotherm in terms of the energy levels of the adsorbed state.—S. G.

***The Interaction of Atoms and Molecules with Solid Surfaces. V.—The Diffraction and Reflection of Molecular Rays.** A. F. Devonshire (*Proc. Roy. Soc.*, 1936, [A], 156, (887), 37–44).—Cf. preceding abstracts. A theory of the diffraction and reflection of molecular rays at crystal surfaces is worked out. It is shown that the minima in the diffraction and reflection curves of He and LiF observed by Frisch and Stern are capable of a simple explanation, and that they can be used to deduce information about the potential energy of the gas in the field of the solid.—S. G.

II.—PROPERTIES OF ALLOYS

(Continued from pp. 389-395.)

***Running Properties of Aluminium-Bearing Metals (Quarzal).** Maximilian (Frhr.) von Schwarz (*Z. Metallkunde*, 1936, 28, (9), 272-275).—The Quarzal alloys consist of aluminium with 5-15% copper and small amounts of heavy metals and constituents which produce precipitation-hardening. The running properties of 5 of these alloys are shown graphically, and photomicrographs of their structure are reproduced. The 5% copper alloy will withstand bearing pressures of up to 150 kg./cm.², but is most satisfactory at 80 kg./cm.²; it can be used with running speeds up to 10 m./sec. and in well-lubricated bearings the running temperature averages 70°-90° C. Since the coeff. of expansion is about double that of steel, due allowance must be made for this in constructing the bearings. The Quarzal alloys have a low sp. gr., wear better than tin-base bearing metals especially under impact conditions, and withstand higher temperatures without seizing or melting.—A. R. P.

***Vanadium and Zirconium as Constituents of Aluminium-Bronze.** C. Panseri (*Alluminio*, 1936, 5, (2), 37-45).—The effects of small additions of vanadium and zirconium to α -aluminium-bronzes has been investigated, and the results are shown in micrographs and in data for the mechanical properties. Vanadium is insoluble in both liquid and solid copper, but up to 0.25% can be introduced into aluminium-bronze to improve the tensile strength at the expense of the ductility. Zirconium tends to embrittle the alloy and even small additions greatly reduce the rolling properties.—A. R. P.

***Influence of the Method of Deformation and Thermal Ageing on the Fatigue Strength of Aged Aluminium Alloys.** H. Bohner (*Metallwirtschaft*, 1936, 15, (35), 813-814).—Alternate bending tests have been made on an aluminium alloy with copper 5.65, manganese 0.67, silicon 0.14, and iron 0.23% after various heat- and mechanical treatments. With age-hardened rods, those produced by extrusion show an endurance limit of 1 kg./mm.² less than that of those produced by rolling or drawing, both of which give 14.5 kg./mm.². Quenching temperatures had no effect on the results, but increase in ageing temperature or time increases the endurance limit.—v. G.

***Mechanism of the Decomposition of Aluminium-Magnesium Solid Solutions.** Paul Lacombe and Georges Chaudron (*Compt. rend.*, 1936, 202, (21), 1790-1792).—The difference of potential between the calomel electrode and an electrode of the alloy immersed in an aerated solution of 3% sodium chloride was measured with a Curie electrometer. A 9% magnesium-aluminium alloy made of very pure metals was quenched and tempered at 300° and 200° C. for periods of from 30 minutes to 400 hrs. After tempering below 280° C., the potential of the solid solution first rises and then, after prolonged treatment, reverts to its initial value. Corrosion measurements confirmed this. Curves representing the rate of corrosion as a function of the time of tempering were drawn by the Thyssen-Bourdouxhe method. For low temperatures, the rate of corrosion has a distinct and high maximum, but after prolonged tempering, the rate of attack tends towards the original value. Alloys made with commercial metals, and containing 0.2% silicon and 0.15% iron, have a higher rate of precipitation. It appears that the constituent precipitated at a low temperature and at the beginning of the phenomenon is unstable and richer in magnesium than the compound Al_3Mg_2 , which constitutes the β -phase. Such a mechanism implies necessarily a magnesium content of the α -phase lower than that at equilibrium.—J. H. W.

***Light Metal Alloys with an Aluminium-Magnesium Base for Use in Automatic Cutting Machines.** Hans Bohner (*Z. Metallkunde*, 1936, 28, (9), 290-293).—Hydrionalium alloys are especially suitable for cutting on automatic

machines as they give short, brittle turnings owing to the presence of Al_2Mg_3 . Addition of up to 2% manganese and small amounts of chromium, which form hard intermetallic compounds with magnesium, aluminium, and Al_2Mg_3 , improves still further the cutting properties. The presence of Mg_2Si , Mg_2Zn , and the ternary aluminium-magnesium compounds with zinc or copper also acts favourably.—A. R. P.

***On the Question of Aluminium for Automatic Machines.** Georg Masing and Günther Ritzau (*Z. Metallkunde*, 1936, 28, (9), 293-296; discussion, 296-297).—Addition of lead to aluminium results in short brittle turnings when the metal is cut or drilled in a lathe. The lead may be added by stirring the molten metal with lead chloride or, in the case of Duralumin, by adding it as an alloy with copper and nickel, e.g. copper 62.5, nickel 12.5, and lead 25%. Segregation of the lead is very small in the second case, but may be fairly considerable in the first. The presence of lead reduces the resistance of Duralumin to corrosion somewhat but has no effect on its ductility.—A. R. P.

Influence of the Structure on the Working Properties and Cutting Surface of Aluminium Alloys for Automatic Cutting Machines. E. Vaders (*Metallwirtschaft*, 1936, 15, (35), 814-817).—The hardenable aluminium alloy Tordal (composition not given) is, on account of its good workability, a suitable substitute for lead-brass.—v. G.

***X-Ray Investigation of the Transformations in Aluminium-Silver Alloys.** W. Hofmann and K. E. Volk (*Metallwirtschaft*, 1936, 15, (30), 699-701).—The compound Ag_3Al (aluminium 7.7%) is cubic face-centred above 600° C. (at 700° C. $a = 3.24$ A.), between 600° and 400° C., it is close-packed hexagonal (at 570° C. $a = 2.90$, $c = 4.71$ A., $c/a = 1.62$), and at lower temperatures it has a β -manganese structure.—v. G.

***On the Age-Hardening Mechanism in Silver-Aluminium Alloys.** Masahide Kosaki (*Kinzoku no Kenkyu (J. Study Metals)*, 1936, 13, (8), 342-348).—[In Japanese.] In order to investigate the mechanism of age-hardening in silver-aluminium alloys, a study was made with an alloy containing 40% silver quenched from 550° C. in water, after heating at that temperature for 30 minutes, followed by ageing at room temperature for 20 days and tempering for 6 hrs. at 60°, 100°, 150° C., &c., respectively, and then cooling slowly in the furnace. The variation in lattice constant, density, and hardness of the specimen due to the above-mentioned treatments was measured; dilatation and electrical resistance curves of the quenched specimen during slow heating were also taken. As a result of these measurements it is concluded that in the course of ageing the hardness attains a maximum value just prior to the separation of the crystallites, while it decreases after their separation. This result is in agreement with the so-called solid solution theory of age-hardening.—S. G.

***The Influence of Sodium and Calcium on Industrial Aluminium.** (Grashtchenko and Darovski.) See p. 439.

***X-Ray Study of the Aluminium-Zinc System.** Ichiji Obinata, Masami Hagiya, and Sigeyuki Itimura (*Tetsu to Hagane (J. Iron Steel Inst. Japan)*, 1936, 22, (8), 622-629).—[In Japanese.] The aluminium-zinc alloys in the range of the β and the γ fields were studied by means of X-rays, with both ordinary and precision cameras. The powder photograms were taken not only at room temperatures but also directly at high temperatures. From the lattice constant-concentration curves obtained it is confirmed that the β -phase is merely a continuation of the γ -phase; the solid solubility of zinc in the latter phase was determined. By adding a small amount of magnesium to the alloy, the intermediate stages during decomposition of quenched β due to ageing were studied. The results showed that the eutectoid transformation of the β phase is simply a process of decomposition into α and γ , which are in equilibrium concentration, and that no intermediate metastable phase exists

during the process. It should be noted, however, that the lattice constant of quenched β decreases anomalously during ageing and that the complete decomposition of the phase is scarcely attainable at ordinary temperature. The complicated changes in physical properties of the quenched alloys due to ageing are explained crystallographically.—S. G.

Endurance Impact Tests on Light Metals. Kurt Laute (*Z. Metallkunde*, 1936, 28, (8), 233-236).—Results obtained with the Maybach impact bending machine on Duralumin, Bondur, Elektron, and Silumin are compared with those obtained with the Schenk machine. The higher results given by the first-named method are attributed to the increased rate of deformation in the impact test.—A. R. P.

†**Properties and Alloys of Beryllium.** (Stott.) See p. 440.

Cadmium-Silver-Copper Bearing Alloy. L. C. Blomstrom (*Machinist (Eur. Edn.)*, 1936, 79, (51), 768E-769E).—A cadmium-silver-copper bearing alloy has been developed to provide a higher melting point and greater fatigue-resistance than tin-base Babbitt. The addition of silver makes the cadmium less susceptible to oxidation at the casting temperature, improves the fluidity, and has a marked influence on the structural and physical characteristics of cadmium. The hardness increases with the silver content, but the addition of copper permits a reduction of silver for the same hardness. The alloy has a lower coeff. of friction than tin-base or copper-base alloys.—J. H. W.

***The System Iron-Chromium-Chromium Carbide (Cr_7C_3)-Cementite (Fe_3C).** Walter Tofaute, Carl Küttner, and Alfred Büttinghaus (*Arch. Eisenhüttenwesen*, 1935-1936, 9, (12), 607-617).—The system iron-chromium-carbon up to 70% chromium and to the $\text{Fe}_3\text{C}-\text{Cr}_7\text{C}_3$ line has been examined by metallographic, thermal, dilatometric, magnetic, and X-ray methods. The existence of the cubic and trigonal chromium carbides discovered by Westgren, Phragmén, and Negresco was confirmed and their capacity to take up iron by atom exchange established. The γ -phase field of the iron-carbon system is restricted by addition of chromium, and no longer occurs in alloys with 20% chromium or more. 4 four-phase equilibria involving a liquid phase occur: (1) liquid (chromium 38.6, carbon 2.2%) + $(\text{Cr}, \text{Fe})_4\text{C}$ (chromium 76.0, carbon 8.34%) \rightleftharpoons α (chromium 50, carbon 0.1%) + $(\text{Cr}, \text{Fe})_7\text{C}_3$ (chromium 80.0, carbon 5.44%) at 1300° C.; (2) liquid (chromium 30, carbon 2.4%) + α (chromium 26, carbon 0.3%) \rightleftharpoons γ (chromium 20, carbon 0.6%) + $(\text{Cr}, \text{Fe})_7\text{C}_3$ (chromium 76, carbon 8.26%) at 1260° C.; (3) liquid (chromium 8, carbon 3.6%) + γ (chromium 3, carbon 1.5%) \rightleftharpoons $(\text{Cr}, \text{Fe})_7\text{C}_3$ (chromium 54, carbon 7.68%) + $(\text{Fe}, \text{Cr})_3\text{C}$ (chromium 15, carbon 6.78%) at 1130° C. The four-phase equilibrium γ + $(\text{Cr}, \text{Fe})_7\text{C}_3$ \rightleftharpoons α + $(\text{Fe}, \text{Cr})_7\text{C}_3$ occurs at 790° C. in the solid state, the composition of the participating phases being chromium 2.6, 2.0, 62.0, and 9.6% and carbon 0.05, 0.70, 9.74, and 6.80%, respectively. Annealing at 800°-950° C. of alloys with 40-60% chromium results in the separation of the brittle, non-magnetic FeCr compound irrespective of the carbon content. Detailed equilibrium diagrams for alloys with a constant chromium content of 12, 15, 20, 30, 35, 40, 45, 50, and 60% are given, together with photomicrographs of numerous characteristic structures.—A. R. P.

***The System Iron-Cobalt-Copper.** Werner Jellinghaus (*Arch. Eisenhüttenwesen*, 1936-1937, 10, (3), 115-118).—In the molten state iron, cobalt, and copper are miscible in all proportions, but as is the case with the copper-iron and copper-cobalt systems separation of the metals takes place on solidification; alloys in the iron corner solidify as δ -solid solution which changes to γ and then to α on cooling, all alloys with up to 8% copper except those in the iron corner solidify as γ -ternary solid solution, and alloys with 8-96% copper solidify as a heterogeneous mixture of γ and copper. The γ - α transformation occurs in all alloys the composition of which lies in the field between the iron corner of the ternary diagram and a straight line joining the copper corner

with the 79% cobalt, 21% iron point. The eutectoidal equilibrium of the iron-copper system is displaced to higher temperatures by addition of cobalt, reaching a maximum temperature in the section 100% copper-50:50 iron-cobalt, and falling to room temperature with further increase in cobalt. X-ray examination and density measurements have confirmed the existence of the compound FeCo.—A. R. P.

***X-Ray and Electrical Investigations in the Copper-Gold System.** C. H. Johansson and J. O. Linde (*Ann. Physik*, 1936, [v], 25, (1), 1-48).—A new phase with an ordered rhombic lattice with 40 atoms in the unit cell has been discovered in copper-gold alloys with 47-53 atomic-% gold after quenching from about 420° C. In alloys with 36-47 and with 53-65 atomic-% gold the new phase can be obtained by prolonged tempering at 200°-400° C. Alloys with 65-80 atomic-% gold after a similar treatment show only very feeble superstructure lines. The electrical conductivity has been measured throughout the system after various heat-treatments and the bearing of the results on the structural changes is discussed.—v. G.

***Constitutional Diagram of the Copper-Silicon-Aluminium System.** Chiuyo Hisatsune (*Tetsu to Hagane (J. Iron Steel Inst. Japan)*, 1936, 22, (8), 597-622).—[In Japanese.] The constitution of the whole ternary system was investigated. No ternary intermetallic compound was observed. 15 definite constituents that have been determined in each binary system were also found to occur in the ternary system. There are 11 surfaces of primary separation, and 8 invariant points on the liquidus surface; among them 2 points are ternary eutectic, one point ternary peritectic, and 5 points peritecto-eutectic. Both the β -phases of the copper-silicon and copper-aluminium systems are completely soluble in all proportions in the ternary system, and decompose into $\alpha + \gamma_i$; the univariant reaction line of this decomposition has a minimum point at about 500° C. Two invariant reactions in the solid state, $\gamma_i + \gamma_j \rightleftharpoons \chi + \alpha$, $\gamma_i + \chi \rightleftharpoons \alpha + \epsilon_s''$, are found to exist at 675° and 495° C. Five invariant reactions: $\gamma_i + \epsilon_2 a \rightleftharpoons \delta + \text{Si}$, $\epsilon_2 a \rightleftharpoons \delta + \zeta_1 + \text{Si}$, $\zeta_1 \rightleftharpoons \delta + \zeta_2 + \text{Si}$, $\epsilon_2 a + \eta_1 \rightleftharpoons \zeta_1 + \text{Si}$, $\zeta_1 + \eta_1 \rightleftharpoons \zeta_2 + \text{Si}$, and two ternary polymorphic changes due to the $\eta_1 \rightleftharpoons \eta_2$ phases take place at almost the same temperatures as in the binary system copper-aluminium. Four ternary polymorphic changes due to the $\epsilon_s \rightleftharpoons \epsilon_s'$ and $\epsilon_s' \rightleftharpoons \epsilon_s''$ take place at: 600° C., $\gamma_i + \epsilon_s \rightleftharpoons \epsilon_s' + X$; 550° C., $\gamma_i + \epsilon_s' \rightleftharpoons \epsilon_s'' + X$; 585° C., $\gamma_i + \epsilon_s \rightleftharpoons \epsilon_s' + \text{Si}$; and 525° C., $\gamma_i + \epsilon_s \rightleftharpoons \epsilon_s'' + \text{Si}$, respectively. The limit of solubility of silicon and aluminium in solid copper was also determined.—S. G.

The Static Tensile Properties of German Standard Tin-Bronzes (Phosphor-Bronzes) in the Cast (Annealed and Unannealed) State at Room Temperature and at Higher Temperatures. Willi Claus and Claus Goetzel (*Giesserei*, 1936, 18, (7), 154-158; (9), 206-219).—Tables are given showing the tensile properties of annealed and unannealed castings of phosphor-bronzes (containing 6, 10, 14, and 20% tin) at temperatures between 20° and 500° C.; notes on the micro- and macro-structure are also included and the results summarized in a series of space models. Except in the case of the 14% tin alloy annealing the castings without previous deformation has little or no effect on the properties at any temperature. The 14% tin alloy has a tensile strength in the as cast state of 23 kg./mm.², a yield point of 15 kg./mm.², an elongation of 7%, and a Brinell hardness of 79; after annealing the corresponding values are 32, 13, 33, and 67. All the alloys can be heated to 300° C. without undergoing any appreciable loss of strength or ductility. Since all four alloys when properly cast have superior mechanical properties to those specified in DIN 1705, C. and G. suggest that the tin content in the specification be reduced by 2% (1% in the cast of the 6% alloy).—A. R. P.

***The Photoelectric Effect of Metallic Alloys.—I. [Copper-Tin].** Luigi Belladen and Giulio Galliano (*Annali chim. applicata*, 1936, **26**, 30–34; *C. Abs.*, 1936, **30**, 6636).—The photoelectric sensitivity to the entire range of radiation of a mercury arc of alloys of copper with tin with variation in composition was measured. A special cell was used which permitted comparison of the emission from 4 alloys, as well as from copper as reference, to be made simultaneously. A photoelectric sensitivity–composition diagram was constructed. There are singular points corresponding to the compounds Cu_4Sn , Cu_3Sn , and Cu_2Sn_3 .
—S. G.

***On the Diffusionless Transformation of the β -Phase of Copper-Zinc Alloys.** E. Kaminski and G. Kurdjumow (*Metallwirtschaft*, 1936, **15**, (39), 905–907).—At $-14^\circ C.$ β -brass appears to undergo a transformation into a tetragonal phase with $a = 3.755$, $c = 3.586$ A.—v. G.

***Precipitation-Hardening of Gold-Nickel Alloys.** Werner Köster and Walter Dannöhl (*Z. Metallkunde*, 1936, **28**, (9), 248–253).—Nickel and gold form a continuous series of solid solutions at high temperatures, but at room temperature the alloys containing 5–98 atomic-% nickel consist of 2 face-centred solid solutions, a nickel-rich and a gold-rich. The heterogeneous range extends from 8 to 97 atomic-% nickel at $400^\circ C.$, from 22 to 95 atomic-% nickel at $600^\circ C.$, and from 58 to 88 atomic-% nickel at $800^\circ C.$ Alloys quenched from above $850^\circ C.$ begin to decompose on reheating at $400^\circ C.$, generally along the grain boundaries; on more prolonged heating new nuclei are formed in the grain centres and decomposition proceeds from these outwards and from the grain boundaries inwards; simultaneously the electrical resistance falls and the coercivity, remanence, magnetization, and hardness rise, the first and last much more rapidly than the second and third. The hysteresis loop of quenched alloys is very small, but rapidly broadens as precipitation occurs and then contracts again as the new phases coagulate. Maximum precipitation hardness is obtained with the 60 atomic-% nickel alloy; the quenched alloy of this composition has a lattice parameter of 3.77 A. instead of the theoretical 3.86 A. and appears to contain an unstable gold-nickel compound, possibly $AuNi_3$ or $AuNi_5$.—A. R. P.

***Effect of Silver on Lead.** J. Neill Greenwood (*Chem. Eng. Min. Rev.*, 1936, **28**, (335), 384).—Small additions of silver to lead, although not greatly affecting the hardness, appreciably reduce the rate of deformation under stress. The alloys were tested under a stress of 500 lb./in.² in direct tension in the “as rolled” condition and after annealing at $125^\circ C.$ for 24 hrs. The percentage increase in length after 300 days was as follows: virgin lead, containing 0.0008% silver, 6.0 (as rolled) and 6.6 (annealed); silver 0.001%, 9.5 and 10.6; silver 0.01%, 3.0 and 3.2; silver 0.05%, 3.2 and 3.4; silver 0.10%, 6.4 and 7.3. Although 0.05% tellurium increases the Brinell hardness of lead from 3.5 to 7, as opposed to 3.5–4.5 for the same amount of silver, the hard tellurium alloy creeps at a much greater rate than virgin lead under a stress of 500 lb./in.². The properties of these silver alloys are appreciably altered by heat-treatment, and this is being further investigated.—J. H. W.

†New Equilibrium Diagrams for the Systems Lead-Thallium and Lead-Thallium-Cadmium. Correction. Ernst Jänecke (*Z. Metallkunde*, 1935, **27**, (6), 141).— *Cf. Met. Abs.*, 1935, **2**, 153. New experimental work by Ölander (*Met. Abs.*, 1934, **1**, 421) indicates that the two-phase field between the lead and $PbTl_3$ solid solutions should extend from 49 to 55% lead, and that the $PbTl_2$ field should end at about 10% lead on the thallium side. No changes are required for the lead-thallium-cadmium system.—S. G.

***Physical Properties of Soft Solders and the Strength of Soldered Joints.** B. W. Gonser and C. M. Heath (*Metals Technology*, 1936, **3**, (5), 23 pp.; and *A.I.M.M.E. Tech. Publ.* 727; also (summaries) *Iron Age*, 1936, **137**, (9), 30–33; and *Mech. World*, 1936, **99**, (8), 347–348).—Four series of solders were prepared

from lead and tin of different purities. In each series, solders of 7 or 8 compositions were prepared in the range 15–63% of tin, and the physical properties were systematically compared. Data are given for the electrical conductivity, impact strength, shear strength, tensile strength, and elongation values of the solder alloys, and also for the strengths of soldered lap joints of 70 : 30 brass. A method of soldering was devised which practically eliminated porosity in single lap joints; this consisted in flowing solder into a properly prepared wide joint, and then squeezing the joint members to the desired standard narrow width whilst the solder was still molten. In all four series, solders containing 35 and 40% tin gave markedly superior joints. The electrical conductivity of all the solders increased by about 5% on ageing at room temperature for 6 months. No great differences existed between the four series, and the original must be consulted for details of the impurities and their effects

—W. H. R.

***On the Heat Conductivity of Superconductive Alloys.** H. Bremmer and W. J. de Haas (*Physica*, 1936, 3, (7), 692–704; and *Comm. K. Onnes Lab. Leiden*, No. 243c).—[In English.] The heat resistance of lead-tin alloy, Rose's metal, and indium-lead alloys of three different concentrations was determined. The heat resistance increases rapidly at very low temperatures, but more slowly than ζ/LT , which was predicted by theory. The influence of the magnetic field is complicated and gives rise to the hypothesis that the field penetrates at values which do not disturb superconductivity. Discontinuities may appear at the threshold values of either the alloy or of any of the superconductive components.—S. G.

Contribution to Our Knowledge of Magnesium Casting Alloys. H. Busch (*Giesserei*, 1936, 23, (13), 290–295).—The structure of magnesium alloys containing up to 10% of aluminium, zinc, manganese, and silicon is described with reference to the equilibrium diagrams and micrographs. The mechanical properties and microstructure of Elektron containing aluminium 9.5, zinc 0.5, and manganese 0.3% after various heat-treatments are shown in tables and photographs. The following table illustrates the changes produced by various heat-treatments in a nitrogen atmosphere :

	Brinell Hardness.	Yield-Point, Kg./mm. ² .	Ultimate Strength, Kg./mm. ² .	Elongation. %.
As cast	67.5	11.8	16.75	1.6
$\frac{1}{2}$ hr. at 390° C., quenched	65.9	11.7	17.6	2.25
32 hrs. at 425° C., quenched	55.5	10.8	20.5	4.2
32 hrs. at 425° C., cooled at 10° C./hr. to 350° C., quenched	53.3	10.3	25.3	9.5
5 hrs. at 440° C., cooled at 4°–2° C./minute to 20° C.	66.2	12.8	20.7	3.5

—A. R. P.

***Advances and Present Position of the Use of Elektron Metal.** Walther Schmidt and Paul Spitaler (*Z. Metallkunde*, 1936, 28, (8), 220–222; discussion, 222–224).—Elektron AZ855 contains zinc 0.5 and manganese 0.1% and has a tensile strength of 32.8 kg./mm.² at 20° C. and 19.2 kg./mm.² at 200° C. with corresponding yield points of 23.6 and 15.4 kg./mm.², elongations of 12.6 and 23.9%, and Brinell hardness values of 68 and 50. Alloy AV9 is a hardenable alloy for sand-castings and has a similar composition except that the manganese content is 0.3%; after homogenization at 420° C. in a sulphur dioxide atmosphere or in a bichromate salt-bath (a 3 : 1 mixture of sodium and potassium bichromate, melting point 266° C.) and ageing at about 200° C. the alloy has



a tensile strength of 24–27 kg./mm.², a yield point of 10–11 kg./mm.², and an elongation of 10%. Several examples of the use of these alloys for making drop forgings and other parts for aircraft work are illustrated.—A. R. P.

***Magnetic Atomic Moment of Manganese Dissolved in Copper, Silver, and Gold.** Gotthard Gustafsson (*Ann. Physik*, 1936, [v], 25, (6), 545–560).—The magnetic susceptibilities of copper, silver, and gold containing up to 4–7 atomic-% manganese have been determined at temperatures between 20° and 450° C.—v. G.

***X-Ray Analysis of Manganese-Rich Manganese-Silicon Alloys.** K. Åmark, B. Borén, and A. Westgren (*Metallwirtschaft*, 1936, 15, (36), 835–836).—Manganese alloys with 14–25% silicon quenched from 1000° C. show lines of the cubic phase Mn₃Si. After annealing at 600°–800° C. the X-ray diagram shows numerous feeble lines, difficult to interpret, but apparently indicative of complex transformations. The atomic arrangement in the hexagonal phase Mn₅Si₃ was also investigated.—v. G.

***Magnetic Anisotropy of Nickel-Cobalt Single Crystals.** J. W. Shih (*Phys. Rev.*, 1936, [ii], 50, (4), 376–379).—The magnetic properties of single crystals of nickel-cobalt alloys have been studied in the face-centred cubic range with a pendulum magnetometer. The direction of easiest magnetization changes from <111> to <100> as the cobalt content increases from 3 to 10%, but changes back to <111> when the cobalt content is more than 20%. The theory of Powell and Fowler (*Proc. Roy. Soc.*, 1930, [A], 130, 167) is inadequate to explain those results. There is a discrepancy between the present results and those of Masumoto (*J. Inst. Metals*, 1927, 38, 413) for polycrystalline specimens.—W. H. R.

A "Free Machining" Monel Metal. O. B. J. Fraser (*Iron Age*, 1936, 138, (7), 37).—Briefly describes the properties of "R" Monel metal.—J. H. W.

***X-Ray Investigations in the Ternary System Nickel-Copper-Zinc.** J. Schramm and O. Vaupel (*Metallwirtschaft*, 1936, 15, (31), 723–726).—The phase fields at low temperatures in the system have been determined by X-rays.—v. G.

***Rolling and Recrystallization Textures of Iron-Nickel Alloys in Relation to the Magnetic Properties.—II.** Otto Dahl and Franz Pawlek (*Z. Metallkunde*, 1936, 28, (8), 230–233).—The variations in the tensile strength, elongation, coercivity, and magnetic permeability of 60 : 40 iron-nickel alloy in directions inclined at various angles to the direction of rolling are shown in polar coordinates after different heat and mechanical treatments. After cold-rolling to 80% reduction, annealing at 1000° C., and cold-rolling to 50% reduction there is relatively little directionality in any of these properties; the same is true for 50% cold-rolling before and 94% after the annealing operation, but this treatment increases the values of all the properties except maximum permeability. After cold-rolling to 50% reduction, annealing at 700° C., cold-rolling to 98.5% reduction, and annealing at 1100° C. to produce a fibre structure the elongation is a maximum at 45° to the direction of rolling and a minimum in the direction of rolling and perpendicular thereto while the remanence, permeability, and tensile strength behave conversely and the coercivity is constant in all directions. After 98.5% reduction by cold-rolling, annealing at 1000° C. and cold-rolling to 50% reduction the maximum permeability and remanence are very high perpendicular to, and very low in the direction of rolling, the converse being true for the other properties. Somewhat similar results are obtained with an alloy of nickel 34.8, copper 13, and iron 52.2%; after quenching from 1000° C. and cold-rolling to 94% reduction the initial permeability is a maximum at 30° to the direction of rolling, the coercivity a maximum at 30° and 60° to this direction and a minimum at 45° while the tensile strength is fairly constant. The same alloy after furnace cooling from 1000° C. and cold-rolling to 94% reduction shows remarkable

increases in all the magnetic properties and a somewhat smaller degree of directionality.—A. R. P.

***The Influence of Elastic Stresses on the Magnetization Curve [of Nickel-Iron Alloys] with Alternating Current.** Hans Littmann (*Ann. Physik*, 1936, [v], 27, [v], 27, (3), 186–200).—The effects of annealing and of tensile pulls and torsion on the magnetization curve of nickel-iron alloy wires have been investigated.

—v. G.

***On the Effect of Tensile, Compression, and Torsion Stresses on the Longitudinal Magnetostriction.** Hermann Kirchner (*Ann. Physik*, 1936, [v], 27, (1), 49–69).—The results obtained on nickel, nickel-iron alloys, and nickel containing 0.5% beryllium are recorded.—v. G.

***On the System Nickel-Zinc.** W. Heike, J. Schramm, and O. Vaupel (*Metallwirtschaft*, 1936, 15, (28), 655–662).—A re-examination of the system has confirmed the results obtained in the authors' earlier work (in 1933) in all the essential points, despite adverse criticisms of Tamaru and of Caglioti.

—v. G.

White Metal and Bronze Bearings from the Manufacturer's Point of View. M. Melhuish (*Proc. Inst. Automobile Eng.*, 1936, 30, 431–443; discussion, 444–452).—The manufacture of tin-base and lead-base white metals, the common impurities and their influence, and the effects of methods of alloying are discussed. The several methods of lining with white metals are compared and pressure die-casting is recommended. The properties and applications of leaded bronzes, and copper-lead are described, followed by a brief reference to phosphor-bronze in the cast and rolled conditions. In the discussion (at the 3 centres of the Institute where the paper was presented) adhesion of the lining metals, clearances and lubrication were the principal points raised.—J. E. N.

Steam, Dry Air Anneal, and Normal Ageing Test Data on the Zamak Alloys. —(*Zinc Alloy Pot*, 1934, 2, (1), 8).—A table giving 3 types of data: 3-year indoor ageing data representing a direct service test under normal conditions; 2-year ageing at 95° C. representing a service test under continuous exposure to the maximum temperature likely to be encountered; and 10-year steam test—a reliable accelerated test accurately predicting the effect of long tropical exposure.—S. G.

†**Diffusion in Solid Metals.** Robert F. Mehl (*Metals Technology*, 1936, 3, (5), 46 pp.; and *A.I.M.M.E. Tech. Publ.* No. 726).—In the Institute of Metals Division Lecture for 1936, M. gives a complete and critical review of the phenomena of diffusion in solid metals, with a *bibliography* of references to 302 original papers. The paper deals with (1) the fundamental diffusion equations and methods of determining the constants, (2) the physical theory and the equations of Dushman and Langmuir, (3) rates of diffusion, (4) results of metallographic investigations of structures produced by diffusion, (5) anisotropic effects, (6) lattice distortion effects, (7) grain boundary diffusion, (8) surface diffusion, and (9) applications to industrial processes of the results of research work on diffusion. The lecture is an exceptionally interesting review of the subject.—W. H.-R.

Precipitation from Cast and Worked Material. —(*Metallurgist* (Suppt. to *Engineer*), 1936, 10, 134).—Discussion of work by H. Bumm and V. Dehlinger, *Metallwirtschaft*, 1936, 15, (4), 89; see *Met. Abs.*, this vol., p. 301.—S. G.

III.—STRUCTURE

(Metallography; Macrography; Crystal Structure.)

(Continued from pp. 396–397.)

†**The Boundaries of Metal Crystals. A Critical Review.** E. H. Bucknall (*Met. Ind. (Lond.)*, 1936, 49, (13), 311–316; (15), 369–373; (16), 396–399).—The properties of crystal boundaries have been the subject of speculation and

research for 35 years. The various theories are critically reviewed in the light of most recent knowledge, and the development of Rosenhain's theory is traced. The properties of thin films and electrodeposited metals have been studied, and led to the hypothesis that an adsorbed film is the material between metal grains. It is suggested that a consideration of inter-crystalline penetration by diffusing elements has indicated the importance of active adsorption and points to the probability of formation of adsorbed layers at grain boundaries as well as external surfaces. A bibliography of 125 references is given.

—J. E. N.

***Some Studies in Microstructure of Zinc Coatings.** W. E. Buck (*J. Amer. Zinc Inst.*, 1936, 17, 70-75).—Samples of hot-dipped spelter-coated or galvanized sheets of long and short service were sectioned and examined microscopically. Coating weights were determined either by the standard $2\frac{1}{4}$ in. \times $2\frac{1}{4}$ in. spot test of the American Society for Testing Materials, stripping the coating with hydrochloric acid and antimony chloride, or by a variation of Cushman's hydrogen evolution test. It is shown that the microscopic confirmation of the nature of the coatings may throw much light on unexplained coating failures.—J. H. W.

***The Influence of Valency Electrons on the Crystal Structure of Ternary Magnesium Alloys.** F. Laves and H. Witte (*Metallwirtschaft*, 1936, 15, (36), 840-842).—The connection between the concentration of valency electrons and the structure of some ternary magnesium alloys has been detected. (Analogy to the Hume-Rothery Rule.)—v. G.

***The Crystal Structure of β -Titanium.** W. G. Burgers and F. M. Jacobs (*Z. Krist.*, 1936, 94, (4), 299-300).—[In English.] β -titanium which is stable above about 900° C. ($882^\circ \pm 20^\circ$ C. according to de Boer, Burgers, and Fast (*Proc. K. Akad. Wet. Amsterdam*, 1936, 39, 515), has a body-centred cubic structure with 2 atoms in the unit cell. The lattice constant just above the transition temperature is $a = 3.32$ Å.—W. H.-R.

***Energy Bands in Metallic Tungsten.** Millard F. Manning and Marvin Chodorow (*Phys. Rev.*, 1936, [ii], 50, (4), 399).—Abstract of a paper read before the American Physical Society.—S. G.

***Anisotropy in the Atomic Vibrations of Zinc Crystals. I.—Evidence from X-Ray Scattering.** G. E. M. Jauncey and W. A. Bruce (*Phys. Rev.*, 1936, [ii], 50, (5), 408-412).—W. H.-R.

***Anisotropy in the Atomic Vibrations of Zinc Crystals. II.—Diffuse Scattering of X-Rays from Single Crystals.** G. E. M. Jauncey and W. A. Bruce (*Phys. Rev.*, 1936, [ii], 50, (5), 413-416).—W. H.-R.

***Anisotropy in the Atomic Vibrations of Zinc Crystals. III.—The (0002) and (1010) Reflections of MoK_α X-Rays from Powdered Zinc.** D. D. Miller and E. S. Foster, Jr. (*Phys. Rev.*, 1936, [ii], 50, (5), 417-418).—W. H.-R.

***On the Intensity of X-Rays Reflected from Zinc.** Clarence Zener and S. Bilinsky (*Phys. Rev.*, 1936, [ii], 50, (5), 489).—A theoretical note.—W. H.-R.

Comparison of Linear and Volume Contraction in Intermetallic Compounds. F. Laves (*Metallwirtschaft*, 1936, 15, (27), 631-639).—The lattice dimensions of intermetallic compounds can be predicted only within certain limits.

—v. G.

***The Elimination of Systematic Errors in Powder Photographs.** M. U. Cohen (*Z. Krist.*, 1936, 94, (4), 288-298).—[In English.] A general method is developed for eliminating the most important systematic errors in X-ray powder photographs when the camera is of such a type that the X-ray beam enters the camera at the middle of the film. If the camera construction is such that the X-ray beam enters at the ends of the film, a further correction for film shrinkage must be made. The adverse criticism by Straumanis (*Met. Abs.*, this vol., p. 306) of C.'s method is due to a misunderstanding.

—W. H.-R.

*The Calculation of Precise Lattice Constants from X-Ray Powder Photographs. M. U. Cohen (*Z. Krist.*, 1936, **94**, (4), 306-310).—[In English.] The details of C.'s method (preceding abstract) for eliminating errors in powder photographs are further discussed.—W. H.-R.

Determination of Parameters in Debye Photographs of Polished Sections. L. S. Palatnik (*Zhurnal Tehnicheskoj Fiziki (J. Tech. Physics)*, 1935, **5**, (8), 1353-1355).—[In Russian.]—N. A.

Analysis of Material by X-Ray Diffraction Method.—I-II. Herbert R. Isenburger (*Machinist (Eur. Edn.)*, 1936, **80**, (28), 422-424E; (29), 477-479E).—(I.—) Discusses the theoretical considerations of X-ray diffraction analysis and describes the equipment required. (II.—) Describes the method of carrying out the analysis and the interpretation of the results.—J. H. W.

*Theory of the Effect of Temperature on the Reflection of X-Rays by Crystals. III.—High Temperatures. Allotropic Crystals. Clarence Zener and S. Bilinsky (*Phys. Rev.*, 1936, [ii], **50**, (2), 101-104).—W. H.-R.

IV.—CORROSION

(Continued from pp. 397-402.)

*Corrosion Tests with Pure Aluminium and Aluminium Alloys. E. Zurbrügg (*Gas- u. Wasserfach*, 1935, **78**, 946; *C. Abs.*, 1936, **30**, 2156).—Experiments were made with aluminium of varying purity in Neuhausen water. Aluminium of 98-99% purity was distinctly attacked by carbon dioxide, but 99.3% aluminium was not. In the past, corrosion of aluminium has been attributed to the presence of copper or lead on the aluminium surface, due to introduction during rolling, &c. These metals may also come from water previously passing through lead or copper tubing. Weakly acid water, containing as little as 0.05 mg. copper per litre, precipitated copper on the aluminium and caused corrosion.—S. G.

*Intensification of the Tower Process and the Corrosion of Lead. I. E. Adadurov, A. I. Dmitrieva, and V. M. Zinovich (*Zhurnal Khimicheskoi Promishlennosti (J. Chem. Ind.)*, 1936, **13**, 660-663; *C. Abs.*, 1936, **30**, 6515).—[In Russian.] Cf. *Met. Abs.*, 1935, **2**, 596. Lead is more strongly attacked in the tower system the higher the temperature, strength of acid, and amount of N_2O_3 present. To obtain a minimum loss of lead, the acid in the Glover tower should not be stronger than 58°-59° Bé, and the N_2O_3 should be 2.3-3%. The acid entering the Gay-Lussac tower should not be weaker than 59° Bé at not over 30°-35°. The intensity of the process is not effected by these limits.—S. G.

Corrosion. V.—Corrosion and Water Mains. — Thiesing (*Gas- u. Wasserfach*, 1935, **78**, 429-431; *C. Abs.*, 1936, **30**, 3389).—The phenomenon associated with the corrosion of iron and lead water mains and the preventive means adopted are briefly reviewed.—S. G.

The Chemical and Electrolytic Corrosion of Subterranean Conductors. R. Gibrat (*Ann. Postes, Télégraphes Téléphones*, 1936, **25**, (8), 717-743).—Corrosive attack on underground conductors may be initiated either by chemical action between the metal and the soil, or through the influence of stray currents from an external source. The conditions governing both types of attack are reviewed, and a description is given of the use of the "differential" soil-corrosion apparatus of Schlumberger in the investigation of 2 cases of electrolytic corrosion, which are both due to stray currents.—P. M. C. R.

Corrosion Tests on Galvanized Sheet. W. Räderer and R. Haarmann (*Illust. Zeit. Blechindustrie*, 1936, **65**, (36), 1073-1074).—The Schreiber boiling test, in which the corrosion products are retained on the surface of the test-piece, is considered preferable to other methods (salt-spray, copper sulphate,

solvent attack) which involve the removal of the corrosion product. The Schreiber method is described. It is emphasized that actual atmospheric exposure is necessarily more valuable than any accelerated method, and the results of a series of such tests are given in the case of sheet manufactured by different methods.—P. M. C. R.

***The Action of Cream and Butterfat on Metals and the Influence of Metals on the Quality of Butter and Butterfat.** W. Mohr and A. Eichstädt (*Molkerei-Zeit. (Hildesheim)*, 1936, **50**, 1480–1482; *C. Abs.*, 1936, **30**, 6837).—Cf. *Met. Abs.*, 1935, **2**, 384. Of numerous metals and alloys studied, V2A steel, aluminium, and chromium-plated or tinned copper strips were corroded least when exposed in heated or soured cream. The same metals had least effect on the flavour of butter. Chromium-plated copper and tinned copper were corroded less than other metals by cream when exposed in combination with V2A steel, aluminium, and copper. No flavour defects were produced in butterfat by the use of tinned or enamelled containers, or by V2A steel containers.—S. G.

***Corrosion in Cooling Brines.** H. Osterburg (*Milchwirtschaftl. Zentr.*, 1935, **64**, 303–307; *Chem. Zentr.*, 1936, **107**, (I), 170).—Investigations with solutions of chemically-pure salts showed that alkali salt brines have least effect on iron, while magnesium chloride solutions have the greatest. Potassium and sodium chlorides are preferred for use with zinc. Alkali brines have the greatest corroding effect on tin and aluminium. The quantity of metal dissolved was remarkably small.—L. A. O.

Principles for the Simplification of the Testing Conditions in Corrosion Tests. DIN 1703. — (*Z. Metallkunde*, 1936, **28**, (1), 20–21; and (abridged) *Light Metals Research*, 1936, **4**, (22), 384–385).—Standard conditions are laid down for the selection of the test-piece, the preparation of the surface, and the dimensions. In reporting results the nature and concentration of the corroding medium, the temperature, and the presence or absence of air and agitation should be specified. The results should be reported as change in weight and change in mechanical properties; information should also be given on the change in surface appearance, any change in structure, the nature and type of corrosion products, and the change in the composition of the corroding medium.—A. R. P.

Cleaning Copper Strips Used in the Determination of the Corrosive Action of Petroleum Products. E. G. Ivanova (*Neft (Petroleum)*, 1936, **7**, (6), 21–22; *C. Abs.*, 1936, **30**, 6178).—[In Russian.] Satisfactory results were obtained by treating copper strips with 5% ammonia and neutralizing with oxalic acid.—S. G.

V.—PROTECTION

(Continued from pp. 402–404.)

***Modern Plated Aluminium-Copper-Magnesium Alloys and Their Properties.** Paul Brenner (*Z. Metallkunde*, 1936, **28**, (9), 276–280; discussion, 280).—A thin coating of pure aluminium (1% of the total thickness) on sheet of the Duralumin type of alloys considerably increases the resistance to corrosion without appreciably affecting the strength; with a 5% coating the strength is reduced by 5–7%, but the resistance to corrosion is practically equal to that of pure aluminium and the metal will withstand more prolonged heat-treatment without depreciation of the protective value of the coating by diffusion. A very high resistance to corrosion without reduction in strength is obtained by plating with the Hydronalium alloy BSS, which has a high surface hardness and resists diffusion of the copper from the base-metal during heat-treatment.

—A. R. P.

Protection of Aluminium Alloys from Corrosion. D. N. Shevzov (*Sudostroenie (Shipbuilding)*, 1936, (5), 329-334).—[In Russian.] A review.—N. A.

Measures Against Corrosion in Aviation. V. O. Kroenig (*Aviopromishlenost (Air Industry)*, 1936, (4), 23-26).—[In Russian.] A review.—N. A.

Aluminium Plating for the Protection of Metals from High-Temperature Oxidation. V. F. Negreev and S. G. Znaichenko (*Neft (Petroleum)*, 1936, 7, (5), 24-25; *C. Abs.*, 1936, 30, 5924).—[In Russian.] The advantages of aluminium plating various parts of equipment exposed to high temperatures are discussed.—S. G.

***Porosity Tests for Zinc-Coated Iron and Steel.** W. A. Koehler and R. O. Burford (*Electrochem. Soc. Preprint*, 1936, Oct., 241-244).—It has been found practical to apply the Walker test for pin-holes, when iron or steel is coated with zinc, using an external e.m.f. to produce ferrous ions at the points where the iron is exposed. Paper impregnated with a test solution can also be used for the test with or without an external e.m.f., depending on the nature of the metal coating on the iron.—S. G.

***Some Studies in Microstructure of Zinc Coatings.** (Buck.) See p. 458.

***Influence of Hot-Dip Galvanizing on the Endurance Bending Strength and the Regularity of the Tensile Properties of Drawn Steel Wire.** Franz Greis and Herbert Ruppik (*Arch. Eisenhüttenwesen*, 1936-1937, 10, (2), 69-71).—Hot-dip galvanizing of steel wire reduces the endurance limit (alternate bending test) owing to the formation of the hard zinc-iron intermediate layer and the roughening of the surface in the pickling bath. These effects are enhanced by irregular quenching as the wire leaves the zinc bath, but may be mitigated to a considerable extent by annealing followed by a careful quenching.—A. R. P.

Longer Life for Galvanizing Furnaces. Wallace G. Imhoff (*Machinist (Eur. Edn.)*, 1936, 80, (1), 18E-20E).—The destructive forces acting on the pot in hot-galvanizing are briefly considered, with particular reference to the action of galvanizers' dross and of sal ammoniac.—J. H. W.

A New Galvanizing Furnace. W. H. Spowers, Jr. (*Heat-Treat. and Forging*, 1936, 22, (7), 356-358; and *Indust. Heating*, 1936, 3, (6), 375-378).—Heating of a large galvanizing pot by radiation from electrical elements showed many advantages, but cost of electric power in many districts in U.S.A. prevented its wider adoption. The principle has been extended to other fuels, and an installation is described in which the galvanizing kettle is heated by vertical tubes of chrome-nickel alloy, heated from the inside by gas, and applying to the side walls of the galvanizing kettle heat given off by the glowing tubes. Perfect heat control, long life for the kettle, fuel economy, very low dross formation, and low heat losses are among the advantages claimed.—J. E. N.

To Exhibit New Zinc Plating Process at Metals Exposition. — (*Amer. Metal Market*, 1936, 43, (200), 3).—A brief note of a new process using a new brightening agent, which is claimed to be particularly adaptable for use in barrel plating of building hardware, radio parts, electrical fixtures, and other metal equipment where attractive appearance is important. The new brightening agent is a liquid which is easy to handle and control. It is non-corrosive, non-inflammable, and non-toxic.—L. A. O.

The Protection of Zinc by Phosphate and Chromate Processes. Hugo Krause (*Illust. Zeit. Blechindustrie*, 1936, 65, (35), 1037-1038).—An account is given of the "Granodizing" process as applied to zinc and its alloys, plain or cadmium-plated, and of a dichromate immersion process for the treatment of zinc, cadmium, and the zinc-cadmium alloys. References to the relevant patents are given.—P. M. C. R.

***On the Chemical Polarization of the Hydrogen Electrode by Oxygen and the Problem of Electrolytic Corrosion Protection.** Arthur F. Lorch (*Electrochem. Soc. Preprint*, 1936, Oct., 173-178).—The chemical polarization of the hydrogen electrode by oxygen was investigated and found to bear a simple relation to its

electrical polarization. The current equivalent of a given concentration of oxygen remains constant over a wide range of potentials except that at sufficiently positive potentials oxygen ceases to react at the cathode. From the results obtained it is possible to explain the failure of electrolytic corrosion protection in some cases.—S. G.

The Adhesion of Rubber to Metals. V. Evstratov and N. Trankovskaya (*J. Rubber Ind. (U.S.S.R.)*, 1936, 578–582).—[In Russian.] A description, with 50 references.—S. G.

The Corrosion Problem. Paints and Anti-Corrosive Coatings. Georges Genin (*Indust. chimique*, 1935, 22, 802–806; 1936, 23, 10–15, 322–325, 402–405; *C. Abs.*, 1936, 30, 6217).—A general discussion of various types of metallic coatings, aluminium paints, and anti-rust coatings resistant to high temperatures.—S. G.

VI.—ELECTRODEPOSITION

(Continued from pp. 404–407.)

Cadmium-Plating in Precision Industry. A. M. Sokov (*Tochnaja Industrija (Präzisions Ind.)*, 1936, (8–9), 19–20).—[In Russian.] The Westbrook bath is recommended and a description of the process given.—N. A.

***The Theory of Electrolytic Chromium Plating.—II.** Robert Weiner (*Z. Elektrochem.*, 1936, 48, (8), 585–598).—See *Met. Abs.*, this vol., p. 366. Further theoretical explanations on the process of electrolytic chromium plating are given. The difference in behaviour of gold, platinum, and carbon from that of base metals was thoroughly, if not exhaustively, investigated, and the important metals in chromium plating practice, namely iron, nickel, and copper, were examined. Owing to the extraordinarily varying, and at first completely contradictory, results, a rigorous explanation was put forward, bringing other base metals into consideration; although this led to further complications, a satisfactory theory to account for the many and varied phenomena was evolved.—J. H. W.

The Nickel and Chromium Plating of Aluminium and Aluminium Alloys. E. Raub (*Mitt. Forschungsinst. Edelmetalle*, 1936, 9, (11/12), 111–121; and *Metallwaren-Ind. u. Galvanotech.*, 1936, 34, (8), 150–154).—When aluminium sheet is nickel- or chromium-plated by any of the standard methods the first step in which involves an etching operation to remove the surface oxide film, the resulting plated metal does not withstand corrosive conditions well since the plate is invariably porous due to the roughness of the surface of the aluminium. Examples of this are shown after exposure to salt-spray (which produces intense pitting) and steam (which causes the plate to flake off). It is stated that there is now available a method of treating the aluminium surface, which removes the oxide film without spoiling the polish of the metal and provides a smooth surface on to which first nickel and then chromium can be plated in such a way that the coatings do not flake even when the plated sheet is bent; such coatings are claimed to be absolutely non-porous, but no details are given of the method.—A. R. P.

Special Appliances for Chromium-Plating of Round Calibration Instruments. P. E. Fomin (*Tochnaja Industrija (Präzisions Ind.)*, 1936, (6), 11–13).—[In Russian.] The workshop plant and the process of chromium-plating adopted at the works are described.—N. A.

Electrolytic Lead Coating (from Fluosilicate Solutions). P. P. Beljaev and J. B. Gurevich (*Zhurnal Khimicheskoy Promishlenosti (J. Chem. Ind.)*, 1936, 13, (10), 602–605).—[In Russian.] The method and apparatus used at the "Dorkhim" works are described.—N. A.

Nickel Anodes. Tentative Standards DIN 1702. — (*Z. Metallkunde*, 1936, 28, (6), 182).—The following specification is suggested: composition—

nickel not less than 99, copper not more than 0.25, iron less than 0.05, manganese less than 0.01, zinc less than 0.01, and magnesium less than 0.05%; the anodes must be tough and free from brittleness, have a homogeneous structure free from segregations along the grain boundaries, and be free from a casting or rolling skin.—A. R. P.

Nickel Anodes. E. Raub (*Mitt. Forschungsinst. Edelmetalle*, 1936, 10, (4), 37–43).—Various types of nickel anodes are described and their relative merits discussed. The effect of small amounts of impurities in the anode on its rate of corrosion in the bath and on the plating process is briefly described.

—A. R. P.

***Electroplating of Aluminium and Its Alloys with Zinc, Cadmium, Copper, Nickel, and Chromium.** V. I. Lainer and S. I. Orlov (*Legkie Metalli (Light Metals)*, 1936, (2), 22–33).—[In Russian.] A common method of preparing an aluminium surface for electroplating is to immerse it for 1–3 minutes in sodium zincate solution d 1.25–1.4, then to degrease in an alkaline cyanide bath. Plating with zinc is best carried out at 1–1.5 amp./dm.² in a bath containing zinc oxide 45 and sodium cyanide 100 grm./litre without addition of colloids, but for cadmium plating an acid bath containing cadmium sulphate crystals 100, ammonium sulphate 65, and peptone 1.5–2 grm./litre at p_H 3–4 with 0.7 amp./dm.² is the most satisfactory. A copper undercoat should be used only when the article is to be subsequently plated with nickel or cadmium; this is preferably obtained by flashing in a cyanide bath, then building up the deposit in the ordinary acid sulphate bath. Nickel or chromium plating over the copper layer is sufficiently good in ordinary baths.—D. N. S.

***The Electrolysis of Aqueous Solutions of Sodium and Zirconyl Sulphates. I.—A Preliminary Report.** W. E. Bradt and Henry B. Linford (*Electrochem. Soc. Preprint*, 1936, Oct., 363–371).—Aqueous solutions of sodium and zirconyl sulphates were electrolyzed under controlled conditions. Difficulties due to the hydrolysis of zirconyl sulphate were partially avoided by the addition of sodium sulphate. Factors investigated were: concentration of zirconyl sulphate, concentration of sodium sulphate, hydrogen ion concentration, current density and temperature of electrolyte. Electrodeposited metallic zirconium was obtained in 2 forms. One is a silver-white, compact, adherent metal similar to nickel electroplate in appearance. This slowly changes to the other modification which appears to be a non-adherent aggregation composed of a black powder which may be zirconium or some oxidation product of zirconium. Conditions are described for obtaining thin deposits of compact, bright metal.—S. G.

***The Formation and Growth of Pits in Electrodeposited Metals.** Michel Cymboliste (*Electrochem. Soc. Preprint*, 1936, Oct., 347–362).—Pits in electroplating, notably nickel deposition, are attributed to bubbles, either of hydrogen or other gases. The origin of these gas bubbles is discussed at length, and different types of pits are illustrated with the aid of numerous photomicrographs. Furthermore, it is emphasized that most bubbles are non-adherent. The adherence of bubbles to the basis metal, or to the surface of the electrodeposited metal, is attributed to a wide variety of possible irregularities in this surface, such as scratches, nodules, foreign particles which have anchored themselves to the surface, &c. Gas bubbles may continue to adhere without increasing in volume, or they may grow in size and either remain at the surface or detach themselves and escape from the solution. The interposition of a thin coat of copper between 2 coats of nickel is suggested as a practical means for the elimination of pits.—S. G.

***The Co-deposition of Metals of the Same Valence in Acid Solutions.** W. George Parks and I. Milton LeBaron (*Electrochem. Soc. Preprint*, 1936, Oct., 235–239).—The co-deposition of 2 metals of the same valence was investigated. The following systems were included: zinc-cadmium, copper-cadmium,

nickel-copper, zinc-copper, and silver-thallium. The cathode potential method previously described (*Met. Abs.*, this vol., pp. 163, 406) was employed at different current densities, at room temperature, in solutions of p_{H_2} 5. The variation of co-deposition with difference in electrode potential has been determined, and the equation derived for co-deposition of monovalent and bivalent metals of the same valence.—S. G.

Overpotentials in the Electrodeposition of Metals on Indifferent Cathodes. A. G. Samartzev and K. S. Eustropiev (*Izvestia Akademii Nauk S.S.S.R. (Bull. Acad. Sci. U.R.S.S.)*, 1934, [vii], 603-613; *Brit. Chem. Abs.*, 1934, [A], 1178).—[In Russian.] The deposition of metals (cadmium, silver) begins at a higher potential than that attained after a few minutes; this phenomenon is not due to growth of the crystals but to the passage of the metal through a state intermediate between the ionic and the metallic.—S. G.

***Some Peculiarities of Electrodeposited Metals.** Ladislav Jenicek (*Rev. Mét.*, 1936, 33, (6), 371-378).—Electrodeposited chromium and iron contract on heating, much more than nickel, and the softening that occurs follows a curve of the same form as that for contraction. No contraction was observed with copper, and there was very little reduction in hardness on heating. Change of structure also results from heating, and recrystallization occurs on heating to temperatures higher than those required to reduce the hardness.

—H. S.

The Development of Electroplating. D. J. Macnaughtan (*Met. Ind. (Lond.)*, 1936, 49, (13), 323-324).—A paper forming the introduction to a discussion on electroplating at the 1936 meeting of the British Association.—J. E. N.

The Future of Electrodeposition. H. J. T. Ellingham (*Met. Ind. (Lond.)*, 1936, 49, (13), 324-325).—The concluding contribution to the discussion on electroplating at the 1936 meeting of the British Association.—J. E. N.

VII.—ELECTROMETALLURGY AND ELECTROCHEMISTRY

(Other than Electrodeposition.)

(Continued from pp. 407-408.)

***The Mechanism of Electrolytic Separation of Hydrogen by Palladium and Platinum.** L. Kandler and C. A. Knorr (*Z. Elektrochem.*, 1936, 42, (9), 669).—Experiments on the cathodic polarization of pure palladium and platinum electrodes in 2*N*-sulphuric acid solution showed that quite different current-e.m.f. curves are obtained according as to whether: (1) no gas, (2) hydrogen, or (3) nitrogen is introduced into the cathode vessel during the measurement. The curves of the e.m.f. against the logarithm of the current density in (1) and (3) are straight lines; that in (2) is a curve lying between (1) and (3). According to Tafel, in case (2) with the highly active palladium and platinum electrodes, the reaction $2H \rightarrow H_2$ occurs, together with the determining back-reaction, $H_2 \rightarrow 2H$. In case (1), in the absence of the gas phase, the migration of the molecular hydrogen from the electrode to the solution is, according to Nernst, a slow process, and the hydrogen concentration on the electrode, and hence the velocity of the back reaction $H_2 \rightarrow 2H$, increases linearly with the current density. Thus it appears possible that with pure palladium and platinum electrodes and under suitable conditions, the mechanism of the electrolytic separation of hydrogen according to both Nernst and Tafel can be realized.—J. H. W.

***The Potential Differences at Metal-Vapour, Vapour-Liquid, and Liquid-Metal Interfaces of Partially Immersed Electrodes.** Colin G. Fink and Richard C. Dehmel (*Electrochem. Soc. Preprint*, 1936, Oct., 245-284).—A method was devised and special apparatus has been designed and constructed for verifying the existence and measuring the magnitude of the potential difference existing across the vapour between the exposed portion of a partially immersed electrode

and the surface of the solution into which it is dipping. A shielded oscillating electrode has been developed which makes possible the measurement of rapidly changing contact potential differences. The oscillating electrode system permits the use of an a.c. amplifier and an audible detector, thereby providing high sensitivity with excellent electrical stability. Quantitative determinations of the potential across the vapour were made with copper, gold, and platinum, each dipping into aqueous molar solutions of their salts. The change resulting from oxygen admission which occurred in the potential drop across the vapour was studied quantitatively. The effects of dissolved oxygen on the solution potentials were also determined. The effect of the potential difference existing across the vapour at a partially immersed electrode on its corrosion is discussed.—S. G.

Electrolytic Separation of Light Metals from Non-Aqueous Solutions. I.—Preliminary Experiments of Electrolysis of Alkali Metal Salt Solutions. M. A. Klochko (*Zhurnal Prikladnoi Khimii (J. Applied Chem.)*, 1936, 9, (3), 420–433).—[In Russian.] Electrolysis of solutions of double alkali-aluminium halides (formed by fusing the two salts together) in nitrobenzene affords cathodic deposits of the alkali metal in current yields of 35–70%. Li, Na, K, and Rb have been obtained from the double bromides and Li and Na from the double chlorides.—N. A.

***Studies of Overvoltage : The Effect of Fusion of the Cathode and the Effect of Temperature on Gas Polarization.** Allison Butts and W. A. Johnson (*Electrochem. Soc. Preprint*, 1936, Oct., 205–220).—Cell voltages were measured and gas polarization voltages determined in cells with Wood's alloy cathode and with a gallium cathode, while the temperature of the cell varied so as to cause the cathode to melt and to freeze. Voltage-temperature curves and voltage-time curves were obtained at constant current densities. No change of polarization was found during melting or freezing except in the case of Wood's alloy when the alloy had not reached equilibrium. Sharp increases of voltage were observed with the liquid gallium cathode (not during freezing), and also sudden pronounced flattening of the liquid gallium. Overvoltages of hydrogen were measured on solid and liquid Wood's alloy and gallium.—S. G.

***On the Problem of Hydrogen Overvoltage.** P. P. Porfirov (*Zhurnal Obshchei Khimii (J. General Chem.)*, 1934, 4, 1311–1321 (in Russian); and *Dokladi Akademii Nauk S.S.S.R. (Compt. rend. Acad. Sci. U.R.S.S.)*, 1935, [N.S.], 1, 386–390 (in Russian), 390–392 (in English)).—Experiments are described which were carried out in an attempt to settle the controversy regarding the existence of the so-called contact (or transfer) resistance on the cathode during the evolution of hydrogen.—S. G.

***Electrolysis of Alumina with Incombustible (Metal) Electrodes.** A. I. Beliaev and J. E. Studentsov (*Legkie Metalli (Light Metals)*, 1936, (3), 15–24).—[In Russian.] The possibilities of alumina electrolysis with copper, nickel, chromium, and silver anodes were investigated. The use of an equimolecular mixture of potassium and sodium cryolites as electrolyte allows of a minimum working temperature of 936° C. The solubility of aluminium oxide in this bath is 13% at 830° C. In all cases rapid destruction of the anodes by oxidation occurred.—D. N. S.

IX.—ANALYSIS

(Continued from pp. 408–409.)

Researches on Spectrographic Analysis. W. Gerlach and W. Rollwagen (*Metallwirtschaft*, 1936, 15, (36), 837–840).—In most cases it is much easier to detect impurities with the flaming arc than with the spark method of exciting the spectrum. The sensitivity is improved if the arc is electrically interrupted.

—v. G.

Fractional Reaction for Antimony. N. A. Tananaev and L. M. Rabinovich (*Zhurnal Prikladnoi Khimii (J. Applied Chem.)*, 1936, 9, (2), 369-371).—[In Russian.] As little as 0.1 mg. of Sb per c.c. may be detected as HSbO₃ or by reaction of HgCl₂ with tervalent Sb.—N. A.

***Quantitative Separation and Determination of Aluminium and Zinc.** F. H. Fish and J. M. Smith, Jr. (*Indust. and Eng. Chem. (Analyt. Edn.)*, 1936, 8, (5), 349-350).—The neutral solution of the two metals is treated with LiCl, 5 gm. of CH₃·CO₂NH₄, and NH₄OH until the liquid is faint pink with phenolphthalein. The precipitate is washed with a 2% solution of CH₃·CO₂NH₄, dissolved in dilute HNO₃, and reprecipitated as before; the second precipitate is ignited and weighed as 2Li₂O·5Al₂O₃ (47.40% Al). Zn in the filtrate is precipitated as ZnNH₄PO₄, which is ignited to Zn₃P₂O₇ for weighing.—A. R. P.

Volumetric Determination of Arsenic in the Presence of Iron Salts. Wilhelm Daubner (*Angew. Chem.*, 1936, 49, (7), 137-138).—The solution is neutralized with NH₄OH, made feebly acid with CH₃·CO₂H, and treated hot with (NH₄)₃AsO₄ to precipitate a mixture of AlAsO₄ and FeHASO₄. The washed precipitate is dissolved in acid and the As determined volumetrically. Fe is determined in the usual way in another portion of the solution and the Al calculated by difference.—A. R. P.

***Determination of Bismuth as Phosphate.** W. C. Blasdale and W. C. Parle (*Indust. and Eng. Chem. (Analyt. Edn.)*, 1936, 8, (5), 352-353).—A critical study of the conditions under which Bi can be precipitated quantitatively as phosphate showed that in the absence of Cl' and SO₄'' complete precipitation is obtained from solutions 0.2M with respect to HNO₃ if the excess of (NH₄)₂HPO₄ added is sufficient to give a 0.065M solution. K, Mg, Zn, Cu, and Ca do not interfere, Cd causes the results to be slightly high, and Pb renders the method inaccurate. The chief source of error is the co-precipitation of basic salts; this difficulty is overcome by precipitating from a hot solution with a hot dilute phosphate solution and digesting for 1 hr. at 80° C. Too great an excess of precipitant should be avoided to prevent contamination of the precipitate with excess of PO₄'''. The precipitate is finally ignited at 800° C. and weighed as BiPO₄.—A. R. P.

Microchemical Determination of Bismuth by Quinoline-Thiocyanate. M. V. Gapchenko and O. G. Sheintsis (*Zhurnal Prikladnoi Khimii (J. Applied Chem.)*, 1936, 9, (3), 544-566).—[In Russian.] A saturated aqueous solution of quinoline containing NH₄CNS gives with acid Bi solutions a characteristic golden-yellow crystalline precipitate; Zn'', Sn'', Sb''', Hg', and Ag' interfere, but Cu is without effect if the solution contains 10% of citric acid.—N. A.

***Separation and Determination of Bismuth with Gallic Acid.** L. Kieff and G. C. Chandlee (*Indust. and Eng. Chem. (Analyt. Edn.)*, 1936, 8, (5), 392).—Bi is quantitatively precipitated by addition of gallic acid to the hot (70° C.) nitrate solution containing 3% of HNO₃. The precipitate is washed with 2% gallic acid containing 3% of NH₄NO₃, dissolved in 20 c.c. of HNO₃, and precipitated as basic carbonate by addition of CH₃·CO₂NH₄. Pb, Cd, Cu, Zn, Al, Cr, Fe, Ni, Ba, Ca, K, and Na do not interfere although reprecipitation of the gallate is advisable if much of these metals is present. Sb, Hg, Sn, and Ag interfere.—A. R. P.

***Quantitative Determination of Cadmium and Lead in Zinc Using a Grating Spectrograph with a Sector Disc.** Harris M. Sullivan (*Indust. and Eng. Chem. (Analyt. Edn.)*, 1936, 8, (5), 382-383).—The sample is placed in the lower (positive) graphite electrode and an arc of 5 amp. at 220 v. passed between the electrodes (1 cm. gap). The arc is placed at the focal centre of a convex lens so that a parallel beam of light is thrown on the slit of the spectrograph. The logarithmic sector disc rotates at 300 r.p.m. and is adjusted, as close to the slit as possible, so that about 3 mm. length of the 16 mm. slit is left open at all times, the remainder of the slit opening varying during the time of exposure

as the sector disc rotates in front of it to cause the lengths of the lines on the film to vary according to their intensity. The lengths of the lines Cd 3261 and Pb 2833 and 2663 Å. are a measure of the proportion of these elements present although the relation is not exactly linear. The method gives results accurate to 10–15% for quantities of Pb or Cd in Zn of the order of 10 p.p.m.—A. R. P.

***Determination of Gold in Dental Alloys.** J. Lewis Maynard (*Indust. and Eng. Chem. (Analyt. Edn.)*, 1936, 8, (5), 368–369).—The chief constituents of dental alloys are Au, Ag, Pt, Pd, and Cu with sometimes minor amounts of Ir, Ni, Zn, Sn, and In. The alloy is dissolved in *aqua regia* and the Ag, Ir, and Sn removed by Swanger's method (*J. Inst. Metals*, 1926, 36, 519). The Au is then precipitated with SO₂, washed with hot 1% HCl, and redissolved in *aqua regia*. After removal of the HNO₃ by boiling with HCl and evaporating to 3 c.c.; 20 c.c. of H₂O are added followed by 4 c.c. of 15% N(C₂H₅)₄Cl for every 0.1 gm. of Au present. After 15 minutes the precipitate of N(C₂H₅)₄AuCl₄ is collected, washed 4 times with 5 c.c. of the precipitant, and boiled with 35 c.c. of 20% glucose solution containing 2 gm. of NaOH. The precipitated Au is collected, washed with water, then with hot HCl, and finally with hot water, dried, ignited, and weighed. The filtrate from the second Au precipitation is treated with H₂S to recover any Pt or Pd co-precipitated in the SO₂ process.—A. R. P.

†**Determination of the Fineness of Gold Alloys by the Streak Test.** K. Bihlmaier (*Mitt. Forschungsinst. Edelmetalle*, 1936, 10, (2/3), 27–34).—Full details are given of standard tests for ascertaining the carat of gold alloys, including white golds, by the streak test.—A. R. P.

***Investigation of the Microreactions of Lead.** I. I. Korenman and Sh. Sh. Mesongenik (*Zavodskaja Laboratoria (Works' Lab.)*, 1936, 5, (2), 168–169).—[In Russian.] The best conditions were investigated for the microdetermination of Pb as PbCl₂, PbI₂, PbSO₄, and K₂CuPb(NO₂)₆. Precipitation of PbCl₂ is best effected in 0.1N-HCl, precipitation of PbI₂ in 0.3N-KI solution, and precipitation of PbSO₄ in 1N-H₂SO₄. Sn interferes in the PbCl₂ and K₂CuPb(NO₂)₆ methods.—D. N. S.

***The Qualitative and Quantitative Determination of Lithium, Rubidium, and Cæsium by the Spectrum Method.** U. M. Tolmachev (*Izvestia Akademii Nauk S.S.S.R. (Bull. Acad. Sci. U.R.S.S.)*, 1934, [vii], 904–920).—[In Russian.] See *Met. Abs.*, 1935, 2, 244.—S. G.

Microchemical Determination of Magnesium with 8-Hydroxyquinoline. M. V. Gapchenko and O. G. Sheintsis (*Zhurnal Prikladnoi Khimii (J. Applied Chem.)*, 1936, 9, (3), 541–543).—[In Russian.] Mg can be determined by Hahn's method (*Z. anorg. Chem.*, 1926, 139, 1198) in the presence of NH₄⁺, Na, K, Li, Cs, Rb, Ba, Sr, and Ca.—N. A.

***Determination of Manganese in Tungsten and Ferrotungsten.** G. Frederick Smith, J. A. McHard, and K. L. Olson (*Indust. and Eng. Chem. (Analyt. Edn.)*, 1936, 8, (5), 350–351).—The finely powdered material (1 gm.) is heated with 30 c.c. of a 1 : 2 mixture of 72% HClO₄ and 85% H₃PO₄ at 200°–215° C. until solution is complete. The cold solution is boiled with 20 c.c. of HNO₃ until Cl₂ and HCl are expelled, cooled, treated with a few drops of FeSO₄ solution, then with 15 c.c. of H₂SO₄, and boiled with 1 gm. of Na bismuthate. The bismuthate is removed by filtration through a Gooch crucible, an excess of standard FeSO₄ solution is added, and the excess titrated with Ce(SO₄)₂ using diphenylaminesulphonic acid as indicator. The Mn may also be oxidized to HMnO₄ by boiling the solution of the metal obtained as above with 200 c.c. of water and 0.3 gm. of KIO₄; the excess of oxidizer is removed by addition of 4–5 gm. of Hg(NO₃)₂, and the filtered solution treated with an excess of FeSO₄ and titrated with KMnO₄.—A. R. P.

Fractional Reaction for Zirconium. N. A. Tananaev and A. V. Tananaeva (*Zhurnal Prikladnoi Khimii (J. Applied Chem.)*, 1936, 9, (3), 526–531).—[In

Russian.] Zr can be detected and determined approximately, in the presence of all elements except Si, by precipitation as phosphate from a 25-30% H_2SO_4 or 20% HCl solution.—N. A.

Electrometric Titration Processes: Potentiometric Analysis. Fritz Liene-weg (*Arch. tech. Messen*, 1935, 5, (54), 1163-1164).—The method described depends on the accurate comparison of the potential of a given system with that of a standard. The conditions of comparison are discussed, and an illustrated description is given of an automatically recording titration apparatus. The method is applicable to a wide variety of mineralogical and metallurgical analyses, and permits the estimation of several metallic ions in presence of each other (e.g. of Ag, Cu, Cd, and Zn in certain solders). A list of applications and a *bibliography* are appended.—P. M. C. R.

X.—LABORATORY APPARATUS, INSTRUMENTS, &c.

(See also "Testing" and "Temperature Measurement and Control.")

(Continued from pp. 409-410.)

On the History of the Metallurgical Microscope. H. Freund (*Giesserei*, 1936, 23, (19), 491-502).—An account is given of the developments in the metallurgical microscope between 1891 and 1934.—A. R. P.

Some Improvements in the Field of Material Testing Methods and Their Importance in Foundry Practice. A. Karsten (*Giesserei*, 1936, 23, (11), 265-268).—The Busch "Metaphot" is described and its use in the examination of the macro- and microstructure of castings is discussed.—A. R. P.

Advances in the Investigation of Microstructure, and Their Value in Testing Materials in the Motor Industry. A. Karsten (*Automobiltech. Z.*, 1936, 39, (15), 393-394).—The characteristics and applications of a small portable apparatus for the X-ray examination of microstructures are considered, and such an apparatus, intended primarily for use on light alloy parts, is described and illustrated.—P. M. C. R.

Spectrograph for Rapid Industrial Application. M. F. Hasler and R. W. Lindhurst (*Metal Progress*, 1936, 30, (3), 59-63, 90).—The exceptional resolving power of the equipment described is due to the substitution of a diffraction grating for the usual prism. The construction and mounting of the arch-chamber facilitates rapid work, whilst rapid comparison with a reference spectrograph is permitted by a special projector. The use of the apparatus in typical works' analyses is described.—P. M. C. R.

Thermostat of the Ural Physico-Technical Institute. P. G. Strolkov (*Zhurnal Tehnicheskoy Fiziki (J. Tech. Physics)*, 1935, 5, (8), 1502-1510).—[In Russian.] The thermostat, which will maintain a temperature of 600° C. within $\pm 0.1^\circ$ C. for at least 40 hrs. is described in detail.—N. A.

The Rotap Testing-Sieve Shaker. — (*Engineering*, 1936, 142, (3685), 237).—The determination of the percentages of different-sized particles by passing the material through a series of sieves, which are shaken by hand, results in appreciably different values being obtained. A machine is described and illustrated which performs the operation mechanically—the sample being passed successively through the series of different openings at one operation.—R. Gr.

A Sachs Camera. A. P. Kamar and V. S. Averkiev (*Zhurnal Tehnicheskoy Fiziki (J. Tech. Physics)*, 1935, 5, (9), 1653-1655).—[In Russian.] A new type of Sachs camera for X-ray examinations at high temperature and *in vacuo* is described.—N. A.

XI.—PHYSICAL AND MECHANICAL TESTING, INSPECTION, AND RADIOLOGY

(Continued from pp. 411–412.)

†The Significance of the Numerical Values of Mechanical Tests of Metals. L. Delville (*Métaux*, 1936, 11, (131), 140–147).—The nature of the physical and mechanical properties of metals is considered, and their definitions and dimensions are tabulated. From these considerations, the relation of the various properties one to another are discussed. All testing comprises measurement, interpretation, and comparison. Measurement depends on the magnitude of the properties and the accuracy required, and on the cost; interpretation must take into account all the fundamental variables concerned; comparison can only properly be made between properties of the same dimensions, unless not purely numerical parameters are introduced to make up for the missing dimensions.—J. H. W.

New Application of a Three-Point Amplifier for Recording Results of Mechanical Tests. Pierre Chevenard (*Rev. Mét.*, 1936, 33, (4), 280–287).—A new machine constructed by the Imphy laboratories employs very small test-pieces for tensile, bend, and shear tests. Stress-strain diagrams are recorded autographically by a pen attached to a three-point amplifier, stress being measured by deflection of a spring.—H. S.

Microchemical Analysis of Welds. Pierre Chevenard and Albert Portevin (*15me. Congrès chim. indust. (Bruxelles 1935)*, 1936, 223–241; *C. Abs.*, 1936, 30, 5925).—After reviewing the causes of mechanical heterogeneity of welds resulting from chemical and physico-chemical reactions, from fusion effects, from hardening and from tempering, C. and P. discuss their consequences as regards: (1) mechanical tests of welds, the interpretation and analysis of which imply the use of micro test-pieces; (2) the definition of weldability, the characterization of which necessitates a complete and accurate exploration of the weld. The problem has been solved by the use of the micro-machine based on the principle of the optical lever with photographic record, after large amplification, of the deformations of the tensile, shearing and bending micro test-pieces, as a function of the loads measured by the elastic deformation of the frame of the machine. A series of examples of selected welds is presented in the form of micro tensile and micro shearing diagrams, which give the variations of strength, elastic limit and elongation determined at a number of closely situated points. The examples comprise both gas and electric welds of ferrous materials; they reveal clearly the complex influence on the mechanical properties of fusion in the welded zone, and the hardening and tempering effects on the heated zone as a whole. Unlike tests carried out on large test-pieces, micro-mechanical testing makes it possible to ascertain both the position and the value of the maxima and minima of the various mechanical properties, and this in turn makes it possible to find their causes and to reduce them as much as possible so as to improve the homogeneity.—S. G.

On Anti-Friction Properties of a Material. N. N. Serafimovich (*Metallurg (Metallurgist)*, 1936, (6), 102–108).—[In Russian.] Deals with the method of determining anti-friction properties on a Mohr-Federhof machine, and gives examples of the determination of friction moments of bronzes.—N. A.

On the Question of the Upper and Lower Yield-Point and the Breaking Load. G. Welter (*Metallwirtschaft*, 1936, 15, (38), 885–889; (40), 936–938).—W. repeats and amplifies the false conclusions reached (see *Met. Abs.*, this vol., p. 50) on the influence of the construction of the tensile machine on the contour of the load-elongation curves.—v. G.

Contribution to the Question of the Tensile Test with Simple Gravity Loading. E. O. Bernhardt (*Metallwirtschaft*, 1936, 15, (38), 889–892).—Polemical against Welter (preceding abstract).—v. G.

Contribution to the Question of the Tensile Test with Simple Gravity Loading. G. Welter (*Metallwirtschaft*, 1936, 15, (41), 960-964).—See preceding abstracts.—v. G.

Vibration Tests (Simultaneous Series) of Flat Metal Specimens for Fatigue. I. I. Mihailovskiy (*Vestnik Inzhenerov i Tekhnikov (Messenger Engineers and Technologists)*, 1936, (5), 309-311).—[In Russian.] A review.—N. A.

Criticism of the Short Time Methods of Determining the Alternate Bending Endurance Limit. W. Späth (*Metallwirtschaft*, 1936, 15, (31), 726-729; (32), 750-752).—The various accelerated methods of determining the endurance limit of metals are described. S. considers that the test-piece should be subjected to a preliminary 10^5 alternations at not too high frequency prior to making the test proper.—v. G.

A Bend Test for Tinsplate. C. C. Willis (*Metal Progress*, 1936, 30, (3), 50-55).—An illustrated description is given of a recording apparatus the purpose of which is to expose the sheet to stresses similar to those encountered during manufacture (*i.e.* of the bending-tensile type). Records of alternate bending and unbending tests on common varieties of tinsplate are reproduced and correlated with the results of Olsen cup tests and with the respective micro-structures, and the interpretation of the curves is discussed.—P. M. C. R.

German Machines and Apparatus for Determining Hardness. G. Richter (*Germanskaja Tehnika (Z. deut. Technik)*, 1936, 15, (4), 68-74).—[In Russian.] Description of Brinell, Rockwell, Shore, and other special apparatus for determining hardness, manufactured by German firms.—N. A.

Manufacture of Experimental Apparatus and Machinery at the "Rukhmovitch" Works. A. J. Rostovih (*Tochnaja Industrija (Präzisions Ind.)*, 1936, (5), 1-4).—[In Russian.] Description of apparatus for mechanical tests on metals (hardness, resistance to impact, extension, &c.).—N. A.

RADIOLOGY.

The Application of X-Rays to Metallurgy.—III. C. Hubert Plant (*Metallurgia*, 1936, 14, (83), 121-122).—See also *Met. Abs.*, this vol., pp. 373, 412. In this, the final article, on the application of X-rays to metallurgy, the practical side of the subject is dealt with. Particular attention is given to the X-ray apparatus so far as the type of tube, transformer, general arrangement, radiation dangers, and manipulation are concerned. The results obtained from X-ray photographs in analyzing and identifying metals and alloys by means of spectrographs are considered, and reference is made to photographs of the Laue type and the information obtained from them regarding the structure of materials. A brief account is also given of the application of the X-rays to the examination of metals for defects.—J. W. D.

The Influence of Stresses Normal to the Surface on the Deformation as Measured by X-Rays. G. Kurdjumow and M. Scheldak (*Metallwirtschaft*, 1936, 15, (39), 907-908).—In measuring stresses by the X-ray method it must be remembered that the thickness of the surface film is not negligible and that, therefore, the magnitude of the stresses perpendicular to this must also be taken into account in the calculations.—v. G.

On the Relation Between the X-Ray Photograph and the Strength of Cast and Extruded Piston Alloys. E. Schiedt (*Metallwirtschaft*, 1936, 15, (37), 857-862).—A series of X-ray photographs of pistons is shown which indicate that it is not possible to draw conclusions about the mechanical properties directly from such photographs.—v. G.

Radiographic Use of Radium. V. E. Pullin (*J. Roy. Soc. Arts*, 1934, 82, 307-322; discussion, 323-326; *Sci. Abs.*, 1934, [B], 37, 133).—After referring in general terms to the production and important properties of γ -rays, their use is described in detecting flaws in materials, and the advantages of γ -rays over X-rays in certain circumstances are pointed out. Examples are given of

the practical application of the γ -ray method, together with reproductions of radiographs. The process of estimating the position and size of flaws is referred to.—S. G.

XII.—TEMPERATURE MEASUREMENT AND CONTROL

(Continued from p. 413.)

Electric Recorder and Controller. — (*J. Sci. Instruments*, 1936, 13, (9), 306-307).—A note describing the "Multelec" recorder. The instrument works on the potentiometer principle, and automatically standardizes its own circuit voltage every 54 minutes. It is stated that $\frac{1}{1000}$ in. deflection of the galvanometer needle is shown on the chart, and that any change in conditions is recorded within 2 seconds of its occurrence. A wide range of industrial uses is claimed.—W. H. R.

Methods for Measuring and Regulating Temperature, and Apparatus Used. R. Boye (*Germanskaja Tehnika (Z. deut. Technik)*, 1936, (6-7), 101-106).—[In Russian.] A review.—N. A.

Recent Revisions of High Temperatures. H. T. Wensel (*J. Amer. Ceram. Soc.*, 1936, 19, (3), 81-86).—W. points out that to convert temperature values recorded in the literature to the present International Temperature Scale, a correction must be applied which is calculated from the constants that define the particular scale in which recorded values are expressed. Applying the same corrections to all previous scales leads, in many cases, to values which depart from the present scale more than the values actually recorded. Examples are given showing the correct method of converting temperature values based on Wien's Law to the International Scale.—S. G.

XIII.—FOUNDRY PRACTICE AND APPLIANCES

(Continued from pp. 413-415.)

Correction of Porosity in Non-Ferrous Casting by Impregnation with Bakelite Varnish. Z. I. Shnaiderman (*Liteinoe Delo (Foundry Practice)*, 1936, (4), 25-26).—[In Russian.] A description of the thermal treatment of Bakelite varnish, and the process of impregnation of bronze and aluminium sections.—N. A.

On Light Metal Ingot Castings. H. Röhrig (*Z. Metallkunde*, 1936, 28, (2), 43-45; and (abridged) *Light Metals Research*, 1936, 4, (22), 386-387).—Practical hints are given on the correct methods of casting aluminium and its alloys to prevent segregation and undue piping, and the causes of faulty castings are discussed.—A. R. P.

Casting a Trough 5300 mm. Long of Aluminium Alloy. K. P. Lebedev (*Liteinoe Delo (Foundry Practice)*, 1936, (4), 26-27).—[In Russian.] A description of the method of moulding.—N. A.

Causes of Rejects in Aluminium Castings and Methods for Their Elimination. A. M. Brezgunov (*Aviopromishlenost (Air Industry)*, 1936, (3), 17-25; (4), 27-31).—[In Russian.] Deals with the classification and nomenclature of rejects in the casting of aluminium alloys.—N. A.

Casting of a Bronze Manipulator Subjected to a Hydraulic Test of 30 Atmospheres. Z. S. Lavut (*Liteinoe Delo (Foundry Practice)*, 1936, (5), 36-37).—[In Russian.] A technical description of the casting process.—N. A.

The Bronze Casting Technique of Our German Ancestors. Erich Becker (*Giesserei-Praxis*, 1936, 57, (37/38), 409-413; (39/40), 440-442).—Read at the International Foundry Congress at Düsseldorf. Discusses the composition, shape, and probable method of casting of old bronzes in Germany.—J. H. W.

Magnesium Alloys in Aero Engine Construction. A. S. Lugaskov (*Aviopromishlenost (Air Industry)*, 1936, (4), 31-40).—[In Russian.] A review, describing the composition of the alloys, their preparation, moulds, testing, and the treatment of castings and rectification of their defects.—N. A.

Measures Against Rejects and Improvement of the Quality of Magnesium Alloy Castings. A. S. Lugaskov (*Aviopromishlenost (Air Industry)*, 1936, (5) 27-35).—[In Russian.] A review.—N. A.

***On the Deoxidation of Technical Silver Alloys.** E. Raub, H. Klaiber, and H. Roters (*Metallwirtschaft*, 1936, 15, (33), 765-770; (34), 785-788).—The efficiency of numerous deoxidizers for the silver alloy with 16.5% copper has been examined; only phosphorus and lithium were found satisfactory in all respects. Phosphorus removes the oxygen as cuprous metaphosphate which separates relatively slowly from the molten metal, but is harmless if not completely eliminated. Small amounts of retained lithium are also without effect on the mechanical properties, but reduce slightly the resistance to corrosion by acetic acid and increase considerably the resistance to corrosion by nitric acid; lithium does not affect sulphide tarnishing.—v. G.

Preheating Bearings for Tinning with Babbitt. John E. Hyler (*Machinist (Eur. Edn.)*, 1936, 79, (51), 915E).—The advantages of heating bearings before tinning them with Babbitt are counteracted if the heating is excessive. If the bearings are damp, they should be heated relatively hot, but allowed to cool until comfortably warm to the hand before pouring in the Babbitt.—J. H. W.

The Problem of Porosity of Aluminium Alloys in Die-Casting. P. E. Liamin (*Liteinoe Delo (Foundry Practice)*, 1936, (4), 22-25).—[In Russian.] Different types of porosity and their causes are examined.—N. A.

Changeable Cores for a Die-Casting Die. E. Stevan (*Machinist (Eur. Edn.)*, 1936, 80, (3), 46E-47E).—The use of interchangeable pads in a die-casting die for, say, a zinc-base alloy, enables drill stands for fractional, metric, and wire gauge sizes to be made with one set of tools.—J. H. W.

Die-Casting Problems in the U.S.S.R. B. A. Jungmaister (*Liteinoe Delo (Foundry Practice)*, 1935, (10), 3-4).—[In Russian.] General views on the desirability of developing this branch of casting.—N. A.

What Points Must be Observed in the Construction of Moulding Boxes? Gustav Krebs (*Giesserei-Praxis*, 1936, 57, (35/36), 365-368).—Discusses the wall thickness, cooling, strength, and general construction of moulding boxes, and describes the production of large moulds for special castings.—J. H. W.

Material for the Production of Pattern Plates. Joh. Mehrtens (*Giesserei-Praxis*, 1936, 57, (37/38), 418-426).—Read before the International Foundry Congress at Düsseldorf. Describes the economics of moulding materials and the construction of a large variety of moulds. The use of wood, cast iron, non-ferrous metals (alloys of copper, lead, aluminium, and magnesium), and non-metallic materials for this purpose is discussed, and alternative materials of domestic origin for various applications are suggested.—J. H. W.

On the Use of Cements as Binders for Foundry Sands. Max Paschke, Carl Weyman, and Eugen Schneider (*Giesserei*, 1936, 23, (16), 381-386).—Good foundry sands can be made from sharp silica sand with cement as a binder; the permeability to gases and the refractoriness of moulds made from the mixture are sufficiently good for most foundry purposes. Fused alumina cement is better than Portland cement as it gives better permeability and a higher tensile strength. The sand used should be as pure as possible as even iron oxide reduces the refractoriness owing to the lime present in the cement.—A. R. P.

On the Practical Applications of Moulding Sand Testing in Foundries. Aulich (*Giesserei*, 1936, 23, (18), 431-437).—Methods and apparatus for determining the sand, clay, and moisture contents of moulding sands, the apparent volume, the permeability and the compression, tensile, and shear strengths are described.—A. R. P.

Driers for Foundries. — Schmidt (*Giesserei*, 1936, 23, (14), 341-342).—Types of ovens for drying moulds and cores are described and illustrated.

—A. R. P.

XIV.—SECONDARY METALS : SCRAP, RESIDUES, &c.

(Continued from p. 415.)

Basic Principles of the Refining of Simple Copper Alloys while Molten in the Foundry. Willi Claus (*Metallwirtschaft*, 1936, 15, (37), 862-865).—The treatment of copper alloys containing, as impurities, aluminium, iron, antimony, oxides, sulphides, or hydrogen is broadly discussed.—v. G.

On the Principles of Converting Old into New Metal. E. J. Kohlmeyer (*Metallwirtschaft*, 1936, 15, (29), 677-683).—The effects of oxidizing salts and salt fluxes on the treatment of scrap copper, aluminium, lead, zinc, and their alloys are discussed.—v. G.

XV.—FURNACES AND FUELS

(Continued from pp. 415-416.)

Tempering Furnace with Mechanically-Controlled Convection Currents. — (*Engineering*, 1936, 142, (3682), 158-159).—Describes and illustrates a gas-heated furnace. The heating chamber is situated within an insulated combustion chamber, and the ascending products of combustion are deflected downwards into it by means of a fan. Automatic temperature control is employed.—R. Gr.

What the Electric Furnace Has Done for Civilization. P. H. Brace (*Electrochem. Soc. Preprint*, 1936, Oct., 115-122).—The early beginnings of the electric furnace are briefly described. The effects of metallurgical electric furnace technique on present ways of living are set forth with special reference to the part played by the electric furnace in the production and uses of aluminium, magnesium, beryllium, chromium, tungsten, calcium carbide, phosphoric acid, silicon, manganese, and tantalum. Its use as a processing tool in shaping metals and in "copper brazing," &c., is mentioned.—S. G.

***Progress Report on Tests of Various Electric Heating Elements for Furnace Temperatures Between 1100° and 1500° C.**—I. M. G. Toole and R. E. Gould (*Electrochem. Soc. Preprint*, 1936, Oct., 139-159).—The results of tests on silicon carbide resistors for electric heating for temperatures between 1100° and 1500° C. showed relatively high power loss, a material decrease in mechanical strength of bars with use, and failure when the resistance had increased 500%. No difference in resistance increase was noted for steady load as compared with on-and-off control. A more rapid resistance increase on bringing up to temperature after a shutdown and also a daily increase when operated at maximum temperature were noted. A rapid current increase just prior to failure was also noted. An average life of 1700 hrs. was observed. Tests on graphite resistors showed successful operation when protected from oxidation by propane gas, using a silicon carbide protection tube. The outside terminal block is the weakest part of the resistor assembly. A self-control terminal greatly improved the over-all thermal efficiency. Further tests are described using high-frequency induction heating. The general conclusion reached is that non-metallic heating units can be developed to operate at comparatively small cost per unit of material to be heated.—S. G.

Small Electric Furnaces. — (*J. Sci. Instruments*, 1936, 13, (9), 305).—A brief note describing small resistance furnaces suitable for heating soldering irons, tempering small tools, &c.—W. H.-R.

Electro Refractories. (Paoloni.) See p. 475.

A Graphical Method of Calculating Heat Loss Through Furnace Walls. Clarence E. Weinland (*J. Amer. Ceram. Soc.*, 1936, 19, (3), 74-80).—Cf. *Met.*

Abs., 1935, 3, 720. The expression of thermal conductivity data in the form of "true" conductivity is discussed, and a graphical method for the solution of problems in steady state heat-flow is developed. No account is taken of certain disturbing factors in furnace-wall calculations, such as joint resistances and conductances, air infiltration, and lack of temperature equilibrium. W. believes that the theory will serve as a basis for future developments along this line, and that the method of calculation described is reliable, workable, and also results in a saving of time.—S. G.

XVI.—REFRACTORIES AND FURNACE MATERIALS

(Continued from p. 416.)

Properties of Insulating Refractories. S. M. Phelps (*Heat-Treat. and Forging*, 1936, 22, (5), 251–253).—Insulating fire-bricks are being used as exposed linings for certain types of industrial furnaces on account of their low heat-flow, small heat capacity, lightness in weight, and satisfactory refractoriness. It is pointed out that the usual methods applied to the testing of refractories under load at high temperatures should not be used for these materials as they depart widely from furnace conditions. It is stated that a load test in which the bricks are heated on one face only indicates satisfactory mechanical strength at the maximum temperature which they are intended to stand in service and more closely simulates working conditions.—J. E. N.

***Contribution to the Study of the Action of Carbon Monoxide on Refractories.** Léon Scheepers (*15me. Congrès chim. indust. (Bruxelles 1935)*, 1936, 1003–1011; *C. Abs.*, 1936, 30, 6151).—The dissociation of carbon monoxide produces deterioration of refractories, particularly in the internal region of blast furnaces, where the average temperature is 400°–900° C. Various catalysts such as the oxides of iron promote the action. The catalytic action of silica, porcelain, kaolin, alundum, graphite, Fe_3O_4 , iron silicate, bauxite, and iron filings was studied by a method (described in detail) based on the automatic measurement of the carbon dioxide formed on passing a given amount of carbon monoxide over the catalyst in a given time, at a given temperature, in a specially designed vertical electric furnace. Bauxite and natural magnetite are particularly active.—S. G.

***Testing Silico-Aluminous Refractory Materials at High Temperatures.** B. Long (*Céramique*, 1935, 38, (571), 219–224; *Ceram. Abs.*, 1936, 15, (6), 182).—A small thermostatically controlled electric furnace is used for measuring the load-bearing properties of refractory materials at high temperatures. It is found that the failing curve under pressure at 1500° C.: (1) gives evidence of the total porosity, and (2) furnishes under the name of coefficient of apparent viscosity, a measure of its value in practice.—S. G.

***Influence of the Addition of Fluxes on the Softening and Melting Points of Silico-Aluminous Refractories.** Marcel Lepingle (*15me. Congrès chim. indust. (Bruxelles 1935)*, 1936, 300–318).—The results confirm previous work.—S. G.

Developments of Refractories Containing Magnesia. L. Litinsky (*Ber. deut. keram. Ges.*, 1935, 16, (11), 565–596; also *Iron Steel Ind.*, 1936, 9, (12), 462–466; (13), 495–499; 1936, 10, (2), 101–105; and *Ceram. Abs.*, 1936, 15, (9), 276).—A comprehensive review of recent developments in the industry and of the manner in which new ideas have been put into practice. The problems encountered and methods whereby they were overcome are discussed at length.—S. G.

***The Use of Penetrating Radiations in the Measurement of the Porosity of Refractory Brick.** J. B. Austin (*J. Amer. Ceram. Soc.*, 1936, 19, (2), 29–36).—A method of determining the porosity of a refractory brick by measuring the absorption of some penetrating radiation has been tested on silica brick of known porosity, using both X-rays and γ -rays, and has been found to be

entirely feasible. The test is simple, quickly and easily made, non-destructive, and can be made continuous. The apparatus must be calibrated for each composition, but once standardized can be used for different thicknesses of the same material. The ionization method of determining the intensity of the beam after passing through the sample is much superior to the photographic method.—S. G.

Refractory Products for Metal Melting Furnaces. Karl Lentzen (*Giesserei-Praxis*, 1936, 57, (37/38), 404-407).—Read before the International Foundry Congress at Düsseldorf. The nature and use of the refractories available for the construction of metal melting furnaces are discussed.—J. H. W.

The Destruction of Refractory Smelting Furnace Bricks by Softening and Melting. E. T. Richards (*Feuerungstechnik*, 1936, 24, (5), 73-77).—The softening and melting of refractory materials used in smelting furnaces by mechanical forces, gases, metallic vapours, and dust are referred to, and means of preventing such destruction are briefly mentioned. These comprise: (1) suitably supporting the materials, particularly the furnace arch, and (2) protecting the materials against impurities which can lower their melting points, by reducing their surface porosity.—J. S. G. T.

Electro Refractories. A. Paoloni (*Corriere ceram.*, 1935, 16, (7), 279-284; *Ceram. Abs.*, 1936, 15, (2), 63).—The electrothermal treatment of raw materials for the production of refractory and ultra-refractory synthetic materials (silicon carbide products and artificial graphite) and a description of an electric furnace devised by P. for temperatures of 1400°-1800° C. are given.

—S. G.

XVIII.—WORKING

(Continued from pp. 417-418.)

***Contribution to the Knowledge of Material Flow in the Rolling Process.** Hermann Unckel (*Arch. Eisenhüttenwesen*, 1936-1937, 10, (1), 13-18).—An ingot of pure aluminium was drilled at regular intervals and channels cut in the surface, all being filled with a 0.5% copper-aluminium alloy; the composite material was then rolled to various degrees of reduction, sectioned, and etched to produce blackening of the alloy inclusions. In this way a complete picture was obtained of the relative flow in the various parts of the ingot. Broadening of the ingot takes place uniformly over the whole surface, but the rate of flow in the core of the ingot is less than that at the upper and lower surfaces, *i.e.* the normal to the rolling plane is bent against the direction of rolling. The effect of stresses produced transversely to the direction of rolling may be seen by making short longitudinal slits in the ingot prior to rolling; when a lead ingot so cut is rolled both ends are splayed outwards and the slit becomes triangular in shape showing the presence of stresses directed from the centre outwards to the edges.—A. R. P.

Multiple-Stage Rolling Mills. Wilhelm Rohn (*Z. Metallkunde*, 1936, 28, (6), 139-142; and (abridged) *Met. Ind. (Lond.)*, 1936, 49, (11), 259-260).—A description of modern types of 20-high rolling mills and their performance.

—A. R. P.

On Spreading in Rolling. W. Trinks (*Blast Fur. and Steel Plant*, 1936, 24, (9), 785-788).—Discusses the factors which influence the spreading of metal in rolling and reviews the formulæ suggested for its estimation. Written from the ferrous point of view.—R. Gr.

***Preparation of Silver Sheet. The Tensile Properties of Sheet of Commercial Silver Alloys in Relation to the Method of Manufacture.** (Moser and Raub.) See p. 444.

Modern Extrusion for Tube Manufacture. Gilbert Evans (*Metallurgia*, 1936, 14, (83), 142-144).—The adaptation of hydraulics to the piercing and

extrusion of non-ferrous metals for finishing into tubes is discussed in relation to improvements of design for the hydraulic operation, the adaption of the tools to the conditions regulated by the material to be extruded, and improvements in design, which aim at greater manufacturing accuracy, and consistent dimensions in extensive production. Vertical and horizontal types of presses are compared, and a description is given of a modern 3500-ton horizontal hydraulic extrusion press for non-ferrous metal sections and tubes, which is the outcome of prolonged research and experiment.—J. W. D.

Henley Lead Extrusion Machine. — (*Machinist (Eur. Edn.)*, 1936, 80, (11), 187E-188E).—Describes the construction and operation of a machine for extruding lead pipes and sheathing cables. It is claimed that a fine tolerance in the thickness of the sheathing throughout the entire length of the pipe or cable is obtained. Non-circular sections can be satisfactorily extruded. The heat radiation is low and the temperature is controlled by a series of thermocouples.—J. H. W.

Four-Unit Wire-Drawing Machine. — (*Engineering*, 1936, 142, (3684), 195-196).—A wet drawing rod machine is illustrated and described, which is specially suitable for the drawing of bronze wire. Hard phosphor-bronze may be drawn from 5-gauge rod in 4 drafts to approximately 12-gauge at an approximate rate of 600 ft./minute.—R. Gr.

Theoretical Premises for Designing a Process of Wire-Drawing. S. N. Jakovlev (*Zvetnye Metally (Non-Ferrous Metals)*, 1936, (1), 120-127).—[In Russian.] General views.—N. A.

Power Used in Drawing-Rolls of Multiple Mills. S. N. Jakovlev (*Zvetnye Metally (Non-Ferrous Metals)*, 1936, (2), 107-119; (3), 90-101).—[In Russian.] The distribution of forces on the rolls, back tractive effort, and coefficient of friction of wire-drawing rolls are studied. Coefficients of friction in relation to drawing rates are shown graphically for copper, brass, and bronze wire, and the wire pressure on the rolls is estimated. Nomograms are constructed for practical use.—N. A.

***Formation of Ears in the Deep-Drawing of Silver Sheet.** E. Raub (*Mitt. Forschungsinst. Edelmetalle*, 1936, 10, (5/6), 53-67).—In the cold-rolling of copper-silver alloys the copper and silver crystallites tend to become oriented in the direction of rolling, and hence directionality of the tensile properties is developed, the tensile strength being at a maximum at right angles to the direction of rolling and a minimum at an angle of 45° thereto. Preliminary forging of the casting, change in the copper content of the alloy, precipitation heat-treatment, and the addition of 0.3% phosphorus or 0.94% cadmium to the metal have no effect on this directionality. Even annealing has little effect on the directionality of the tensile strength and elongation, and may, under certain conditions, intensify it by reducing still further the strength and increasing the ductility at 45° to the direction of rolling. After high-temperature anneals the strength in the direction of rolling becomes equal to that at right angles thereto except when the alloy contains phosphorus. Cross-rolling prevents the formation of the usual fibre structure but does not prevent the development of anisotropy; in the hard-rolled state the strength is at a minimum at 45° to the rolling direction but on annealing this slowly disappears. From these results it appears that ear formation in deep-drawing can be prevented by cross-rolling, frequent annealing at not too high a temperature and avoiding too high a degree of reduction at any stage. The development of a regular crystal structure takes place only at 800° C. and this temperature is too high for annealing the relatively low-grade Continental standard silver alloys since they contain a high proportion of eutectic.—A. R. P.

The Production of Metallic Films. R. V. Jones (*J. Sci. Instruments*, 1936, 13, (9), 282-288).—The methods for producing thin metallic films by deposition (sputtering, evaporation, and electrodeposition) and by the reduc-

tion of bulk metal (beating, planishing, and rolling) are summarized with references to original papers, and some electrical properties are described. Foil produced by rolling is in general much superior. If the foil is rolled from sheet metal, it is necessary to reduce the diameter of the rolls as the foil becomes thinner, and a suitable machine is suggested. If strips of foil are rolled from wire, the diameter of the rolls has little influence since the distortion of the metal is at right angles to the direction of feed (*i.e.* parallel to the rolls), whereas when sheet is rolled the distortion is longitudinal. Practical details of the production of films of the order 0.1μ in thickness are described, and also methods for cutting and manipulating thin films.

—W. H.-R.

The Press Forging of Brass. — (*Heat-Treat. and Forging*, 1936, 22, (7), 327-328).—A brief account of the advantages of die-pressings of brass and related alloys over sand-castings.—J. E. N.

Comparator Gauge for Drop Forgings. Frank Hartley (*Machinist (Eur. Edn.)*, 1936, 80, (14), 276E-277E).—Describes a gauge for gauging the entire outline of the contour of a drop forging having off-set surfaces that cannot be measured by ordinary means.—J. H. W.

Investigation of Piston Forgings from AC-11 Alloy. V. A. Livanov (*Zvetnye Metally (Non-Ferrous Metals)*, 1936, (1), 127-137).—[In Russian.] From examination of the macro- and micro-structure and tensile and impact tests, it is concluded that the best material for pistons is that produced from rolled and pressed rods.—N. A.

Methods of Employing Perforation Boring of Hard Strata by Means of Hard Alloys. V. P. Banul and M. M. Kravtsov (*Redkie Metalli (Rare Metals)*, 1936, (1), 16-26).—[In Russian.] Hard sintered alloys of the "Pobedit" type are unsatisfactory for drilling hard strata, sharpened strips 8-10 mm. thick inserted in the drill-heads breaking at the first impact. With a special tougher alloy ("Pobedit 13") it is possible to drill up to 2 metres at one effort at one quarter the cost with a steel drill.—D. N. S.

XIX.—CLEANING AND FINISHING

(Continued from pp. 418-419.)

***The Cleaning of Tinned Equipment in the Dairy.** G. Genin (*Lait*, 1936, 16, 612-615; *C. Abs.*, 1936, 30, 6838).—The corrosion of tin and tinned copper by sodium carbonate and sodium hydroxide solutions depends essentially on the quantity of oxygen dissolved in the solution and very little on the temperature and concentration of the alkali. The presence of a reducing agent permits a marked reduction in the corrosion. For this purpose sodium sulphite was found very effective. Thus, pure tin on treatment with 0.5% solutions of sodium carbonate lost 6.6 mg./dm.² while when the carbonate solution contained sodium sulphite the loss was reduced to 0.8 mg./dm.². Sodium sulphite has the advantages of low cost, relative stability in a solid state, and ready solubility in water and alkaline solution; moreover, its product of oxidation, sodium sulphate, exerts no deleterious effect. By the addition of sodium sulphite it is possible to reduce to about $\frac{1}{10}$ the attack of alkaline solutions on tin. It is suggested that proper proportions of mixing sodium sulphite and carbonate or hydroxide are 1 part sodium sulphite to 10 parts of crystallized sodium carbonate or 1 part sodium sulphite to 4 parts of sodium carbonate or sodium hydroxide. The protective action of the sodium sulphite on tin is exerted until all of it has been oxidized to the sulphate.—S. G.

***Methods of Caring for Cream Separators and Their Influence Upon the Quality of Cream [Cleaning of Separator Parts].** C. K. Johns (*Sci. Agric.*, 1936, 16, 373-390; *C. Abs.*, 1936, 30, 6072).—A rinse of sodium hypo-

chlorite containing 50 p.p.m. was very effective in reducing contamination in separator bowls. Metsco, a commercial sodium metasilicate detergent, proved to be very corrosive to metal separator parts.—S. G.

Colouring of Metals. IV.—Zinc and Die-Castings. Herbert R. Simonds and C. B. Young (*Iron Age*, 1936, **138**, (10), 30-35, 110).—Describes the few commercial methods available for colouring zinc and outlines the chief research now in progress. The Cronah method involves simple immersion in acidified sodium bichromate, which causes an insoluble film to be deposited on the surface of the metal. The possibilities for electrodeposited coatings on zinc are the same as for other metals previously described (*Met. Abs.*, this vol., p. 324), but the procedure sometimes requires specific adaptation. The compositions of both inorganic and organic baths for nickel plating are given, and the method of alloying for colour (nickel-brasses) and the use of nickel for producing colour effects are described.—J. H. W.

The Use of Steel Wool for Grinding and Polishing Aluminium and Other Metals. R. Böing (*M.S.v.Z. für Metall- u. Schmuckwaren Fabrikation sowie Verchromung*, 1936, **17**, (7), 11; *Neuhausen Wochenbericht*, 1936, (**28**), 299).—The steel wool used for polishing should be soft rather than brittle, should consist of long threads, and should be degreased to avoid smearing. Owing to the sharp edges of the separate strands it has been found suitable for fine grinding. Irregularly shaped articles can be treated with steel wool as the latter readily follows all the irregularities of the surface and does not leave dirt or dust on the surface of the metal.—L. A. O.

Applying the Grinding Wheel to New Production Operations. Fred Horner (*Canad. Mach.*, 1936, **47**, (8), 20-22, 46).—Complex grinding operations have been considerably developed and extended as a result of the demand for standardized metal parts and of the introduction of artificial abrasives. Examples of plunge-cut work, centreless grinding, tapering, and recessing are described and illustrated.—P. M. C. R.

Sand-Blasting from the Point of View of Economy. R. Engelhart (*Werkstatt u. Betrieb*, 1936, **69**, (17/18), 233-235).—Sand-blasting installations are classified according to the method of introduction of the abrasive. In plant for light work (e.g. production of a matt surface), the sand is sucked in by the air stream; a gravity feed is used in heavier ornamental work, whilst in the cleaning of foundry pieces, &c., the abrasive is introduced under pressure. Modern plant is described and illustrated, with an estimate of costs.—P. M. C. R.

Pickling Tank Tie-Rods. — (*Engineer*, 1936, **162**, (4210), 299).—Considers the defects of tanks constructed of wood and outlines the mechanism of tie-rod corrosion. Suggests and illustrates methods of minimizing corrosion.
—R. Gr.

XX.—JOINING

(Continued from pp. 419-421.)

***Contribution to the Testing of Tin-Lead Soldered Joints.** Willi Tonn and Heinrich Günther (*Z. Metallkunde*, 1936, **28**, (8), 237-239).—The strength of butt and lap joints in tinplate and zinc sheet soldered with pure lead-tin solders of various compositions has been determined. For joints in sheet zinc the strength increases with the tin content of the solder, but for joints in tinplate no further increase in strength takes place above a tin content of 30% in the solder. In both cases lap joints are about twice as strong as butt joints. Using an electric soldering iron the time taken to solder a joint and the amount of solder used decrease with increasing tin content of the solder so that the apparent saving in tin in using a low-tin solder is offset by the necessity of using much more solder.—A. R. P.

***Physical Properties of Soft Solders and the Strength of Soldered Joints.** (Gonser and Heath.) See p. 454.

Properties of Metals and Alloys and Their Importance in Welding and Soldering. Erich Lüder and Karl Heinemann (*Z. Metallkunde*, 1936, 28, (7), 188–192).—The effect on the soldering and welding properties of metals and alloys of the following factors is discussed; the heat transfer properties of the metals to be joined, the freezing range of alloys used as solders, the reducibility of the various oxides by the torch flame, the solubility of the oxides in the fluxes used, and the solubility of gases in the welded metal.—A. R. P.

Low-Temperature Brazing with Silver Alloys. Philip Kriegel (*Welding Eng.*, 1936, 21, (8), 32–36).—The advantages of silver solders are enumerated and advice on their use is given. Oxy-acetylene is recommended for heating the seam to be jointed, the solder being applied to the preheated seam after removal of the flame. Lap joints are preferred to butt joints or fillets, and a close fit is desirable. Applications to copper, bronze, stainless steel, and nickel alloys are illustrated and described.—H. W. G. H.

New Brazing Alloy Increases Applications [Phos-Copper]. — (*Amer. Metal Market*, 1936, 43, (159), 6). **Westinghouse "Phos-Copper" Brazing Alloy.** — (*Machinist (Eur. Edn.)*, 1936, 80, (38), 779–780).—A brief note. Phos-copper, an alloy of phosphorus and copper, has been developed to replace expensive silver solders. Its properties, uses, and the forms in which it is available are described.—L. A. O.

***Does Loss of Alloying Constituents Occur in Light Metal Welding?** M. Maier (*Aluminium*, 1936, 18, (8), 373–374).—In the oxy-acetylene welding of good grades of technical aluminium the loss of iron and silicon is practically negligible, but with Hydronalium there is a loss of about 4% of the magnesium content but no reduction in the manganese content. In gas-welding Silumin very little silicon is lost under a good flux but about 3% is lost without a flux; no loss of copper occurs in welding "German alloy," but about 2–3% of the zinc may be lost. In welding the American 8% copper alloy, however, the copper content of the weld may be as much as 0.5% less than that of the surrounding metal, a loss of over 7% of the total copper.—A. R. P.

Electrical Spot Welding of Light Alloys. I. M. Brailovskiy (*Aviopromishlenost (Air Industry)*, 1936, (4), 41–43).—[In Russian.] The advantages of spot welding over riveting in aircraft construction are indicated.—N. A.

Technical Standardization and Costs of Gas Welding of Copper and Aluminium Sections. J. S. Smirnow (*Avtogennoe Delo (Autogenous Practice)*, 1935, (12), 24–25).—[In Russian.] A study of causes, with numerical data, affecting expenditure of time and materials.—N. A.

The Sheathed Electrode for the Welding of Copper. A. Matting and W. Lessel (*Elektroschweissung*, 1936, 7, (9), 161–170).—The new electrode has four coatings: the first, immediately surrounding the core of substantially pure copper, forms a slag of approximately the same melting point as the latter; the second forms, under the heat of the arc, large quantities of a gas which is not absorbed by copper; the third and fourth form the sheath, being fused away less readily than the core, so as to form a tube which directs the stream of gas on to the seam. This tubular stream of gas enables a long arc to be held without difficulty and without risk of oxidation of the molten metal. Lengthening the arc reduces the melting speed of the electrode and allows high voltages to be used, so that sufficient heat is given to the work to compensate for the high thermal conductivity, without the need for auxiliary blowpipe flames. The weld metal passes steadily through the "tubular arc" instead of falling in large drops. The electrode is connected to the + pole; the voltage used varies from 40 v., for 8 mm., to 100 v. for 30 mm. length of arc, and the current is between 220 and 120 amp. for a 4-mm. diam. electrode. Preheating to 200° C. is necessary at the beginning of a seam and may be carried out by

carbon arc. The welding speed is about 3.3 m. per hr. for 10 mm. thick material. Tensile tests on the welds give 90% of the strength of the parent metal and 18–22% elongation. The electrodes can be used for vertical welding.—H. W. G. H.

Welding in Repairs of Bronze Articles. B. I. Belov (*Avto-gennoe Delo (Autogenous Practice)*, 1936, (5), 21–22).—[In Russian.] A description of the welding process.—N. A.

Methods of Lead Welding Differ Widely from Practices with Other Metals. F. E. Rogers and W. H. Carter (*Welding Eng.*, 1936, 21, (8), 24–27).—For tank linings, lap seams are normally used, butt joints being made only in thick material. The technique to be adopted is described for both types of joint, great emphasis being laid on the need for scrupulous cleanliness. Various types of joint for pipe work are also discussed. Hydrogen is recommended for welding.—H. W. G. H.

Hints on Maintenance of Resistance Welding Machines. A. M. Macfarland (*Welding Eng.*, 1936, 21, (8), 19–20).—Attention is particularly directed to the need for keeping constant the area of the electrode tips, cleaning switch and contactor contacts, and preserving the close fit of dies and clamp for butt- or flash-welding.—H. W. G. H.

High-Power Machinery for Spot Electrical Welding of the AGA-175 Type. G. V. Nedzevezkiy (*Vestnik Elektropromishlennosti (Messenger Elect. Ind.)*, 1936, (8), 10–13).—[In Russian.] Descriptive.—N. A.

Phenomena Determining the Process of Spot Welding. A. S. Orlev (*Avio-promishlennost (Air Industry)*, 1936, (4), 44–48).—[In Russian.] The thermal, electrical, power, and geometrical phenomena in spot welding are examined and conditions for attaining good results laid down.—N. A.

The Atomic Physics Basis of the Welding Capacity of Metals. A. S. Ogievezkiy (*Avto-gennoe Delo (Autogenous Practice)*, 1935, (12), 14–17).—[In Russian.] A survey of general principles.—N. A.

Oxy-Acetylene Welding. L. C. Percival (*Indust. Gases*, 1936, 17, (1), 24–33; (2), 69–73, 79–83).—See *Met. Abs.*, this vol., p. 177.—H. W. G. H.

Novel Constructions of Welding Torches. A. S. Falkevich (*Avto-gennoe Delo (Autogenous Practice)*, 1935, (11), 25–26).—[In Russian.] The new lighter type of welding torches made of aluminium and its alloys, as constructed at the First Autogenous Works, and other types are described.—N. A.

XXI.—INDUSTRIAL USES AND APPLICATIONS

(Continued from pp. 422–424.)

Shaping and Constructing in Light Metals. Walther Zarges (*Aluminium*, 1936, 18, (8), 353–360).—A lecture dealing with the industrial applications of aluminium and its alloys in the form of sheet and castings. Among the uses discussed are the construction of coach-work, deck superstructures in steam-boats, non-magnetic metal parts of magnetic separators, ventilating apparatus for railway trains, railway and omnibus doors, sign plates, stands for scientific instruments, and parts of electrical apparatus.—A. R. P.

Light Articulated Unit of Welded Construction in Aluminium Alloys. Maurice Leroy (*Allégement dans les Transports*, 1936, 5, (3/4), 30–36).—An account of the 3-car rail units adopted on the French Chemin de Fer du Nord. The annealing of the welded body-work is obviated by the use of M.G.7, a light alloy containing 7% of magnesium; the properties of this material when fully annealed are given.—P. M. C. R.

New Light Metal Car for the Milan Tramways. R. Ferrari (*Allégement dans les Transports*, 1936, 5, (9/10), 114–121).—[In French and German.] An

experimental tramcar constructed for the Milan city authorities has a superstructure mainly of Avional, whilst Duralite castings and forgings are used in bogey construction. An 18% reduction in weight has been effected in the complete unit, the reduction in the case of the superstructure being estimated at 40%. Details of design and construction are illustrated.—P. M. C. R.

Light Metal Speed-Boat. Ad.-M. Hug (*Allégement dans les Transports*, 1936, 5, (1/2), 14–17).—[In French and German.] Peraluman, an easily welded light alloy of high resistance to corrosion, has been used in the construction of the hull and most of the stressed members of a 300-h.p. speed-boat recently launched at Vitznau. Other light alloys employed are Aluman A (petrol tank), Anticorodal B (seats), Silumin-Gamma (steering-levers), and Peraluman 2 (bearing-boxes). The properties of these materials are tabulated, the treatment being indicated in each case.—P. M. C. R.

Autothermic Piston Controls Clearance. P. M. Heldt (*Automotive Ind.*, 1936, 75, (12), 376–378).—Undesirable expansion effects in aluminium-silicon alloy pistons are eliminated by the inclusion of light steel inserts and by oval grinding of the skirt. The design is fully described and illustrated.

—P. M. C. R.

Non-Vibrating Cables for Aerial Conductors. M. Preiswerk (*Bull. Assoc. Suisse Élect.*, 1936, 27, (9), 543).—A short note on the satisfactory service and freedom from vibration of a composite aerial cable of Aldrey with a core of galvanized steel wire.—P. M. C. R.

†**The Manifold Uses of Aluminium Powder.** E. Herrmann (*Aluminium*, 1936, 18, (8), 376–381).—A review of the patent literature showing the many useful applications of aluminium powder.—A. R. P.

Aluminium Powder Paints. — Freitag (*Oberflächentechnik*, 1935, 12, 152–153; *C. Abs.*, 1935, 29, 5286).—A much better and denser coat of aluminium paint is obtained if the aluminium powder and the binder are mixed just shortly before the coat is applied than when the paint stands ready mixed for some time. Aluminium paints are particularly advantageous where the materials to be protected are exposed to strong sunshine (tropics) or where vessels, rooms, &c., must be protected from heat radiation (airships, railroad cars, storage tanks for inflammable liquids).—S. G.

Use of Electrolytic Cadmium in the Manufacture of Syphons for Carbonated Beverages [Toxicity of Cadmium]. — Bordas (*Ann. Falsif.*, 1936, 29, 233–234; *C. Abs.*, 1936, 30, 4935).—As cadmium offers considerable analogy with zinc and seems to be more toxic, it is recommended that its use be prohibited for articles that come into contact with foodstuffs.—S. G.

Substitution of Tin-Bronzes by Special Bronzes, Special Brasses, and Other Metals, DIN 1705. — (*Z. Metallkunde*, 1936, 28, (8), 243).—Suitable substitutes for phosphor-bronzes containing 6, 10, 14, and 20% tin are indicated for various purposes, also alloys free from tin which can be used in place of standard German red brasses.—A. R. P.

On the Use of Calcium Babbitts in Shipbuilding. I. T. Kolenov (*Sudostroenie (Shipbuilding)*, 1936, (8), 575–577).—[In Russian.] A review.—N. A.

Filling of Bearings with Calcium-Sodium Babbitt and Bronze Turnings. — Frankfurt (*Uralskaja metallurgia (Metallurgy of Ural)*, 1936, (5), 38).—[In Russian.] The inclusion of bronze turnings in calcium-sodium Babbitts has made their use in heavy plant possible.—N. A.

Some Troubles with Plumbers' Materials. F. L. Brady (*J. Inc. Clerks Works Assoc. Gt. Britain*, 1935, 52, (627), 75–78; *Building Sci. Abs.*, 1936, 9, 11).—Considering lead as a plumber's material, B. points to the proved durability of lead when correctly used. Cases of failure would appear to be due but rarely to the lead itself. The marked resistance of lead to weathering results from the protective film of corrosion products which is quickly formed. Instances are described of the corrosion of lead by water containing lime in

solution from Portland cement mortar. In that case the protective film is not formed. The corrosion product is a red oxide which appears to be formed in annual layers, which indicate the number of years during which corrosion has proceeded. The corrosion of lead in contact with timber, especially hard woods such as oak or teak, is thought to be due to acid substances in the wood, particularly if unseasoned. In flat-roof construction where sheet lead is laid over timber it is advisable to insert a layer of protective material, such as bituminized felt, between the two materials. Good workmanship is essential to prevent the penetration of moisture between the wood and the lead. Attention is directed to the need for further investigation of the behaviour of lead pipes in different types of soil. Failure of lead pipes under pressure may be due to a weak weld. Failure of lead results also from fatigue due to alternating stresses. Brief reference is made to the ternary alloys of lead with cadmium, antimony, or tin.—S. G.

Lead Poisoning Caused by Drinking Water. A. Pellè and — Artus (*Bull. acad. mèd.*, 1935, **113**, 54–57; *C. Abs.*, 1936, **30**, 6861).—Lead is frequently found in drinking water of low mineral content. Covering the interior of tubes with tin gives little protection because the coating usually has rather a high lead content itself. Numerous cases of poisoning have been reported.

—S. G.

Nickel Alloys as Working Materials in Rotary Deep-Drilling Technique. K. Kallos (*Oel, Kohle, Erdoel, Teer*, 1936, **12**, 389–394).—S. G.

The Sputtering of [Silver for] Large-Aperture Fabry-Perot Interferometer Mirrors. S. Tolansky and E. Lee (*J. Sci. Instruments*, 1936, **13**, (8), 261–263).—A method of producing large-aperture Fabry-Perot interferometer mirrors by sputtering silver in argon is described.—W. H.-R.

Strontium. E. G. Erick and Gordon H. Chambers (*Footc Prints*, 1936, **9**, (1), 11–19).—The occurrence and uses of strontium and its compounds are reviewed.—S. G.

Ways to Use Domestic Materials as Substitutes for Bearing Metals and Methods of Fashioning Them. R. Kühnel (*Giesserei*, 1936, **23**, (15), 357–363).—Aluminium- or zinc-base bearing metals containing copper have been used satisfactorily as substitutes for imported tin-base alloys in Germany. Lead-bronzes, special brasses, aluminium, bronze, cast iron, and some light metals can be used instead of high tin-bronzes. The various applications of these substitutes are discussed and standard bearing constructions are described.

—A. R. P.

How to Select Electric Heating Alloys. F. P. Peters (*Machinist (Eur. Edn.)*, 1936, **80**, (15), 245E–247E).—The composition and properties of 12 of the most useful resistance materials are tabulated. For operation in air above 2400° F. (1315° C.), platinum or platinum-rhodium alloy is used; these are expensive and have inconvenient electrical properties. For temperatures between 2100° and 2400° F. (1150°–1315° C.), iron-chromium-aluminium or iron-chromium-aluminium-cobalt alloys are very satisfactory. Down to 1000° F. (540° C.), nickel-chromium alloys with or without iron are used. (Tophet alloys), and below 1000° F. (540° C.), Cupron, nickel-steel, or nickel silver can be used.—J. H. W.

Uses of Metal in Electrical Machinery Construction. P. N. Ivanov (*Vestnik Elektropromishlennosti (Messenger Elect. Ind.)*, 1936, (6), 27–31).—[In Russian.] The problem of metal scrap in electrical plant manufacture and of metal reserves in electrical machine construction are examined.—N. A.

Substitution and Economy of Non-Ferrous Metals in the Electrical Industry. B. M. Tareev and A. U. Shpirt (*Vestnik Elektropromishlennosti (Messenger Elect. Ind.)*, 1936, (7), 15–18).—N. A.

Factors Responsible for Off Flavours in Milk. P. H. Tracy (*Milk Dealer*, 1936, **25**, (8), 114–117; *C. Abs.*, 1936, **30**, 4938).—Contamination of milk with

copper or iron gives flavour defects characterized as cappy, metallic, tallowy, or oily. Copper and iron catalyze oxidation processes in the milk. The use of dairy equipment which will not allow contamination with copper or iron is therefore recommended.—S. G.

***The Influence of Metals on Milk.** W. Ritter (*Schweiz. Milchzeitung*, 1936, 62, 331-332, 337-338; *C. Abs.*, 1936, 30, 6837).—The presence of traces of copper or its alloys was found to be detrimental to the flavour of milk, and caused the development of tallowiness and similar catalytic oxidation flavours. Iron, nickel, and zinc were less harmful. Aluminium and its alloys and different types of stainless steel were without effect. The latter metals are most desirable for storing, conveying, or pasteurizing milk and milk products.

—S. G.

XXII.—MISCELLANEOUS

(Continued from pp. 425-426.)

The Institute of Material Research of the D.V.L. P. Brenner (*Metallwirtschaft*, 1936, 15, (32), 745-750; (33), 770-772).—The new building of the Institute of Material Research of the Deutsche Versuchsanstalt für Luftfahrt is described.—v. G.

Recent Advances in the Aluminium Industry. Francis C. Frary (*Electrochem. Soc. Preprint*, 1936, Oct., 179-189; also (abridged) *Metallurgia*, 1936, 14, (84), 175-176; and *Met. Ind. (Lond.)*, 1936, 49, (17), 412-413).—Advances in fabricating technique have enabled the industry to use alloys which have superior properties but which were formerly found not to be practical because of fabricating difficulties. The aluminium-base alloys containing magnesium, first proposed many years ago but only recently commercialized, are examples of this. New equipment and knowledge have also permitted the fabrication of larger wrought articles (structural shapes, forgings, &c.), special extruded shapes and tubing. Alclad sheet, anodic oxidation, electrolytic brightening processes and fundamental studies of the design of aluminium alloy structures are enlarging the field of use of aluminium alloys.—S. G.

Care and Disinfection of Gas Masks Used to Protect Against Chronic Lead Poisoning. Otto Giesenhaus (*Gasmask*, 1936, 8, 50-54; *C. Abs.*, 1936, 30, 4945).—The importance of frequent inspection of gas masks used in atmospheres containing lead smoke or vapour is stressed, and methods of inspection and care are described. The article is illustrated by photographs.—S. G.

†**Safety in the Metal Industry.** E. A. Bolton (*Met. Ind. (Lond.)*, 1936, 49, (16), 391-393).—Presidential Address to the Birmingham Metallurgical Society. Attention is directed to the hazards incurred in the manufacture of finished rod, strip, sheet, &c., from ingot metal and scrap, by careless handling and operation in the respective processes. The greatest risk lies in the fact that daily contact with machinery, melting equipment, pickling tanks, &c., removes the recognition of danger, and it is urged that every effort be made to educate the workers themselves in methods of safe working, and in the development of the right attitude towards safety.—J. E. N.

Subject Indexes to Volumes of Periodicals. S. C. Bradford (*Engineer*, 1936, 162, (4206), 180-181).—Outlines some methods of indexing.—R. Gr.

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XXIV.—BOOK REVIEWS

(Continued from pp. 434-438.)

Werkstoffkunde der Hochvakuumtechnik: Eigenschaften, Verarbeitung, und Verwendungstechnik der Werkstoffe für Hochvakuumröhren und gasgefüllte Entladungsgefäße. Von W. Espe und M. Knoll. Roy. 8vo. Pp. viii + 383, with 405 illustrations. 1936. Berlin: Julius Springer. (R.M. 48.)

The standard books on the subject of high vacuum technique, such as those of Dushman, Dunoyer, and Kaye, are now somewhat out of date. They were written at a time of rapid change, and developments of technique, if not of principle have gone on continually. The necessities of the lamp and radio-valve industries have given birth to most of the advances in this field, and it is refreshing to find a book of this kind treated from the strictly practical point of view. It is important to realize, however, that the book deals with the materials used in high-vacuum technique and not the apparatus. That is to say, the reader will find excellent information on particular types of glass-metal or glass-ceramic seals, but no information as to the best way of evacuating such a vessel when he has made it. In this the book differs markedly from most of its predecessors, which have tended to concentrate on high *vacua* rather than high-vacuum technique.

The book is divided into twenty-five chapters, the first six of which are concerned with the metals and alloys used in vacuum work. The reader will find here information on metals such as beryllium, platinum, and tantalum, as well as the commoner metals, copper, iron, and nickel. Physical properties are tabulated and illustrated clearly and profusely.

Other important chapters in the book are concerned with the degassing of metals, properties of glasses for vacuum work, hot and cold electrodes, gettering methods, glass-to-metal joins, &c. The technique of sealing tantalum and molybdenum foils directly into silica glass, now of great importance in extra-high pressure discharge lamps, is discussed and details are given. Those interested in cathode-ray tubes will even find several pages of information on luminescent powders. In a work of this kind, covering a wide range of applications, there are bound to be certain superficialities; the authors have avoided any serious accusation of this kind by supplying eighteen pages of detailed references to the original literature, much of it in the form of patents.

It is safe to say that no vacuum physics laboratory could do without this book, and the authors are to be congratulated on carrying out their work so well; a special word of commendation is due to the publishers who have reproduced original photographs with great clarity.—J. T. RANDALL.

Deterioration of Structures of Timber, Metal, and Concrete Exposed to the Action of Sea-Water. (Fifteenth Report of the Committee of the Institution of Civil Engineers.) Edited by S. M. Dixon and H. J. Grose. Roy. 8vo. Pp. xvi + 138, with 135 illustrations and 51 tables. 1935. London: H.M. Stationery Office. (12s. 6d. net.)

Two sections of this volume will be found of interest to non-ferrous metallurgists who are concerned with corrosion and protection, although they refer to work on ferrous materials: namely, "Corrosion of Steel and Iron" (38 pp.) and "Protection of Steel and Iron by Means of Paints and Other Preservatives" (26 pp.). In these reports, Dr. J. Newton Friend co-ordinates data obtained as a result of experiments that have been in progress for many years in different parts of the world. Corrosion experiments on steel include the examination of effects due to additions of copper, chromium, and nickel, respectively. The work on protective coatings includes galvanizing. The results obtained are well illustrated by means of tables, graphs, and photographs.—E. S. HEDGES.

A Bibliography on the Cutting of Metals. By Orlan W. Boston. Part II. Demy 8vo. Pp. 202. 1935. Ann Arbor, Mich.: Edwards Bros., Inc. (\$2.25.)

This book, a bibliography on the cutting of metals, comprises 1257 references mainly for the years 1929-1934 inclusive. The volume can be regarded as the second supplementary part of the original bibliography published in 1930, and containing some 700 references. The great majority of the references are abstracted very briefly, but in an adequately informative manner.

This survey of the literature of cutting tools is not only extraordinarily comprehensive, but has very obviously been compiled with a desire for accuracy. Whilst the reviewer makes no pretence to have verified all the references, he can say that a considerable number have been checked and found accurate in text and agreeing in substance with the abstracts.

The references are arranged chronologically and there are subject and name indexes. The book has been published privately and is reproduced photographically from typescript. The make-up has, however, in no way suffered on this account, and in fact the book is very pleasant to handle and consult.—W. D. JONES.

Wirkung von Druckvorspannungen auf die Dauerfestigkeit metallischer Werkstoffe. Von Gerhard Seeger. (Mitteilungen aus der Materialprüfungsanstalten an der Technischen Hochschule Stuttgart. DIN AS.) Demy 8vo. Pp. vi + 56, with 39 plates. 1935. Berlin: V.D.I.-Verlag G.m.b.H. (Br., R.M. 5; V.D.I.-Mitgl., R.M. 4.50.)

The author has published in this booklet a detailed account of his researches into the effects of initial compressive stressing upon the fatigue characteristics, in torsion and bending, of the following materials:—an IZ steel, a 50-11 steel annealed and heat-treated to 70 kg./mm.², a 60-11 steel, an annealed nickel-chrome steel, cast iron, and Lantal. The test-pieces were in the form of drilled rods, a bolt being passed through the bore to apply the initial compressive stress. The effect of interfering factors such as corrosion and notching were examined.

There are fifty-seven references in the text but no indexes. The book has apparently been printed by photographic reproduction of typescript. The illustrations and photomicrographs are not well reproduced. This booklet should form a useful adjunct to the existing publications on the subject of fatigue.—W. D. JONES.

Vorspannung und Dauerhaltbarkeit von Schraubenverbindungen. Von A. Thum und F. Debus. (Mitteilungen der Materialprüfungsanstalt an der Technischen Hochschule, Darmstadt, Heft 7.) Med. 8vo. Pp. viii + 72, with 90 illustrations. 1936. Berlin: V.D.I.-Verlag G.m.b.H. (Brosch., R.M. 6.50.)

This booklet comprises an account of the researches conducted by the joint authors on the fatigue characteristics of screwed joints, pre-stressed, as in practice. Since very little information upon this subject has hitherto been published, the booklet should prove of value to engineer designers concerned with this type of work. The illustrations are excellently reproduced, and the various photographs of apparatus assist in making clear the procedures adopted in a number of somewhat complicated investigations. The bibliography contains twenty-one items and there are subject and name indexes. The booklet is well printed on good paper, although every page required cutting.—W. D. JONES.



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