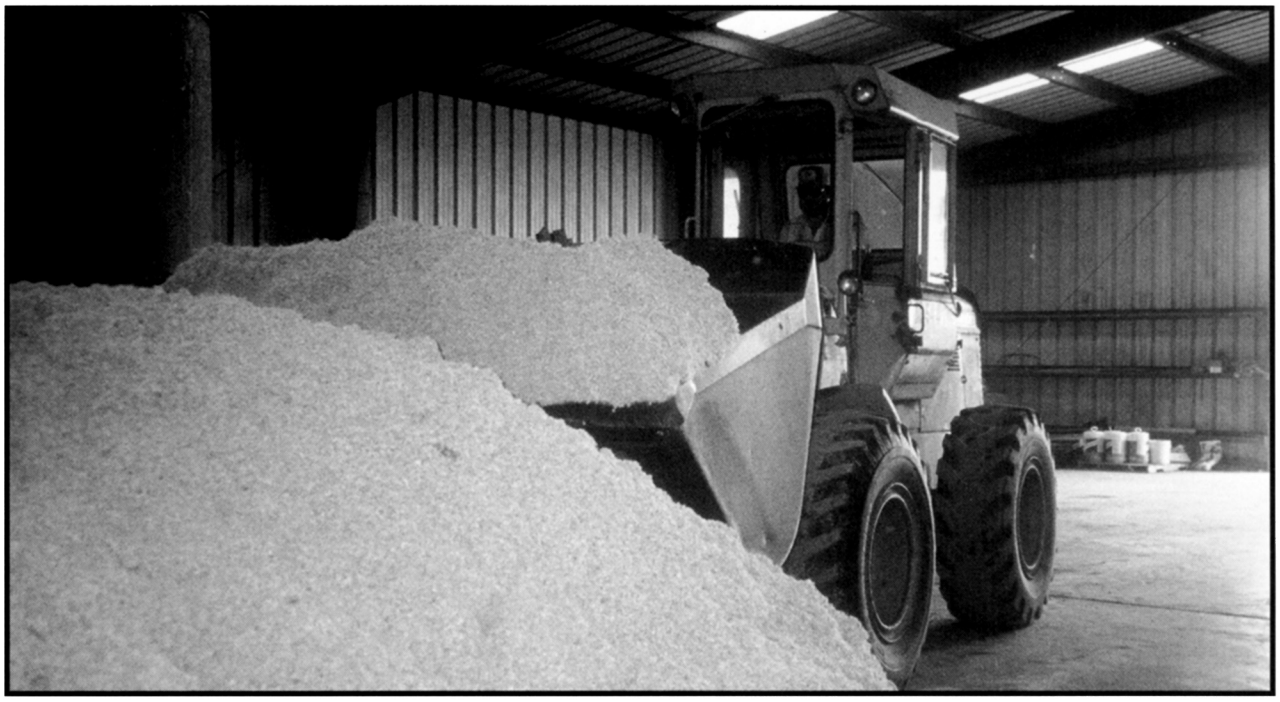

COTTONSEED STORAGE

By
Herbert M. Willcut, Mississippi Cooperative Extension Service
William D. Mayfield, USDA Extension Service, Memphis, TN
Thomas D. Valco, Cotton Incorporated, Raleigh, NC.

For every bale of cotton ginned approximately 850 pounds of seed must be handled from beneath the gin stands and placed either in a temporary or long-term storage facility. For long-term storage, aeration is necessary to reduce seed temperature and moisture, and minimize mold growth and insect activity within the seed.

This paper briefly describes structural and aeration requirements to maintain seed quality during storage. A complete discussion of design criteria is reported in the USDA Marketing Research Report No. 1020, "Aeration of Cottonseed in Storage" (Smith, 1975).

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Characteristics of Cottonseed

The bulk density of gin-run cottonseed averages about 25 lb/ft^3 and requires about 80 ft^3 of storage space per ton. Cottonseed is hygroscopic and therefore absorbs moisture from or gives up moisture to the surrounding air. Storage temperatures below 60°F and 10% moisture content wet basis (mc w.b.) provide best storage conditions.

Whole, fuzzy cottonseed has some unique characteristics which make it difficult to handle with common grain handling facilities. Unlike grain, cottonseed has a variable angle of repose. The angle of repose when an unrestricted pile of cottonseed is formed is about 45°. However, after the seeds have settled, they will bridge -- an indication that the angle of repose is greater than 90°.

Cottonseed may be handled by belts, screw conveyors, or pneumatics. Pneumatics is the most effective way to load seed into storage facilities (Shaw &

Table 1. Basic properties of cottonseed and cottonseed products.

Product	Bulk Density (lb/ft³)	Bulk Volume (ft³/ton)	Weight (lb/bu)	Specific Count (seed/lb)
Whole Seed				
Loose on Conveyor	20	100		
<24 ft deep	25	80	32	1,800-2,400
24-50 ft deep	27	75		
>50ft deep	30	70		
Machine Delinted	35	57	44	2,400-3,200
Acid Delinted	34-37	54	42-46	4,800-5,600
Meal (extracted)	38	53		
Hulls	12	167		
Oil	57	35		

Franks, 1963). The basic handling and storage characteristics of whole cottonseed and cottonseed products are shown in **Table 1**.

Buildings

Many types of buildings can be used to store cottonseed at gins, however clear- span metal buildings are the most popular. Lining interior walls with 3/4-inch plywood helps prevent damage to the outside building walls, facilitates clean out, increases wall strength, and reduces settling pressure on exposed framework. The top of this inside wall should be sealed to prevent seed and lint from accumulating between the walls.

Cottonseed storage facilities should have moisture-proof concrete floors. Floor loads from seed alone will be approximately 500 lb/ft^2 for a 20 foot seed depth. Also, floors should have sufficient concrete and reinforcement to support a 60,000 lb truck.

Buildings used to store cottonseed must be designed to withstand the lateral forces exerted by the cottonseed as it is loaded and unloaded. Wall pressures for flat storage of cottonseed are a function of bulk density, seed depth and a pressure coefficient. The non-dimensional pressure coefficient for cottonseed is estimated at .20, based on a 45° angle of repose. Higher values can occur when cottonseed is blown into a storage building. Lateral wall pressures can be estimated by the following formula:

$$WP = k \times D \times H$$

Where: WP = lateral wall pressure (lb/ft^2)
k = pressure coefficient (.20)
D = Density (25 lb/ft^3)
H = Height or seed depth (ft).

Based on the above factors, the lateral pressure at the base of 20 ft seed depth would be 100 lb/ft^2 distributed at the base of the building. Maximum force and wall failure usually occur at 10 to 20% of wall height above the floor due to boundary effects of the floor.

Several side wall failures have recently occurred in cottonseed storage facilities. Walls of existing buildings converted to cottonseed storage should be analyzed and strengthened as needed before filling with seed.

Aeration System Design

Long-term cottonseed storage facilities must be equipped with an aeration system. A properly designed aeration system must have: 1) aeration ducts to distribute air through the cottonseed, 2) properly sized supply pipes to transport the air, and 3) fans to supply the required volume of air for a given static pressure or resistance. Factors that influence the design and selection of aeration equipment are: 1) the size and shape of storage facility, 2) airflow rate per ton of cottonseed, and 3) the maximum depth of stored cottonseed.

A safe airflow rate for cottonseed in flat storage is 10 cubic feet per minute per ton (cfm/ton). At this rate, cottonseed at 10% mc w.b. can be safely stored. An aeration rate of 5 cfm/ton has worked satisfactorily in areas with cooler and dryer climatic conditions. With careful monitoring of seed temperature, lower capacity aeration systems can be used.

Aeration Ducts

Aeration ducts can be many different shapes. Perforated, half-round ducts are preferred for easy handling and storage. Two important design criteria for cottonseed aeration ducts are (1) adequate open surface area and (2) adequate cross-sectional area.

Table 2. Surface area of corrugated half-round ducting.

Duct Diameter (in)	Surface Area[1] (ft²/lin.ft)
16	2.09
18	2.36
20	2.62
22	2.88
24	3.14
26	3.40
28	3.66
30	3.93
32	4.19
34	4.45
36	4.71
38	4.97
40	5.23
42	5.50
44	5.76
46	6.02
48	6.28
50	6.54

1. Double surface area for round duct.

Open surface area is defined as the open area along the duct surface through which air can pass. It is generally described as a percent of the total area. Ducts should have at least 10% total open surface area; 15% is better. Pressure losses can be held to a minimum by limiting the velocity of the air into the duct (face velocity) from 10 to 15 ft/min.

The air velocity within an aeration duct should range from 1,500 to 2,000 ft/min. This will reduce static pressure losses and fan power requirements. Air velocities above 2,500 ft/min can transport seed that may have entered the duct and should be avoided.

Ducts should be evenly spaced on the floor of a seedhouse to keep the airflow path uniform within the seed mass. Duct spacing is determined by the depth of seed and the airflow rate used. For depths less than 20 ft a spacing no greater than the seed depth is preferred and should not exceed 1 1/2 times the cottonseed depth (Smith, 1975).

Ducts installed across the width of a rectangular building provide better airflow distribution and allow aeration to be started as soon as the first duct is covered with seed. The airflow can be concentrated in selected areas to remove hot spots that sometimes develop. For extra wide storage buildings, a central manifold pipe can be used to reduce duct length.

Manifold and Supply Pipes

An air manifold and supply lines distribute air between the fan and the aeration ducts. Air velocities between 1,500 and 2,000 ft/min are also desired (Rayburn & Mayfield, 1987). Pipe diameter or cross-sectional area for the designed airflow rate can be determined from **Table 3** or by the equation A = cfm / v.

It is desirable to have slide valves between the manifold and supply line. This allows air to be directed to specific ducts during filling and maintenance.

Fans and Motors

Most aeration systems are designed with downward airflow through the cottonseed. This helps minimize moisture condensation and accumulation in the top layers of cottonseed, which can occur when warm, moist air moves upward into the cold top layers of seed. In addition, temperature and odor of the exhaust air from the fan can give an indication of cottonseed condition.

To select a fan, the required volume of air to aerate the number of tons of seed must be known as well as the static pressure. Static pressure or resistance to air flow is measured in inches of water and depends on the depth and density of the seed. Static pressures for different airflow rates and cottonseed depths are shown in **Table 4**. Knowing airflow and

Table 3. Airflow rates for selected air velocities and duct across sectional areas.

Pipe Diameter (in)	Cross[1] Area (ft²)	Airflow (cfm)[2] @1500ft/min	Airflow (cfm)[2] @2000ft/min
5	0.14	210	280
6	0.20	300	400
7	0.27	405	540
8	0.35	525	700
9	0.44	660	880
10	0.55	825	1100
11	0.66	990	1320
12	0.79	1185	1580
13	0.92	1380	1840
14	1.07	1605	2140
15	1.23	1845	2460
16	1.40	2100	2800
17	1.58	2370	3160
18	1.77	2655	3540
19	1.97	2955	3940
20	2.18	3270	4360
21	2.40	3600	4800
22	2.64	3960	5280
23	2.88	4320	5760
24	3.14	4710	6280
25	3.41	5115	3820
26	3.69	5535	7380
27	3.97	5955	7940
28	4.27	6405	8540
29	4.58	6870	9160
30	4.91	7365	9820

1. Cross sectional area of inside air duct, not necessarily circular.
2. Airflow through duct in cfm = A x v

static pressure, a fan and motor can be selected from a suppliers catalog to meet the design specifications.

Aeration Examples

To better understand cottonseed aeration systems, the following typical systems are considered:

Example 1. Design a storage and aeration facility for 1,200 tons of cottonseed. The cottonseed will be carried into storage with an existing small-pipe seed-handling system and unloaded with a front-end loader:

I. Building

Volume required for 1,200 tons of cottonseed is 96,000 ft^3. The storage structure could be 60 ft wide and 100 ft long with an eve clearance of 18 ft to accommodate the front-end loader. It will be filled to a depth of 16 ft. The building should be constructed 120 ft long to provide access for unloading without using a bulkhead door.

II. Aeration System

System capacity = 1,200 tons of cottonseed.

Design airflow rate = 10 cfm/ton.

1. Total air volume needed: 1,200 tons x 10 cfm/ton = 12,000 cfm.
2. Duct layout as shown in **Figure 1** with 5 rows spaced 20 ft apart, 50 ft long (Maximum duct spacing: 1.5 x 16 ft = 24 ft).
3. Duct Design: Each duct carries 1/5 of the total air or 2,400 cfm per duct. Total surface area needed for a 10 ft/min face velocity is 240 ft^2 (2,400 cfm/ 10 ft/min = 240 ft^2) or 240 ft^2 / 50 ft = 4.8 ft^2/linear ft. From **Table 2** select a 36-inch diameter half-round or 18-inch diameter round duct.
4. Supply pipes: Each supply pipe carries 1/5 of the total volume of air or 2,400 cfm. From **Table 3** select an 18-inch diameter supply pipe that will carry 2,651 cfm at a velocity of 1,500 ft/min.
5. Manifold pipes: The manifold pipe carries air for two supply pipes or 4,800 cfm. From **Table 3** select a 24-inch diameter pipe that will carry 4,713 cfm at a velocity at 1,500 ft/min.
6. Fan and motor: At a cottonseed depth of 16 ft and an airflow rate of 10 cfm/ton the static pressure to be overcome by the fan is 4.0 inches of water (**Table 4**).

From a manufacturers's catalog, select a centrifugal fan with a wheel diameter of 27 inches operating at 1,400 rpm with a 15 horsepower motor which would deliver 12,570 cfm at 4 inches static pressure. An alternative would be to use five small fans and motors capable of 2400 cfm per fan. This would require 3 hp motors which could be operated with 220 volt single phase power and eliminate the manifold pipe.

Table 4. Airflow resistance and fan power requirements for cottonseed at different storage levels and airflow rates.

Depth of Cottonseed (ft)	Airflow Rate (cfm/ton)	Static Pressure (in H_2O)	Power Required (hp/100 tons)
10	5.0	1.0	0.1
	7.5	1.1	0.2
	10.0	1.6	0.4
12	5.0	1.0	0.1
	7.5	1.6	0.4
	10.0	2.3	0.7
14	5.0	1.3	0.2
	7.5	2.1	0.6
	10.0	3.1	1.2
16	5.0	1.7	0.2
	7.5	2.8	0.6
	10.0	4.0	1.2
18	5.0	2.2	0.3
	7.5	3.5	0.8
	10.0	5.0	1.5
20	5.0	2.7	0.4
	7.5	4.5	0.9
	10.0	6.3	1.7
22	5.0	3.3	0.5
	7.5	5.3	1.1
	10.0	7.7	1.9
24	5.0	4.1	0.6
	7.5	6.4	1.4
	10.0	9.5	2.5
26	5.0	4.7	0.6
	7.5	7.6	1.6
	10.0	11.6	2.9
28	5.0	5.5	0.8
	7.5	9.0	1.7
	10.0	13.5	3.4
30	5.0	6.3	0.9

Example 2. Design a storage and aeration system for 2,000 tons of cottonseed. The cottonseed will be carried into storage with an existing small-pipe handling system and unloaded with a front-end loader.

I. Building

The storage structure would be 60 ft wide and 160 ft long with 18 ft eve clearance. It will be filled to an average cottonseed depth of 17 ft. The building should be constructed 180 ft long to allow access for unloading.

II. Aeration System

System capacity = 2,000 ton.

Design airflow rate = 10 cfm/ton.

1. Total air volume required is 2,000 ton x 10 cfm/ton = 20,000 cfm.
2. Duct layout is shown in **Figure 2** with 8,50 ft rows spaced 20 ft apart.
3. Duct Design: Each duct carries 1/8 of the total air or 2,500 cfm per duct. Total surface area needed

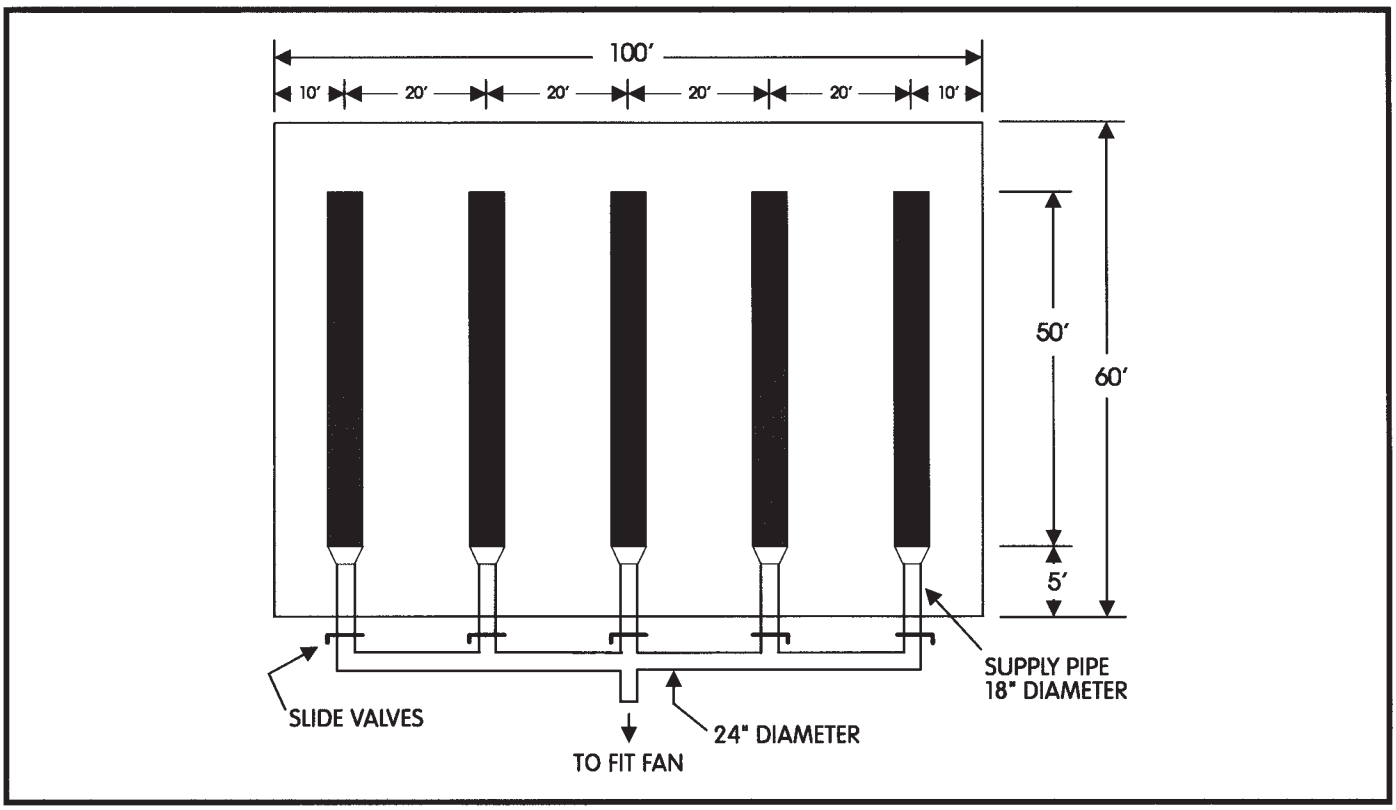

Figure 1. Aeration duct layout for 1,200 tons of stored cottonseed.

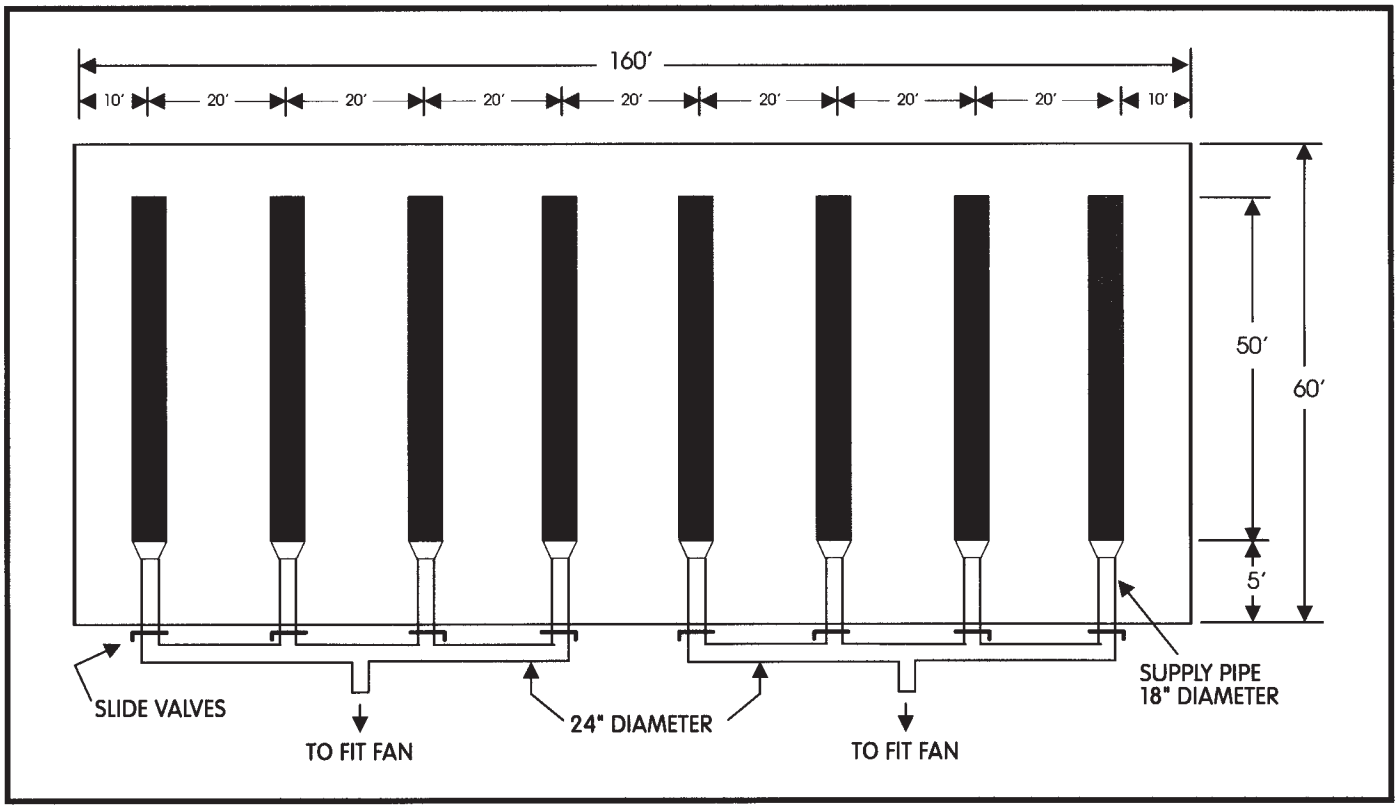

Figure 2. Aeration duct layout for 2,000 tons of stored cottonseed.

for a 10 ft/min face velocity is 240 ft^2 (2,500 cfm/ 10 ft/min = 250 ft^2) or 250 ft^2 / 50 ft = 5.0 ft^2/linear ft. From **Table 2** select a 38-inch diameter half-round or 20-inch diameter round duct is needed.

4. Supply pipes: Each supply pipe carries 1/8 of the total air volume (1/8 of 20,000 cfm = 2,500 cfm. From **Table 3** select an 18-inch diameter supply pipe.

5. The manifold pipe carries air for two supply pipes or 5,000 cfm. From **Table 3** select a 24-inch diameter pipe that would be satisfactory.

6. Fans and motors: At a cottonseed depth of 17 ft and an airflow rate of 10 cfm/ton (**Table 4**), the static pressure requirement is 4.5 inches of water (interpolate between 16- and 18-ft depths).

From a manufacturer's catalog, select a centrifugal fan with a wheel diameter of 27 inches operating at 1,370 rpm, with a 10-horsepower motor that would deliver 10,056 cfm at 4.5 inches of water, static pressure. Two fans and motors would be required for this system.

Managing Aeration Systems

Good judgment should be used in selecting cottonseed to store. Cottonseed from cotton harvested in the early morning after a heavy dew, cotton harvested soon after a rain or snow, or cotton that may have gotten wet on a trailer or module should not be stored. Seed can be stored up to 15 % mc w.b. providing seed temperatures are reduced to 50° to 60°F (Smith, 1975).

Being hygroscopic, cottonseed will absorb moisture from or give up moisture to its surrounding air. Therefore, aeration fans should not be operated during high humidity periods of rain or fog. Ideally, cottonseed in storage should be cooled to 50° to 60°F by selecting cool dry days to run the fans.

Usually no additional aeration is necessary once the seed has been cooled to the desired temperature. Even so, seed temperatures should be monitored throughout the storage period, since hot spots occasionally develop.

Many seed storage facilities are equipped with temperature monitoring systems. Seed temperature monitoring can also be accomplished by placing a thermometer in the exhausting aeration airflow and/or by hand inserting thermocouple probes attached to steel rods or electrical conduit.

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Useful Terms

A	- cross sectional area of duct (ft^2), A = L x W (rectangular)
cfm	- cubic feet per minute of air flow (ft^3/min)
cfm/ton	- air volume per ton of stored cottonseed
D	- diameter (ft)
in of H20	- inches of water of air pressure
L	- length (ft)
% mc w.b.	- percent moisture content wet basis = moisture weight * 100 / weight of wet sample
ton	- 2,000 pounds of cottonseed
v	- velocity in ft/min of air flow, v = cfm/A
W	- width (ft)

For further information please contact:
Herbert Willcut, Mississippi Cooperative Extension Service, 601-325-3103
William D. Mayfield, USDA ES, Memphis, TN 901-766-7690
Thomas D. Valco, Cotton Incorporated, Raleigh, NC 919-782-6330

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