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DRYING, PROCESSING AND STORAGE OF CORN SEED IN TROPICAL AND SUBTROPICAL REGIONS

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SUMMARY

Some problems and solutions peculiar to the drying, processing and storage of corn seed in tropical and subtropical countries are discussed. Several processing facilities designed specifically for corn seed in Central and South America are presented in detail.

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INTRODUCTION

The gravest problem facing the world's burgeoning population is a critical shortage of food. Today's food production levels cannot prevent mass starvation and suffering, and the American farmer's vaunted productivity cannot feed the world's population. Developing countries must learn, both for economic development and as a matter of survival, to produce the greater part of their food needs.

Many conditions must be altered and improved before adequate food supplies can be produced. No factor, however, is more important than securing maximum efficiency and productivity, especially in developing nations where production inputs are scarce and expensive.

Good seed are the basic tool for increasing food production efficiency levels. Yet, the use of improved seed requires no change in local crop production technology as do other improved practices such as fertilizers, insecticides, and herbicides. Good seed are the farmer's only means of selecting better-adapted varieties with higher yield potentials. Tests in underdeveloped tropical areas have shown significant yield increases, often over 50% greater than yields from unimproved local varieties, from the use of improved seed alone.

The present world seed industry cannot supply all the improved seeds needed by developing nations, even if these nations could purchase them. Improved seed in the quantities needed can be supplied only by seed production in the consuming areas. Local seed production could make available the needed seed supplies with minimum transportation and storage costs, and without using often scarce foreign exchange.

Producing adequate seed supplies locally requires more than production fields; proper drying, processing and storage facilities are essential. These facilities must be designed for economical construction and efficient operation, and with room for expansion as the seed improvement program gains momentum. Mississippi State University has been under contract to the U.S. Agency of International Development to provide technical assistance in the area of seed technology to cooperating countries since 1958. During this period, technical assistance has been provided to many countries in Latin America, Southeast Asia, South Asia, the

Far East, and Africa Facilities have been designed specifically for the drying, processing and storage of corn seed in Peru, Colombia, Honduras, and Brazil. Portions of these designs and recommendations for the processing of corn seed in tropical and subtropical regions are presented herewith.

HARVESTING

Corn seed attain physiological and functional maturity at seed moisture contents ranging from 52% to 40%. At that time the seed have reached maximum dry weight, germinability, and vigor (1). Therefore, during the interval from maturation to harvest, seed are - in effect - stored in the field, which seldom provides a favorable environment for storage, and the longer crops are left in the field after maturity the lower the yield.

In areas of sufficient drying conditions man has relied on the sun for drying his corn usually in the field on the stalk. However, even in these regions there are several disadvantages, such as excessive weathering, insect damage and overdrying which results in mechanical damage during harvesting and shelling of the corn seed. Early harvest is even more important under tropical conditions since it is not possible to dry corn under these conditions in the field sufficiently low for storage due to the prevailing high relative humidities.

We must keep in mind that the handling of seed is somewhat different than that for grain, since the seed is a live, viable organism and this condition must be maintained. Thus, it is recommended that the corn seed be harvested on the cob by hand or mechanical corn snapper at a moisture content of 25-35% moisture. Although combines have been used for harvesting corn seed it is not recommended since the resulting mechanical damage lowers the vigor and viability of the seed (2).

Harvesting seed after maturation but while they are still high in moisture content poses an immediate and serious problem, for such seed will heat and deteriorate rapidly unless moisture content is quickly reduced to a safe level The only practical and dependable way to reduce the moisture content of "high moisture" seed is by artificial drying

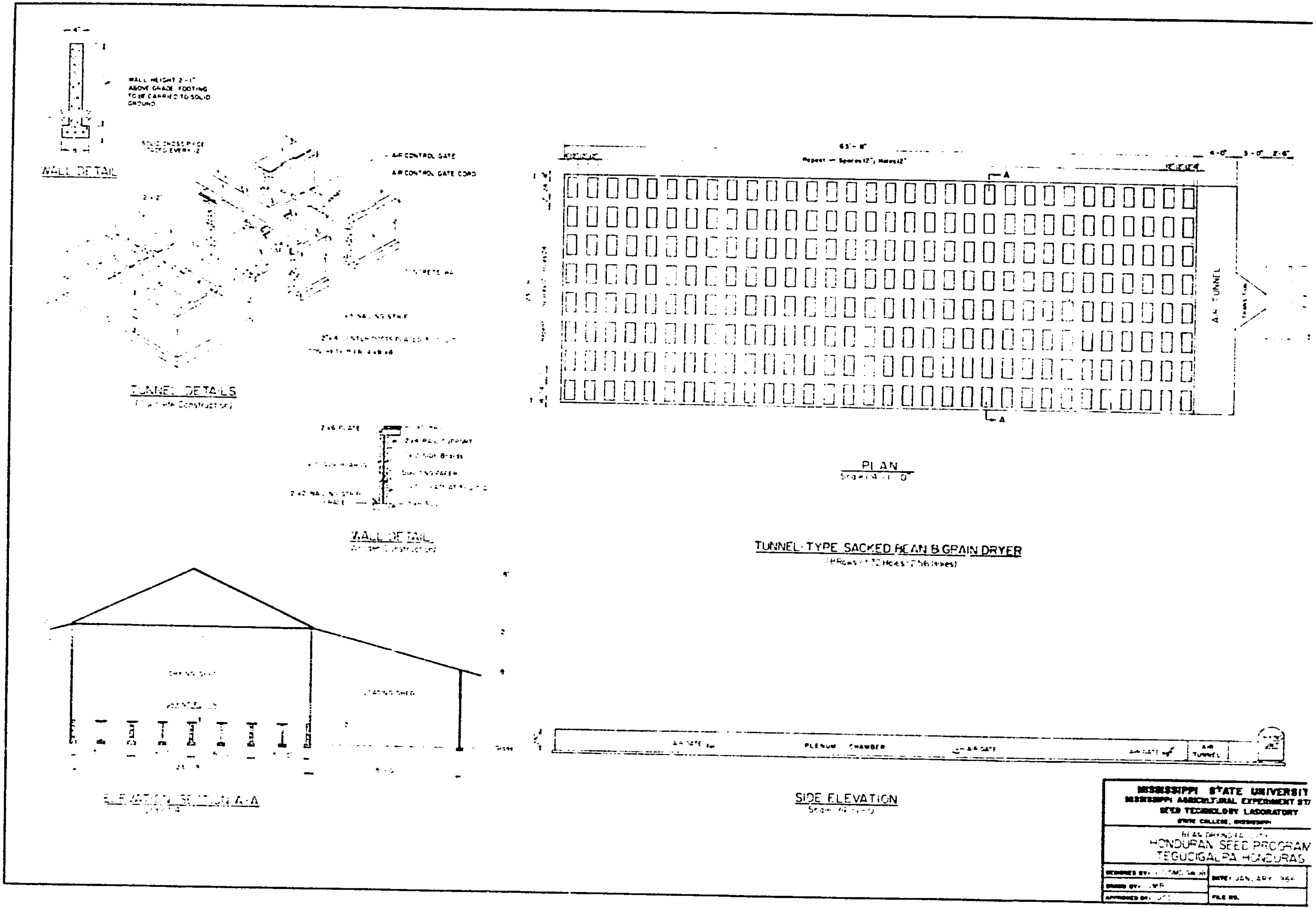

Figure 1. A sack-type drier.

DRYING

In our designs we recommend that corn seed be dried on the cob to 12% moisture content, which is sufficiently dry for storage, in either a sack drier or a bin drier with drying air temperature not to exceed 110°F. When dried on a sack drier, the corn is handled in a jute type bag, and when dried in bins it is handled in the bulk.

A sack dryer has advantages over a bulk dryer primarily because it requires a minimum amount of technical supervision for proper operation and small lots of different varieties of seed can be dried without concern of mixing.

The complete dryer, or sections of it, can be converted to a temporary bulk type dryer if conditions warrant. All that is required is the construction of bin side-walls and the placement of wire mesh over the sack openings in the floor.

The sack dryer (Figure 1) designed for a seed drying facility in Tegucigalpa, Honduras (3), consists of four horizontal tunnels or plenum chambers with openings regularly spaced over the top for placing sacks. A manifold, from the blower and heater unit, distributes the air to the four plenum chambers. The heated air enters the manifold from the blower, passes into the horizontal plenum chambers through adjustable air gates, then through the seed and is discharged into the atmosphere. Each of the four horizontal tunnels have 2 rows of openings for drying 64 sacks at one time for a total capacity of 256 sacks. The opening size is based on a 2 bushel sack (24" x 34"). A 5-inch overlap on all four sides of the sack prevents air escaping and assures even flow of air through the material.

Temperature controls on the heater will hold the air temperature at the maximum safe temperature (less than 110°F). When the dryer is only partially loaded, air gates in the tunnels not being used can be closed. The air gates can also be used to regulate the amount of air flowing into each tunnel. If the total capacity, as designed, is not required at the beginning of the program, the two center tunnels can be omitted. This decreases initial expenditures and offers some advantages in loading and unloading the dryer.

Sacks should be loaded on top of a single tunnel until it is completely covered; the dryer fan and heater unit can then be started. During the drying operation additional sacks are added as the sacks of dry seed are removed.

Various schedules for turning the sacks are followed. However, from the standpoint of moisture movement, a sack should be left in its first position longer than one-half the total required drying time; in general, five hours out of eight is not too long. This will result in the seed in the lower side of the sack being slightly overdried at the end of the first period, but when the sack is turned upward migrating vapor from the wetter seed replenishes some of this lost moisture, thus producing uniformly dried seed.

Sampling the seed for moisture content is one of the most important operations in a drying facility because moisture content determines both turning and drying time. Samples should be drawn in a manner that will give an accurate assessment of the average moisture content of the seed received in each load. During sampling, care should be taken to determine whether sacks of seed with moisture contents differing greatly from the average are present. If so, these sacks should be marked, kept separate, and handled as their condition requires. To accomplish the best results, each load of seed should be randomly sampled. Samples, as drawn, should be examined for feel and appearance before adding them to the composite sample that is used to determine the average moisture content.

The sack dryer can be operated in areas where no electrical power is available and is suitable for most types of seeds which are handled in jute bags. These bags are universally used in tropical areas.

A bin dryer (Figure 2) designed for a corn drying facility in San Pedro Sula, Honduras handles ear corn in the bulk. The bins are built with an angled, slatted floor for ease of unloading. The bins are loaded with a portable drag conveyor and unloaded in to a trough conveyor. The heated air is distributed from a burner and fan to a plenum chamber in each bin through a central air tunnel. The air is exhausted to the atmosphere. Air flow to each bin is regulated by a sliding door.

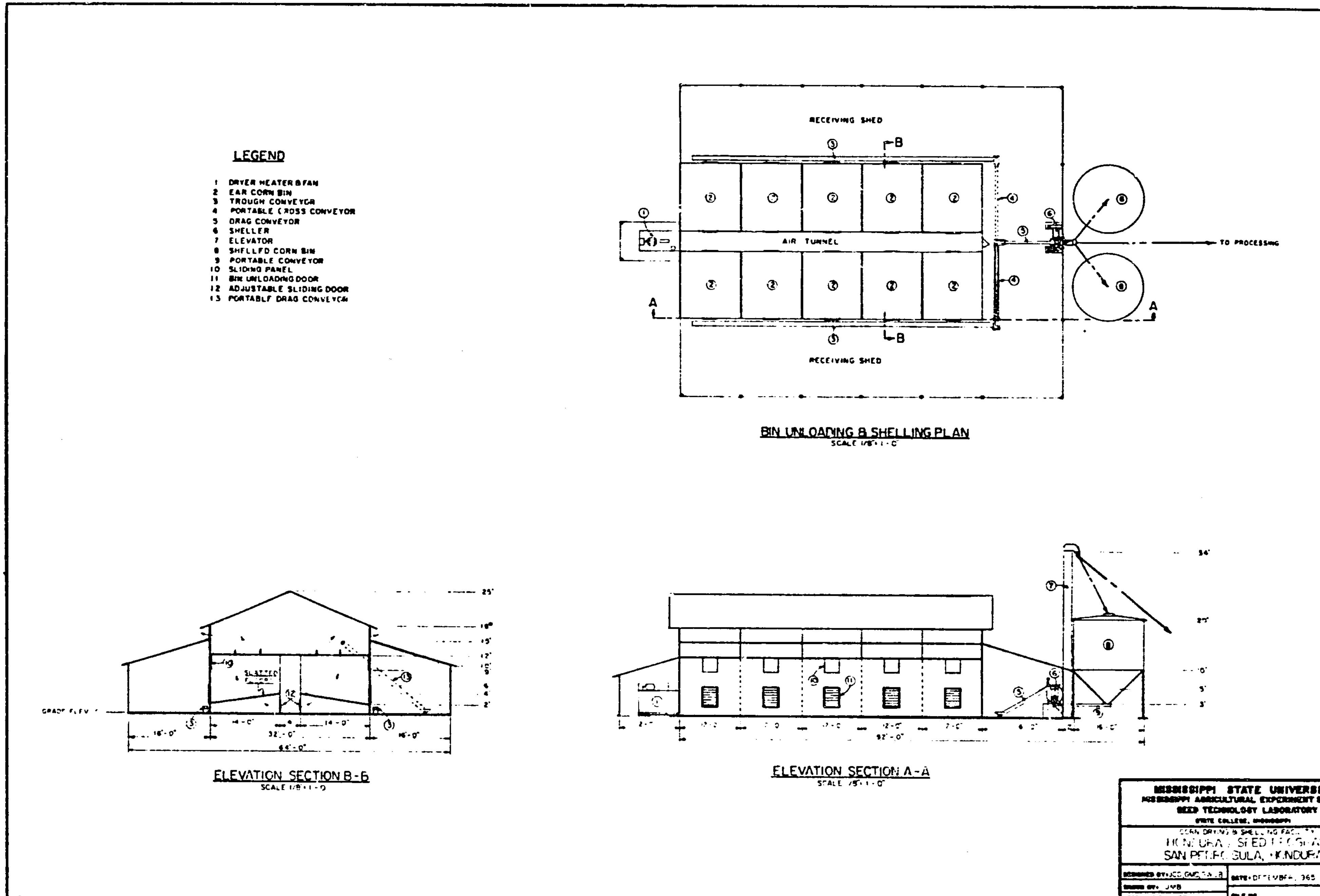

Figure 2. A bin-type drier for ear corn.

SIMPLE MOISTURE DETERMINATIONS OF CORN SEED

In developing countries there is a need for a simple inexpensive method for determining when seeds have been sufficiently dried for storage. There are several reliable methods used for determining the moisture content of seed, but generally they are time consuming, complicated or expensive.

We have developed a simple, inexpensive method for determining when seed have been sufficiently dried for storage. It consists of a sealed container and a lithium strip which changes from blue to pink at a particular relative humidity. By use of a calibration curve this strip will indicate when a seed sample is less than 12% moisture content.

A seed has an equilibrium moisture content for each temperature and relative humidity condition of the surrounding air. On the other hand, the air surrounding a sample of seed in a closed container will equilibrate at a particular relative humidity depending upon the moisture content of the seed sample and the temperature.

If a sample of seed is placed in a sealed container and allowed to equilibrate with the surrounding air, the equilibrium relative humidity is an indication of the moisture content of the seed. In order to use this method to determine the moisture content of seed, it is necessary to measure the relative humidity of the surrounding air and to determine the relationship of the equilibrium relative humidity to the moisture content of the particular type of seed.

Indicator strips manufactured by Humidial Company, Colton, California, were used to measure relative humidity. These strips contain several blocks which are blue or pink, depending on whether the relative humidity is less than or greater than a particular percent. They have the ability to change color as the lithium compound absorbs moisture, and the relative humidity at which the color changes depend on the concentration of lithium in the indicator.

Prior to use, these strips were tested in desiccators of known relative humidity obtained by using salt solutions. Relative humidities used were 0, 35, 48, 52, and 75 percent and the strips indicated 0, 35, 45, 55, and 75 percent, respectively. The strips can be read to the closest 5 percent.

Corn seed were placed in a germinator to increase their moisture content. At 20 percent moisture the seed were removed and allowed to air dry. Periodically, as the seed were dried, samples were sealed in airtight bottles.

The relative humidity in the bottles was determined by indicator strips and the moisture content of each sample was determined by the oven method. The rate of increase of relative humidity decreased sharply after two hours of equilibration time; therefore, two hours of equilibration time were used in obtaining the calibration curves. And two hours were designated as the time required to determine the moisture content of seed using the indicator strips.

The curve is not a standard equilibrium curve since this method of measuring relative humidity is not sufficiently accurate. Rather it is considered a calibration curve for correlating the relative humidity reading of the strips with the moisture content of corn seed after two hours equilibration time. For corn seed, the recommended moisture content for storage is 11-12%. From the calibration curve in Figure 3 you will note that when a sample of corn seed equilibrates with 45% relative humidity the moisture content is 11.5%. Therefore, at this point we are assured that the seed are sufficiently dry for storage.

We designed an indicator strip, Figure 4, with three squares (1, 2, and 3) which turn from blue to pink as the relative humidity increases past 45%, 55%, and 65%, respectively. When square number 2 and 3 are blue, and 1 is pink at equilibrium conditions sufficient drying conditions are being approached. When 1, 2, and 3 are blue the moisture content for corn seed is low enough for storage.

A test was run to evaluate the use of the strips by inexperienced operators, and it showed that the strips could be used satisfactorily by an inexperienced operator. Indicator strips are being distributed to AID missions in developing countries for further evaluation.

PROCESSING

After the corn has been dried to 12% moisture, it is run through a corn sheller. It is then cleaned in a three-screen air screen cleaner with screen sizes as follows: top screen - 32/64, 2nd screen - 28/64 and bottom screen - 18/64 (4). The materials which passes over either of the

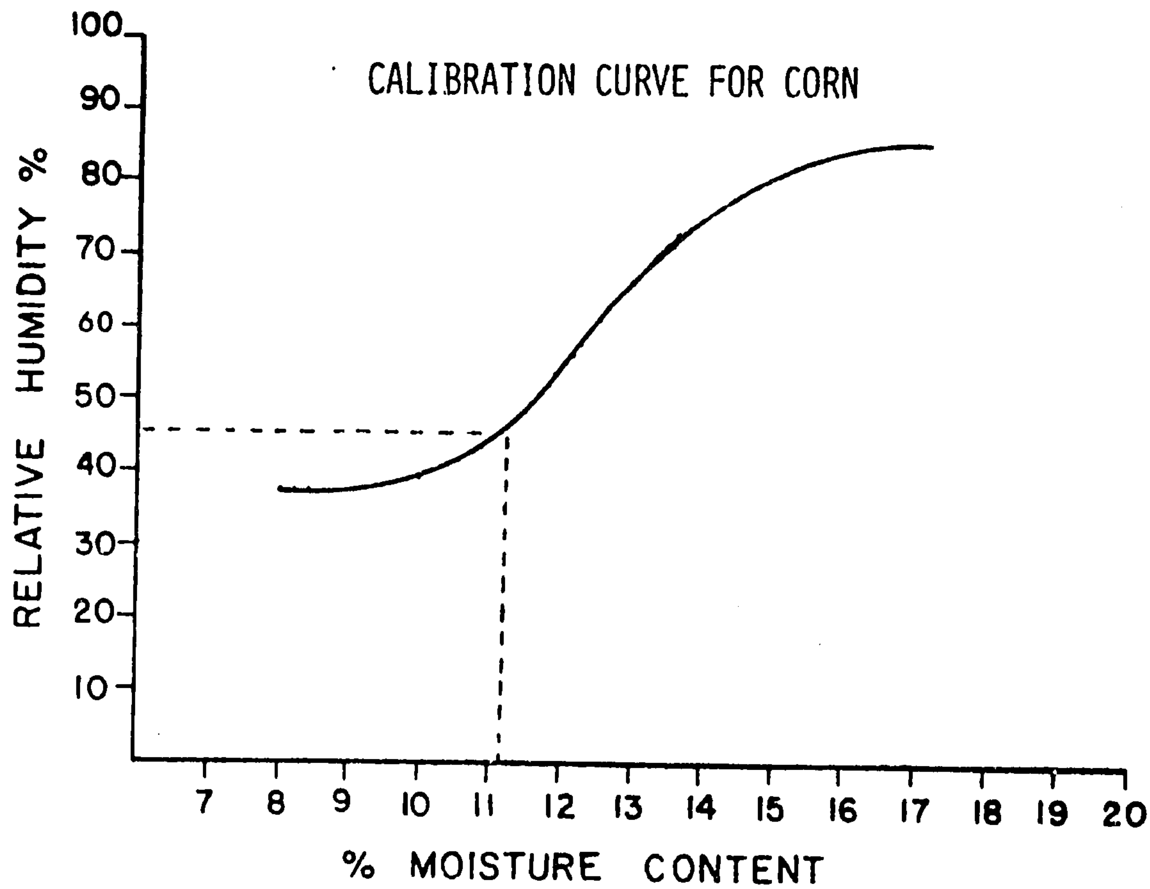

Figure 3. Moisture content - relative humidity calibration curves for corn.

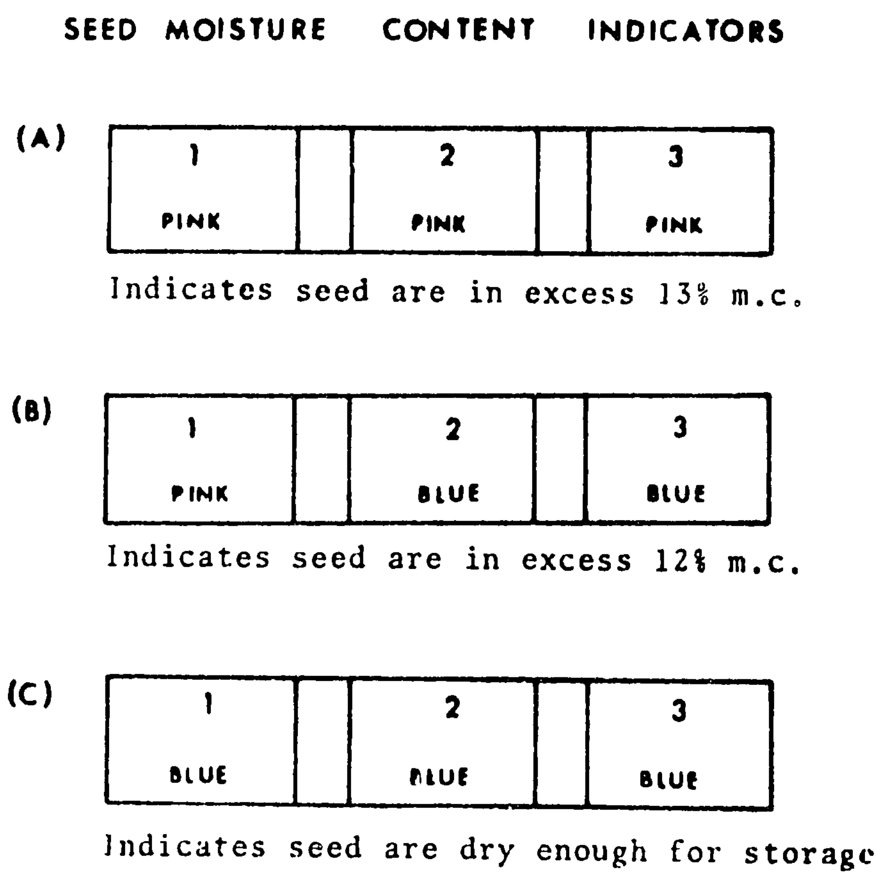

Figure 4. Seed moisture indicator strips.

two top screens or through the bottom screen are discarded. The corn seed which passes through the two top screens and over the bottom screen is good seed and is retained.

The corn seed is now ready for grading i.e., separation of the flats and rounds and then sizing these two separates into small, medium and large. A corn grading flow diagram is shown in Figure 5 for the La Moline Seed Processing Plant, Lima, Peru. In some cases it is desirable to divide the flats and rounds into only two sizes, medium and large.

The "flats" and the "rounds" are separated on a thickness separator which is a cylinder separator with a 14/64 slotted shell. This unit is referred to as a "splitter". The "overs", which are the materials which ride over the slotted shell, are the round seed. They can be conveyed to a holding bin until the "flats" are sized since they normally make up only about 25% of the total corn seed, and the same sizing separators are used for both the "flats" and "rounds".

The "throughs", which are the materials which pass through the slotted shell, are the flat seed. These seed are conveyed to the first sizing unit which is also a cylinder separator, but contains a 24/64 round hole shell. The "overs" are the large "flats" and they are sent to the treater or the bagging bin. This product represents approximately 37% of the total seed; therefore, it should be removed from the system promptly.

The "throughs" which are a mixture of the medium and small "flats" are conveyed to the second sizing unit which contains a 21/64 round hole shell. The "overs" in this unit are medium "flats" and the "throughs" are small "flats". These seed can be accumulated in a holding bin to be treated and bagged after the large "flats".

The "rounds" are then graded into large, medium and small on the same shells used for the "flats", and then they are treated and bagged.

PREDICTING SEED STORABILITY (6)

During the course of routine operations, a corn processing facility will handle many different lots of the same variety of seed. Judgements as to the relative quality of these seed lots are based primarily on the results of standard purity and germination tests.

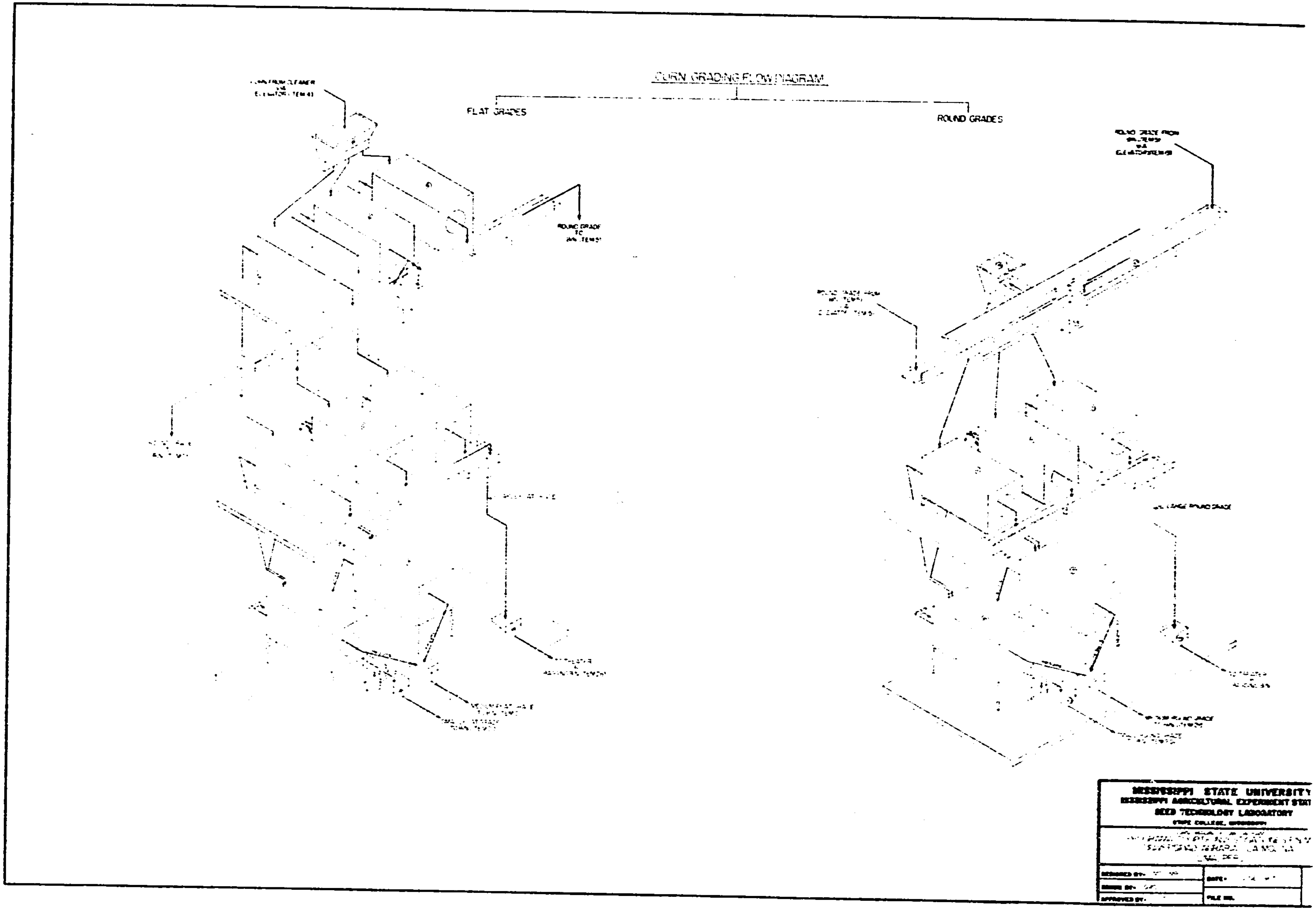

Figure 5. A corn grading flow diagram.

The seedsman, however, faces several situations in which the information normally available to him concerning seed quality does not provide a suitable basis for making a decision. One such situation is a determination of which lots from among many available should be marketed first and which lots should be held for possible carry-over, if necessary. Germination percentages of the lots provide some useful information for making this decision if there is a considerable range in germination among the lots. However, germination percentages among various lots are often quite similar. Hence, a seedsman is reduced to a more or less random selection of lots for possible carry-over, and he often finds the next season that several of the lots have drastically declined in germination. Such experiences involving seed lots of the same kind, variety, chronological age, and germination that do not maintain viability equally well under similar storage conditions are common. The failure of a seed lot of apparent good germination to maintain that germination in storage at a retail outlet or at the wholesaler constitutes a serious problem.

It is apparent that some important aspects of seed quality are not reflected with any consistency in the information provided by standard seed tests. A high germination percentage does not necessarily mean that a seed lot will store well or that it will produce a satisfactory stand even under relatively faverable conditions.

The solution to problems related to storability and vigor of seed lies in the development of a test - other than the standard germination test - which will differentiate among seed lots with respect to storage potential and field emergence capability. It is quite possible that one test would determine both of these important attributes of seed quality.

Several tests and methods have been advocated for evaluating the vigor and storage potential of seed. In most instances the methods recommended have been either too technical or tedious for economical and practical use by seedsmen. In order for a test to be successful in evaluating any aspect of seed quality, it should be relatively simple and easy to perform and produce the desired information in a consistent and uniform manner.

During the past several years, the Seed Technology Laboratory has been working on the development of an accelerated aging test for evaluating the storability of crop seed lots that - so far with the limited data obtained - has met the criteria indicated above.

The accelerated aging test involves the exposure of small samples of seed from the available lots to very adverse environmental conditions for a specific period. After accelerated aging, the percentage survival of the seed in the various samples is determined by standard germination tests.

Environmental conditions and periods of exposure required to obtain maximum differences in response for corn seed are 42°C - 100% relative humidity for 132 hours. Accelerated aging is accomplished in an accelerated aging chamber where the desired environmental conditions are maintained.

The following table show some of the results obtained from use of the accelerated aging technique in predicting seed storabil'ty for corn seed.

Table 1. Accelerated aging and seed storage data from selected lots of corn.

Lot #	Initial Germ. (%)	A.A. 42°C, 100% R.H. 132 hrs. (%)	Storage 20° - 75% 6 mos.	Storage 30°-75% 24 wks.
1	97.5	35.0	84.5	32.5
2	99.0	96.0	98.0	98.5
3	96.0	20.0	74.0	31.0

Thus, the accelerated aging technique is very effective in predicting eventual deterioration trends of the various seed lots. For example, the standard germination percentages of all 3 corn lots were above 95 percent. However, after accelerated aging for 132 hours, the germination percentage of lot 2 was still very high while lots 1 and 3 were severely reduced in germination. Thus, one would "predict" that lot 2 would maintain viability longer in storage than either lots 1 or 3. The validity of such a prediction, however, can only be verified by actual storage of a portion of each seed lot under various conditions. As indicated, germination values after 24 weeks storage at 30°C. - 75% R.H. verified the original prediction of the storage potential of each lot.

STORAGE

Seed are hydroscopic, i.e. they tend to either gain or lose moisture depending on how much moisture they contain and on the humidity of the air with which they are in contact. At a given temperature for each level of seed moisture content, there is a corresponding specific level of atmospheric humidity at which there will be no net exchange of moisture between seed and the air. Anytime seed moisture content and ambient relative humidity are not in equilibrium, there will be an exchange of moisture tending to bring them into equilibrium.

When seed that are sufficiently dry for storage are placed in a room with high relative humidity, they will increase in moisture until hygroscopic equilibrium is obtained. Deterioration of seed can be quite rapid when such conditions exists, particularly if temperature is also high. Seed moisture content and ambient temperature are the two most important factors affecting the rate of deterioration of stored seed. Moisture content of seed is dependent upon the initial moisture content of the seed and the relative humidity under which they are stored (7).

There are 3 general rules of "thumb" that are commonly used in seed storage (3):

1. For safe seed storage over periods longer than one season, the sum of the percent relative humidity plus the temperature in degrees fahrenheit should not exceed 110:

2. For each 1 percent decrease in moisture content, the storage life is doubled:

3. For each 10 degree fahrenheit decrease in temperature the storage life is doubled.

According to these rules, seeds stored at 8% moisture content will maintain good quality about twice as long as seeds stored at 9% moisture content, and seed stored at 60°F will maintain good quality twice as long as seed stored at 70°F.

The main purpose of storage is to maintain seed quality. This is best accomplished by storing high quality well dried seed under conditions that will prevent any regain in seed moisture and provide for reasonably moderate storage temperatures Satisfactory storage for corn seed has been accomplished by: (1) warehouse storage for areas such as Peru where the relative humidity is sufficiently low during storage, (2) cold storage rooms with some dehumidification and (3) dehumidified storage rooms with some type of supplemental cooling.

The general prescription for storage is that conditions should be dry and cool (1). A recommendation such as this is meaningless unless specific levels or at least ranges of moisture content and temperature are giver, and these cannot be given unless the desired period of storage is known.

Corn seed will store quite well for one season at a moisture content of 11 to 12% and a warehouse temperature less than 70°F. It must be kept in mind that the 12% moisture content cannot be maintained in warehouse storage if the ambient relative humidity is in excess of 60%. Storage periods longer than one season (carryover) require seed moisture contents of about 10% and some protection against high temperature for maintenance of viability and vigor. Long term storage of valuable seed stocks requires still more rigorously controlled conditions - relative humidity of 40% or less and temperature of 50°F. or less.

Thus, although most seeds can be stored for a year or more without loss of germination when properly dried or if stored under cold temperatures, the use of proper drying is normally more successful The ideal of course would be to dry seed to moisture content from 10 to 12 percent and then store in cool temperatures (8).

To provide good storage conditions, we must begin with a tightly constructed room, well insulated and provided with a good vapor barrier to reduce or eliminate the movement of water vapor through the walls, ceiling and floor. The most important factor in a dehumidified storage is an effective vapor barrier. To minimize condensation of water vapor on vapor barrier, it is necessary that it be located on the warm side (or outside) of the insulation.

Doors should be fitted with gaskets to prevent infiltration of air, and airlocks provided at all outside entrances to reduce air changes, particularly, where there is heavy traffic in and out of the room.

The relative humidity in a seed storage room can be controlled by mechanical refrigeration, dehumidification (refrigeration or desiccant) or a combination of air conditioning and dehumidification.

Desiccant dehumidifier: One method for controlling the humidity in a storage room is by the use of a desiccant dehumidifier (Figure 6). This type of dehumidifier dries the air as it passes into the storage room through a bed of dry desiccant such as silica gel. This is a highly porous hydroscopic material capable of holding as much as 40 percent of its own weight in water.

A factor that should not be overlooked is that a desiccant dehumidifier will add heat to the storage room. In some cases, the temperature of the air being dried increases as much as 30 to 40°F. as it passes through the drying bed. This is due to the latent heat of absorption and sensible heat gains from the reactivation of the desiccant. If this results in an inside temperature higher than desired, some means of removing the excess heat must be provided. This can be accomplished by air conditioning or water cooled heat exchangers in the discharged ducts of the dehumidifier.

Refrigeration dehumidifier: A self contained refrigeration dehumidifier is also satisfactory for controlling the relative humidity in storage rooms. However, it becomes inefficient at temperatures below 65°F. and relative humidities before 50%. This type dehumidifier will also liberate heat and cause an increase in temperature inside the storage room unless used in conjunction with a supplemental air conditioner for cooling.

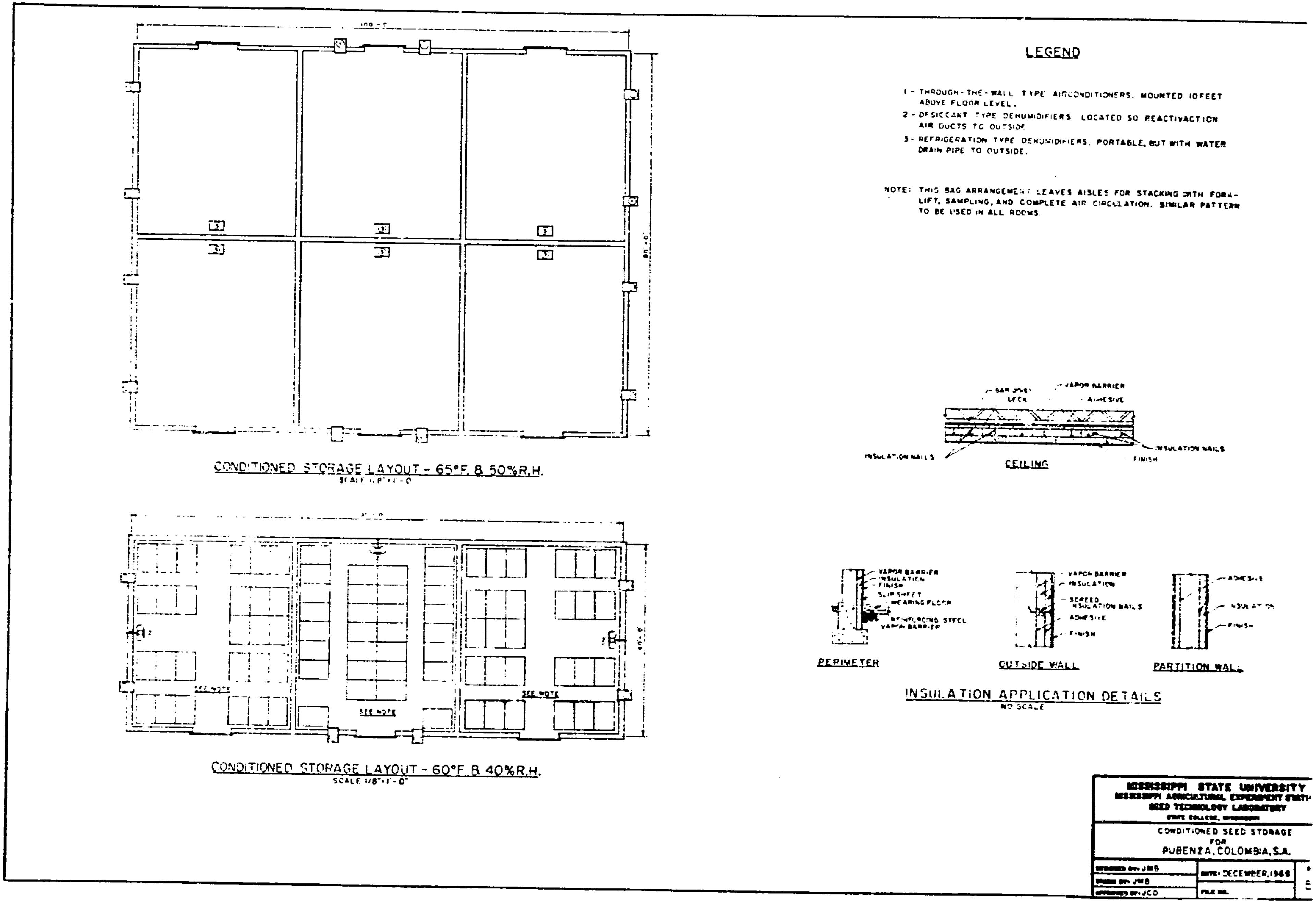

Figure 6. Conditioned storage using refrigeration and dehumidification.

Combination of Cooling Systems Dehumidifiers: A desiccant and refrigeration dehumidifier can be used quite satisfactorily when the desired relative humidity is below that which can be maintained by the cooling system. The cooling system will maintain desired temperature and remove some of the moisture from the air. A dehumidifier will reduce the relative humidity to the desired level.

FACILITY ARRANGEMENTS

No two corn processing facilities are alike but they are arranged according to local resources and needs. As illustrative of this point two corn processing plants in South America are presented; both have the same major objectives - to dry, process, and store corn seed - but each accomplishes this task by somewhat different means.

Basically, a descriptive flow diagram such as shown in Figure 7 is applicable to both plants.

The layout of the plant designed for Lima, Peru is given in Figure 8 with the major features being the dryer building, the sheller area, the processing area and warehouse storage. Conditioned storage is not necessary because of the prevalent low atmospheric moisture conditions in Peru.

The bin dryer is shown in Figure 9. It consists of six self-unloading bins with a central air tunnel similar to that shown in Figure 2. A unique feature of this dryer is the telescoping conveyors used to load the bins. The conveyors are built on casters which allows them to be moved around in all directions on the dryer's concrete top. This allows filling of all eighteen bin loading doors.

The equipment layout for the corn processing plant is shown in Figure 10. This plant is on three levels with a precision grader on each level. The arrangement of precision graders is clearly shown in Figure 5.

The layout for facilities designed for Pubenza, Colombia are shown in Figure 11. The major components of this facility are a two deck sack dryer, a processing plant and nine conditioned storage rooms.

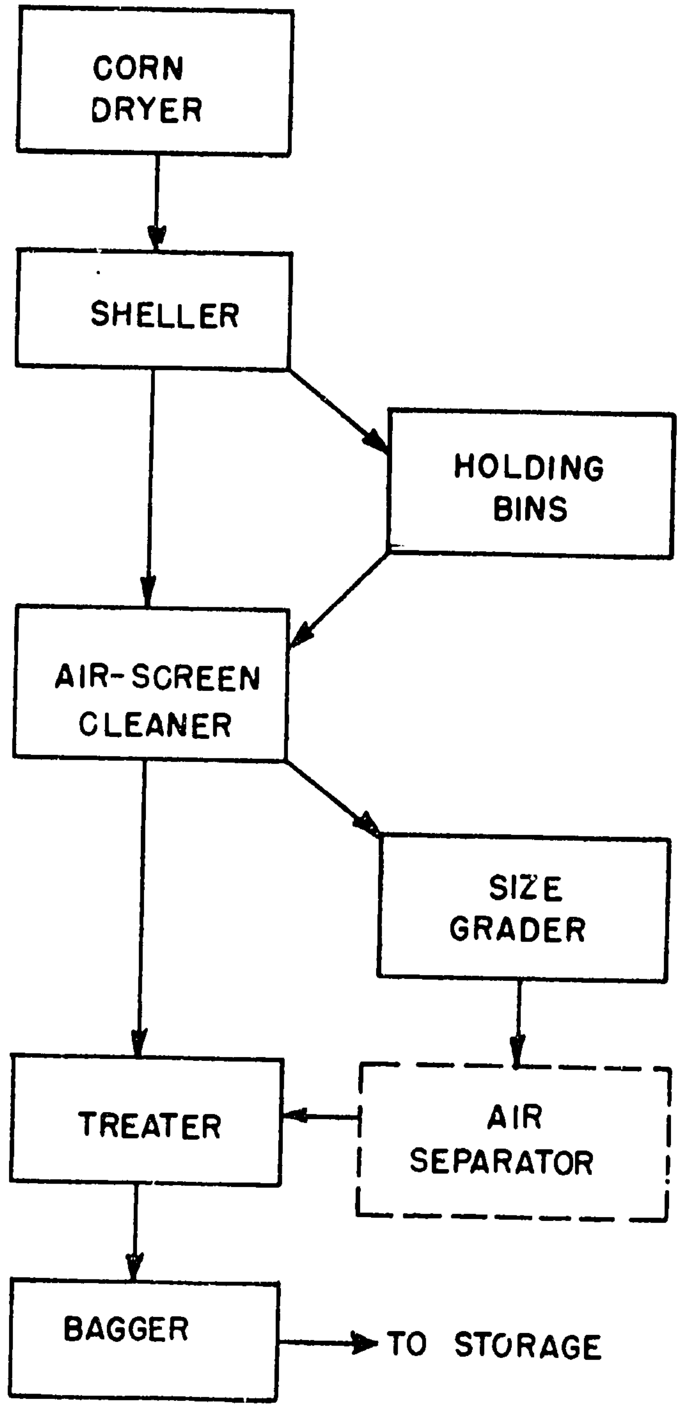

Figure 7. A flow diagram for processing seed corn.

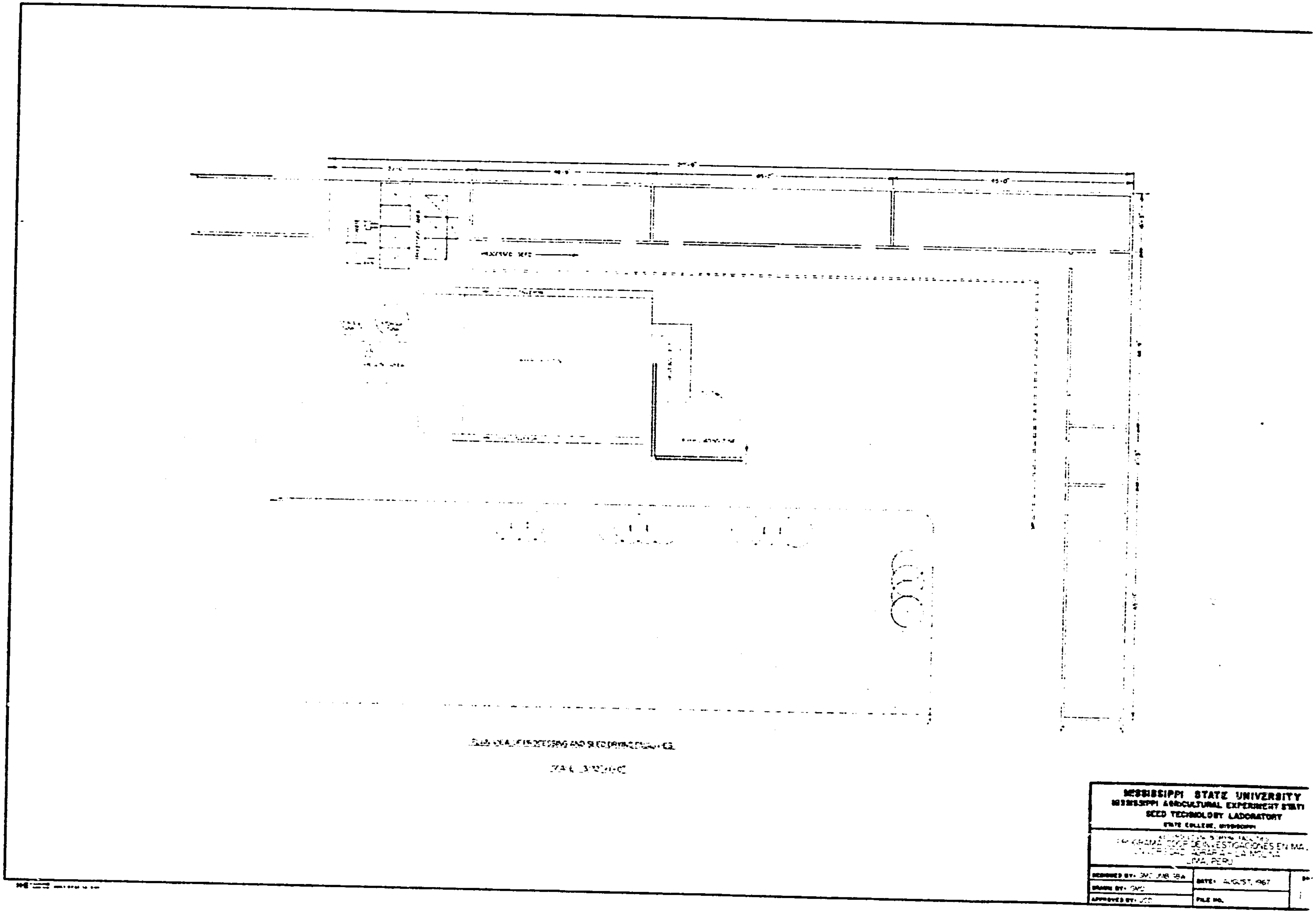

Figure 8. The seed processing facility in Lima, Peru.

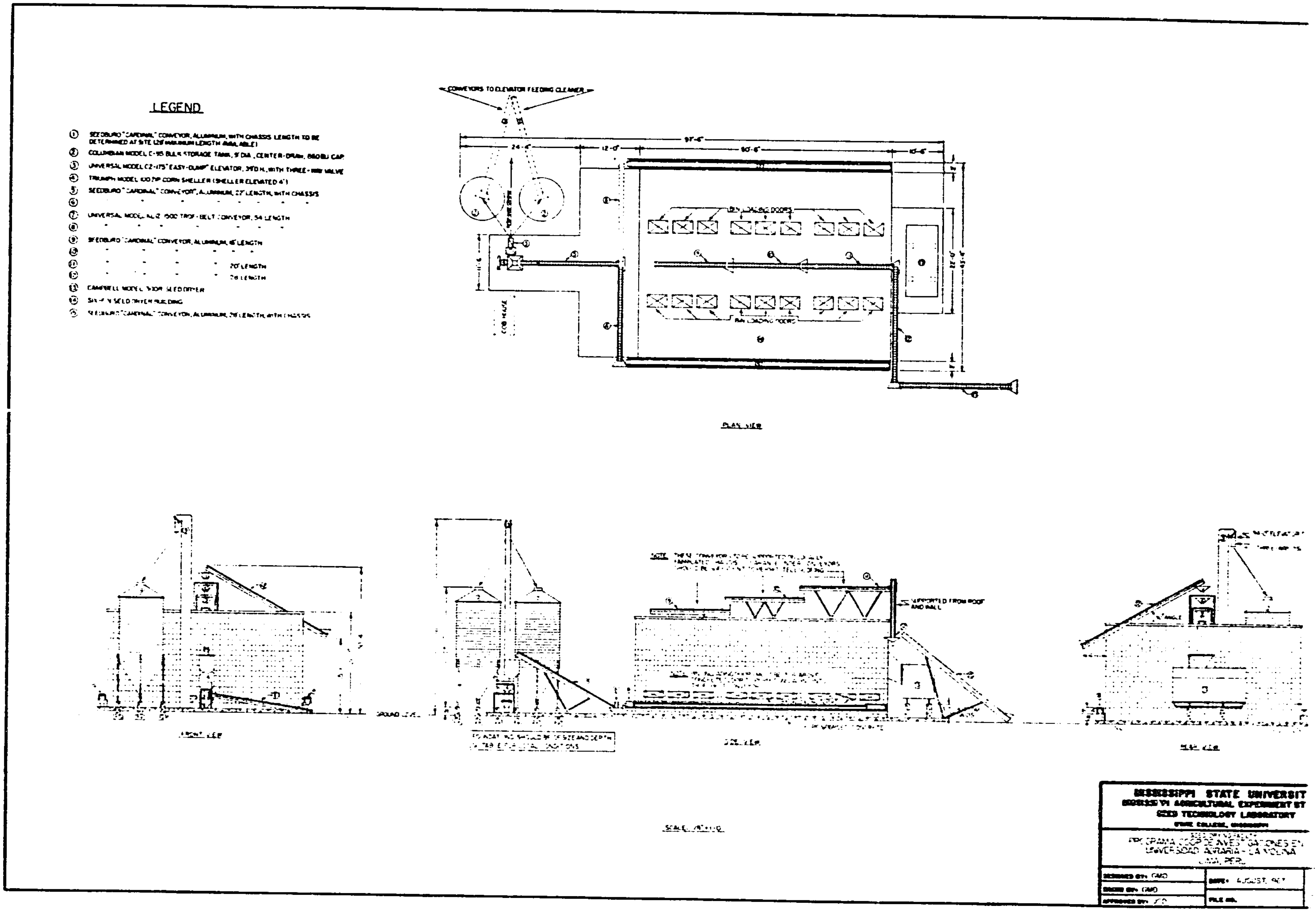

Figure 9. The seed drying facility in Lima, Peru.

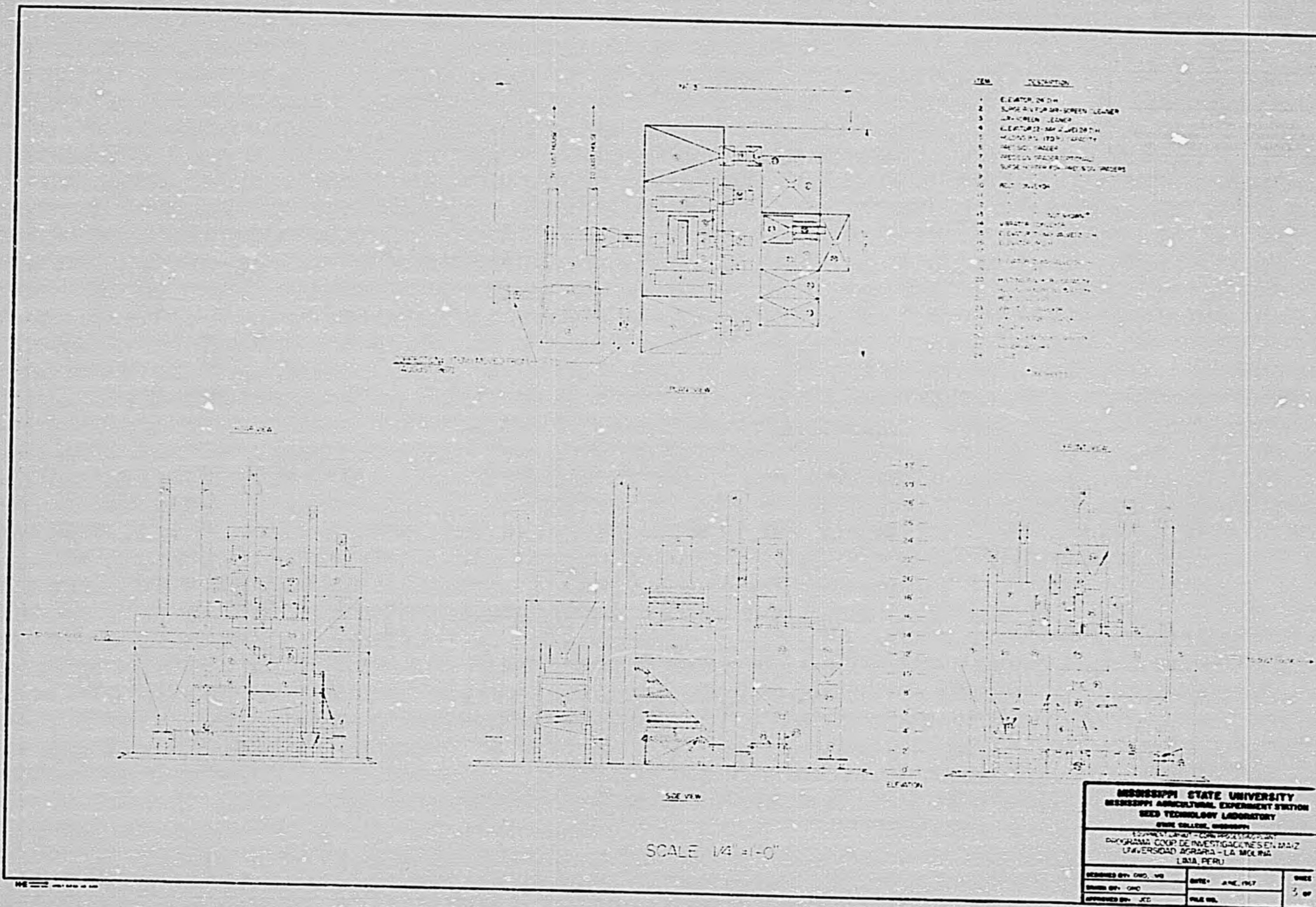

Figure 10. The equipment layout in Lima, Peru.

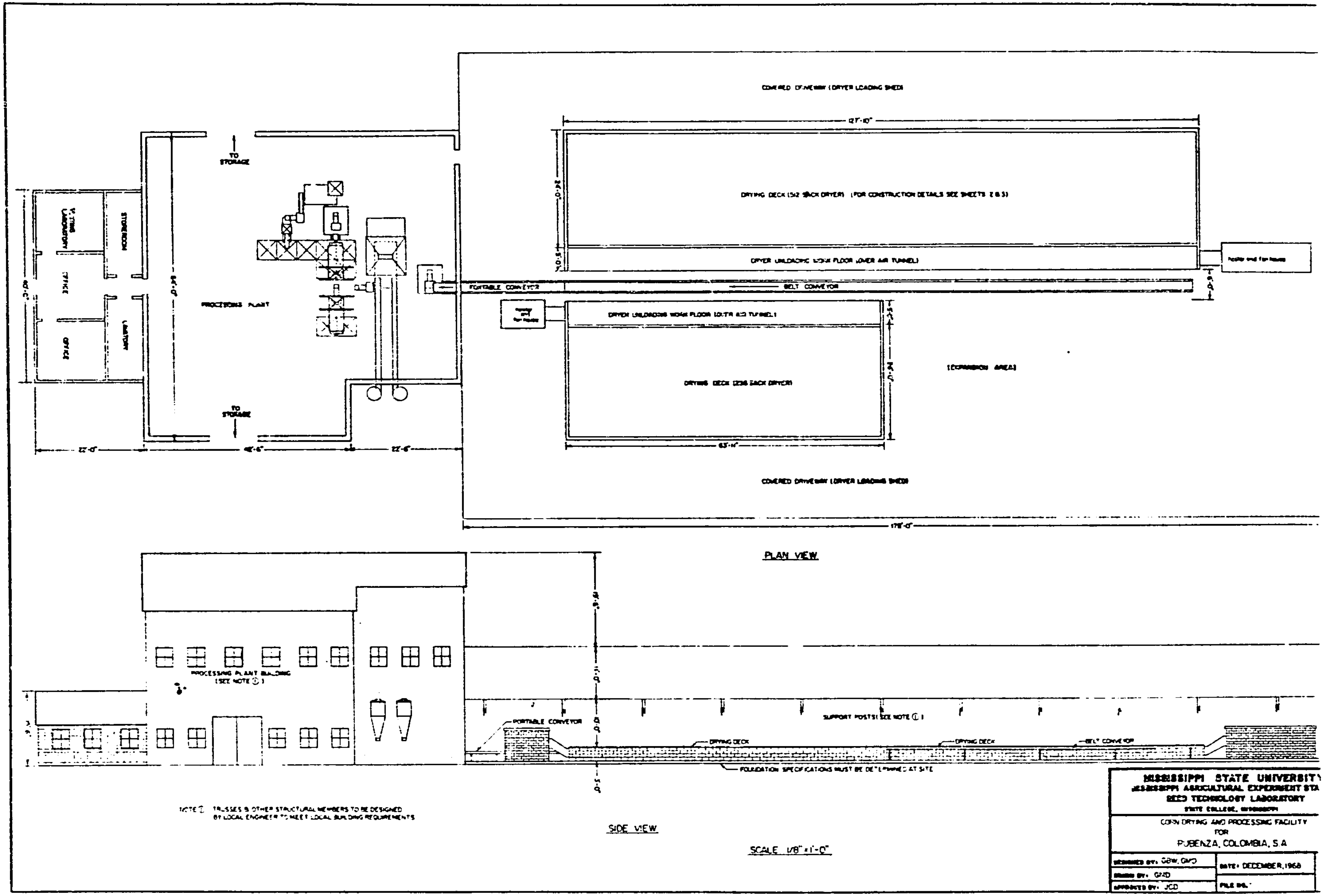

Figure 11. The corn drying and processing facility in Pubenza, Colombia.

The drying is accomplished on two sack dryers with a belt conveyor between them. When the seed has dried the sacks are emptied on the conveyor and sent to the sheller. One dryer has a capacity of 512 bags with the choice of drying through any or all of 16 plenum chambers and the other dryer has a capacity of 256 bags with 8 plenum chambers.

The equipment layout is shown in Figure 12 which is arranged on two levels. Note that there are two precision graders; therefore, the grading process is less straight forward than for the Lima plant and requires more holding in tanks between separations. An extremely important component of any seed processing plant is a dust collector. It is particularly important that a seed plant be kept clean.

Since the storage conditions in Pubenza, Colombia are quite severe it is necessary to provide environmental controlled storage rooms (Figure 5). Two different types of storage are shown. One is for 65°F and 50% relative humidity using refrigerator type dehumidifiers and air conditioners, and the other is for 60°F and 40% relative humidity using desiccant type dehumidifiers and air conditioners. Note the bag arrangement in the rooms. Aisles are provided for stacking with a forklift, sampling and complete air circulation. The rooms are ten feet high, and we figure 30% of the room as effective storage volume. Therefore, a 30' x 40' room has a storage capacity of 2400 bushels.

Thus it is rather evident that two corn processing facilities in two locations in South America while having some things in common, have many things which are particular to each plant's locality.

SUMMARY

Problems related to the drying, processing, and storage of corn seed in tropical and subtropical regions are discussed.

It is recommended that corn for seed be harvested on the ear by hand or with a picker at 25-35% moisture content. The corn should be dried on the ear in a sack drier or a bin drier to a moisture content of 11-12% with drying air not to exceed 110°F. Several designs for both types of driers are presented.

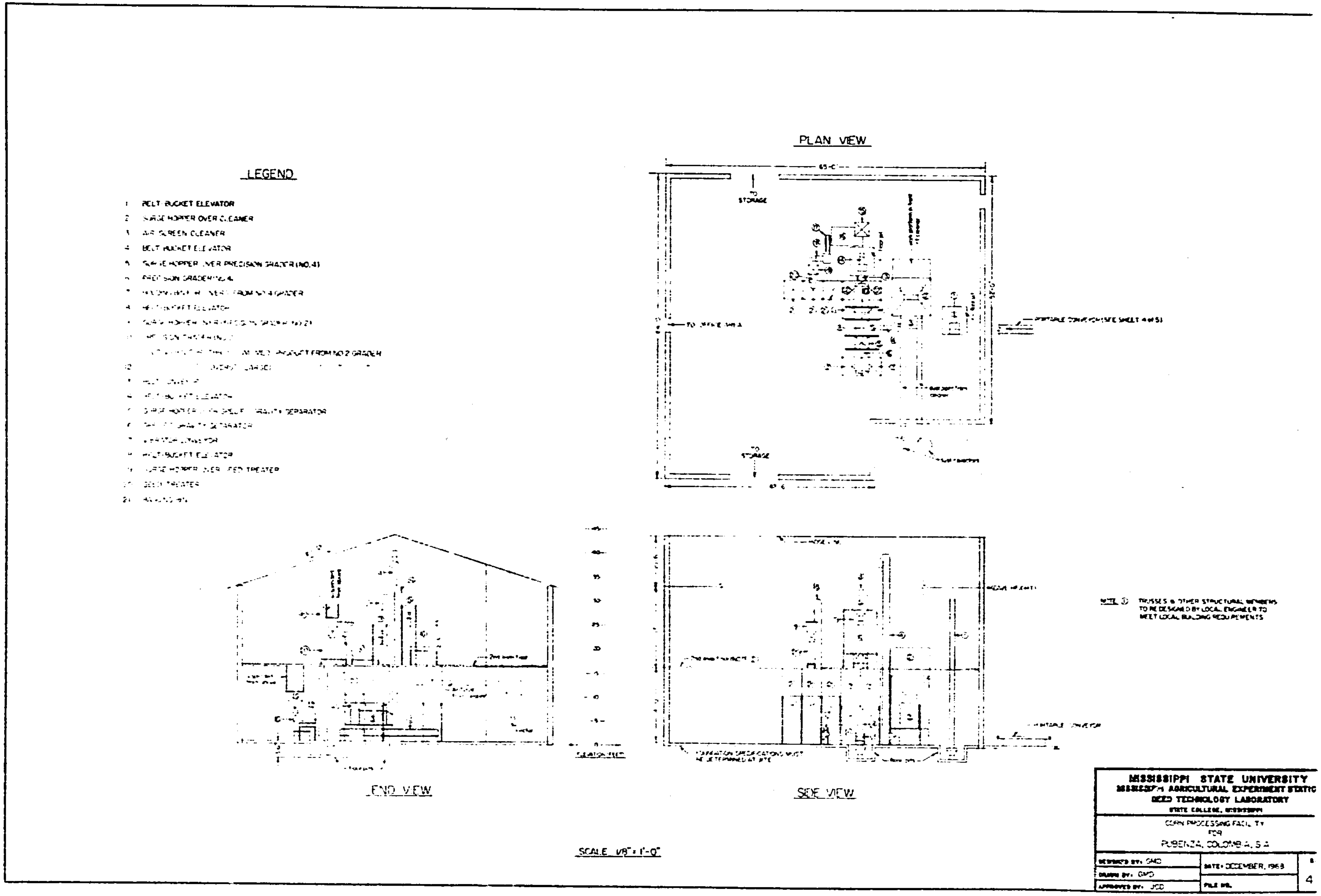

Figure 12. The equipment layout in Pubenza, Colombia.

A simple, inexpensive method for determining when seed are sufficiently dry for storage has been developed. The details of its use are presented.

When the corn is dried to 11-12% moisture content, it is ready to be shelled. And from the sheller, it goes to an air-screen machine to remove the trash, and then to precision graders to separate the "rounds" and the "flats" and divide them into small, medium, and large sizes. A final cleaning is accomplished on an air separator.

A method for predicting seed storability is presented. This method called "accelerated aging" subjects the seed to unfavorable storage conditions for about five days, and the resulting germination percent is a good indication of what the viability of the seed will be after being in storage.

Methods of storage are discussed. In a few circumstances warehouse storage is recommended even in tropical or subtropical regions. If high relative humidities are prevalent it is necessary to provide cool, dry storage.

Two corn seed processing facilities designed for two different countries in South America are presented in detail. Even though the objectives of each plant is the same, different methods are used to suit the particular local conditions.

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