Aeration Studies of Commercially Stored Planting Cottonseed

L. L. Smith
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Lloyd L. Smith 1/

In recent years there has been considerable concern over the loss in germination and other deterioration of cottonseed during the storage period. You, as seedsmen, I'm sure are more aware of this than I am. A number of factors can contribute to this loss. Two important factors are the moisture content and temperature of the cottonseed; if either one is too high, deterioration in cottonseed can result. Warehousemen in the Delta endeavor to store cottonseed at a moisture content of 8 to 10 percent and to cool it to 50° to 70° F. To date, reliable research information is not available to confirm these limits or to determine other combinations of satisfactory seed moistures and temperatures.

For a number of years, cottonseed has been aerated to help maintain its temperature and moisture content at satisfactory levels. However, only limited technical or engineering data on requirements for satisfactory aeration of stored cottonseed are available.

Reliable information on the resistance of cottonseed to airflow is necessary in designing an aeration system. Only a limited amount of such information is available. Some basic work done by Allen Brashears, Agricultural Engineer, Agricultural Research Service, and by Texas A & M University, supplies the best information available on the subject. Some data are available on the equilibrium moisture content of cottonseed at certain conditions of air temperature and relative humidity. Little information is available on the resistance to airflow of cottonseed having different amounts of lint.

In its 1961 meeting, the Cotton and Cottonseed Research and Marketing Advisory Committee to the U. S. Department of Agriculture expressed concern over germination loss in cottonseed and gave high priority to research on equipment and facilities for conditioning stored cottonseed. In October 1962, the Department and the Mississippi Agricultural Experiment Station began work on the problem at the Delta Branch

1/ Mr. Smith is Agricultural Engineer, Transportation and Facilities Research Division, Agricultural Research Service, United States Department of Agriculture, Stoneville, Mississippi.
Work during the 1962-63 storage season was devoted to studying aeration systems in commercial storages with capacities of 450 to 2,400 tons. Included were the so-called flat storage, Butler or Stran-Steel, and the Muskogee type. In many of the storages, the common pallet-type aeration duct and small-diameter air pipes in the floor were used for air movement.

Measurements were made of total airflow delivered by various types and sizes of fans, static pressure losses through the cottonseed and cottonseed temperatures. Air volume deliveries were measured with a pitot tube in the fan exhaust duct. Static pressure losses were measured by probing into the cottonseed at known depth intervals. The static pressures and velocity pressures were read on an inclined manometer. Some of the many factors that affected the rate of airflow through the cottonseed were: (1) The depth of the cottonseed; (2) the compaction of the cottonseed; (3) the velocity of the air; and (4) the amount of lint and foreign material present in the seed.

Wide differences in the amount of air moved through cottonseed were observed. The use of large fans and large motors did not necessarily mean that large amounts of air were being moved through the cottonseed. Electric motor sizes of 10- to 75-horsepower are being used in presently installed aeration systems. Some oil mill storages are using as large as 200-horsepower motors. It is felt that in many of these systems, from 25 to 75 percent of the power is used in moving the air through the system. Researchers feel that only 10 percent of the power output should be needed to move air through the ducts, leaving 90 percent to move the air through the cottonseed.

High friction losses in the duct system reduce the quantity of air moved through the cottonseed. Much of this friction is created by air moving at a high velocity through undersized ducts and supply pipes connecting the ducts to the fan. The number and size of open areas in the duct surface for air to pass from the cottonseed into the duct affect the pressure losses that occur in the seed surrounding the duct. For example, the wood pallets commonly used in existing aeration systems have only a small open area beneath the pallet. Figure 1 illustrates how the air must converge to enter the wood pallets. As it converges at this point, the velocity of the air increases in the seed near the openings and this, in turn, increases the static pressure. Thus more power is required to move the necessary air through the cottonseed.

With a properly designed aeration duct of sufficient duct surface area, velocities in the seed surrounding the duct can be held within the generally recommended limits of 10 to 20 feet per minute. Adequate duct surface areas can be obtained by using A-frame, round, half round, or other similar designs,
Wood Pallet
Open Area 1.37 sq. ft.

FIG. 1. AIR VELOCITIES--AND STATIC PRESSURES LOSSES--ARE RELATIVELY HIGH IN SEED SURROUNDING WOOD PALLETS WITH ONLY SMALL AIR OPENINGS BENEATH THE PALLETS.
FIG. 2. AIR VELOCITIES--AND STATIC PRESSURES LOSSES--ARE RELATIVELY LOW IN SEED SURROUNDING AN A-FRAME DUCT WITH AIR OPENINGS SPACED UNIFORMLY OVER DUCT SURFACE.
with openings uniformly spaced over the entire surface area. Figure 2 shows an A-frame type of duct with openings where air can enter over the entire surface, instead of through small, restricted openings as in the pallet shown in figure 1. Ducts can be designed with sufficient perimeter and length to provide the necessary surface area once the amount of air each duct is required to carry is known.

During the 1963-64 and 1964-65 storage seasons, some aeration systems of improved design were installed and studied. One system has been studied for two seasons and the other only during the past season.

In one storage with an improved system, a 40-horsepower motor was replaced by a 10-horsepower motor. The smaller motor aerated 48,000 cubic feet of cottonseed with an air movement of 3,380 cubic feet per minute. The larger motor aerated 32,000 cubic feet of cottonseed with an air movement of only 2,140 cubic feet per minute. Less power is required to move air through efficiently designed ducts.

The moisture content of the cottonseed going into this storage during the 1963-64 storage period was between 9.5 and 10.5 percent, with an occasional sample of 13.0 percent or slightly above. This cottonseed had a temperature range of 85° to 95° F, in September when harvesting started. On December 6, the average cottonseed temperature was 55° and the range was 47° to 63° F. During this cooling process, the fan was operated a total of 550 hours. Germination of the initial cottonseed samples ranged between 85 and 90 percent. There was no appreciable change in germination or other quality factors during the storage period.

Similar results were obtained in this storage during the past season. Cottonseed started into the storage a little later, about October 11. The cottonseed temperatures were approximately the same, in the 80° to 90° F range. Moisture content was a little lower, ranging between 9.0 and 9.5 percent. On January 4, 1965, the average temperature was 46° and the range was 39° to 57° F. Fan operation was longer -- 676 hours through January 4. Initial sample germinations were between 81 and 87 percent. Germination of samples taken during unloading of the storage in April were 88.5 percent.

For comparison, observations were made of a storage of similar size at the same location. This storage had an aeration system of a different design. Two 10-horsepower motors and two fans were used. The cottonseed temperatures were only slightly higher, an average of 86° F., when the seed started into storage around September 15. On December 1, after about 1,000 hours of operation of the two fans, the
average temperature was $55^\circ$ F. These two fans delivered only about 50 percent more air than did the one fan and 10-horsepower motor in the improved system. These fans were manually started and stopped, while the fan in the improved system was automatically controlled with a thermostat and humidistat for most of the operation.

At another storage facility, observations were made of a 75-horsepower motor and fan moving 5,500 cubic feet of air per minute through 14,500 cubic feet of cottonseed. This is a good airflow rate, about 1/3 cubic foot of air per minute per cubic foot, but the horsepower is tremendous for moving such a small amount of air. The velocity of the air through the cottonseed near or around the pallets was calculated to be at least several times more than the 10 to 20 feet per minute recommended. The velocity of the air in the 6-inch tile laid in the floor was calculated to be 5,500 feet per minute. The recommended air velocity is 1,500 feet per minute in the supply pipes. However, velocities as high as 2,500 feet per minute are permissible without severe friction losses in relatively short pipe lengths.

During the past storage season, an improved aeration system was designed and installed in a portion of one storage accommodating 35,000 to 40,000 cubic feet of cottonseed. Aeration ducts were designed of the A-frame type to provide an air velocity of 10 feet per minute or less through the cottonseed near the duct surface. One end of each duct was placed against the unloading tunnel and exhausted into it. That part of the unloading tunnel was then sealed off at both ends, so it became the main supply pipe leading to the fan. An air-moving, industrial exhauster-type fan and a 7 1/2-horsepower motor were used to aerate this quantity of cottonseed.

Cottonseed started moving into this storage the first week in October. It had an initial moisture content of 10.0 to 10.5 percent with a germination around 80 percent. The fan was not started until November 9. The average cottonseed temperature was then $81^\circ$ F. with a range of $75^\circ$ to $90^\circ$ F.

The fan was operated by automatic controls consisting of a thermostat and humidistat wired in series in the control circuit. The humidistat was set to allow fan operation when the atmospheric air was below 75 percent relative humidity. The initial thermostat setting was $75^\circ$ F., the setting was lowered as the weather permitted, with the lowest setting being $45^\circ$ F.

On January 26, 550 hours of fan operation had occurred, and the average temperature of the cottonseed was $48^\circ$ F. The average cottonseed temperature on April 2, when the last readings were made, was slightly above $50^\circ$ F. Moisture content of samples taken during the unloading of the storage in April was 9.5 to 10.0 percent, and germination was 80 to 82.5 percent.
A typical cottonseed aeration system, with wood pallets on the floor and small diameter supply pipes laid in the floor, is shown in figure 3. The top sketch shows cottonseed temperatures in October before any fan operation or cooling had taken place. The lower sketch shows seed temperature for the following February after aeration was stopped. The temperature lines indicated that proper cooling had taken place near the outer walls in the lesser depths of cottonseed, where the larger pallets were located. Temperatures as high as 74°F in the deepest cottonseed along the main tunnel illustrate unequal air distribution and inadequate cooling resulting from the poor system design.

An improved aeration system, with A-frame ducts and the main tunnel used as a plenum chamber, is shown in figure 4. The top sketch shows the temperature of the cottonseed in November. The lower sketch illustrates the cottonseed temperatures in February after 550 hours of fan operation. These relatively uniform temperatures indicate a much more uniform airflow distribution and cooling pattern through the cottonseed mass than in figure 3. This emphasizes the fact that proper system design is necessary for uniform airflow distribution and cooling.

Every aeration system installation has its own individual design problems. Before designing a system and selecting aeration equipment, the following factors should be considered: (1) The size and type of structure in which the system is to be installed; (2) the depth of the cottonseed through which the air will be moved; (3) the airflow rate per cubic foot to be provided; and (4) the quantity of cottonseed to be served by each fan. After these points have been considered, determinations should be made for: (1) Total air volume to be supplied; (2) the static pressure against which the fan must operate; (3) the size and type of fan and motor needed; and (4) the kinds of aeration ducts and supply pipes needed.

Automatic controls -- a thermostat and humidistat -- provide for maximum use of desirable air when it is available. Satisfactory weather conditions in the early morning and late evening may be lost with manual controls, because many times the warehouse manager may not be available to start and stop the fans.

Unequal seed depths always present a problem in designing the duct system to obtain relatively uniform airflow distribution through the seed. A storage with a 45-degree roof slope offers a major problem in difference of seed depth. As the width of this type of storage increases, the difference in seed depth increases, and the problem of designing the duct system becomes more difficult.
FIG. 3. TYPICAL COTTONSEED AERATION SYSTEM WITH FLOOR PALLET'S AND SUPPLY PIPES IN FLOOR. (ABOVE) INITIAL COTTONSEED TEMPERATURES WHEN SEED STORED IN OCT. (BELOW) COTTONSEED TEMPERATURES IN FEB. AFTER AERATION WAS STOPPED; SHAD ED AREA 50° F. AND ABOVE.
FIG. 4. IMPROVED COTTONSEED AERATION SYSTEM WITH A-FRAME DUCTS AND AIR EXHAUSTING INTO THE MAIN TUNNEL. (ABOVE) INITIAL COTTONSEED TEMPERATURES WHEN SEED STORED IN NOV. (BELOW) COTTONSEED TEMPERATURE IN FEB. AFTER 550 HOURS OF FAN OPERATION: SHADED AREA 50° F. AND ABOVE.
Studies are presently being made in a 14,000-ton oil mill storage where cottonseed depths range from 12 feet up to as much as 80 feet. All of the existing aeration system is above the floor, with the unloading tunnel serving as an air tunnel and aeration duct. Two 36-inch-diameter concrete tiles are used as the supply pipes, connecting the air tunnel with the two fans and motors outside the building. The tunnel doors along the sides of the unloading tunnel are left open to serve as a major part of the aeration duct system. Some pallets are used, but the greater part of the air moving through the cottonseed enters the unloading tunnel through these openings.

Air is successfully being moved through the 80 feet of cottonseed, but the rate and uniformity of airflow is at present not known. Indications are that air velocities through the cottonseed surrounding the tunnel may be as high as 50 feet per minute. This is much higher than the recommended velocity. Cottonseed temperatures were in the $40^\circ$ to $50^\circ$ F. range when last read in April. Samples taken at that time had free fatty acid readings of 0.5 to slightly over 1.0 percent.

These are some of the observations that have been made of presently used aeration systems and a few indications of increased efficiencies when improved designs are applied. Considerable improvement is still needed in the design, equipment, and operating schedules of aeration systems for cottonseed.