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Research on Farm Drying and Storage of Sorghum Grain

TEXAS AGRICULTURAL EXPERIMENT STATION
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IN COOPERATION WITH THE UNITED STATES DEPARTMENT OF AGRICULTURE

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SUMMARY

Research was conducted by the Texas Agricultural Experiment Station and the U. S. Department of Agriculture at Substation No. 1 near Beeville during 7 crop years (1949-50 through 1955-56) to develop methods and procedures for on-the-farm drying and storage of sorghum grain in South Texas.

High moisture and excessive trash (stems, leaves and grass seed) lead to insect, mold and heat damage, and are the basis for most of the troubles encountered in storing grain. High moisture may result from the leakage of outside moisture through bin walls or from the placing of high-moisture grain in storage.

A tight structure for protecting the grain from the weather, insects and rodents was found to be essential. Properly constructed conventional wood or steel buildings and bins, and a cement plaster bin painted with a water-proofing paint and provided with adequate ventilation at the grain surface, were satisfactory for storing sorghum grain.

The maximum moisture content for safe storage of sorghum grain in South Texas was found to be 12 percent. This recommendation is based on storing grain to maintain market value for a single season without systematic turning or aeration, or for longer than 1 year with regularly scheduled aeration practices. Storage of sorghum grain for longer than 1 year without turning or aeration would require limiting the moisture to 11 percent or less. Sorghum grain at 12 to 14 percent moisture, which was aerated or turned during storage, was stored safely for 9 months. Sorghum grain with a moisture content higher than 14 percent did not store satisfactorily.

High concentrations of cracked grain and broken kernels provide favorable conditions for insects known as flour beetles or "bran bugs." The activities of a large number of these insects may cause heating and increase the moisture content of the grain. It was extremely difficult to obtain effective fumigation in grain which had a high percentage of cracked grain and broken kernels.

Excessive trash caused heating in some bins, even though the moisture content of the grain was below 12 percent.

The temperature of low-moisture grain during storage was a good indication of its condition. Dry, clean, insect-free grain did not heat when held in a satisfactory storage structure.

Fourteen species of insects were found in grain samples taken from the experimental bins. The most prevalent were the flour beetle, flat grain beetle, lesser grain borer, rice weevil and a complex of the Indian-meal, rice and almond moths.

No satisfactory protective treatment to prevent infestations was found. Pyrethrum dusts were only partially effective and protected the grain only through the fall. Ryania was effective, but no tolerance has yet been established.

Various liquid fumigants were effective in controlling insects after infestation developed. A minimum dosage rate of 6 gallons per 1,000 bushels was necessary under the most favorable conditions.

Aeration systems were effective for fumigating by recirculating the fumigant through the grain. A recirculated dosage rate of 4 pounds of methyl bromide per 1,000 cubic feet killed all the test insects, as did an application rate of 4 gallons of a 60-35-5 mixture of carbon tetrachloride, ethylene dichloride and ethylene dibromide per 1,000 bushels of grain.

Mineral oil sprayed on the grain surface in August and October prevented infestation by the various species of moths. Pyrethrum dusts were not effective at the concentrations used.

Rats and mice were difficult to control and probably were responsible for considerable losses. Effective control was obtained through approved rodent control procedures.

Aeration was practical and economical in cooling grain during storage. Effective cooling was obtained with air flow rates as low as 0.25 cubic feet per minute (cfm) per 100 pounds of grain (about 1/8 cfm per bushel). Fan and air distribution systems used for drying supplied air at a higher rate, and also were satisfactory for aeration.

Molds that cause deterioration during storage, such as Aspergillus and Penicillium, did not develop as long as the grain was stored in a weather-tight structure and a maximum moisture content of 12 percent was maintained.

Of the several methods of drying used on farms in Texas, bin drying with unheated air seems the most practical. To prevent loss in grade, an air-flow rate of 4.5 cfm per 100 pounds of grain (2.5 cfm per bushel) was found necessary to dry grain with 18 percent moisture. The maximum grain depth for the most economical drying was 8 feet at this moisture level.

In unheated air drying applications in South Texas, the grain moisture in the wettest layer had to be reduced to 15 percent in 8 days or less to prevent undesirable mold development. Further reduction in moisture to a safe level was done over a longer time.

A simple fan-operating schedule, based on pushing air up through the grain, was developed.

A column-type dryer, using heated air, was required when high drying capacities were needed.

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Research on . . . . .

FARM DRYING AND STORAGE OF SORGHUM GRAIN

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THE IMPORTANCE OF GRAIN SORGHUM in Texas has grown steadily during the past 20 years. The development of varieties and hybrids suitable for mechanical harvesting and an increased demand during World War II contributed toward making grain sorghum a major crop in South Texas.

The demand for sorghum grain was so great during most of the 1940's that the crop was moved directly from the field to the waiting market. As a result, the storage of sorghum grain did not become a serious problem to farmers in South Texas until the late 1940's, when there was a sudden and sharp decline in market price. Storage space available to hold the grain for a more favorable market would accommodate only about 10 percent of the grain produced in that area.

The warm, humid climate of South Texas makes it necessary to store grain at a lower moisture content than is required in a cold, dry climate. The lower is the moisture content of stored grain under these climatic conditions, the less is the danger of insect infestation.

In an effort to solve the problems peculiar to this area, research was started in 1949 by the Texas Agricultural Experiment Station and the U. S. Department of Agriculture to develop methods and procedures for the safe storage of sorghum grain on the farm. This study provides information on types of storage structures, maximum moisture content for safe storage, effect of storage conditions on grain quality, insect and rodent control, aeration during storage, losses in weight during storage, grain handling equipment and drying high-moisture grain.

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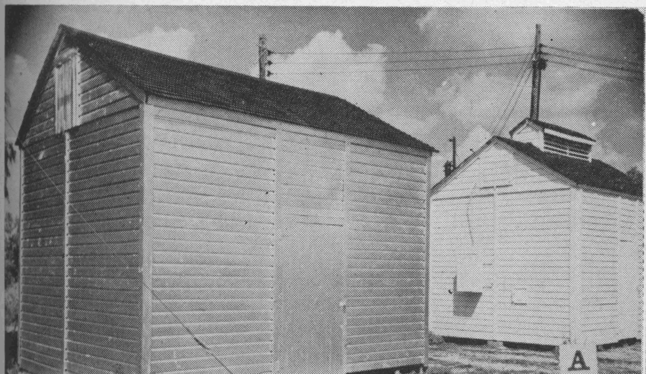
EQUIPMENT AND TEST PROCEDURE

Sorghum grain was stored at different moisture contents at Substation No. 1 near Beeville. Results were obtained for 7 crop years, 1949-50 through 1955-56.

STORAGE BINS

Fifteen conventional farm-type bins, two steel buildings, one cement plaster bin, two temporary-type bins, one glass-lined steel, air-tight bin and five underground pits were used in these tests. Concrete block, earth fill and concrete slab foundations were used.

The conventional bins, shown in Figure 1, were constructed of wood and steel. Capacities ranged from 28,000 pounds (500 bushels) to 123,000 pounds (2,200 bushels). Shapes were round and rectangular. Bin wall colors of white and aluminum were used and some of the bins were left as unpainted galvanized steel. Grain depths were 6 to 10 feet.



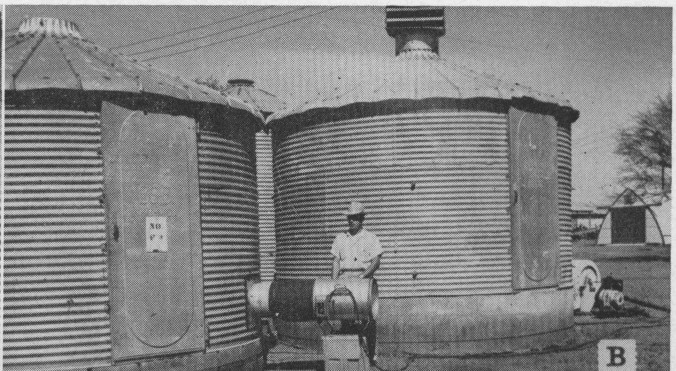
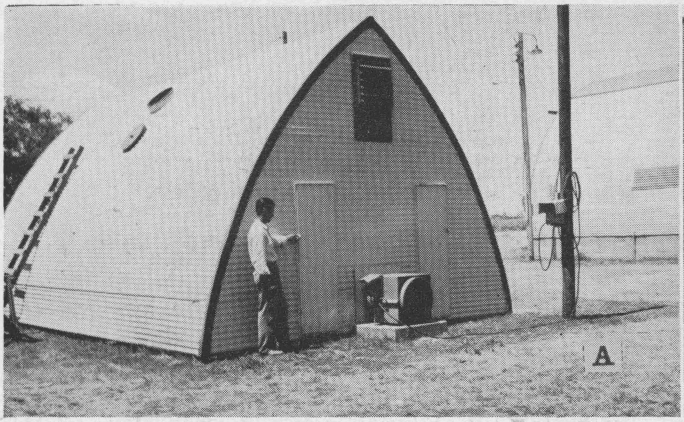


Figure 1. Types of conventional farm-type bins used in sorghum grain drying and storage tests. A. Two 12 x 16-foot and two 14 x 16-foot bins of wood construction, such as shown, were included. B. Two 56,000-pound capacity steel bins equipped with fans and air distribution systems for bin drying grain with unheated air. Capacities of steel bins used in these tests ranged from 28,000 to 123,000 pounds.



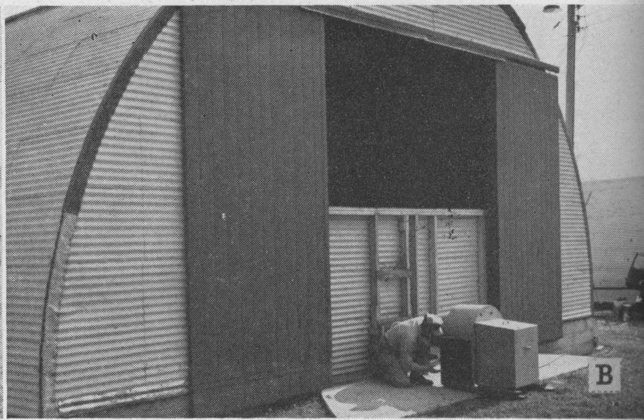


Figure 2. These steel buildings were used for drying and storage tests. A. This 16 x 28-foot building was equipped with a fan and air distribution system for drying and aerating grain. B. Two 50,000-pound capacity bins were constructed in this 32 x 60-foot steel building.

One of the steel buildings was 16 feet wide and 28 feet long. It had a capacity of 123,000 pounds (2,200 bushels). The other was a 32 x 60-foot building in which two 50,000-pound (900 bushels) capacity bins were constructed in one end. These buildings are shown in Figure 2.

The cement plaster bin is shown in Figure 3. This bin was 14 feet in diameter with 8-foot walls and had a capacity of 56,000 pounds (1,000 bushels). A screw-conveyor was installed in the floor to facilitate unloading.

The temporary-type bins are shown in Figure 4. A bin was considered temporary when it was designed for emergency use for a short time, usually for 1 year or less. Temporary-type bins used in these tests were constructed of a low-cost, hardwood veneer material with asphalt-resin-impregnated paper on both sides. The material was black in color and was made in 4 x 8-foot sheets with an overall thickness of 1/7 inch. One of the bins was 12 feet wide, 16 feet long and 4 feet deep. A 2 by 4-inch framework was constructed over the bin to support a tarpaulin cover. The capacity was 45,000 pounds (800 bushels). The other bin was 14 feet in diameter with 8-foot walls. Its capacity was about 62,000 pounds (1,100 bushels).

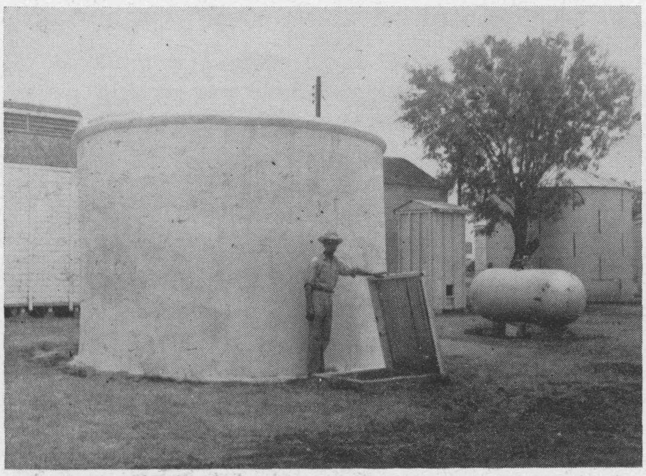


Figure 3. This 56,000-pound capacity cement plaster bin was equipped with a screw conveyor in the bin floor to facilitate unloading. A removable cover, shown in raised position, was used to keep water out of the unloading pit. To prevent spoilage of grain in the surface layer, it later was necessary to install a revolving head ventilator in the bin roof.

A glass-lined steel, air-tight bin, shown in Figure 5, was used to store grain ranging in moisture from 12.4 to 26.3 percent. The bin was 14 feet in diameter with 8-foot walls. It had a capacity of 56,000 pounds (1,000 bushels).

Four small-scale and one large-scale underground pits were tested. Each small pit was approximately 6 feet long, 2 ½ feet wide and 5 feet deep. Each was filled to within 1 foot of the top and had a capacity of about 2,800 pounds (50 bushels). The large-scale pit, shown in Figure 6, was 8 feet wide, 18 feet long and 8 feet deep with a capacity of 40,000 pounds (700 bushels). Materials used to line the floor and walls included asphalted roll roofing, moisture-resistant reinforced building paper, poured concrete, cement plaster and wood. One pit had an earth bottom and walls.

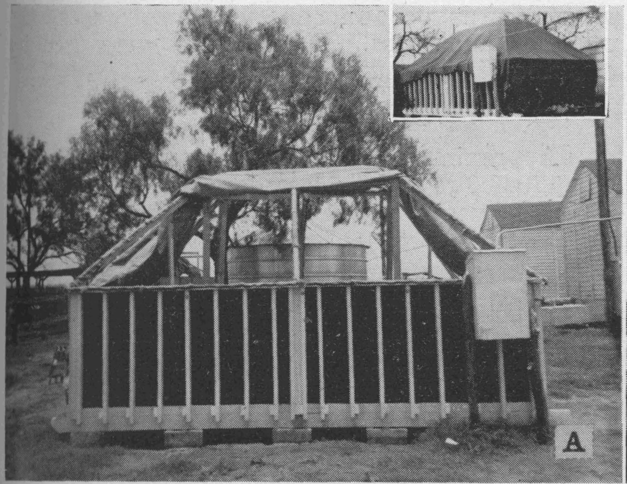
INSECT CONTROL

Tests to control insects were conducted in the round, steel bins and in the smaller of the steel buildings. Studies were made to determine the possibilities of using protective treatments, to develop surface treatments as a means of retarding invasion of insects from outside sources and to evaluate and improve standard fumigation practices. The test bins were sampled at regular intervals and the species of insects and their abundance were recorded.

AERATION

Aeration is the moving of small amounts of outside air through stored grain, for purposes other than drying, to maintain or improve its value.

During the first 2 years, grain was turned (moved from one bin to another) when heating



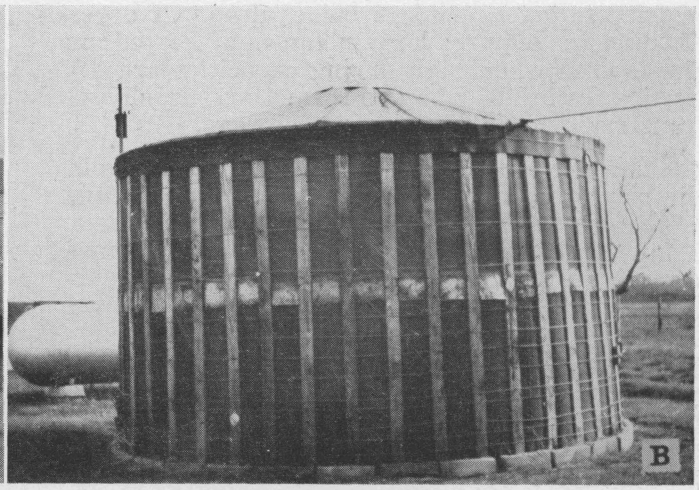


Figure 4. These temporary-type bins were used to store dry grain. A. A 2 x 4-inch framework was constructed over this 45,000-pound capacity bin to support a tarpaulin cover. Inset shows the cover in place after the bin was filled with grain. B. This 62,000-pound capacity round bin was erected on a tamped earth fill foundation. The grain was peaked at the center and covered with roll roofing.

occurred. After the second year, air distribution systems were installed in most of the bins to cool the grain by aeration. Air flow rates of 0.2, 0.6, 0.9 and 1.3 cubic feet per minute (cfm) per 100 pounds of grain (0.12, 0.33, 0.50 and 0.75 cfm per bushel) were used.

DRYING

Tests were conducted with unheated and heated air. Unheated air is normal atmospheric air without the addition of heat. Heated air removes large amounts of moisture from the grain. Heated air is used for fast drying and unheated air is used for slow drying.

With Unheated Air

A bin dryer was used for the unheated air drying tests. A bin dryer is one in which grain is dried in the same bin in which it is to be stored. Tests were conducted with small-scale and full-scale bins. Initial moisture content of the grain was 14.2 to 20.0 percent, wet basis. Grain depths were 6 to 10 feet. Small-scale bins were used to determine minimum air flow requirements for drying with unheated air. Air flow rates of 1.8, 2.7, 3.6, 4.5, 5.4 and 7.2 cfm per 100 pounds of grain (1.0, 1.5, 2.5, 3.0, and 4.0 cfm per bushel) were used.

With Heated Air

Heated air drying tests were conducted with bin dryers and batch-type dryers. A portable batch dryer, as shown in Figure 29, was used in these studies. Results of tests conducted in 1947 with a column-type-batch dryer (1)[1] are summarized in this report.

In the bin drying tests, grain was dried with air temperatures of 119° to 135° F. Initial moisture content of the grain was 15.4 to 23.0 percent, wet basis. Grain depths were 1.25 to 6.25 feet.

A batch dryer is one which dries a fixed quantity of grain at one time, with additional batches dried on a repeating basis. Usually grain

[1]Numbers in parentheses refer to the references.

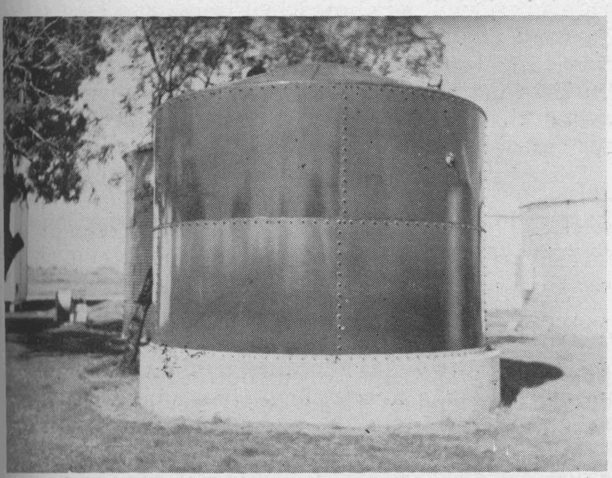


Figure 5. This 56,000-pound capacity glass-lined steel, air-tight bin was used to store high-moisture grain.

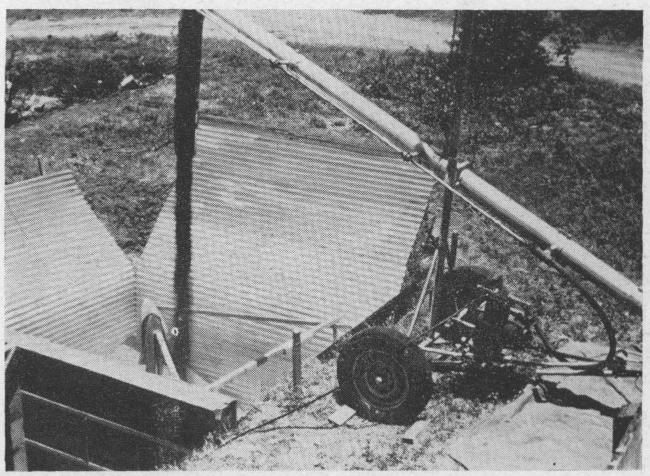


Figure 6. Underground pits were used to determine the practicability of this type of storage in South Texas.

is dried in layers 6 to 18 inches deep. A dryer of this type requires large volumes of heated air and is used when high drying capacities are desired. Grain dried by this method usually is transferred to another bin for storage.

Air temperatures of 125 to 230° were used in the batch drying tests. Initial moisture content of the grain was 13.4 to 26.3 percent, wet basis. Grain depths were 10 to 18 inches. Air volumes were 70 to 107 cfm per square foot of grain surface exposed to the air.

QUALITY DETERMINATIONS

Temperature observations were made at regular intervals during the drying and storage period. Samples for moisture content, grade, fat acidity, germination, fungal infestation and insect counts were taken as the grain was stored and at intervals during the storage period.

The fat acidity value was used as a measure of the quality of grain. It is defined as the number of milligrams of potassium hydroxide required to neutralize the free fatty acids in 100 grams of dry grain. Tests made by the U. S. Department of Agriculture (2) indicate that freshly harvested grain sorghum of unquestionable soundness usually has fat acidity values less than 25. In these experiments, 157 samples of freshly harvested grain of the 1952, 1953, 1954 and 1955 crops were analyzed. Fat acidity values for these samples were 13 to 37, with an average of 23.

INSTRUMENTS

A portable potentiometer and copper-constantan thermocouples were used to determine temperatures at various locations in the grain. Standard moisture testing equipment was used for moisture determinations. A deep bin probe was used to obtain samples of grain from the bins. Recording instruments were used to obtain continuous records of atmospheric temperatures and relative humidities. Manometers were used to measure air pressures.

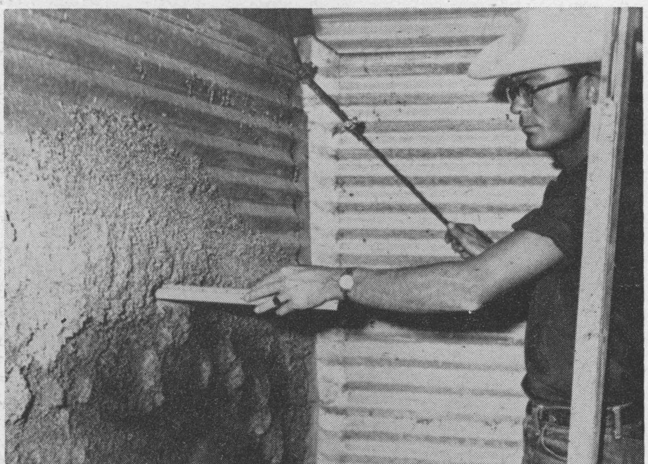


Figure 7. A tight structure was necessary to prevent leakage of outside moisture. Moisture leakage caused high insect infestation and heating which resulted in considerable spoilage of grain.

GRAIN

Approximately 4,500,000 pounds of Martin and 170,000 pounds of Texioca 54 were used during the 7-year test period. Initial moisture contents were 10.4 to 26.3 percent, wet basis.

FOR SAFE STORAGE OF GRAIN

High moisture and excessive trash (stems, leaves and grass seed) lead to insect, mold and heat damage, and are the basis for most of the troubles encountered in storing grain. High moisture may result from the leakage of outside moisture through bin walls or from the placing of high-moisture grain in storage.

BIN CONSTRUCTION

Properly constructed conventional wood or steel buildings and bins and a cement-plaster bin painted with water-proofing paint and provided with adequate ventilation at the grain surface, were satisfactory for storing sorghum grain.

Wooden bins with single walls were not tight enough to exclude moisture or prevent loss of fumigants. Single-wall bins can be made tight by lining the walls with roofing felt, but repairs usually are necessary before each filling of the bin.

Moisture leaked through the bin walls in some of the steel bins where wall joints and bolt heads were poorly sealed, causing heating and high insect infestation. Moisture leakage was prevented by caulking all joints and sealing all bolt heads properly.

In some cases, moisture leaked through the floor-wall joint in round steel bins. It was found that bins should be located on well-drained areas and the floor elevated enough so that water cannot collect and leak through the floor-wall joint. A tamped earth fill encircled by a concrete block retaining wall, as shown in Figure 8, was a satisfactory foundation for round steel bins. Bins were anchored to "dead men" buried in the ground to prevent the possibility of windstorm damage when the bins were empty.

Grain stored in temporary-type bins kept satisfactorily, but the temporary use of the structures did not justify the cost of construction and the periodic maintenance required.

Grain with a moisture content of 15 to 16 percent was stored in an air-tight bin for as long at 4 ½ months without loss in market value when the grain was transferred to another bin for drying at the end of the storage period. Germination dropped to zero after 3 months' air-tight storage. Some difficulty was experienced in unloading since the grain would not flow readily. Grain with an average moisture content of 17.2

percent was stored in 1953 in this air-tight bin and was used satisfactorily in a 112-day feeding trial at the Beeville station (3).

Underground storage was found to be undesirable when storing grain for market purposes. It was almost impossible to prevent soil from mixing with the grain during the loading and unloading operations. There was no satisfactory way to control insects and rodents. Even if grain is stored for feed on the farm, the expense involved in constructing bulkheads to hold the grain and to protect it from the weather during the feeding out period is as great, if not more, than aboveground storage.

MOISTURE CONTENT OF GRAIN

The purpose for which grain is to be used is a factor which determines the maximum moisture for safe storage. For example, if it is desired to maintain germination of seed or to prevent a serious increase in fat acidity value, the moisture content must be lower than for grain for which maintenance of market grade is the sole consideration. If the grain is trashy or contains a large percentage of cracked and broken kernels, a lower moisture content usually will be required than if the grain is clean and sound. Grain aerated during storage can be held at a higher moisture content than when no provision is made for aeration.

Grain was stored at the following moisture contents to determine the maximum moisture for safe storage in South Texas: below 11 percent, 11 to 12 percent, 12 to 13 percent, 13 to 14 percent and 14 to 15 percent. Moistures within these ranges represent the maximum moisture in the bin and not the average moisture content of the grain. Length of storage was 8 to 33 months.

The maximum moisture content for safe storage of sorghum grain in South Texas was found to be 12 percent. This recommendation is based on storing grain to maintain market value for a single season without systematic turning or aeration, or for longer than 1 year with regularly scheduled aeration practices. Storage for longer than 1 year without turning or aeration requires limiting the moisture to 11 percent or less. Grain at 12 to 14 percent moisture, aerated or turned during storage, was stored safely for 9 months. Grain with a moisture content higher than 14 percent did not store satisfactorily.

Below 11 Percent

At initial moistures of 9.7 to 11 percent, one lot of 1949 grain was stored, without turning or aeration, for 2 years and then fed out to beef cattle over an additional 6 months. It did not heat or develop an abnormal odor during storage. An increase of cracked kernels and trash from 2.8 to 5.3 percent caused a change in grade from Number 1 to Number 2. There was no change in test weight during the 2 years. Average moisture increased from 10.5 to 11.2 percent.

Nine other lots were stored without aeration or turning for 9 to 17 months. There was no loss in grade except in one lot where a slight increase in percentage of cracked kernels caused a change in grade from Number 1 to Number 2. Changes in test weight varied from no change to a reduction of 5 pounds per bushel. No significant loss in germination occurred during 9 months storage, but germination usually decreased gradually in lots stored longer.

11 to 12 Percent

Out of 14 lots stored 9 to 10 months, no change in grade occurred in five aerated and three unaerated bins. Grade changed from Number 1 to Number 2 in four aerated bins and from Number 1 to Number 3 in one aerated bin. The reduction in grade of all five lots was caused by an increase in percentage of cracked kernels and trash.

One of the lots was high in trash content and became heavily infested with insects. Frequent aeration was necessary during the fall and winter to reduce high temperature areas and resulted in considerable reduction in moisture content of both the grain and the trash. This bin graded Sample, Sour, after 9 months storage.

One lot of grain stored in 1951 and aerated during storage did not change in grade for 26 months, but became musty and graded Sample after 32 months storage. Reduction in grade was due to heating and heavy insect infestation resulting from leakage of outside moisture. Average moisture decreased about 0.5 percent during the 32 months. Germination decreased considerably after 8 months storage. Test weight per bushel decreased less than 1 pound.

Another lot of grain dried with unheated air in 1955 was held in aerated storage for 2 years and then fed out to beef cattle over an additional 3 months. Germination dropped from 90 percent at the start of storage to 72 percent after 24 months. There was no loss in grade during the 2 years. Average moisture decreased about 0.5

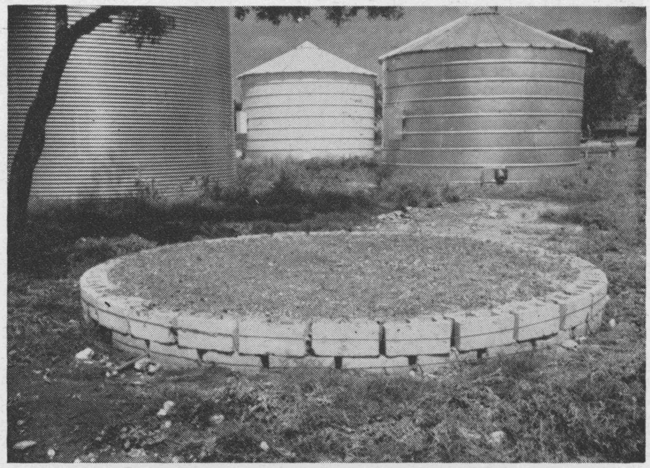


Figure 8. Foundations made by setting a ring of concrete blocks and filling the inside with well-tamped earth were used for most of the round steel bins.

percent. Test weight changed from 58.5 to 57.5 pounds per bushel. Fat acidity values increased from 18 to 28 during the first year, and to 41 at the end of the second year.

Aerated grain in this moisture range, which was relatively free of trash and insects, was stored for 9 months without loss in germination. Fat acidity values of 16 to 30 at the start were increased to 26 to 45 during the same period. There was little change in average moistures of grain stored without aeration but moistures decreased in aerated lots from 0.3 to 1.7 percent, with an average 1.1 percent.

12 to 13 Percent

As in the lower moisture ranges, the amount of trash in the grain and the degree of insect infestation were the most important factors in maintaining high quality grain. Extremely trashy grain, together with high insect infestations, caused heating in two unaerated bins and resulted in Sample Grade grain, Sour, at the end of 9 months storage.

Seven lots free of trash and low in insect activity were not reduced more than one grade during 9 months storage in four aerated and three unaerated bins. Changes in test weight were not great enough in any of the lots to cause a reduction in grade. There was no loss in germination during 9 months storage in the aerated bins, but a significant loss occurred in all of the grain stored without aeration. Average moistures decreased 0.3 to 1.1 percent in the aerated bins, but changed very little in bins that were not aerated. A considerable increase in fat acidity value occurred, except in one aerated lot that remained free of insects throughout the storage period.

Figure 9. An example of how trash rolls down into pockets as the bins are filled. This material causes air to channel and results in musty and heat-damaged grain. Proper adjustment of combines at the time of harvest will reduce the amount of trash.

13 to 14 Percent

Five lots of grain in this moisture range started to heat after a few weeks storage. Since none of the bins was equipped for aeration, grain in four bins was turned from one bin to another to reduce hot spots. None of the lots was reduced more than one grade during 9 months storage, but there was a significant loss in germination in all four lots. Changes in test weight ranged from 1.5 pounds per bushel increase to 2.0 pounds decrease. The fifth lot, held in storage without turning or aeration, decreased in grade from Number 2 to Sample, Sour, during 9 months storage.

These tests showed that grain in this moisture range can be stored without significant losses in commercial grade when facilities are available for turning the grain. This is expensive and time consuming and is not practical for farm storage; however, turning could have been eliminated had provision been made for aeration. Even then, good management practices are required to prevent losses from heating and insects.

14 to 15 Percent

At initial moistures of 14 to 15 percent, two lots of grain started to heat a few days after storage. One lot of 1949 grain was held in storage for 9 months without aeration. Grade was reduced from Number 3 to Sample Grade during this period. Test weight per bushel decreased from 58.0 to 56.5 pounds per bushel. Germination dropped from 85 percent to zero during the first 3 months storage.

High temperatures developed in a lot of 1953 grain a few days after storage. To prevent excessive losses, unheated air was used for 8 days to reduce the moisture to below 11 percent. No further heating occurred during 9 months storage, but an increase in percentage of cracked kernels and trash caused a reduction in grade from Number 2 to Number 4 during the same period. Test weight per bushel changed from 55.0 to 54.5 pounds. Germination decreased from 86 to 76 percent and fat acidity value increased from 25 to 50.

CRACKED GRAIN AND TRASH

The amount of cracked grain and broken kernels is an important factor in grain storage. High concentrations of these materials provide favorable conditions for insects known as flour beetles or bran bugs. These insects feed primarily on broken kernels or on grain damaged by other insects. The activities of large numbers of these insects may cause heating and increase the moisture content of the grain. It also is extremely difficult to obtain effective fumigation in grain which has a high percentage of cracked grain and broken kernels.

Excessive trash caused heating in some bins even though the moisture content of the grain was below 12 percent. Stems and leaves of sorghum plants usually are higher in moisture than the grain at the time of harvest. Since this material is lighter than the grain, it accumulates in pockets as the grain is loaded into the bin. This high-moisture material will soon start to heat and also make favorable conditions for the development of insects, which in turn liberate more moisture and cause the grain to heat. This condition, if allowed to continue, will spread throughout the bin and may result in excessive spoilage from insects and mold fungi. Control by aeration and fumigation usually is satisfactory under these conditions. However, in extreme cases, it may be necessary to turn the grain to break up and redistribute trashy areas.

TEMPERATURE

The temperature of low-moisture grain was a good indication of its condition. Dry, clean, insect-free grain did not heat when it was held in a satisfactory storage structure. Any increase in temperature indicates an increase in moisture due to trash, insects or leakage of outside moisture. When hot spots occur, steps should be taken to eliminate the cause of heating.

Low temperatures are desirable in any area to prevent loss in germination and serious increase in fat acidity value. They also are desirable in South Texas to reduce insect activity. Aeration was effective in maintaining relatively low temperature during the winter, but it was not practical to attempt to reduce temperatures much below 90° during the summer.

Typical temperatures of grain stored in 18-foot diameter bins are shown in Figure 11. In both aerated and unaerated bins, average grain temperatures were not reduced much below 90° during July and August, but they dropped below this level during September when there was a corresponding drop in atmospheric temperature. In the unaerated bins, average temperatures gradually decreased to 65 to 70° by February and remained at that level for the remainder of the storage period. Average grain temperatures in the aerated bins were reduced quickly below 80° during September and reached 60 to 65° by November. Continued aeration during the winter reduced average temperatures below 60° by January. They remained below this level until the last of April when they started to increase with a corresponding increase in atmospheric temperatures.

Effect of Structure and Bin Wall Color on Temperatures

Table 1 shows variations in the temperature of air above the grain and at the west bin wall for several types of bins. This information was compiled for different seasons of the year and at different times of the day during 1951-53, with the exception of the double-wall bin in the 32 by 60-foot steel building. Temperatures in this building are for the 1951-52 storage year only.

Air temperatures above the grain and bin wall temperatures were considerably higher in unpainted round steel bins than in painted steel bins and buildings and in a cement plaster bin. The greatest temperature difference occurred during the summer. Air temperatures above the grain at 2:00 p.m. during August were as much as 10° lower in white-painted round steel bins than in unpainted round steel bins. In no case were the grain temperature differences enough to have an important effect on commercial grade. However, the lower temperatures are desirable for storing planting seed and for effective insect control.

INSECTS

Infestation of stored grain usually takes place after the grain is placed in storage; however, in many areas of the State, grain is infested frequently in the field with rice weevils and Angoumois grain moths. Some of the grain received for these studies had a light initial infestation of insects originating during the handling from the grower to the storage site.

Conditions are very favorable for insect development in South Texas and stored-grain insects invade the bins as soon as they are filled. Even when the grain is fumigated in late July or August, it often will become reinfested within a month or two. Insect activity is greatly reduced after temperatures of 60° or less are reached; therefore, the movement of insects into bins is at a minimum during the winter, and those in the surface layers remain inactive. However, insects already established deep in the bin will continue to flourish, because the grain temperatures usually remain in the 70's unless the grain is cooled by aeration. Activity is resumed in the spring as the temperatures rise. The rate of insect development is greater in high-moisture than in low-moisture grain.

Fourteen species of stored-grain insects were found in samples taken from the experimental

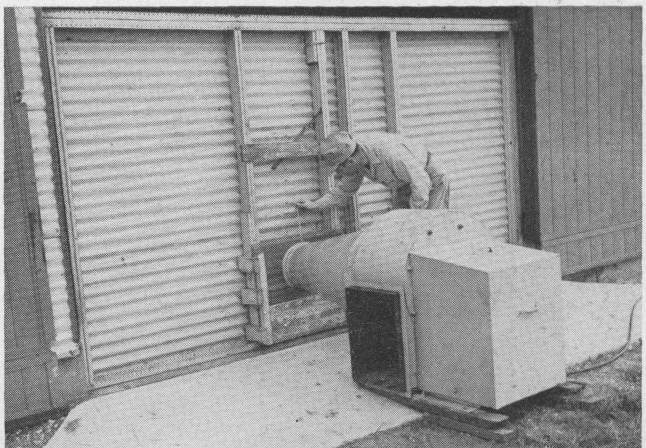


Figure 10. When grain was aerated by pulling air down through it, a reasonably accurate average grain temperature was determined by placing a good quality thermometer in the duct between the fan and grain close to the bin wall, as shown here.

bins between December 1952 and April 1955. The most prevalent species were the flour beetle, flat grain beetle, lesser grain borer, rice weevil and a complex of the Indian-meal, rice and almond moths. The moth larvae infested the surface layers of grain, and the other species were scattered throughout the bins.

Tests were conducted in the 1952-53, 1953-54 and 1954-55 seasons on protective-treatment insecticidal formulations applied as dust or sprays directly to the grain as it was placed in the bin. Dusts containing pyrethrum, which are recommended for use on stored wheat, gave only fair protection from the time of binning until cold weather and did not prevent moth infestations in the surface layers. An experimental protective dust containing ryania gave excellent protection for 9 months, but it cannot be recommended until a tolerance for residues of this material has been established.

Since the infestations first appeared in the surface layers of grain, studies were made to evaluate surface applications that might prevent infestations from becoming established. A refined light mineral oil applied as a spray to the surface layer at a rate of 2 quarts per 100 square feet in August and again in October gave excellent protection through February against infestation by moths. Ryania dust also gave excellent protection when applied in August and December. Pyrethrum dusts were not effective at dosages of 0.9 to 2.7 ppm of pyrethrins, but recent tests

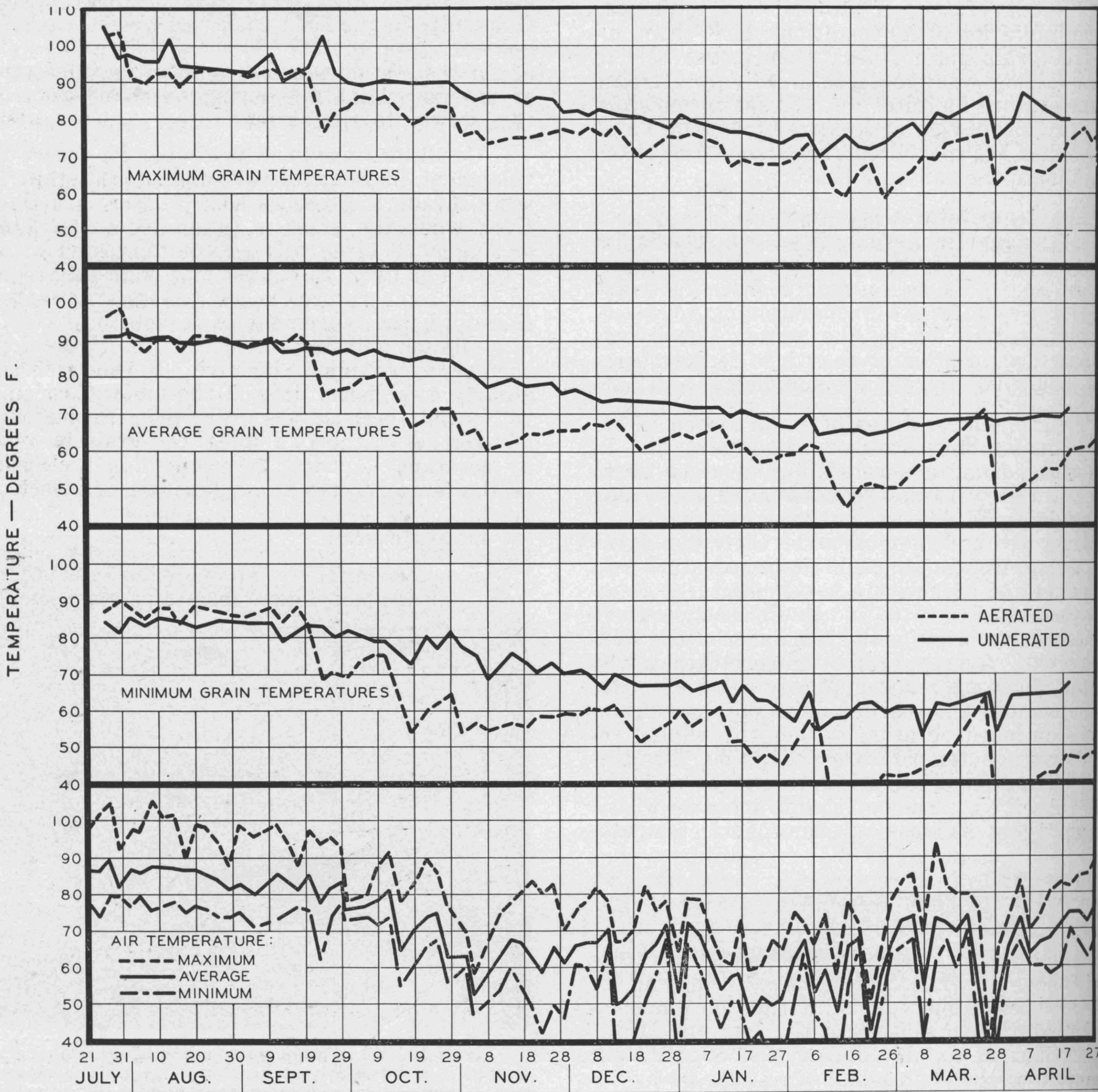


Figure 11. Typical temperatures of grain stored in 18-foot diameter steel bins from July 1954 to April 1955. Air temperatures during the same period are shown in the bottom graph.

elsewhere on other grains at higher concentrations are promising. Tolerances for residues have been established for mineral oil and for pyrethrum, but not for ryania.

Various liquid fumigants were effective in controlling insect populations after infestation developed. These were the standard liquid grain fumigant mixtures containing carbon tetrachloride and carbon bisulfide in an 80-20 ratio by volume; carbon tetrachloride, ethylene dichloride and ethylene dibromide in the 60-35-5 ratio; ethylene dichloride, carbon tetrachloride, ethylene dibromide and sulfur dioxide in a 70-24-3-3 ratio; and a formulation containing carbon tetrachloride, ethylene dichloride, ethylene dibromide and carbon bisulfide.

TABLE 1. COMPARISON OF ABOVE GRAIN AND BIN WALL TEMPERATURES IN VARIOUS TYPES OF BINS AT DIFFERENT TIMES DURING THE DAY

Atmospheric temperature, type of bin and time of day	Average temperature, degrees F[1]		
	August	September	December
Atmospheric temperature			
8:00 a.m.	84	78	53
2:00 p.m.	97	91	65
18-foot diameter steel bin, painted aluminum			
Above grain			
8:00 a.m.	85	80	51
2:00 p.m.	103	98	70
West bin wall			
8:00 a.m.	86	81	52
2:00 p.m.	105	100	72
18-foot diameter steel bin, painted white			
Above grain			
8:00 a.m.	84	78	53
2:00 p.m.	100	91	69
West bin wall			
8:00 a.m.	82	76	53
2:00 p.m.	104	95	70
14-foot diameter steel bin, unpainted			
Above grain			
8:00 a.m.	89	83	54
2:00 p.m.	110	100	69
West bin wall			
8:00 a.m.	87	80	59
2:00 p.m.	—	—	70
14-foot diameter cement plaster bin			
Above grain			
8:00 a.m.	78	74	49
2:00 p.m.	95	89	62
West bin wall			
8:00 a.m.	80	75	52
2:00 p.m.	94	88	63
Double-wall bin in 32 x 60 foot steel building, painted cream			
Above grain			
8:00 a.m.	85	78	54
2:00 p.m.	98	92	70
West bin wall			
8:00 a.m.	83	79	54
2:00 p.m.	98	91	68

[1]Average temperatures during 1951-53 with the exception of the double-wall bin in the 32 x 60 foot steel building. Temperatures in this building are for the 1951-52 storage year only.

A dosage rate of 6 gallons per 1,000 bushels was considered an absolute minimum for use in circular metal bins. Partial failures occurred with this dosage rate in small bins (less than 600 bushels), in bins where the fumigant was applied when the temperatures in the headspace were well above 100°, when there was a 12 to 15 mph wind when the fumigant was being applied and where the bins were not tight.

No deterioration of the quality of the grain occurred from repeated fumigations with these mixtures. Germination and fat acidity remained at nearly the same level after the fifth fumigation of one lot of grain.

These tests demonstrated that proper fumigation will destroy the current infestation, but will not prevent reinfestation from outside sources.

Fumigants were recirculated through the grain mass in storages where aeration systems were installed. A duct was attached to the blower discharge to direct the fumigant back to the headspace, as shown in Figure 13. Fumigants were distributed more effectively and the dosage rate reduced considerably with this method.

Methyl bromide which will not penetrate bulk grain well by gravity diffusion was distributed uniformly through the grain mass by recirculating it for 15 minutes after the gas was introduced. A dosage rate of 4 pounds per 1,000 cubic feet killed test insects implanted in all parts of

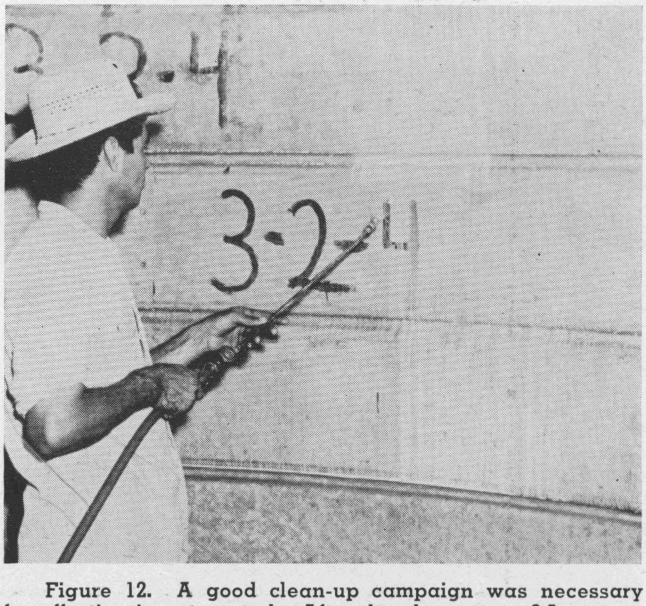


Figure 12. A good clean-up campaign was necessary for effective insect control. After the clean-up, a 2.5 percent methoxychlor spray was applied, to the point of runoff, to the inside walls, as shown here. A DDT spray was applied to the outside walls and to the soil near the bin, but was not used where it might contact the stored grain.

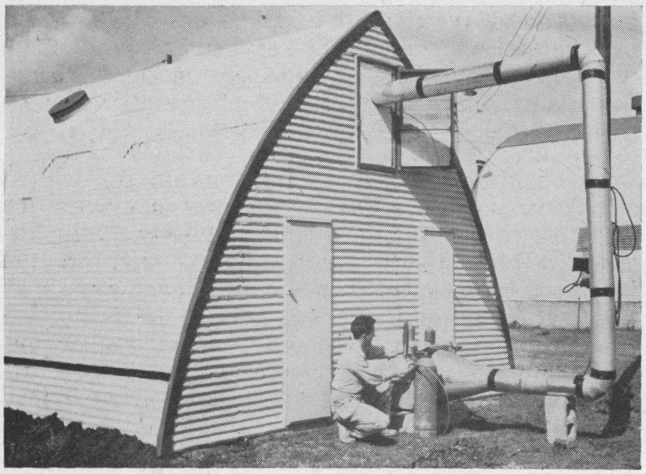


Figure 13. A return duct installed on a steel building to recirculate fumigants.

the bin. A 60-35-5 mixture of carbon tetrachloride, ethylene dichloride and ethylene dibromide was distributed evenly by recirculating the vapors for 30 minutes after the mixture had been sprayed uniformly over the surface of the grain. An application rate of 4 gallons per 1,000 bushels killed test insects implanted in all parts of the bin. A 3-gallon rate killed all but five of the hundreds of test insects. (Some fixed bromide residue accrues from each fumigation with methyl bromide, so that repeated fumigations will result in a residue in excess of the tolerance of 50 ppm. Users of methyl bromide are cautioned not to fumigate sorghum grain more than three times, unless chemical analysis for already incurred bromide residue is first made to assure adequate margin for another fumigation.)

Other tests were made with the recirculation method in a round metal bin which was completely covered with a polyethylene sheet, as shown in Figure 14. The aeration fan pulled air down through the grain and discharged it outside the bin but beneath the cover, where it was pushed back to the surface of the grain. A dosage rate of 4 pounds of methyl bromide per 1,000 cubic feet killed test insects implanted in all parts of the bin, as did an application of 3 gallons per 1,000 bushels of the 60-35-5 fumigant mixture. A 3-gallon rate of the 60-35-5 mixture was applied in the same polyethylene-covered bin, without the recirculation, as a check. In this test the vapors were allowed to disperse by gravity diffusion. This resulted in only partial mortality of test insects in the middle and lower levels in the bin. This was considered an apt demonstration of the unequal distribution resulting from natural diffusion of the fumigant vapors. It also showed why dosage rates of 6 gallons per 1,000 bushels, or greater, are needed when fumigants are applied in this manner.

Figure 14. A circular steel bin covered with a polyethylene sheet to aid in recirculating fumigants.

RODENTS

Rats and mice were difficult to control and probably were responsible for considerable losses.

Effective control was obtained through approved rodent control procedures. Areas surrounding bins were kept free from rat-harboring places. Outside openings in aeration ducts were sealed tightly when not in use to prevent the entrance of rats and mice. Sprinkling DDT powder between double walls was effective in controlling mice, but it should be spread when the bins are empty to protect the grain from the DDT.

MOLD DEVELOPMENT

Fungi that infect grain in the field before harvest do not seem to be associated with deterioration of sorghum seed during storage. Christensen (4) designated the fungal genera that invade seed as field and storage fungi. Field fungi invade the seed while it is still on the plant. Storage fungi develop on and within the seed during storage. Some fungi designated as storage fungi were present on the grain in these tests at harvest, but generally in low percentage.

The percentage fungal infestation at harvest and the beginning of storage apparently depends on the maturity of the grain and the climatic conditions during the latter part of the growing season. Grain harvested at 14 to 15 percent moisture in 1954 was infested 98 percent with species of Alternaria while grain harvested at 18 to 20 percent moisture was infested with 70 percent Alternaria. There was considerable year-to-year variation in the percentage of overall infestation as the seed were harvested. Ninety-three percent of the seed were invaded by fungi in 1951, 35 percent in 1952, 64 percent in 1953 and 88 percent in 1954. The year-to-year spread of infestation by specific genera of fungi was just as great. Twenty-seven genera of fungi were noted. Sixty-one percent of the seed were infested with species of Alternaria in 1951, 73 percent in 1952 and 50 percent in 1953. Twenty-four percent were infested with species of Hormodendron in 1951, a trace in 1952 and 4 percent in 1953. Species of the black molds, Alternaria, Curvularia, Helminthosporium, Hormodendron and Nigrospora, made up 95 percent of the infestation at the beginning of storage.

In general, fungi found infesting seed at the time of harvest decreased sharply during the first 3 months of storage and continued to decrease gradually during the remainder of the storage period. Sixty-four percent of the seed harvested in 1953 were infested with fungi at the beginning of storage, 25 percent after 3 months and 12 percent after 6 months storage. *In one bin of 1951 grain, only 12 percent of the seed were infested* after 1 year storage. This was reduced to 5 percent after 2 years and to 3 percent after 32 months storage.

Species of storage molds, Aspergillus and Penicillium, developed on seed stored under high moisture conditions and in high-moisture areas resulting from leakage of outside moisture. Samples taken in 1951 from one lot of grain that had an average moisture content of 15.8 percent at the beginning of storage were infested 100 percent by *Aspergillus versicolor,* and the germination dropped to zero at the end of 3 months storage. The grain was transferred to another bin and dried to a moisture content of 12 percent or less. After 3 months additional storage at this lower moisture content, the infestation by *Aspergillus versicolor* was reduced to 32 percent.

An increase in infestation of the grain by species of Aspergillus and Penicillium was associated with deteriorating seed quality. This emphasizes the importance of storing grain in a weather-tight structure and at a low enough moisture content to prevent development of these fungi. Mold development during storage was not a problem in South Texas when grain was stored at a moisture content of 12 percent or less.

AERATION

Aeration was practical and economical in cooling grain during storage. These tests show that: it is desirable to aerate grain as soon as possible after the bin is filled until the temperatures in the grain are reduced to 90° or less; except for operating the fan 2 to 3 hours once a month to change the air in the bin, further aeration is not necessary during the summer unless heating occurs; and grain should be aerated during the winter until temperatures are reduced to 60° or less.

Effective cooling was obtained with air flow rates as low as 0.25 cfm per 100 pounds (about 1/8 cfm per bushel). However, with such a low air flow rate, more time was required to cool the grain. For example, during the 1954-55 storage year, the fan operated a total of 306 hours when air was supplied at a rate of 0.25 cfm per 100 pounds, compared with 181 hours with an air flow of 0.60 cfm per 100 pounds (1/3 cfm per bushel). Grain in these tests was aerated as soon as possible after the bins were filled. Fans were operated during the nights only until grain temperatures were reduced to 90° or less. Aeration fans were not operated again until September when atmospheric temperatures started to drop. Fans were operated during the fall and winter as often as necessary to reduce grain temperatures to 60° or less.

Fan and air distribution systems used for drying grain supplied air at a higher rate, but also were satisfactory for aeration. With the *high air flow rates used for drying, grain was cooled in about one-third the time required to cool* grain with air supplied at a rate of 0.25 cfm per 100 pounds. For this reason, close supervision is required when high air flow rates are used to prevent large losses in weight caused by excessive reduction in the moisture content of the grain.

Air was pushed up and pulled down through grain. These methods seemed equally effective for cooling grain. Pulling air down avoids condensation in the winter. The humid air leaving the grain does not come in contact with cool surface grain or the cool bin roof. Condensation was not a problem, however, when aeration was started early in the season. Pulling air gives an opportunity to smell the air coming out of the bin to detect any off odor which may have developed. As shown in Table 1, air temperatures in the top of the bin were high during the summer. Under these conditions, it was best to push air to prevent pulling hot air through the grain. In bin drying, grain is dried by pushing air up. Therefore, when bins are equipped with drying systems, it would be an advantage to push air for aeration since it would be unnecessary to reverse the fan to change the direction of air flow.

Grain was cooled during the summer by operating the fans at night. There usually was enough difference in grain temperatures and atmospheric temperatures to operate fans during clear nights without danger of increasing the moisture content of the grain. During cool weather, fans were operated any time the atmospheric temperature was 10° or more below the average grain temperature, except during rain or fog.

WEIGHT LOSSES IN STORAGE

Records were kept on the weight of grain loaded into bins at the beginning of storage and at the end of storage. Losses occurring over the 7-year period are shown in Table 2. Total loss in weight for 9 to 10 months storage during 1949-55 averaged 1.8 percent. A large part of this loss was due to a reduction in moisture during aeration. Weight losses during a scheduled drying operation were not considered a storage loss. Since losses occurring under experimental conditions are probably greater than losses under actual farm storage conditions, a loss of 1 to 1.5 percent is probably more representative for a normal operation.

TABLE 2. LOSSES IN WEIGHT DURING STORAGE

Item	1949-50	1950-51	1951-52	1952-53	1953-54	1954-55	1955-56
Length of storage, months	9	9	9.5	9	10	10	3
Amount of new grain received, pounds	926,300	676,030	741,385	554,320	753,965	621,625	313,550
Calculated amount carried over from previous year's test, pounds		263,710	90,000	190,867	94,457		
Calculated moisture loss in drying, pounds	5,701	17,190	6,098	5,440	15,419	25,159	20,218
Total amount of dry grain stored, pounds	920,599	922,550	825,287	739,747	843,003	596,466	293,332
Weight at end of storage, pounds	907,425	904,945	808,407	725,117	825,720	588,100	290,060
Total weight loss from sampling, decrease in moisture, rodents, insects and handling, pounds	13,174	17,605	16,880	14,630	17,283	8,366	3,272
Percentage loss during storage[1]	1.43	1.90	2.04	1.98	2.05	1.40	1.11

[1]Average for 1949-55, inclusive—1.8 percent.

HANDLING IN AND OUT OF STORAGE

A 21-foot auger loader operated by a 3-horsepower electric motor was used for loading and unloading bins. The loader handled an average of 41,000 pounds per hour in moving grain from trucks to storage bins. This capacity was obtained by using a grain tow board, as shown in Figure 15.

Records were kept on different methods of unloading bins. Steel bins 18 feet in diameter and 14 by 16-foot wooden bins were unloaded by shoveling grain into a flight and a screw conveyor. Three men unloaded 23,000 pounds of grain per hour with a flight conveyor and 28,000 pounds of grain per hour through an unloading spout in the wall of an 18-foot diameter bin. With a screw conveyor installed in the bin floor of a 14-foot diameter bin, 32,000 pounds of grain were unloaded per hour. In all cases, the grain was allowed to flow by gravity as long as possible.

DRYING HIGH-MOISTURE GRAIN

The moisture content of grain harvested in South Texas usually is too high for safe storage. For this reason, it is necessary to provide some method of drying to reduce the moisture content to a safe storage level.

WITH UNHEATED AIR

Bin Drying

Bin drying with unheated air offers some advantages as well as disadvantages in comparison with bin drying with heated air. Unheated air drying requires less investment in equipment, reduces fire hazards and usually results in more uniform drying. There are, however, certain specific limitations. One is the uncontrollable weather factor, since the rate of drying with unheated air depends on weather conditions. If the grain is to be sold soon after harvest, the comparatively long time required for drying with unheated air is a disadvantage. In this case, some other method of drying should be used. If the grain is fed on the farm or is held in storage for a period longer than is required for drying with unheated air, the time element is not so important. Considerable supervision over a long period of time is required when unheated air is used as the drying agent.

In South Texas, grain sorghum usually is harvested during late June or early July. Weather records in the Corpus Christi area, Tables 3 and 4, indicate a considerable period of time during a July day when conditions are favorable for unheated air drying, Figure 17. However, the air temperatures occurring at this time are extremely favorable for mold growth. Therefore, for unheated air drying to be successful, the grain moisture content should be reduced below the level favorable for mold development in as short a time as possible.

Drying Equipment. The equipment required for bin drying with unheated air consists of a structure for holding the grain, an air distri-

Figure 15. An auger loader and grain tow board were used for handling grain in and out of storage.

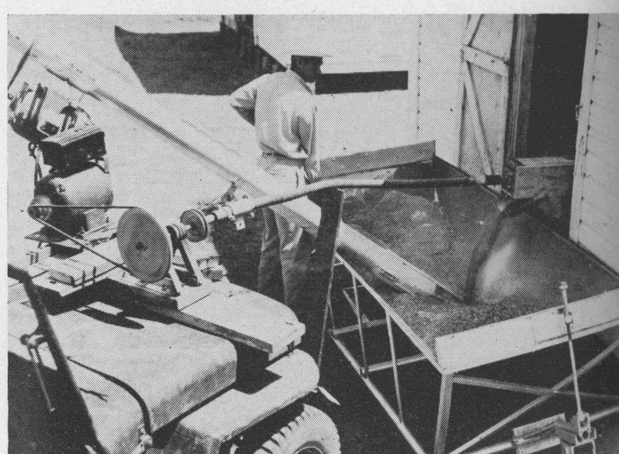


Figure 16. The portable auger, shown inside the bin, was used to unload grain from storage bins. It was driven by a flexible shaft connected to an electric motor.

TABLE 3. AVERAGE MONTHLY ATMOSPHERIC TEMPERATURE DURING THE DAY FOR CORPUS CHRISTI, 1949-55

Month	Temperature, degrees F.							
	Midnight	3:00 a.m.	6:00 a.m.	9:00 a.m.	Noon	3:00 p.m.	6:00 p.m.	9:00 p.m.
January[1]	56.3	54.9	54.2	58.6	66.4	67.9	61.9	58.5
February[1]	58.0	56.4	55.5	60.6	67.7	69.4	63.8	60.0
March[1]	63.0	61.6	61.2	66.6	72.3	72.9	68.2	64.5
April[1]	67.4	66.6	66.1	72.8	77.4	77.9	73.0	69.8
May	73.6	73.9	71.8	78.7	82.9	83.7	79.4	74.7
June	78.6	77.1	77.1	84.4	88.6	88.8	83.1	80.2
July	76.1	78.0	77.2	86.2	90.6	91.1	86.4	81.6
August	80.0	78.0	76.8	86.0	90.7	91.3	86.4	81.7
September	77.6	75.5	74.4	82.3	88.1	88.1	83.6	79.8
October	70.3	68.1	67.5	76.2	81.6	82.0	76.6	72.6
November	60.9	58.4	57.5	64.1	71.3	72.4	66.6	62.9
December	57.1	55.4	54.3	58.6	66.1	68.1	62.3	58.9

[1]Includes 1956 records.

bution system and a fan driven by an electric motor or gasoline engine. Both steel and wood bins and steel buildings were satisfactory storage structures for drying grain. The main consideration is to provide a tight structure to prevent leakage of air and moisture through the bin floor and walls.

An air distribution system should be selected that will provide adequate distribution of air throughout the bin. Types of air distribution systems used in these tests were designated as: (a) false floor, (b) main duct and laterals and (c) center duct. These are shown in Figure 18. Main duct and lateral systems are satisfactory for both round and rectangular bins and buildings. False floors are better suited for round bins than for larger storage structures. A type of construction for a false floor is shown in Figure 19. A center duct is limited to use in a narrow building (a width of 16 feet was used in these tests) and requires a building with openings in the wall to permit uniform distribution of the air through the grain. A main duct and lateral system or a false floor is recommended for farm drying installations.

Centrifugal and axial-flow fans, as shown in Figure 20, are suitable for bin drying grain. Centrifugal fans ordinarily used for farm drying have either "forward-curved" blades or "backward-curved" blades. "Forward-curved" fans are lighter and less expensive than "backward-curved" fans. However, with the "forward-curved" fan, there is a possibility of overloading the motor if the fan operates against static pressures lower than those used in the design of the system. This is an undesirable characteristic for bin drying since grain depths vary during the time bins are being filled. A "backward-curved" blade fan offers the advantage of a self-limiting horsepower characteristic. This means that the maximum horsepower for a given speed and air density is reached in the usual operating range. The practical advantage is that it is unnecessary to provide excess motor capacity beyond that necessary to carry the normal load.

Axial-flow fans used for farm drying are of vaneaxial and tubeaxial types. A vaneaxial fan consists of a fan wheel within a cylinder with a set of air guides either ahead or behind the fan wheel. It is designed to move air over a wide range of volumes and pressures. A tubeaxial fan consists of a fan wheel within a cylinder without air guide vanes, as shown in Figure 20. Its construction is similar to a vaneaxial fan. The tubeaxial fan is designed to move air over a wide range of volumes at medium pressures.

Axial-flow fans designed to operate against static pressures of 3 inches or more usually are suitable for bin drying. The initial cost of these fans is usually lower than the cost of centrifugal fans. Low initial cost, together with the small space required and the ease of installation, are advantages.

Air Flow Requirements. The use of the proper air flow rate to dry grain with unheated air is of primary concern. Interrelated with the

TABLE 4. AVERAGE MONTHLY ATMOSPHERIC RELATIVE HUMIDITY DURING THE DAY FOR CORPUS CHRISTI, 1949-55

Month	Relative humidity, percent							
	Midnight	3:00 a.m.	6:00 a.m.	9:00 a.m.	Noon	3:00 p.m.	6:00 p.m.	9:00 p.m.
January[1]	58.1	86.7	87.9	80.5	64.4	62.1	73.9	81.8
February[1]	83.6	86.5	87.9	78.0	63.2	60.5	72.2	80.8
March[1]	84.3	85.6	86.7	73.6	60.9	59.3	71.0	80.0
April[1]	86.4	88.0	88.8	72.2	62.2	61.0	72.2	83.0
May	88.6	90.5	91.6	75.6	65.2	62.2	70.6	83.2
June	74.0	74.1	78.4	61.9	51.8	49.5	56.7	67.9
July	85.5	89.4	92.0	70.2	57.3	54.6	67.7	79.6
August	84.6	88.7	91.2	72.4	56.5	54.1	62.2	79.0
September	82.8	86.9	88.9	75.8	50.0	56.6	64.3	77.0
October	81.9	85.2	87.3	76.4	58.7	56.2	65.5	85.5
November	80.0	81.6	82.9	74.1	57.4	54.3	65.3	76.3
December	80.9	82.7	82.6	78.7	61.5	56.9	65.5	78.5

[1]Includes 1956 records.

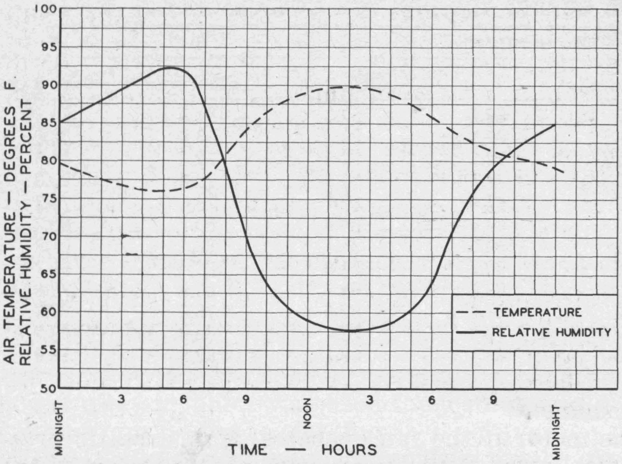


Figure 17. Air temperature and relative humidity for a typical July day in the Corpus Christi area.

air flow requirement are the initial moisture content and the basic drying rate of the grain. Air must be supplied at a rate to complete drying before the grain is damaged by mold growth or other causes. For this reason, the drying rate in the wettest layer of grain provides the basis for selecting the required air flow rate rather than the average grain moisture observed during the drying operation.

The purpose for which the grain will be used determines the air flow rate for drying with unheated air. If the grain is sold on the market, grade is the only factor to consider. A recommended air flow rate of 4.5 cfm per 100 pounds (2.5 cfm per bushel) was indicated by these tests for drying sorghum grain without loss in grade. This rate was based on a grain moisture content of 18 percent, which is near the maximum moisture of sorghum grain harvested in South Texas. The minimum air flow used to dry sorghum grain at this moisture content, without loss in grade during the tests, was 3.5 cfm per 100 pounds (2.0 cfm per bushel). Grain with a moisture content of 16 percent or less was dried without loss in market value at air flow rates as low as 2.7 cfm per 100 pounds (1.5 cfm per bushel). An air flow rate of at least 5.4 cfm per 100 pounds (3.0 cfm per bushel) was required to dry grain successfully with moisture contents of 18 to 20 percent.

If the grain is to be used as seed for planting, germination is the factor that determines the amount of air to use. There was no loss in germination of grain dried with an air flow rate of 5.4 cfm per 100 pounds (3.0 cfm per bushel). This rate is based on a maximum initial moisture content of 18 percent.

As shown in Figure 23, there was a considerable increase in fat acidity value in the top layer of grain at all air flow rates. To prevent substantial increases in fat acidity value, tests indicated that an air flow of 9.0 cfm per 100 pounds would be required for drying 18 to 19 percent moisture grain.

Information required by drying equipment dealers and others who select fans for drying grain are the total air volume and the static pressure requirements. Static pressure is a measure of the resistance that the air distribution system and grain offer to the flow of air. It is designated in inches of water. Static pressures against which fans must operate to develop air flow rates of 3.5, 4.5 and 5.4 cfm per 100 pounds of grain are given in Table 5.

Grain Depth. The recommended air flow rate of 4.5 cfm per 100 pounds limits the grain depth to a maximum of 8 feet for the most economical drying. As stated previously, this rate is based on a maximum grain moisture content of 18 percent. Grain moisture content, as well as weather conditions, vary from year to year. It is important to provide drying equipment of sufficient capacity to insure drying grain without loss in grade under the different conditions encountered. When the initial moisture content of the grain is above or below 18 percent, the grain depth can be varied to increase or decrease the air flow rate as needed for the different moisture conditions. Grain depths for drying grain with various initial moisture ranges are shown in Table 6. This is based on the selection of equipment to provide an air flow rate of 4.5 cfm per 100 pounds at an 8-foot depth.

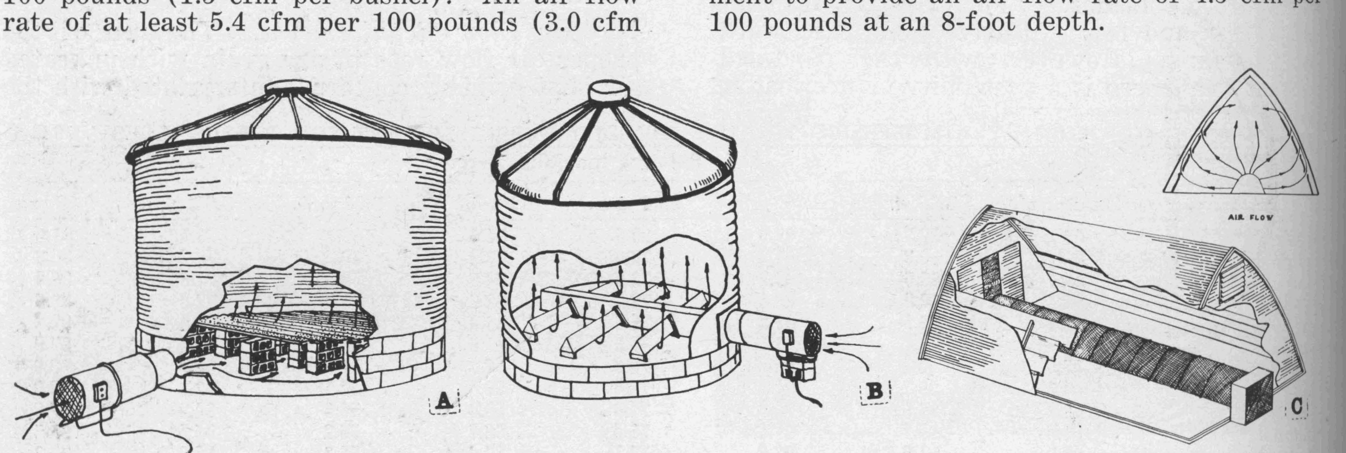


Figure 18. Types of air distribution systems used in the bin drying tests: A. false floor; B. main duct and laterals; and C. center duct.

Drying Time. These tests show the relationship between the length of the drying period and mold development. Under similar weather conditions, the time required to dry grain with unheated air depends on: (1) the rate of air flow, (2) the initial moisture content of the grain and (3) the uniformity of air flow through the grain. In these tests, the percentage of fungal infestation was associated closely with the same three factors. For example, none of the different kinds of molds associated with grain deterioration, such as Aspergillus, was noted in grain dried with an air flow rate of 5.4 cfm per 100 pounds. There was a gradual increase in infestation with a decrease in air flow from 4.5 to 2.7 cfm per 100 pounds. This increase was due to the longer time required to dry the grain to the desired moisture level with the lower air flow rates. Moisture is a major factor influencing the growth of molds. Even at the lowest air flow rate, samples taken at the bottom of the bins were free of harmful infestation, but increased in the upper layers where the grain remained higher in moisture for a longer time.

Mold development was observed on the grain when the moisture content was above 15 percent more than 6 to 8 days. A contributing factor to the rapid mold development was the high grain temperatures. The grain temperature at the time of loading the bins averaged 95 to 100°. Within 24 hours after the start of drying, the average grain temperature dropped to about 80°. As drying progressed, grain temperatures increased to a final average of 90 to 95°.

In unheated air drying applications under South Texas conditions, the moisture in the wettest layer of grain must be reduced to 15 percent in 8 days or less to prevent undesirable mold development. Further reduction in moisture to a safe storage level can be accomplished over a longer period of time, as long as 2 weeks in these tests, without serious mold development.

Fan Operation Schedule. A primary consideration in the selection of a fan operating schedule is the provision for drying at a rate fast enough to prevent mold development. The drying system should be simple to operate and re-

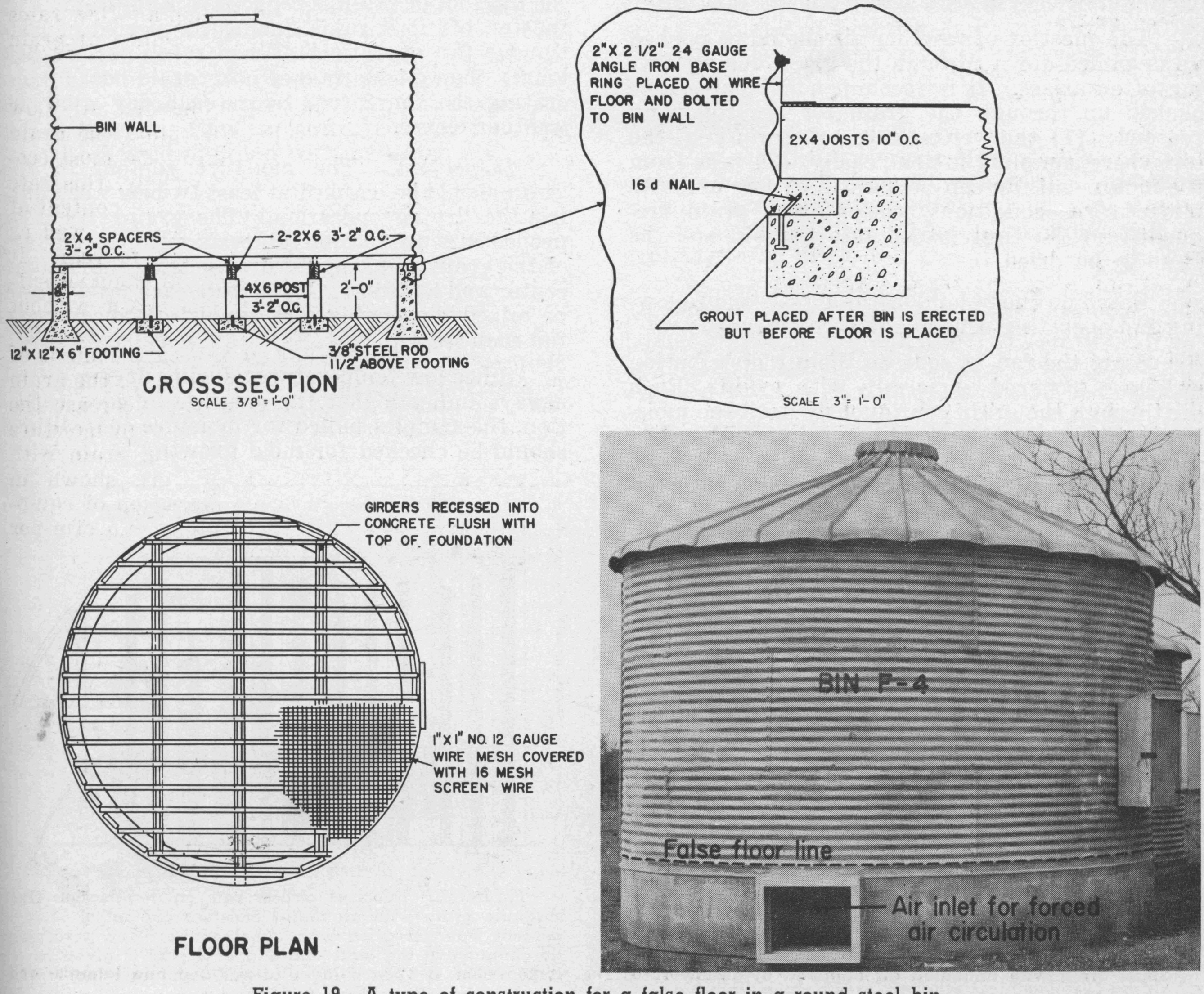


Figure 19. A type of construction for a false floor in a round steel bin.

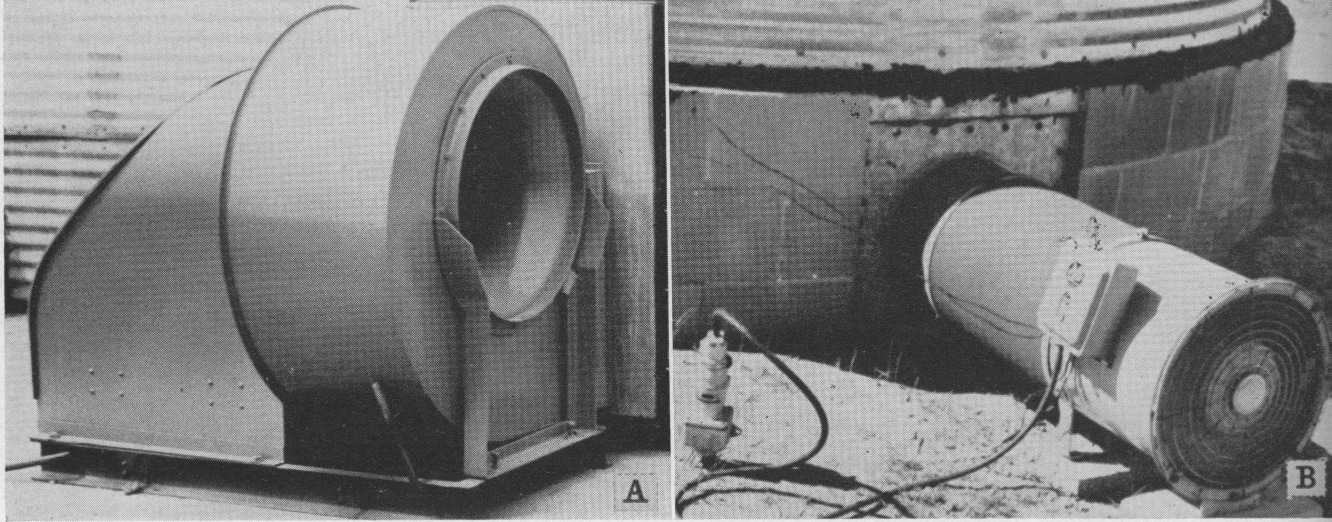


Figure 20. Types of fans suitable for drying grain. The centrifugal fan (A) is designed to move air over a wide range of volumes and pressures. The tubeaxial fan (B) is designed to move air through a wide range of volumes at medium pressures.

quire minimum supervision. Other desirable features in a fan operating schedule are maximum drying efficiency with a minimum air flow rate.

The question of whether air should be pushed up or pulled down through the grain during drying often arises. It is recommended that air be pushed up through the grain for the following reasons: (1) the wettest layer of grain is at the top where sampling is done easily, (2) heat from the motor and fan can be used in drying and (3) under farm conditions, the wettest grain frequently is the first loaded into the bin and the first to be dried.

Based on the results of these tests the following fan operating schedule is recommended:

Start the fan as soon as the air distribution system is covered uniformly with grain. Push air through the grain continuously until the moisture content of the top foot of grain is reduced to about 15 percent. After the moisture is reduced to this level, operate the fans only when the relative humidity is less than 75 percent (usually during daylight hours on clear, bright days). Continue this procedure until the moisture content of the top foot of grain is reduced to 12 percent. Cut the fan off if it rains during the period of continuous fan operation. When rainy periods last longer than 24 hours, keep the grain cool by operating the fan 2 to 3 hours each day until the weather clears.

Inspection. The moisture content of the grain should be checked at least twice a week during the drying operation. The grain should be probed at 8 to 10-foot intervals over the surface of the grain and samples drawn from the bottom, center and top foot. Grain from each level should be mixed thoroughly and a moisture check made for each level.

Since low temperatures during drying do not always indicate that the grain is in good condition, the samples pulled for moisture content also should be checked for mold growth.

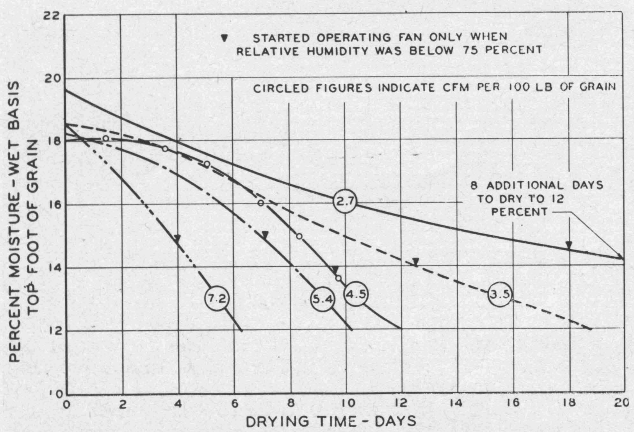


Figure 21. Time required to dry an 8-foot depth of sorghum grain with unheated air supplied at airflow rates of 2.7, 3.5, 4.5, 5.4 and 7.2 cfm per 100 pounds of grain.

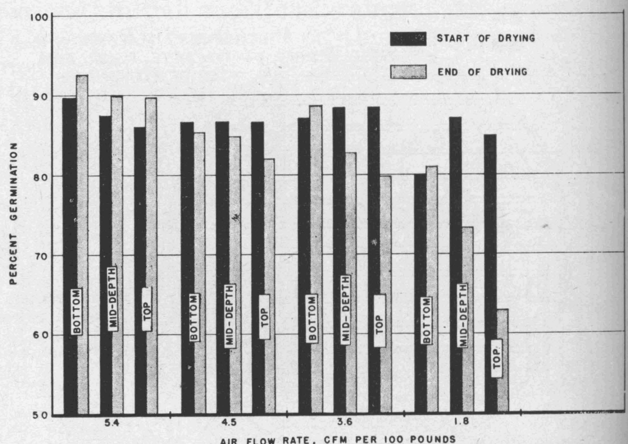


Figure 22. Effect of airflow rate on germination when sorghum grain with an initial moisture content of 18 to 19 percent was bin dried with unheated air. The percentage germination at the start and end of drying is given for the bottom foot, a 12-inch layer at mid-depth and the top foot of grain for different air flow rates.

WITH HEATED AIR

Bin Drying

Bin drying with heated air has the following advantages and disadvantages. The chief advantages are the comparatively short drying period and the fact that drying can be done regardless of weather conditions. Disadvantages to using heated air are the extreme variations in moisture occurring from the bottom to the top of the bin, the higher initial equipment costs, the close supervision required and the fire hazard.

A structure for holding the grain, a fan and an air distribution system, as described for bin dryers using unheated air, were satisfactory for bin drying with heated air. In addition, a burner is required to heat the air to the desired temperature. Automatic controls should be used to eliminate fire hazards caused by fan stoppage and flame failure. A simple installation is shown in Figure 26.

In bin drying, grain usually is dried at depths of 6 to 10 feet. The moisture content of the grain next to the incoming air changes first, and the drying progresses in stages according to the direction of air flow through the grain. There is much greater variation in moisture from the bottom to the top with heated air than with unheated air. Higher air flow rates are required for drying with heated air than with unheated air.

Tests with heated air were made in bins equipped with perforated false floors. Grain ranging in moisture of 15.4 to 23.0 percent was dried with air temperatures of 119 to 135°. Grain depths were 1.25 to 6.25 feet. Drying time varied from 4.5 to 92 hours. As shown in Table 7, there was considerable variation in moisture for all depths above 1.25 feet. The moisture content at various depths during the drying operation is shown for a 6-foot grain depth in Figure 27.

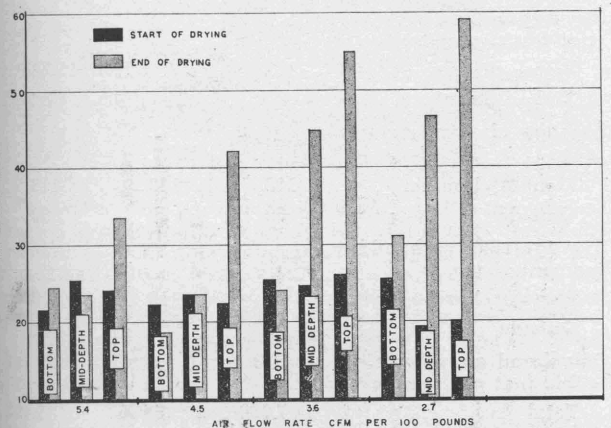


Figure 23. Effect of airflow rate on the fat acidity value when sorghum grain with an initial moisture content of 18 to 19 percent was bin dried with unheated air. The fat acidity values shown at the start and end of drying for each air flow rate were determined from samples drawn from the bottom foot, a 12-inch layer at mid-depth and the top foot of grain.

TABLE 5. STATIC PRESSURES REQUIRED TO DEVELOP DIFFERENT AIR FLOW RATES THROUGH VARIOUS DEPTHS OF GRAIN

Air flow rate per 100 pounds, cfm	Grain depth, feet	Static pressure, inches water column[1]
3.5	8	2.3
	10	3.0
4.5	8	2.8
	10	3.4
5.4	6	2.9
	8	3.7

[1]Includes an estimated 0.25-inch pressure drop in the duct system.

Based on results of these tests, the use of heated air is not practical for bin drying grain. Tests with other grain show that less variation in moisture is obtained with supplemental heat when the temperature of the drying air does not exceed 10 to 15° above the outside air temperature. However, weather conditions during the summer in South Texas usually are favorable for drying sorghum grain with unheated air. For this reason, supplemental heat is not recommended as a standard practice, but may be desirable for use on a stand-by basis in the event of prolonged adverse weather conditions.

Batch Drying

Portable Batch Dryer. A portable batch dryer, as shown in Figure 28, was used. This type is suitable for drying a small quantity of grain, but is not applicable where a large amount of grain is to be dried.

Four batches of grain, ranging in moisture from 17.7 to 18.4 percent, were dried with air temperatures of 175 and 190°. Grain was dried at 11, 12, 14 and 18-inch depths. The amount of air used was the maximum that could be obtained

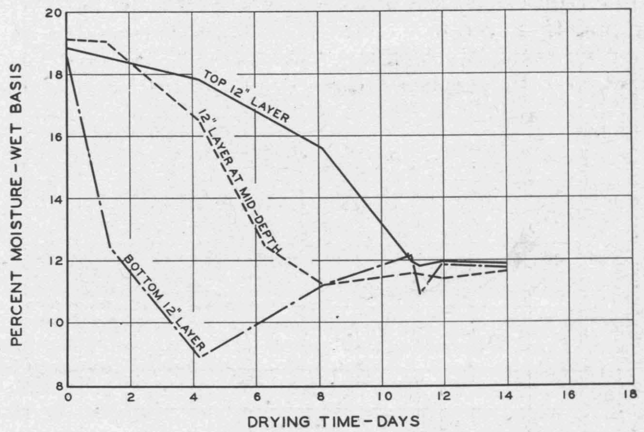


Figure 24. In a bin dryer, the moisture content of the grain next to the incoming air changes first, and the drying progresses in stages according to the direction of air flow through the grain. In this case, unheated air, supplied at a rate of 4.5 cfm per 100 pounds, was pushed up through an 8-foot depth of grain. It is recommended that air be pushed up through grain for bin drying since the wettest layer of grain is at the top where sampling is done easily.

TABLE 6. DEPTHS FOR DRYING GRAIN WITH VARIOUS INITIAL MOISTURE CONTENTS

Initial grain moisture content, percent[1]	Maximum depth of grain at start, feet	Operating procedures
18 to 20	6	When the top foot of grain is reduced to 15 percent moisture, more grain may be added to fill to the recommended depths shown below.
15 to 18	8	When the top foot is reduced to 15 percent moisture, grain with a moisture content of 15 percent or less may be added to fill the bin to a depth of 10 feet.
Below 15	10	Maximum depth recommended.

[1]A moisture content of 20 percent is the maximum recommended for drying with unheated air.

with a 30-inch wheel diameter centrifugal fan and a 5-horsepower electric motor. Air volumes range from 70 cfm per square foot of floor area for an 18-inch depth of grain to 100 cfm per square foot of floor area for an 11-inch depth of grain. The fan operated against a static pressure of 3.60 inches water column.

The moisture content of the grain at intervals during drying for the different grain depths is shown in Figure 29. When grain was dried with an air temperature of 175°, the highest drying capacity was obtained at 12 and 14-inch grain depths. The capacity at these depths was about the same, or about 2,640 pounds of dry grain per hour. The capacity at an 18-inch depth was 2,340 pounds per hour. Operating costs per ton for propane fuel and electricity were 73 to 80 cents. There was a significant loss in germination at all depths.

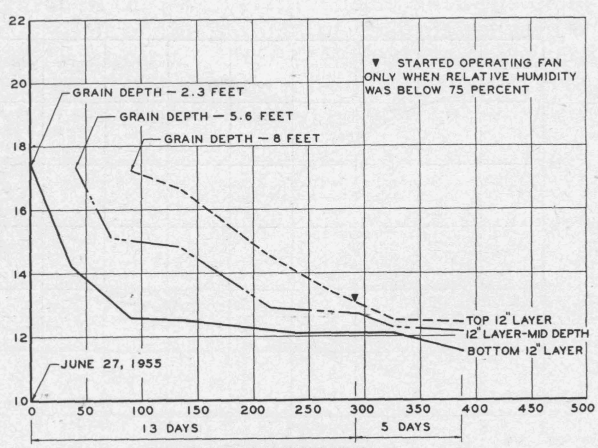


Figure 25. Faster drying was done by loading each bin to a depth of 2 to 3 feet in succession. Then, starting with the first bin, 2 to 3 feet were added to each bin progressively until all the storage space was utilized. In this case, air was supplied at a rate of 4.5 cfm per 100 pounds. The moisture content of all the grain in the bin was reduced to 15 percent in less than 4 days, which is desirable from the standpoint of preventing undesirable mold development.

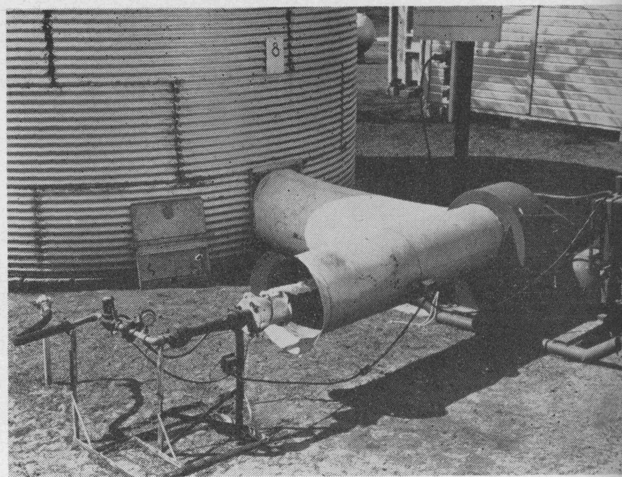


Figure 26. This portable fan and heating unit was used to dry grain in the same bin in which it was to be stored.

An auger grain loader was used to fill the drying bin to the desired depth. The dryer was unloaded with a heavy duty hydraulic wagon dump and with a grain tow board. Total time required for loading and unloading when the dryer was filled to a 12-inch depth was 37 minutes with the hydraulic lift and 25 minutes with the grain tow board.

Column-type Dryer. A dryer of the type shown in Figure 30 is desirable when high drying capacities are needed and large quantities of grain are to be dried.

Tests showed that sorghum grain can be dried successfully with a dryer of this type. The

TABLE 7. BIN DRYING WITH HEATED AIR

Item	Test 1	Test 2	Test 3
Weight before drying, pounds	13,050	40,455	41,890
Depth of grain at start, feet	1.25	3.3	6.0
Moisture content, wet basis, percent			
Before drying	15.8	15.8 to 17.0	15.2 to 15.8
End of drying	11.4	9.0 to 14.6	8.2 to 11.7
Average air temperature, deg. F.			
Plenum chamber	130	133	119
Outside	83	86	83
Average relative humidity, percent			
Plenum chamber	21	18	26
Outside	75	67	79
Calculated air volume, cubic feet per minute			
Total	7,680	8,800	5,400
Per square foot of floor area	40	35	35
Static pressure in plenum chamber, inches of water	2.0	3.2	5.5
Drying time, hours	4.5	14.0	40
Cost per ton for propane and electricity, cents	77	71	73

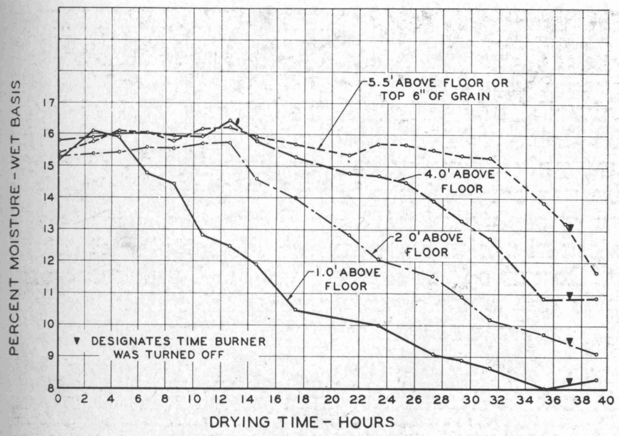


Figure 27. A wide variation in moisture content occurred when sorghum grain, in a round steel bin, was dried with heated air. In this test, an air temperature of 119°F. was used.

fastest rate of drying and the lowest costs for power and fuel were obtained when the velocity of the air through the grain column was 80 to 90 feet per minute. The air temperatures found to be most efficient for drying grain to 12 percent moisture were 150° for grain with 14 to 16 percent moisture, 175° for grain with a moisture content of 17 to 20 percent and 200° for grain above 20 percent moisture.

The wet milling characteristics of Martin and Early Hegari, with initial moisture contents

Figure 28. This portable batch dryer, used in the studies, consisted of a drying bin 7 by 14 feet with walls 6 feet high. A perforated steel floor separated the drying bin from the air chamber. Grain was loaded to the desired depth on the drying floor and heated air was forced into the air chamber and through the grain until the moisture content was reduced to a safe limit. The experimental farm crop dryer attached to the batch drying bin utilized LP gas and electric power during operation.

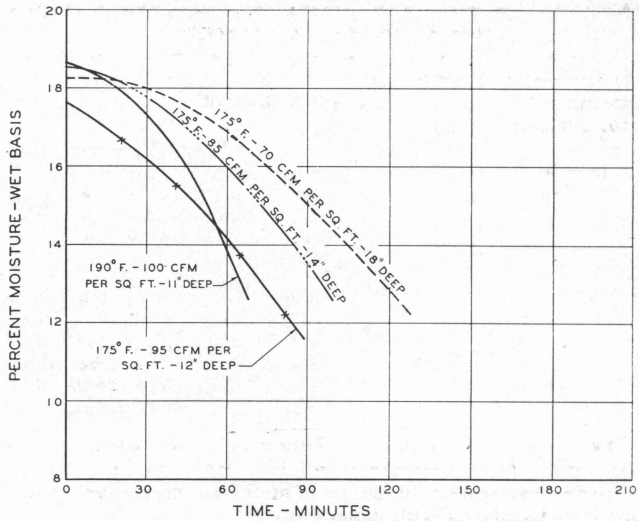


Figure 29. The moisture content of grain at intervals during drying for different depths of grain when dried in a portable batch dryer.

of 14 to 26 percent, were not impaired by drying to 11 to 13 percent moisture with air temperatures of 125 to 200°.

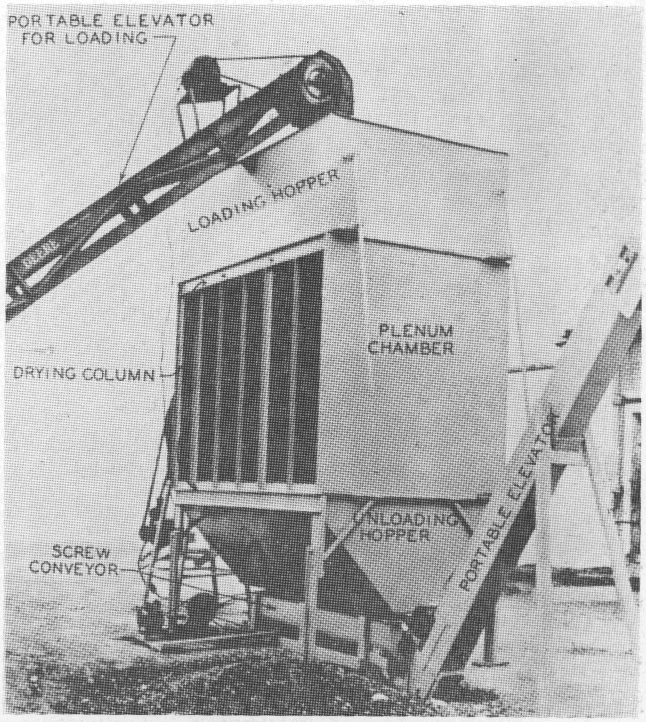
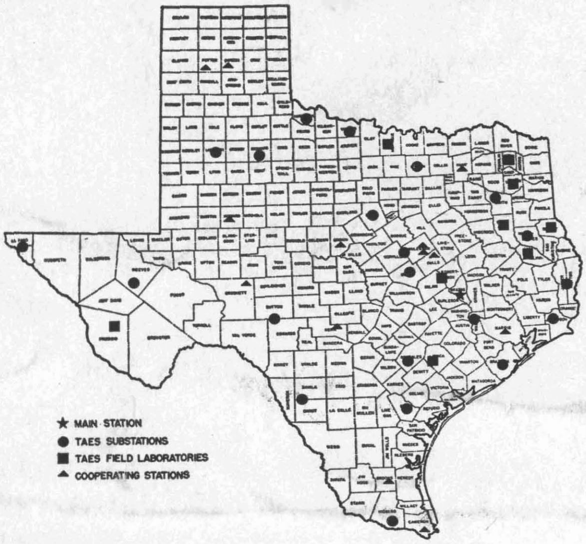


Figure 30. This column-type dryer was used to dry high-moisture grain. The drying unit consisted of two vertical columns separated by an air chamber. Each column was 6 feet high, 9 feet long and 10 inches thick. The holding capacity of the dryer was about 4,500 pounds, dry basis.



Location of field research units of the Texas Agricultural Experiment Station and cooperating agencies

State-wide Research

★

The Texas Agricultural Experiment Station is the public agricultural research agency of the State of Texas, and is one of ten parts of the Texas A&M College System

ORGANIZATION

IN THE MAIN STATION, with headquarters at College Station, are 16 subject-matter departments, 2 service departments, 3 regulatory services and the administrative staff. Located out in the major agricultural areas of Texas are 21 substations and 9 field laboratories. In addition, there are 14 cooperating stations owned by other agencies. Cooperating agencies include the Texas Forest Service, Game and Fish Commission of Texas, Texas Prison System, U. S. Department of Agriculture, University of Texas, Texas Technological College, Texas College of Arts and Industries and the King Ranch. Some experiments are conducted on farms and ranches and in rural homes.

OPERATION

THE TEXAS STATION is conducting about 400 active research projects, grouped in 25 programs, which include all phases of agriculture in Texas. Among these are:

- Conservation and improvement of soil
- Conservation and use of water
- Grasses and legumes
- Grain crops
- Cotton and other fiber crops
- Vegetable crops
- Citrus and other subtropical fruits
- Fruits and nuts
- Oil seed crops
- Ornamental plants
- Brush and weeds
- Insects
- Beef cattle
- Dairy cattle
- Sheep and goats
- Swine
- Chickens and turkeys
- Animal diseases and parasites
- Fish and game
- Farm and ranch engineering
- Farm and ranch business
- Marketing agricultural products
- Rural home economics
- Rural agricultural economics
- Plant diseases

Two additional programs are maintenance and upkeep, and central services.

Research results are carried to Texas farmers, ranchmen and homemakers by county agents and specialists of the Texas Agricultural Extension Service

AGRICULTURAL RESEARCH seeks the WHATS, the WHYS, the WHENS, the WHERES and the HOWS of hundreds of problems which confront operators of farms and ranches, and the many industries depending on or serving agriculture. Workers of the Main Station and the field units of the Texas Agricultural Experiment Station seek diligently to find solutions to these problems.

Today's Research Is Tomorrow's Progress