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2024 BEST PRACTICES STORAGE

HANDLING COTTONSEED

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REQUIREMENTS, REQUEST, AND RECOMMENDATIONS

To have superior quality cottonseed, keep it cool and dry. These bullet points are all *critical* for maximizing the value of that cotton seed and preventing losses:

- Have a building designed to handle the load/density of the cottonseed and aid in the aeration of cottonseed stored in bulk.
- Use solenoid switches on your pipes for quick response to fire in the gin or wet cottonseed, allowing for movement to another location or overhead house.
- Moving the proper airflow evenly through stored cottonseed removes the heat caused during the ginning process, minimizes or eliminates mold growth, and, in most cases, effectively removes any hot spots that may develop during storage from Mild moisture or other causes.
- **Smoking is prohibited on the Gin Premises, Bulk Seed House, or Warehouse. This includes Truck Drivers picking up loads of Bale Cotton or Cottonseed.**
- **NO OPEN FLAMES OF ANY TYPE NEAR ANY COTTON PRODUCTS STORAGE AREA.**
- Install and use a monitoring system that will tell you the moisture and temperatures of the seed stored in the house at as many locations as possible in the various piles. Cooling the stored cottonseed to a temperature range of 50 to 60 degrees Fahrenheit can help prevent the increase in free fatty acids, which harms quality. Also, shooting for a 12% or less moisture level is ideal. Regularly monitor seed temperatures during and after ginning.
- If you are dealing with ***wet cottonseed, call for immediate shipment. DO NOT TRY TO STORE IT. You do not have the Aeration needed or the space to dry it and prevent it from heating up,*** resulting in hot spots that lead to a fire.
- Install spark inhibitors or arrest systems at the Gin.
- Moisture Meter in the seed pipe leaving the Gin.
- Cut off seed flow and turn off aeration fans in case of a fire.
- Clean the storage facility once the house is empty to reduce the risk of severe flashovers.

In summary, these guidelines stress the importance of preventive measures, early detection, and the cautious use of water in case of fires in cottonseed storage facilities, emphasizing minimizing potential damage to quantity and quality.

COTTONSEED BULK STORAGE BUILDING DESIGN RECOMMENDATIONS

1. **Unique Characteristics of Cottonseed:**
   - Cottonseed poses challenges in handling compared to common grains due to its variable angle of repose.
   - The angle of repose is around 45° when forming a pile but can exceed 90° after settling, causing bridging.
2. **Preferred Storage Buildings:**
   - Clear-span metal buildings or Muskogee buildings are popular for storing cottonseed at Cotton gins.
   - A suggested roof pitch of 12-12 for Clear-span or 45% for Muskogee buildings aids in aeration.
   - Lining interior walls with 3/4-inch plywood prevents damage, facilitates cleanout, strengthens walls, and reduces settling pressure on the exposed framework.
3. **Moisture-Proof Floors and Load Capacity:**
   - Cottonseed storage facilities should have moisture-proof concrete floors.
   - Floor loads from seed alone are approximately 700 lb./ft2 for a 20-foot seed depth.
   - Floors must be reinforced to support a 60,000 lb. truck.
4. **Access and Safety Considerations:**
   - Bulk seed house buildings should have roll-up doors on the front, side, and back.
   - The back and Side doors provide emergency access without destroying the structure in case of fire or water leaks. They also aid in access in the event of Hot Spots.
   - Catwalks allow access to blow pipes, observation of the pile, and firefighting in case of a flashover fire.
5. **Design for Lateral Forces:**
   - Buildings storing cottonseed must withstand lateral forces during loading and unloading.
   - Wall pressures for flat storage are a function of bulk density, seed depth, and pressure coefficient.
   - The non-dimensional pressure coefficient for cottonseed is estimated at 0.20 based on a 45° angle of repose.
   - Lateral wall pressures can be estimated using the formula: $WP = k \times D \times H$
     where ***WP*** is lateral wall pressure (lb./ft2), ***k*** is the pressure coefficient (0.20), ***D*** is density (25 lb./ft3), and ***H*** is height or seed depth (ft).
6. **Lateral Pressure Calculation:**
   - Using the provided formula, the lateral pressure at the base of a 20 ft seed depth is calculated as 100 lb./ft2, distributed at the base of the building.
7. **Wall Failure Considerations:**
   - Maximum force and wall failure typically occur at 10 to 20% of wall height above the floor due to boundary effects.
   - Existing buildings converted to cottonseed storage should be analyzed and strengthened before filling with seed to prevent wall failures.

This information provides a comprehensive overview of the considerations and precautions necessary to store whole, fuzzy cottonseed effectively.

COTTONSEED BULK STORAGE AERATION SYSTEMS

There is a distinction between storing bulk cottonseed in the southern and southeastern areas of the country and storing bulk cottonseed in the southwest parts of the country.

- Bulk cottonseed in the south and southeastern areas and moisture and humidity require additional precautions regarding aeration and the hypostatic nature of cottonseed.

- Bulk cottonseed in the Ariad Southwest usually requires aeration to remove the heat from the Gin Process as it is already dry.

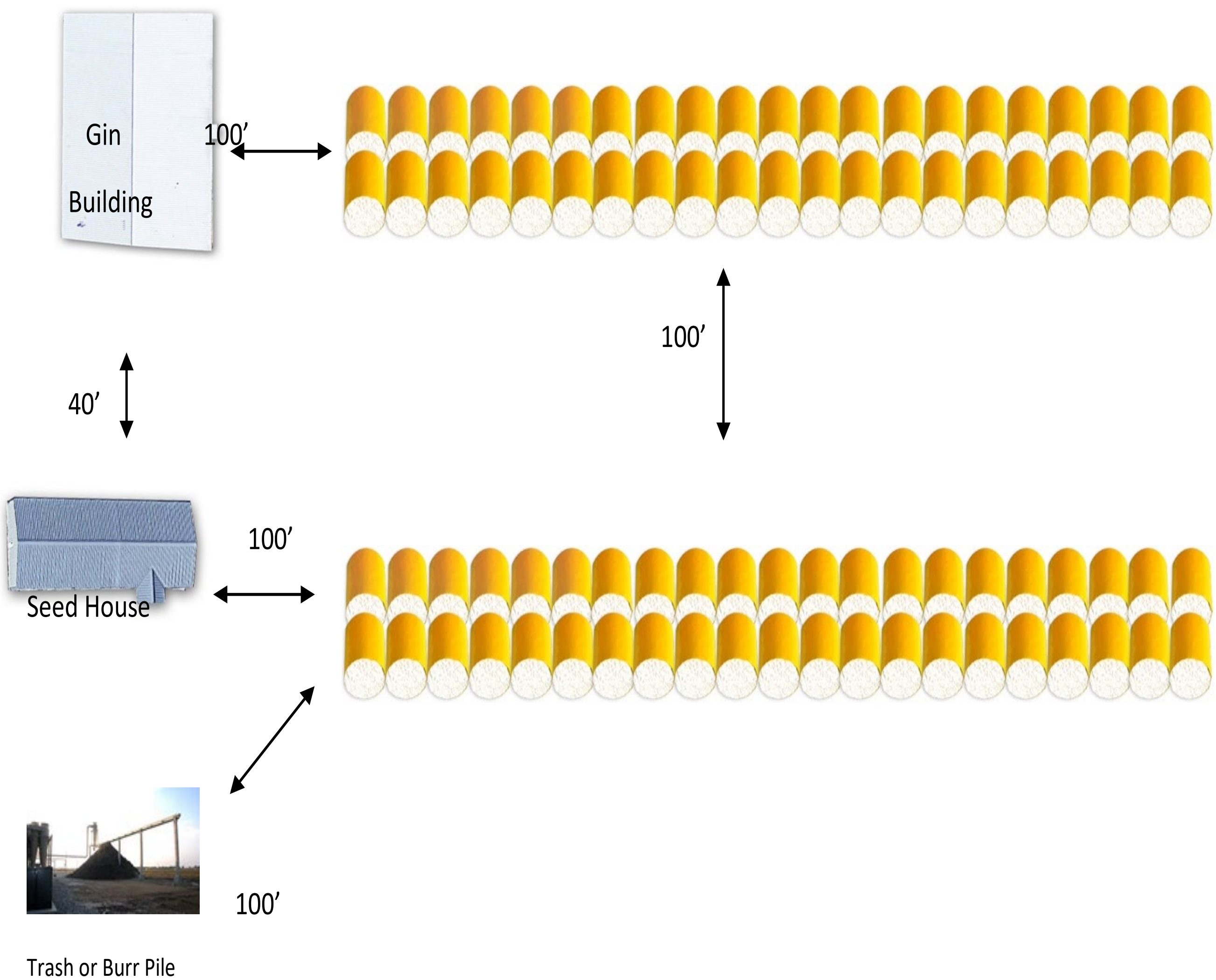
A Strong emphasizes the importance of effective aeration management for cooling cottonseed from the gin, especially when it is initially at high temperatures, often exceeding 100°F. Proper aeration helps prevent hot spots and moisture buildup and maintains seed quality during storage. Here is a breakdown of the key points:

1. **Purpose of Aeration:**
   - Cooling cottonseed is essential, particularly when it is received at high temperatures from the gin.
   - Aeration helps remove heat generated during the ginning process and eliminates hot spots caused by excessive moisture or other factors.
   - It is recommended that aeration fans be continuously operated until the facility is filled and conditioned to ideal temperature and moisture levels.
2. **Management of Aeration:**
   - Continuous aeration helps maintain seed quality.
   - It effectively minimizes mold growth and insect activity within the stored cottonseed.
3. **Hygroscopic Nature of Cottonseed:**
   - Cottonseed is hygroscopic, meaning it can absorb or release moisture based on the surrounding air conditions.
   - Once the gin heat has been removed, aeration fans should ***NOT*** be operated during periods of high humidity, rain, or fog.
   - Ideal conditions for running fans include dry, cool days to cool the cottonseed to 50° to 60°F.
4. **Temperature and Moisture Levels:**
   - Ideal storage conditions include maintaining temperatures between 50° to 60°F.
   - Moisture levels should be kept at 10% or less.
5. **Monitoring and Equipment:**
   - Temperature monitoring systems in cottonseed storage facilities are required.
   - Seed temperature monitoring should also be done by placing a digital thermometer in the exhausting aeration airflow or using thermocouple probes attached to steel rods conduit.
   - Regular monitoring is crucial as hot spots can occasionally develop.
6. **Quantity of Handled Seed:**
   - Approximately 575-725 pounds of seed must be handled for every bale of cotton ginned.
   - Effective aeration is highlighted as a critical factor in controlling temperature and moisture, contributing to higher values for seed tonnage and preventing losses.

In summary, the provided information emphasizes the significance of aeration in managing temperature and moisture levels during cottonseed storage. This maintains seed quality and prevents potential hot spots, mold growth, and insect activity.

LOCATION COTTONSEED BULK HOUSE

Cottonseed Bulk Storage House placement should be relative to the seed pipes of the Gin. Make sure your seed pipes from the Gin to the House are grounded. Cottonseed traveling through these pipes can develop high levels of static electricity, and grounding the pipes will help dissipate the static charge and any issues caused by storm lighting. The first house should be no closer than 40 feet from the Gin. Any additional distance is acceptable if you have the airflow to move the cottonseed. I recommend a clear space of no less than 45 to 50 feet for additional houses. Please bear in mind your placement of the house(s). need to maintain a 100 feet separation from your module yards and bale cotton warehouses as shown below:



FRONT IN LOADERS AND BELT OR DRAG CHAIN CONVEYORS/AGER LOADERS

The information outlines essential maintenance, safety, and operation guidelines for truck-loading equipment, mainly front-end or skid-loaders. Here is a summary of the key points:

1. **Pre-season Preparations:**
   - Truck loading equipment should undergo thorough cleaning before each season.
   - Scheduled maintenance must be performed on all equipment before the start of the season.
   - Operators should receive proper training in equipment operation and handling capacity.
2. **Electrical Safety Measures:**
   - Electrical panels inside buildings should be covered with weatherproof disconnects.
   - Wiring in rubber cords is prohibited unless the cord is encased in a Flexible Metal Conduit (FMC and LFMC) or Electrical Metal Conduit (EMT) for connections to conveyors, auger loaders, or other electrical machinery.
   - Secure these connections out of the way to avoid contact with loaders or other machinery.
   - Ensure the wiring is not exposed to trucks and equipment running over it.
3. **Documentation:**
   - Maintenance, safety, start-up, and shut-down procedures for front-end loading equipment should be documented and provided to operators.
4. **Fire Safety Measures:**
   - All loaders must be equipped with a fire extinguisher.
   - The fire extinguisher should be easily accessible from inside and outside the cab for quick response to loader fires.
5. **General Safety Recommendations:**
   - All operators should be well-trained in safely operating front-end loading equipment.
   - Operators should clearly understand handling capacities to prevent overloading.
   - Air compressed to blow lint off the loader's hot areas (Turbo Charger) during use.
   - Regular equipment maintenance is crucial for safe and efficient operation.
   - Electrical connections should be securely strapped out of the way to avoid hazards.
   - The use of proper conduits for electrical wiring is emphasized to enhance safety.

Implementing these guidelines will ensure the proper functioning, safety, and longevity of front-end loading equipment while minimizing the risk of accidents, fires, or electrical hazards.

COTTON SEED FIRE PROTOCOL

The information outlines important guidelines and precautions for fire prevention and response in cottonseed storage facilities. Here is a breakdown of the key points:

Common Causes of Fires:

1. Sparks from gin machinery, especially Gin Stands, are a primary cause of fires.
2. Installing spark inhibitors or arrest systems at the Gin can significantly reduce the risk of fire being blown into the cottonseed bulk house.
3. Other potential causes include operation and maintenance of front-end loader equipment, improper electrical wiring, or placement of loading equipment.
4. Frontend loader operations: no slamming or dragging the loader bucket on the floor.
5. **NO Open Flames: A general hot works protocol must be implemented.**

Flash Over Situations:

1. Flashovers can occur when excess lint buildup in the cottonseed bulk house catches fire and quickly spreads.
2. After a flashover, check for possible hot spots that may develop.

Detection and Response to Hot Spots:

1. Check outside walls for settled fire and use temperature monitoring systems or portable heat detection sensors to locate hot spots.
2. If a hot spot is found, use water sparingly to cool it.
3. Notify the insurance company immediately.

Specialist Assistance:

1. We will dispatch a cotton seed specialist to handle the situation, reducing the loss of quantity and quality.
2. Until specialists arrive, use the least water required to control the fire.

DO NOTs:

1. Do not spray the entire pile or let the fire department do so, as it may cause chemical reactions and deterioration of cotton seed quality.
2. Do not use chemical foams, as they can destroy any salvage opportunities.
3. Only allow employees to walk or crawl on the cotton seed pile with proper safety measures.

DOs:

1. Notify the insurance company immediately.
2. Have a plan and meet with the local fire department before the season.
3. Cut off the flow of seed from the gin.
4. Turn off aeration fans; do not use them to remove smoke.
5. Clean the Bulk Cotton Seed House at the end of the season to reduce flashover risk and damage.
6. Monitor seed temperatures daily during ginning and weekly after ginning when the cotton seed pile reaches the ideal temperature range.

REMEMBER YOUR COTTON SEED POLICY WARRANTIES

WARRANTIES:

A violation of these warranties wholly suspends coverage for cotton seed stored in building(s) where such violations have occurred.

a. You warrant that daily temperature “monitoring” will be recorded daily during the ginning season, and weekly temperature “monitoring” will be recorded after that (after ginning is complete).
b. You warrant that an aeration system designed explicitly for storing cotton seed will be used.

“Monitoring” means using a device that indicates an actual temperature in degrees. (Digital)

STOCK REPORTING:

Stock Reports are due 30 days after the end of the reporting month. If, at the time of "loss," you have failed to submit:

a. the first required report of value we will not pay more than 25% of the amount we would have otherwise paid; or
b. any required report of value after the first required report; we will not pay more than the amount indicated on your last report of value.

APPENDICES And REFERENCES

Front End Loader Pre-use Inspection Checklist

Operator:		**Make & Model:**	
Company:		**Hour Meter Reading:**	
Location:		**Date:** MM/DD/YYYY	**Unit No.:**

POWER OFF CHECKS	Status OK	NO	N/A	POWER ON CHECKS	Status OK	NO	N/A
1) Underneath machine:				11) Unit starts and runs properly	☐	☐	☐
a) Wheels & Tires	☐	☐	☐	12) Instruments/Gauges	☐	☐	☐
b) Axles	☐	☐	☐	13) Hour Meter	☐	☐	☐
2) Lights/Strobes	☐	☐	☐	14) Warning lights/audible alarms	☐	☐	☐
3) Mirrors/Visibility aids	☐	☐	☐	15) Fuel level	☐	☐	☐
4) Engine/Engine compartment:				16) Horn/audible warning device(s)	☐	☐	☐
a) Belts/Hoses	☐	☐	☐	17) Function controls:			
b) Cables/Wires	☐	☐	☐	a) Drive – forward/reverse	☐	☐	☐
c) Debris	☐	☐	☐	b) Steer – left/right	☐	☐	☐
5) Battery/Batteries:				c) Bucket/Attachment – All movements	☐	☐	☐
a) Terminals tight	☐	☐	☐	d) Accessories	☐	☐	☐
b) Clean/Dry/Secure	☐	☐	☐	18) Emergency/auxiliary controls	☐	☐	☐
6) Hydraulics:				19) Wipers	☐	☐	☐
a) Cylinders/Rods	☐	☐	☐	20) Seatbelt inspected & fastened	☐	☐	☐
b) Hoses/Lines/Fittings	☐	☐	☐	**GENERAL**	**OK**	**NO**	**N/A**
c) Pins/Locks	☐	☐	☐	21) Housekeeping	☐	☐	☐
7) Fluids:				22) Manufacturer's operating manuals	☐	☐	☐
a) Engine oil Level Leaks	☐	☐	☐	23) Decals/Warnings/Placards	☐	☐	☐
b) Engine coolant Level Leaks	☐	☐	☐	24) Misc. parts – loose/missing/broken	☐	☐	☐
c) Hydraulic oil Level Leaks	☐	☐	☐	**WORKPLACE INSPECTION**	**OK**	**NO**	**N/A**
d) Fuel/Battery Level Leaks	☐	☐	☐	25) Drop-offs or holes	☐	☐	☐
8) Chassis:				26) Bumps and floor/ground obstructions	☐	☐	☐
a) Cab/Glass/Doors	☐	☐	☐	27) Debris	☐	☐	☐
b) Emergency Exit	☐	☐	☐	28) Overhead obstructions	☐	☐	☐
c) Entry/exit steps	☐	☐	☐	29) Energized power lines	☐	☐	☐
d) ROPS/FOPS	☐	☐	☐	30) Hazardous locations	☐	☐	☐
e) Counterweight/Counterweight bolt(s)	☐	☐	☐	31) Ground surface and support conditions	☐	☐	☐
f) Fire Extinguisher/Suppression System	☐	☐	☐	32) Pedestrian/vehicle traffic	☐	☐	☐
g) Articulated frame lock present/functional	☐	☐	☐	33) Wind and weather conditions	☐	☐	☐
9) Digging Assembly:				34) Other possible hazards	☐	☐	☐
a) Bucket & cutting edge/work attachment	☐	☐	☐		☐	☐	☐
b) Loader arms & pins	☐	☐	☐		☐	☐	☐
10) Other:	☐	☐	☐		☐	☐	☐
	☐	☐	☐		☐	☐	☐

Report any problems found to your supervisor/employer. ALWAYS lock/tag-out unsafe equipment.

Comments

Operator's initials:

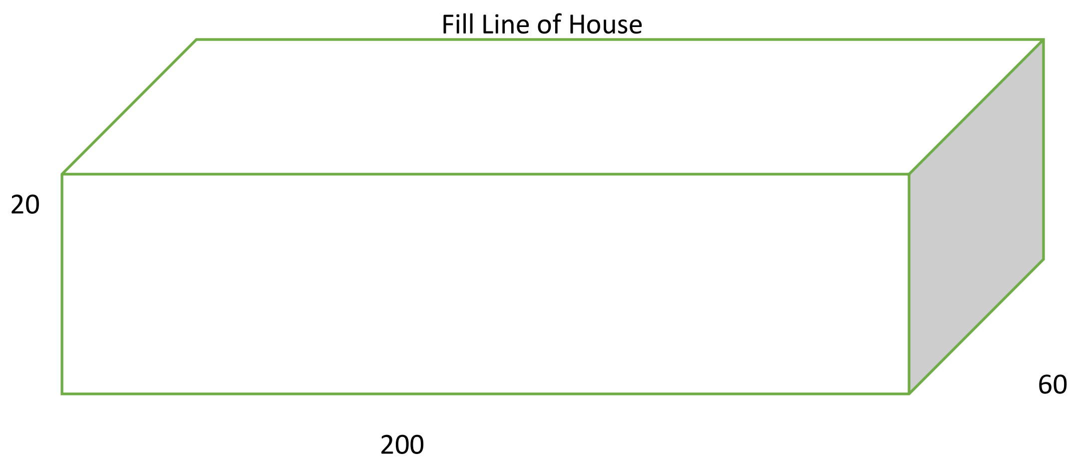
Alternative operator's initials:

WEIGHTS, MEASURES, AND CHARACTERISTICS OF COTTON SEED

Product	Bulk		Weight (lb/bu)	Specific Count (seed/lb)
	Density lb/ft^3)	Volume (ft^3/ton)		
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 De-linted	35	57	44	2,400-3,200
Acid De-linted	34-37	54	42-46	4,800-5,600
Meal (extracted)	38	53		
Hulls	12	167		
Oil	57	35		

Table 1. Basic properties of cotton seed and cotton seed products.

The bulk density of gin-run cotton seed averages about 25 lb/ft3 and requires about 80 ft3 of storage space per ton. Cotton seed 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 the best storage conditions. Whole, fuzzy cotton seed has unique characteristics that make it challenging to handle with common grain handling facilities. Unlike grain, cotton seed has a variable angle of repose. The angle of repose when an unrestricted pile of cotton seed 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°. Cotton seed may be handled by belts, screw conveyors, or pneumatics. Pneumatics is the most effective way to load seeds into storage facilities (Shaw & Franks, 1963). The basic handling and storage characteristics of whole cotton seed and cotton seed products are shown in **Table 1**.



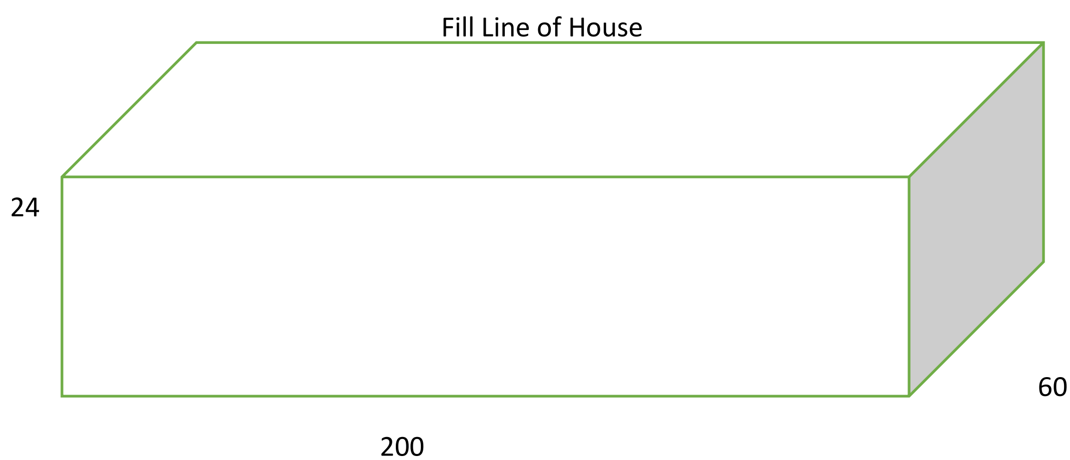
Capacity = in Density is 25lbs/ft3   2,000 lbs. in US Ton

60 * 200 * 20 = 240,000 ft3 * 25 = 6,000,000 / 2,000 = 3,000 US Tons

Capacity = in Volume is 80 US tons/ft3

60 * 200 * 20 = 240,000 ft3 / 80 = 3,000 US Tons

Example:



Capacity = in Density is 25lbs/ft3   2,000 lbs. in US Ton

60 * 200 * 24 = 288,000 ft3 * 25 = 7,200,000 / 2,000 = 3,600 US Tons

Capacity = in Volume is 80 US tons/ft3

60 * 200 * 20 = 288,000 ft3 / 80 = 3,600 US Tons

Fill Line on the House appears to be located here Front of House No Cotton Seed

Fill Line on the House appears to be located about the same the picture faces the Pile that had been partially loaded out

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ENGINEERING AND GINNING

Cotton Seed Air-Handling and Storage Requirements

Harrison Ashley, Joe Thomas, Greg Holt*, Thomas Valco

ABSTRACT

Along with lint, cotton seed is another product of the cotton plant that accounts for 15 to 25% of the crop value. Due to the nature of cotton seed, proper handling, storage, and aeration are critical for maintaining seed quality and minimizing spoilage. Over the last few decades, the mass of cotton seed per bale of lint (500 lbs. [227 kg]) has declined from a national average of 823 lbs. (373 kg) to an average value of 696 lbs. (316 kg). This chapter updates handling, storage, and aeration data based on the smaller mass of seed per bale encountered in today's cotton gins and provides the most current information.

The information presented in this chapter sources earlier cotton ginner handbooks (Smith and Rayburn, 1977; Wilcutt and Mayfield, 1994) and includes up-to-date information for cotton seed handling, aeration, and storage.

For every 500 lbs. (227-kg) bale of lint, approximately 700 lbs. (317.5 kg) of cotton seed are produced. The national average weight of cotton seed per bale of lint has been trending downward over the last few decades (Hughs and Holt, 2015). Typical products generated from cotton seed include linters, hulls, oil, and meal. The breakdown of each of these products, on a mass basis, can vary but generally runs at 10% linters, 25% hulls, 16% oil, 46% meal, and 3% miscellaneous foreign matter (Dowd, 2015). In the past, a greater portion of cotton seed was sent to the mills for crushing; however, today only 35% of the crop is crushed for the products listed above with the remaining 65% being fed to dairy cattle. Because cotton seed accounts for 15 to 25% of the value of the crop, it is important to properly handle, aerate, and store the seed to avoid spoilage. This chapter is divided into the following areas: characteristics of cotton seed, cotton seed storage, cotton seed aeration, and cotton seed conveyance. The idea is that storage needs to be available before the seed can be conveyed and aeration is needed to minimize seed spoilage.

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CHARACTERISTICS OF COTTON SEED

The bulk density of gin-run cotton seed averages approximately 25 lb/ft^3 (400.5 kg/m^3) and requires approximately 80 ft^3 of storage space per ton (2.5 m^3/mt). Cotton seed is hygroscopic and therefore absorbs moisture from or gives up moisture to the surrounding air. Storage temperatures below 60 °F (16 °C) and 10% moisture content wet basis provide best storage conditions. The whole, fuzzy cotton seed has unique characteristics that make it difficult to handle with common grain handling facilities. Unlike grain, cotton seed has a variable angle of repose. The angle of repose is the steepest angle at which a sloping surface of loose material is stable. The angle of repose when an unrestricted pile of cotton seed 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°. Cotton seed can be handled by belts, screw conveyors, or pneumatics. Pneumatics is often the most effective way to load seed into storage facilities.

COTTON SEED STORAGE

Long-term Storage. The type of seed storage facility will dictate how seed will be handled for long-term storage. In more arid production areas, cotton seed can be safely stored in open piles or piles that are covered without any aeration. However, in more humid areas, some aeration is needed to remove heat from the ginning process and any excess moisture present in the seed, minimizing storage losses and quality deterioration. Seed is usually highest in moisture at the beginning of the harvest season and can be as high as 18%. As the season progresses, seed moisture content typically ranges from 10 to 15% but can be as low as 6%. With proper aeration, cotton seed having moisture content below 19% can be successfully stored. In situations where seed moisture is high, as in rain-soaked cotton, seed should be stored separate from dry seed. Most ginners send their high moisture seed to the oil mill for immediate processing and/or into separated storage with high aeration capacity.

Building Design and Considerations. Three types of buildings are commonly used to store cotton seed at gins: clear-span metal buildings, Quonset huts, and Muskogee buildings. The metal building (or flat storage building) is the most popular for new construction. Some flat storage buildings exceed 100 ft (30.5 m) in width, but 60 to 80 ft (18.3-24.4 m) widths are more common. Quonset huts rely on formed panels for structural integrity and have no steel framework to support the outside skin. When constructed as a true Quonset hut, the floor space is not efficiently used. Four to eight-foot sidewalls of adequate strength are sometimes used to increase the storage volume and minimize wall damage from loading equipment. Muskogee houses generally have roof slopes of 45° and a high ridge line to maximize storage volume while minimizing the force, or pressure of seed "flowing" against the walls. The roof slope and height also require a greater steel superstructure. Muskogee houses are normally used for volumes greater than 6,000 tons (5,443 mt). Seed depths of 40 to 80 ft (12.2-24.4 m) and lower air flow rates are found in most Muskogee houses.

Most cotton seed storage facilities have moisture proof concrete or asphalt floors. Floor loads from seed alone will be approximately 700 lb/ft^2 (3417kg/ m^2) for a 20 ft (6 m) seed depth. Floors should have sufficient reinforcement to support a loaded truck in areas where loading will take place.

Several side and end wall failures have occurred in cotton seed storage facilities using rectangular storage buildings. Walls of existing buildings con- verted to cotton seed storage should be analyzed and strengthened as needed before filling with seed. Lining the interior walls with plywood (at least 0.75- in [19-mm] thick), oriented strand board (OSB) or similar materials helps prevent damage to the outside building walls, facilitates clean out, increases wall strength, and reduces settling pressure on otherwise exposed framework. The top of this inside wall should be sealed to prevent seed and lint from accumulating between the walls.

Buildings used to store cotton seed must be designed to withstand lateral forces. Lateral wall forces for storage of cotton seed can be estimated by the following formula (Willcutt and Mayfield, 1994):

$$WP = KA \times D \times H$$

Where: WP = horizontal wall pressure lb/ft^2 (kg /m^2), KA = active pressure coefficient (0.17 to 0.20 when an angle of repose of 45° is used), D = density = mass/volume = 28 lb/ft3 (448.5 kg/m3), and H = height or seed depth ft (m). When the preceding formula is used, the lateral pressure at the base of a 20-ft (6.1-m) seed depth would be 112 lbs./ft^2 (546.8 kg/ m^2). Because of boundary effects of the floor, maximum force and wall failure usually occur at 10% to 20% of wall height above the floor (Willcutt et al., 1996). Walls should be designed to include a safety factor and to accommodate front-end loader pressure against them. When existing buildings are converted for cotton seed storage, the walls should be analyzed and strengthened as needed before filling with seed.

Calculation of Storage Capacity. The capacity of a seed storage house can be calculated by determining the useable storage volume and seed density. Because seed density varies by seed depth, an average value can be used based on the cotton seed properties in Table 1. For example: the capacity of a storage building that is 120 ft by 60 ft (36.6 m by 18.3 m) with a wall height of 18 ft (5.5 m) and a 10 ft (3.1 m) gable height can be determined by calculating the floor and gable volumes.

1. Floor Volume = L x W x H = 120 ft x 60 ft x 18 ft = 129,600 ft^3. (36.6 m x 18.3 m x 5.5 m= 3,669 m^3).
2. Gable Volume = L x W x H/2 = 120 ft x 60 ft x 10 ft/2 = 36,000 ft^3 (36.6 m x 18.3 m x 3.1 m = 1,019 m^3).
3. Total = 129,600 + 36,000 = 165,600 ft^3 (3,669 + 1,019 = 4,688 m^3). Because the house cannot be completely full, the usable volume is approximately 160,000 ft^3. (4,531 m^3).

4. Total seed volume would be approximately 2,000 tons (1,814 mt) =160,000 ft^3 ÷ 80 ft^3/ton (recommended aeration value from the Characteristics of the Cotton seed section above). (4,531 m^3÷ 2.5 m^3/ mt).

This example can be used for different house dimensions and designs. (Note: differences in metric and English unit calculations are due to rounding errors.)

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Table 1. Basic properties of bulk cotton seed and cotton seed products

Product	Density (lb/ft^3)	Density (kg/m^3)	Volume (ft^3/ton)	Volume (m^3/mt)
Whole seed				
Loose on Conveyor	20	320	100	3.12
< 24 ft (7.3 m) deep	25	400	80	2.50
24-50 ft (7.3-15.2 m) deep	27	432	75	2.34
> 50 ft (15.2 m) (((1 5 . 2 m) deep	30	481	70	2.18
Machine delinted	35	561	57	1.78
Acid delinted	34-37	545-593	54	1.69
Meal (extracted)	38	609	53	1.65
Hulls	12	192	67	2.09
Oil	57	913	35	1.09

COTTON SEED AERATION

Aeration Considerations and Design. In humid areas, long-term cotton seed storage facilities must be equipped with an aeration system. Most aeration systems are designed so that the air flows downward through the cotton seed to prevent tunneling and to help minimize moisture accumulation in the top layers of seed (Smith, 1975). If the airflow is not downward, the top layer will become moist when warm, moist air moves upward into the cooler top layers of seed. Downward airflow also counteracts any natural convectional air movement. The temperature and odor of the exhaust air from the fan can give an indication of cotton seed condition.

A safe airflow rate for aerating cotton seed in storage is 10 ft^3/min/ton (0.312 m^3/min/ mt). At this rate, cotton seed with as much as 15% moisture can be safely stored. Drier seed and well managed storage facilities do not require such a high airflow rate, requiring 3 to 5 ft^3/min/ton (0.08 to 0.14 m^3/min/mt).

For storage buildings, static pressure losses and fan horsepower requirements from cotton seed depths ranging from 10 to 30 ft (3.1-9.1 m) are given in Table 2 for airflow rates of 5, 7.5, and 10 ft^3/min/ton (0.15, 0.23, and 0.31 m^3/min/mt). For large Muskogee houses (Smith and Rayburn, 1977), cotton seed depth usually limits the amount of air that can be economically moved. For example (Fig. 1), when cotton seed is 80-ft (24.4-m) deep and the airflow rate is 2 ft^3/min/ton (0.062 m^3/min/mt), the static pressure is 21 in (507 mm) of water.

Usually, no additional aeration is necessary once the seed has cooled to the desired temperature. The safe temperature for long term storage is about 60 °F (15.5°C). Even so, seed temperatures should be monitored throughout the storage period, because hot spots occasionally develop. Usually, a few hours of additional aeration will remove the heat from the trouble spot. Many seed storage facilities are equipped with temperature monitoring systems. Seed temperature should be monitored by inserting thermocouple probes attached to steel rods or electrical conduit into the seed.

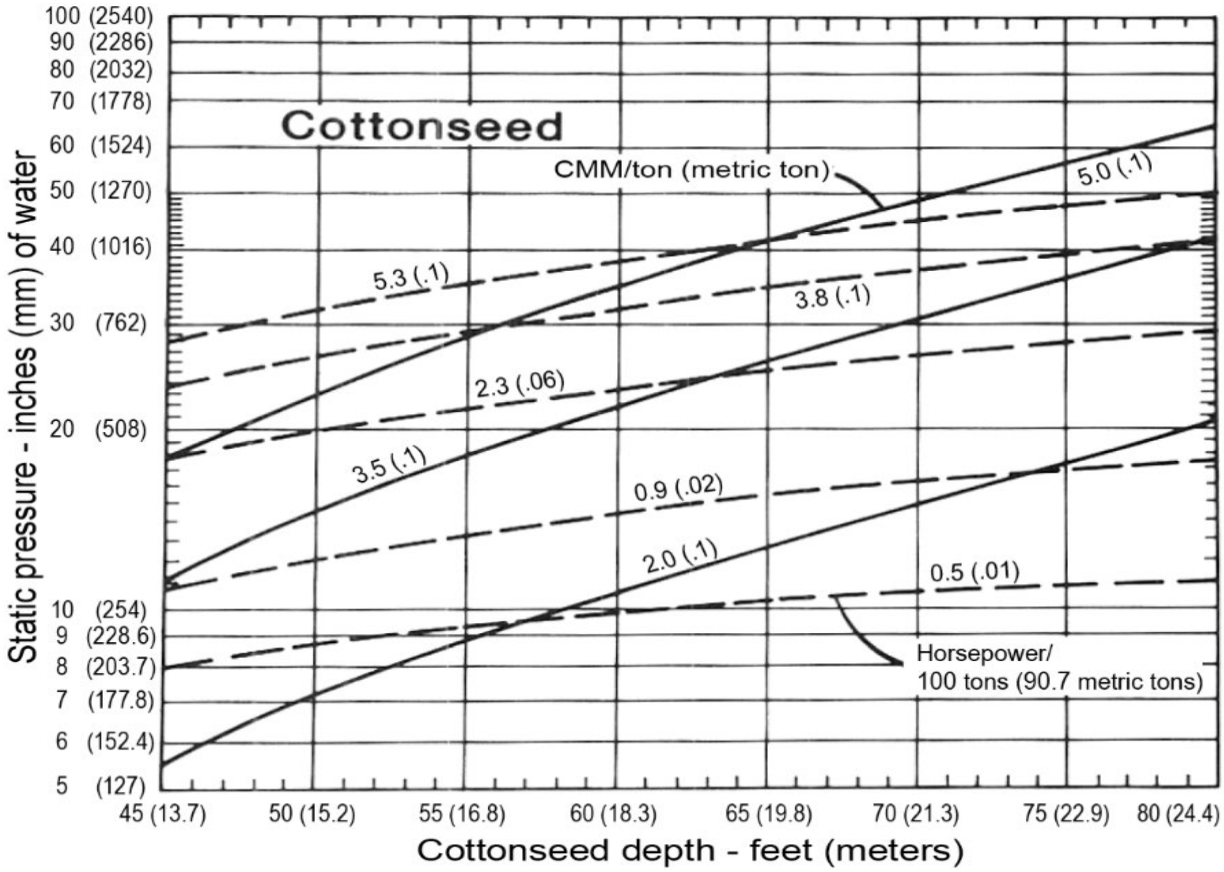

Figure 1. Fan horsepower and static pressure requirements for aerating cotton seed in Muskogee type storage buildings in cubic meters per minute per metric ton (cmm/ton).

Design of Aeration Systems. Aeration systems have four principal parts that must be properly designed: (1) aeration ducts to move air out of the cotton seed, (2) supply pipes to transport the air, (3) fans to supply the required volume of air at a specific static pressure, and (4) motors to drive the fans.

Depth of cottonseed (ft)	Static Airflow rate pressure (ft^3/min/ton) losses (inches		Horsepower required. (per 100 tons)	Depth of cottonseed (m)	Static Airflow rate pressure (m^3/min/mt) losses (mm		Kilowatts required (per 100 mt)
		H_2O)				H_2O)	
10	5	1	0.1	3.04	0.16	25.39	0.08
	7.5	1.1	0.2		0.23	27.93	0.16
	10	1.6	0.4		0.31	40.62	0.33
12	5	1	0.1	3.65	0.16	25.39	0.08
	7.5	1.6	0.35		0.23	40.62	0.29
	10	2.3	0.65		0.31	58.40	0.53
14	5	1.3	0.16	4.26	0.16	33.01	0.13
	7.5	2.1	0.6		0.23	53.32	0.49
	10	3.1	1.2		0.31	78.71	0.99
16	5	1.7	0.22	4.87	0.16	43.16	0.18
	7.5	2.8	0.6		0.23	71.09	0.49
	10	4	1.2		0.31	101.56	0.99
18	5	2.2	0.29	5.48	0.16	55.86	0.24
	7.5	3.5	0.75		0.23	88.87	0.62
	10	5	1.5		0.31	126.95	1.23
20	5	2.7	0.37	6.08	0.16	68.55	0.30
	7.5	4.5	0.9		0.23	114.26	0.74
	10	6.3	1.7		0.31	159.96	1.40
22	5	3.3	0.46	6.69	0.16	83.79	0.38
	7.5	5.3	1.1		0.23	134.57	0.90
	10	7.7	1.9		0.31	195.50	1.56
24	5	4.1	0.55	7.30	0.16	104.10	0.45
	7.5	6.4	1.4		0.23	162.50	1.15
	10	9.5	2.5		0.31	241.21	2.05
26	5	4.7	0.66	7.90	0.16	119.33	0.54
	7.5	7.6	1.6		0.23	192.96	1.32
	10	11.4	2.9		0.31	289.45	2.38
28	5	5.5	0.78	7.90	0.16	139.65	0.64
	7.5	9.9	1.7		0.23	251.36	1.40
	10	13.5	3.4		0.31	342.77	2.79
30	5	6.3	0.9	9.12	0.16	159.96	0.74
	7.5	10.1	2		0.23	256.44	1.64
	10	15.5	3.9		0.31	393.55	3.21

Table 2. Resistance of cotton seed to airflow, measured as static pressure loss, in a storage building.

Aeration Ducts. Two important design criteria for a cotton seed aeration duct are (1) to provide adequate duct surface area to produce even airflow down through the cotton seed piles and (2) to provide adequate cross-sectional area so that all the stored seed can be properly aerated. Aeration ducts can be any shape, but their open surface area or air inlets should be at least 10% of the total duct surface area. Basically, take the total surface area of the ductwork and 10% should be inlets to allow sufficient airflow through the ductwork for proper aeration. Within a duct, pressure losses can be held to a minimum by limiting the velocity of the air leaving the cotton seed through the duct (face velocity) to 10 ft/min (3.1 m/min).

For cotton seed depths up to 25 ft (7.6 m), the air velocity within a duct should range from 1,500 to 2,000 ft/min (457-610 m/min). For duct lengths less than 10 ft (3.1 m), velocities up to 2,500 ft/min (762 m/min) are acceptable. Ducts on the floor of a seed house should be spaced to keep the airflow path to all ducts as equal as possible. Thus, duct spacing should not exceed 1.5 times the depth of the cotton seed.

Ducts can be installed along the length or width of a storage facility. Ducts across the width are preferred because they provide better airflow distribution and allow aeration to start as soon as the first duct is covered with seed. Also, widthwise ducts allow the airflow to be concentrated in selected.
areas to remove hot spots that sometimes develop. Many new seed house designs have aeration ducts constructed flush with the floor to allow for easy equipment movement and unloading.

Supply Pipes. Pipes should be designed to transport air from the ducts to the fan at air velocities ranging from 3,000 to 4000 ft/min (914-1,219 m/min). Pipe size can be determined from Table 3 or by the following equations: area (ft^2 or m^2) = air volume (cubic feet/meter per min) / velocity (feet/ meter per min). After calculating area, diameter (in/ mm) = $[(\text{area} \times 4) \div 3.14159]^{0.5}$

Fans and Motors. Before a fan and mo- tor are selected, the static pressure and the required volume of air to aerate the number of tons of seed must be known. Static pressure depends on the depth of seed (Table 2 and Fig. 1). Once the volume and static pressure are known, a fan and motor can be selected from manufacturers' catalogs. In some seed houses, individual fans are utilized for each aeration duct, eliminating the need for manifold pipes. This simplifies the design and operation of the aeration system.

Table 3. Air-carrying capacities, ft^3/min (m^3/min), for round supply pipes and manifolds

Pipe dia (in)	Cross-sectional area (ft^2)	1500 ft/min	2000 ft/min	3000 ft/min	Pipe dia (mm)	Cross-sectional area (m^2)	457 m/min	610 m/min	914 m/min
6	0.20	295	393	589	152.4	0.018	8.3	11.1	16.7
7	0.27	401	535	802	177.8	0.025	11.4	15.1	22.7
8	0.35	524	698	1047	203.2	0.032	14.8	19.8	29.7
9	0.44	663	884	1325	228.6	0.041	18.8	25.0	37.5
10	0.55	818	1091	1636	254	0.051	23.2	30.9	46.3
11	0.66	990	1320	1980	279.4	0.061	28.0	37.4	56.1
12	0.79	1178	1571	2356	304.8	0.073	33.4	44.5	66.7
13	0.92	1383	1844	2765	330.2	0.086	39.2	52.2	78.3
14	1.07	1604	2138	3207	355.6	0.099	45.4	60.5	90.8
15	1.23	1841	2454	3682	381	0.114	52.1	69.5	104.2
16	1.40	2094	2793	4189	406.4	0.130	59.3	79.1	118.6
17	1.58	2364	3152	4729	431.8	0.146	67.0	89.3	133.9
18	1.77	2651	3534	5301	457.2	0.164	75.1	100.1	150.1
19	1.97	2953	3938	5907	482.6	0.183	83.6	111.5	167.3
20	2.18	3272	4363	6545	508	0.203	92.7	123.6	185.3
21	2.41	3608	4811	7216	533.4	0.223	102.2	136.2	204.3
22	2.64	3960	5280	7919	558.8	0.245	112.1	149.5	224.3
23	2.89	4328	5770	8656	584.2	0.268	122.6	163.4	245.1
24	3.14	4712	6283	9425	609.6	0.292	133.4	177.9	266.9
25	3.41	5113	6818	10227	635	0.317	144.8	193.1	289.6
26	3.69	5531	7374	11061	660.4	0.343	156.6	208.8	313.2
27	3.98	5964	7952	11928	685.8	0.369	168.9	225.2	337.8
28	4.28	6414	8552	12828	711.2	0.397	181.6	242.2	363.3
29	4.59	6880	9174	13761	736.6	0.426	194.8	259.8	389.7
30	4.91	7363	9817	14726	762	0.456	208.5	278.0	417.0
31	5.24	7862	10483	15724	787.4	0.487	222.6	296.8	445.3
32	5.59	8378	11170	16755	812.8	0.519	237.2	316.3	474.5
33	5.94	8909	11879	17819	838.2	0.552	252.3	336.4	504.6
34	6.30	9457	12610	18915	863.6	0.586	267.8	357.1	535.6
35	6.68	10022	13363	20044	889	0.621	283.8	378.4	567.6
36	7.07	10603	14137	21206	914.4	0.657	300.2	400.3	600.5

Aeration Examples. The following are examples of two typical cotton seed aeration systems.

Example 1. A ginner wishes to store 1,200 tons (1,089 mt) of cotton seed on the gin yard. A small pipe seed handling system will be used to put the cotton seed into storage, and the seed will be unloaded with a front-end loader. The design of the aeration system given the building dimensions and calculation of seed storage should be as follows:

1. Building Details
   a. Dimensions of storage structure: 60 ft (18.3 m) wide, 100 ft (30.5 m) long, 16 ft (4.9) wall height, and a gable height of 18 ft (5.5 m) to accommodate the front-end loader.
   b. Building length: 120 ft (36.6 m), enough to provide access for unloading without requiring a bulkhead door, but this additional length will not be part of the aeration system.
2. Calculation of Seed Storage
   a. Assuming the cotton seed will be stored to the full wall height then cotton seed depth = 16 ft (4.9m). Using the building dimensions in 1a above, the volume storage potential is: 60 x 100 x 16 = 96,000 ft^3. Dividing the storage volume by the recommended aeration from the Cotton seed Characteristics section, 80 ft^3/ton = 1,200 tons of seed storage (18.3 x 30.5 x 4.9 = 2734.9 m^3 ÷ 2.5 m^3/mt = 1,089 mt). (Note: differences in metric and English unit calculations are due to rounding errors.)
3. Aeration System
   a. System capacity: 1,200 tons (1,089 mt) of cotton seed.
   b. Airflow rate (from Aeration Considerations and Design section– safe airflow rate): 10 ft^3/min/ton (0.312 m^3/min/mt).
   c. Total air volume needed: 1,200 tons at 10 ft^3/min/ton = 12,000 ft^3/min (1,089 mt at 0.312 m^3/min/mt = 339.8 m^3/min).
   d. Duct layout as shown in Fig. 2 with five ducts spaced 20 ft (6.1 m) apart, 50 ft (15.2 m) long (maximum duct spacing: 1.5 x 16 ft (4.8 m) = 24 ft [7.2 m]).
   e. Duct size: each duct carries 1/5 of the total volume of air needed or 2,400 ft^3/min (67.9 m^3/min). For a maximum air velocity of 2,000 ft/min (610 m/min), the duct cross-sectional area should be 1.2 ft^2 (0.1 m^2). This could be attained by using a 15-in (38-cm) round duct (Table 3). To make sure the duct open surface area does not exceed a face velocity greater than 10 ft/ min (3.1 m/min), take Pitot tube measurements and calculate air volume to ensure the safe airflow rate is not exceeded.
   f. Supply pipes: 18 in (45.7cm). Each duct carries 1/5 of the total volume of air or 2,400 ft^3/min/duct (67.9 m^3/min/duct). From Table 3 we can see that an 18-in (45.7-cm) diameter supply pipe will carry up to 2,651 ft^3/min (75 m^3/min), which is close enough for this example, at a velocity of 1,500 ft/min (457 m/min).
   g. Manifold pipes: 20 in (50.8 cm). The manifold pipe carries air for two supply pipes or 4,800 ft^3/min (136 m^3/min). From Table 3, we can see that a 21-in (53.3-cm) diameter supply pipe will carry up to 4,811 ft^3/min (136.2 m^3/min) at 2,000 ft/min (610 m/min).
   h. Fan and motor: Using Table 2 for a cotton- seed depth of 16 ft (4.8 m) and an airflow rate of 10 ft^3/min/ton (0.31 m^3/min/mt), the static pressure to be overcome by the fan is 4.0 in of water (101.6 mm of water) and a 1.2 hp/100 tons (1.2 hp x 1,200 tons of cotton seed ÷ by 100 tons) equals 14.4 hp, rounding up, a 15 hp (11.2 kW) fan motor would be the best selection.

Note: This system is designed to handle additional air volumes so slide valves can be used to force more or less air into different ducts. For instance, when high moisture seed is stored in a certain area, additional air can be directed to that duct to prevent overheating.

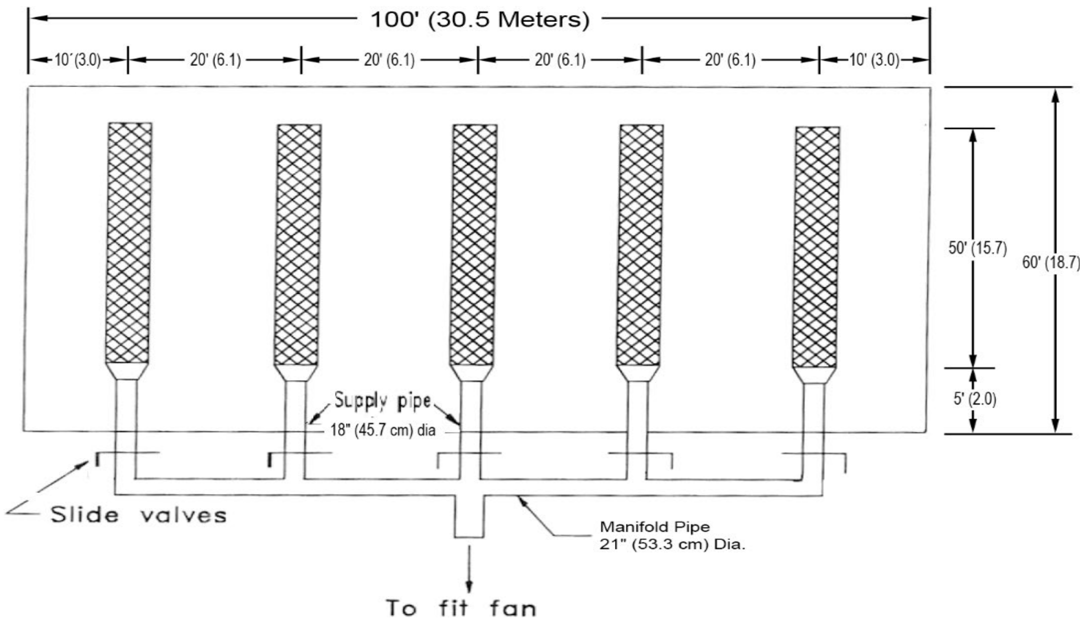

Figure 2. Aeration duct layout for 1,200-ton (1,089 mt) cotton seed storage building.

Example 2. A ginner wishes to store 2,000 tons (2,032 mt) of cotton seed on the yard. Seed will be loaded into the storage house with a small pipe handling system and will be unloaded with a front-end loader. The design of the aeration system given the building dimensions and calculation of seed storage should be as follows.

1. Building details
   a. Dimensions of storage structure: 60 ft (18.3 m) wide, 160 ft (49 m) long; wall height of 18 ft (5.5 m).
   b. Building length: 160 ft (49 m) with a bulkhead door that can be removed when unloading.
2. Calculation of seed storage
   a. Average cotton seed depth: 17 ft (5.2 m). Using the building dimensions in 1a above but substituting the average depth of cotton seed stored, the volume of cotton seed storage needing aeration is: 60 x 160 x 17 = 163,200 ft^3 (4,621 m^3). Dividing the storage volume by the recommended aeration of 80 ft^3/ton (2.5 m^3/mt) = 2,040 tons (1,851 mt) of seed stored. (Note: differences in metric and English unit calculations are due to rounding errors.)
3. Aeration system
   a. System capacity: 2,040 tons (1,851 mt) of cotton seed.
   b. Airflow rate: 5 ft^3/min/ton (0.16 m^3/min/ mt).
   c. Total air volume required: 2,040 tons at 5 ft^3/min/ton = 10,200 ft^3/min (1,851 mt at 0.16 m^3/min/mt = 296 m^3/min).
   d. Duct layout: Shown in Fig. 3.

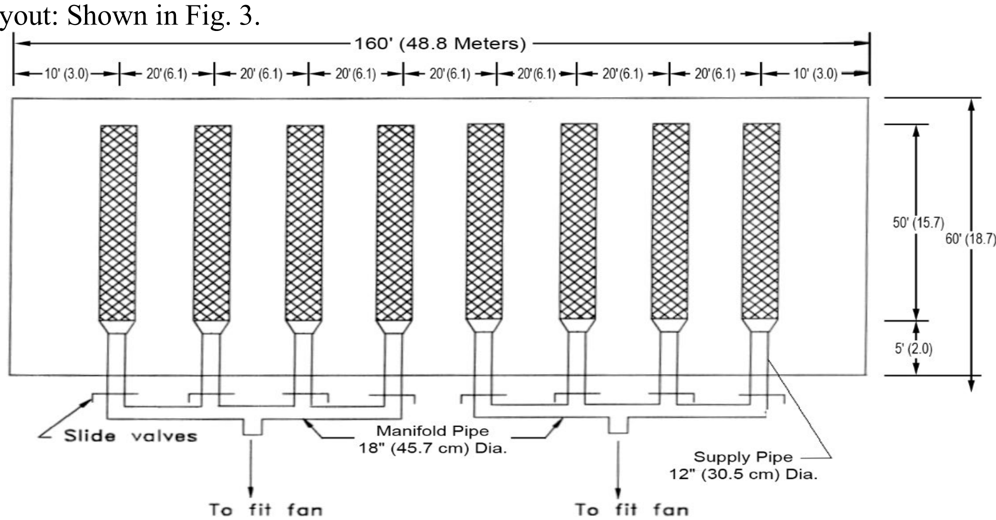

Figure 3. Aeration duct layout for 2,000 ton (1,814 mt) cotton seed storage building.

e. Duct size: Because there are eight aeration ducts, each duct carries 1/8 of the total air volume, 1/8 of 10,200 ft^3/min = 1,275 ft^3/min (1/8 of 296 m^3/min = 37 m^3/min). For a desired maximum air velocity of 1,500 ft/min (457 m/min), the duct cross-sectional area should be 0.85ft^2 (0.08 m^2), obtained by dividing 1,275 ft^3/min by the desired maximum air velocity of 1,500 ft/min (37 m^3/min divided by 457 m/min = 0.08 m^2). Referencing Table 3 under the 1,500 ft/ min (457 m/min) column, the desired conveyance could be attained by using either a 12- or 13-in (305- or 330-mm) round duct. To make sure the duct open surface area does not exceed a face velocity greater than 10 ft/min (3.1 m/ min), take Pitot tube measurements and calculate air volume to ensure the safe airflow rate is not exceeded.

f. Supply pipes: Based on the calculations above, the duct size should be either a 12- or 13-in (305- or 330-mm) diameter pipe. From Table 3, for a velocity of 1,500 ft/min (457 m/min), if a 12-in (305-mm) pipe is used, the volume in each supply line will be 1,178 ft^3/min. If a 13-in (330-mm) pipe is used, the volume in each supply line will be 1,383 ft^3/min. Both are within a reasonable range of 1,275 ft^3/min (37 m^3/min).

g. Manifold pipes: From Fig. 3, 18 in (457 mm). Given the total required air volume of 10,200 ft^3/min (296 m^3/min), each of the four manifold pipes must handle 2,500 ft^3/min (70.8 m^3/min). Table 3 shows that a 15-in (381-mm) pipe can handle a volume of 2,454 ft^3/min (69.5 m^3/min) at a velocity of 2,000 ft/min (610 m/min) and that a 16-in (406.4-mm) pipe can handle a volume of 2,793 ft^3/min (79.2 m^3/min) at the same velocity. Either pipe size would work.

h. Fans and motors: At a cotton seed depth of 17 ft (5.2 m) and an airflow rate of 5 ft^3/min/ton (0.2 m^3/min/mt), using Table 2 and interpolating between 16 and 18 ft (4.9 and 5.5 m) depths, the static pressure to be overcome is 2 in of water (50.8 mm of water). From a manufacturers catalog, select two centrifugal fans that can each deliver at least 5,100 ft^3/min (144.4 m^3/ min) at 2 in (50.8 mm) of static pressure.

Note: This system is designed at a lower air volume, however, slide valves can be used to force more or less air into different ducts for increased aeration.

Managing Aeration Systems. Aeration systems are designed to cool the cotton seed and prevent hot spots and moisture buildup from occurring. Aeration to remove heat created by the ginning process usually should be started as soon as the first lots of cotton seed are in storage. Even though little cooling can occur during storage, experience has shown that seed quality can be maintained if the fans continuously run until the facility is filled to capacity. If the seed house has a manifold aeration system, air volumes in areas of high temperature and moisture should be increased.

NOTE: If cotton seed is to be shipped immediately from the gin, the heat from the ginning process should be allowed to dissipate before loading. Condensation and resulting degradation of the cotton seed might occur if blown directly into containers or van trailers before it has a chance to cool. The use of an overhead storage system is an effective method to allow ginning heat to dissipate.

Being hygroscopic, cotton seed will absorb moisture from or give up moisture to its surrounding air. After the cotton seed has been cooled from the heat generated in the ginning process and because of the hygroscopic nature of cotton seed, aeration fans should not be operated during high humidity periods or during rain or fog. Ideally, cotton seed in storage should be cooled to 50 to 60 °F (10 to 15.5 °C) 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 because hot spots occasionally can develop. If the seed storage is not equipped with a temperature monitoring systems, as many of them are, temperature monitoring can be accomplished by placing a thermometer in the exhausting aeration airflow and/or by inserting thermocouple probes into the seed pile.

COTTON SEED CONVEYANCE

Air-Handling Systems for Cotton seed. The high-pressure, lobed-blower seed handling systems commonly used in gins handle cotton seed effectively, are economical to operate, and are relatively trouble free. They have adequate capacity for moving seed as fast as the cotton is ginned. They may also be used for carrying seed to and from storage facilities on the gin yard (Smith 1975). Systems having a pressure of 1 to 6 psi (6.9-41.4 kpa) can convey cotton seed up to 1,500 ft (457 m) of piping. Because no two systems are alike in length and in the number of risers and elbows, the limitations of pressure and volume must be considered carefully in the design of any particular system.

A typical rotary dropper system is shown in Fig. 4. A screw conveyor is used to feed the drop- per (vacuum lock) that introduces the seed into the positive pressure air pipe. A valve (Fig. 4F) enables the seed to be diverted to a truck, bin, or to long-term storage. Fig. 5 shows a typical seed plug system with a positive pressure air pipe. The main difference between a rotary dropper system (Fig. 4) and a seed plug system (Fig. 5) is the mechanism used to feed the cotton seed into the airline and prevent air leakage into the feeding auger. The dropper system uses a rotary vacuum (Fig. 4C) to prevent air leakage while feeding seed into a positive pressure system, whereas the seed plug (Fig. 5C) uses an auger full of cotton seed to prevent air leakage. The rotary vacuum lock depends on the rotary valve alone, whereas the seed plug depends primarily on an auger loaded with cotton seed to act as the air seal for the feeding system.H

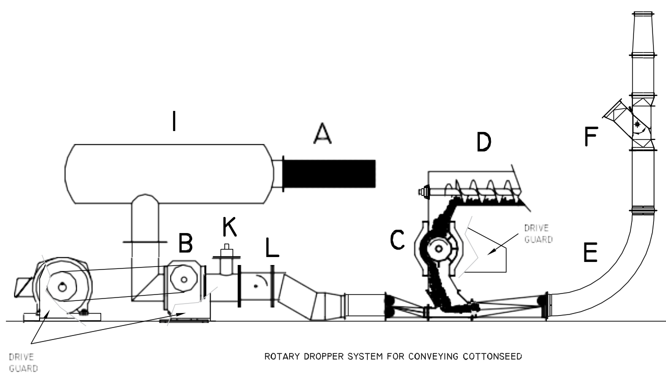

Figure 4. Rotary dropper system for conveying cotton seed. *A*, Steel mesh air filter, or screen box; *B*, Rotary positive- pressure blower; *C*, Rotary dropper, or vacuum-wheel feeder, with eight or more shallow pockets; *D*, Gin stand steel screw conveyor 9- to 24-in (22.9-61 cm) diameter depending on plant capacity; *E*, Long-sweep large-radius elbow; *F*, Valve for diverting seed to bin or storage; *G*, Pipe flange and gasket; *H*, Discharge connection (shown as reducer to accelerate seed when loading vans or box cars. Can be inverted for wider coverage); *I*, Inlet silencer or muffler; *K*, Blower discharge pressure relief valve, typically 4 to 6 psi (27.6-41.4 kpa); *L*, Optional swing-type check valve to prevent material from back-flowing into blower when there is an up-stream blockage.

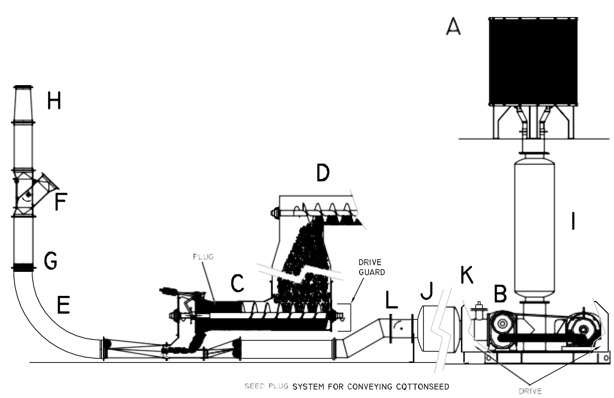

Figure 5. Seed plug system for conveying cotton seed. *A*, Steel mesh air filter, or screen box; *B*, Rotary positive-pressure blower; *C*, Screw type seed plug, 12 and 14-in (30.5- and 35.6-cm) diameter screw depending on plant capacity; *D*, Gin stand steel screw conveyor, 9 to 24-in (22.9-61-cm) diameter depending on plant capacity; *E*, Long-sweep large-radius elbow; *F*, Valve for diverting seed to bin or storage; *G*, Pipe flange and gasket; *H*, Discharge connection (shown as reducer to accelerate seed when loading vans or box cars. Can be inverted for wider coverage); *I*, Inlet silencer or muffler; *J*, Outlet silencer or muffler, typical with larger blower systems; *K*, Blower discharge pressure relief valve, typically 4 to 6 psi (27.6-41.4 kpa); *L*, Optional swing-type check valve to prevent material from back- flowing into blower when there is an up-stream blockage.

Blowers. The positive pressure in a cotton seed conveying system is generated by a two-lobe rotary air pump (Figs. 4B and 5B) known as a positive-pressure blower (Fig. 6) that commonly is used in small- pipe systems operating with an air-pressure range of 1 to 5 lb/in^2 (6.9-34.5 kpa) These blowers can overcome minor chokages by a temporary increase in air pressure. Relief valves are a recommended complement to the pressure blower because they are sized and set for additional pressure to overcome minor chokages yet limit the maximum pressure to protect the electric motor. Air-pressure requirements, suggested equipment, operating parameters, and performance data for rotary blowers to convey seed are shown in Table 4. A screened intake or air filter is imperative on cotton seed-handling blowers to protect the lobes and casing from excessive wear. In some instances, inline swing check valves have been installed immediately after the blower or discharge silencer. Should the blower motor stall due to system chokage, the check valve will stop any cotton seed from backing up into the blower as cotton seed at- tempts to reverse direction due to captured system pressure. Typical rotary blower-lobe clearances are less than 0.020 in (0.51 mm). Any intrusion by mate- rial can have catastrophic effects.

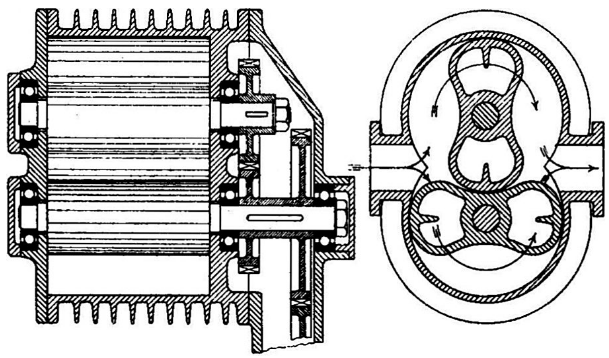

Figure 6. Cross section of a typical positive pressure two-lobe rotary air pump used for conveying cotton seed. Rotation can be reversed if desired.

Piping. Flanged pipes with gaskets at the joints are normally used to transport cotton seed. Table 5 gives the seed-handling capacity of various-sized pipes. Most pipes are made of carbon steel or aluminum, but galvanized pipe or galvanized tubing can be used in areas exposed to the weather. PVC piping causes static electricity problems and should not be used. On the blower intake and discharge, silencers are used to muffle the sound of the blower, which can be in excess of 80 dB. Pressure drop through each silencer is in the range of 0.25 psi (1.73 kpa), which is an acceptable loss for the noise reduction obtained by using the silencer. The air resistance, due to friction that the pump must overcome, can be estimated by referring to Table 6. Each short elbow and valve should be considered equivalent to approximately 12 pipe diameters of straight pipe. Material losses are a function of the material-to-air ratio, type of material to be conveyed, conveying velocity, and distance to be conveyed. It is not unusual for material losses to account for 20% of the total seed system air loss. Losses due to acceleration and vertical lift can account for an additional 5%.

When conveying cotton seed, air velocities for short runs, 100 ft (30.5 m) or less, of seed pipe should be in the 4,200 to 5,200 ft/min (1,280-1,585 m/min) range with 5,000 ft/min (1,524 m/min) the common target. Additionally, screw or belt conveying could be used as an alternative to convey cotton seed for short runs. For long runs of pipe, more than 100 ft (30.5 m) that are straight (i.e., they have few turns that could cause seed damage), velocities can reach 6,000 ft/min (1,828 m/ min). Velocities higher than 6,000 ft/min (1,828 m/min) should be avoided as seed damage can occur due to the seed impacting elbows and transitions in the ductwork. Air volumes from 3 to 5 ft^3 per lb (0.19-0.31 m^3 per kg) of cotton seed are desirable in seed handling systems. No seed should pass through the blower.

Risers in lines should be inclined, not vertical. The angled pipe will prevent 90° bends, allowing larger angles at elbows and saving piping length. Downward pipe slopes should be avoided because they cause chokages.

Seed-handling elbows should be 18 gauge (1.2 mm) or heavier and must be the long-sweep type to give satisfactory service without chokage. An 18-in (45.7-cm) minimum elbow radius is recommended for pipes 4, 5, and 6 in (10.2, 12.7, and 15.2 cm) in diameter. A 24-in (61-cm) elbow radius should be used for 8-in (20.3-cm) pipes and a 30-in (76.2-cm) elbow radius for 10-in (25.4-cm) pipes.

Feeding Seed into Pressure Pipes. Cotton- seed is normally fed into a small-pipe system by a dropper or rotary lock (sometimes called a vacuum wheel) that mechanically drops the seed into the positive-pressure airline on the discharge side of the blower; Fig. 4 shows a typical seed rotary lock installation. The rotary lock should operate at 30 to 60 rpm. Internal seals and pocket divisions are necessary to prevent serious air leakage. More flights on a seed dropper will likely provide a better seal. In some installations, eight-blade droppers without flashing or seed plugs at the end of an auger have been used successfully. Feeder base outlets should be sufficiently tapered to prevent bridging and chokage. Outlets should be set as close to the feeder as possible.

In recent years, high-capacity gins have used seed plug conveyors in lieu of the conventional vacuum feeder (Fig. 5). Commercially available cotton seed plugs have either 12-in or 14-in (30.5- or 35.6-cm) plug conveyors. The general guidance is that 12-in (30.5-cm) plugs are recommended for cotton gins with capacities up to 45 bales/hr, the 14-in (35.6-cm) plug is for higher ginning capacities. Roughly one quarter to a third of the effective conveyor flight is removed from the tail end of the conveyor to allow for the seed plug to form. Ac- cumulation of seed in the region void of flighting is what forms the plug. The purpose of the plug is to create an air seal preventing leakage into the atmospheric surroundings of the seed plug hopper. Variable speed drives could be needed to adjust the conveyor rpm's to enhance the operation of the seed plug by maintaining a constant relationship between the plug densities and processing rate of the gin plant. The nominal fixed conveyor speed for both size plugs is 75 rpm. Power requirements can vary from 7-1/2 to 15 hp (5.5-11.1 kW) depending on the size and number of plugs used. Dual seed plugs are recommended for capacities in excess of 90 bales/hr.

The capacity of seed droppers depends upon their length, flight-wheel diameter, and speed and upon the methods used to seal and feed them. Droppers fed continuously will have more capacity than those fed in pulses from a seed scale. Capacities of cotton seed droppers are given in Table 7.

Valves and Discharges. Valves that are not well fitted for small-pipe systems can give trouble. For lines containing vane-type seed valves, the takeoff angle should not exceed 30°. The deflector vane should be of adequate thickness and should be well fitted into the body of the valve, with the seated end adjusted to prevent blockage by lint or by seed buildup at the valve intake.

The discharge funnel directs the flow of air and seed through the pipe and into the desired container and/or storage location. This flow, however, should not be directed toward a wall or any obstacle that might create hard impacts causing damage to the seed (i.e., cracking or spitting).

Table 7. Capacities of cotton seed droppers

Diameter in (cm)	Length in (cm)	Drive hp	Rotor rpm	cfr (cmr)	Effective cf (cm)/rev	Capacity (assuming 700 lb seed/bale)		
						lb/min (kg/min)	tons/hr (mt/hr)	bales per hr[z]
12 (30.5)	10 (25.4)	1	70	0.52 (.02)	0.13 (.004)	123 (56)	3.7 (3.4)	10
12 (30.5)	18 (45.7)	3	70	0.94 (.03)	0.24 (.007)	227 (103)	6.8 (6.2)	20
16 (40.6)	12 (30.5)	1	55	1.12 (.03)	0.28 (.008)	208 (95)	6.2 (5.6)	20
16 (40.6)	18 (45.7)	2	55	1.67 (.05)	0.42 (.019)	312 (142)	9.4 (8.5)	25
16 (40.6)	24 (61)	3	55	2.23 (.06)	0.56 (.016)	416 (189)	12.5 (11.3)	35
22 (55.9)	12 (30.5)	3	55	2.11 (.06)	0.53 (.015)	394 (179)	11.8 (10.7)	35
22 (55.9)	18 (45.7)	5	55	3.17 (.09)	0.79 (.022)	587 (267)	17.6 (16.0)	50
22 (55.9)	24 (61)	7.5	55	4.22 (.12)	1.06 (.030)	787 (358)	23.6 (21.4)	65
22 (55.9)	36 (91.4)	10	55	6.34 (.18)	1.59 (.045)	1181 (537)	35.4 (32.1)	100[y,x]
34 (86.3)	30 (76.7)	7.5	45	12.61 (.36)	3.15 (.090)	1914 (870)	57.4 (52.0)	165[y,x]

[z] Rounded to nearest multiple of 5

[y] use of seed plug preferred @ capacities in excess of 60 bph

[x] dual seed systems recommended for systems in excess of 90 bph

cfr (cubic ft per rev) (cmr (cubic meters per rev) = area of rotor diameter x length x 0.8

Effective cfr (cmr)/ rev = cfr (cmr) x 0. 5 x 0.5

lb/min (kg/min) = effective cfr (cmr) / rev x rpm of rotor x 18 lb/ft^3 (8.2 kg.m^3) x 0.75

System Design. The following is a system de- sign example for a 30 bale per hour ginning facility: *Example.* A 30 bale per hour (BPH) ginning facility wants to upgrade the seed handling system with new seed vacuum dropper, seed blower and motor, inlet and outlet silencers, and new seed pipe. The average amount of seed per bale experienced by the gin is 700 lb (317.5 kg). The length of pipe from seed vacuum dropper discharge to the outlet of new pipe at seed bunker is 300 ft (91.4 m) with six 90° elbows and a 30-ft (9.1-m) vertical lift. To upgrade the seed handling facility, the ginner needs to determine the following items:

1) volume of seed per minute, 2) cotton seed dropper size, 3) air volume required, 4) pipe size for conveying cotton seed at a target velocity, 5) system friction loss, and 6) cotton seed blower requirement. Example is shown in Imperial units to simplify the explanation. Basic formulas necessary for air calculations when conveying seed at a target velocity of 5,000 ft/min (1,524 m/min) in a cotton gin are:

$Q = VA$ (1)

Where: Q = volume of air in cubic feet per minute (cfm),

V = velocity of air in pipeline in feet per minute (fm) and,

A = cross-sectional area of round seed pipe in square feet (ft^2).

For round pipe, $A=\pi r^2$

Where: π = the constant 3.1416 and

r = the radius of the pipe in inches. (2)

a) Determine volume of seed per minute: Given capacity of 30 BPH and 700 lb of seed per bale, the volume of seed per minute is calculated as follows:

(30 BPH x 700 lb per bale)/60 min = 350 lb/min (3)

b) Determine cotton seed dropper size: Given capacity of seed per minute from Equation 3, 350 lb per min, use Table 7 to determine proper cotton seed dropper. From Table 7, the closest capacity that is greater than 350 lb/min is 394 lb/min. Therefore, a 22-in diameter x 12-in long dropper operating at 55 rpm with a 3-hp drive motor would be the best choice for this example.

c) Determine required air volume (Q): Given a capacity of 30 BPH and 700 lb of seed per bale, the volume of air per minute needed to convey the cotton seed at the recommended upper limit of 5 cfm/lb is calculated to be:

Vol of seed/min (Equation 3) x recommended conveying air volume (5 cfm/lb);
350 lb/min x 5 cfm/lb = 1,750 cfm

d) Determine pipe size(s): Substituting 1,750 cfm and 5,000 fm for Q and V respectively in equation (1), the resulting pipe area A is determined as follows:

Q = VA can be rewritten as, A = Q/V.
Plugging in the values from above for air volume and velocity:
A = 1750 cfm/5000 fm = 0.35 ft2
To convert square feet into square inches, use A (ft2) x 144 in2/ ft2 = A (in2).
Therefore, 0.35 ft2 x 144 = 50.40 in2 Now using Equation 2, the radius and diameter of the preferred pipe size can be determined as follows:
A = πr2 can be rewritten as A/π = r2; 50.40 in2 /π = r2; r = 16.0430.5 = 4.0-in radius or 8.0-in diameter seed pipe.

e) Estimate system friction losses: The system friction losses need to be calculated to ensure the correct rotary blower is selected (Table 4) because the friction loss determines the pressure the blower will work against to convey the cotton seed. Accumulative losses (water column, wc. Shown below in inches of water[1]) for the system can be estimated from Table 6.

Inlet silencer 8.00 in H2O
Outlet silencer 8.00 in H2O
Blower loss (assumed) 1.50 in H20
Venturi 3.00 in H20
300 ft of 8-in pipe @ 2.40 7.20 in H2O in/100 ft, (8 x 2.4 = 7.2)
Six 90° 8-in elbows @ 0.19-in 1.14 in H2O ea, (6 x 0.19 = 1.14)
Cyclone collector 4.00 in H2O
Total friction loss 32.84 in H2O Converting the friction loss from inches water column to psi;
Loss in psi @ 27.7" wc/psi, 1.20 psi (32.84 ÷ 27.7 = 1.2)
Loss due to material @ 20% 0.24 psi (rule of thumb)
Loss due to vertical lift/accel 0.06 psi @ 5% (rule of thumb)
Total relief setting psi > 1.50 psi

f) Determine rotary blower requirement: Consult Table 4 and the manufacturer's catalog for rotary blower specifications to meet your system requirements of 1,750 cfm and 1.5 psi. See footnote at bottom of Table 4 for additional reference.

SUMMARY

Cotton seed is a valuable co-product of the Cotton Gin and as such should be handled and stored in a way that best preserves its quality characteristics. This chapter provides rule-of-thumb guidance and recommendations for handling, conveying, aeration and storage of cotton seed. When applying the examples to one's own gin, the reader should be aware of the impact of ambient conditions such as temperature and humidity and of the cotton gins elevation in regard to sea level. Also, the temperature and moisture of the seed being stored should be accounted for and monitored routinely.

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DISCLAIMER

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REFERENCES

Dowd, M. 2015. Seed. p. 745–781. *In* D.D. Fang and R.G. Percy (eds.). Cotton, 2nd ed. Agronomy Monograph No. 57, Madison, WI.

Hughs, S. and G. Holt. 2015. Ginning. p. 609–664. *In* D.D. Fang and R.G. Percy (eds.). Cotton, 2nd ed. Agronomy Monograph No. 57, Madison, WI.

Smith, L.L. 1975. Aeration of cotton seed in storage. U.S. Department of Agriculture, Marketing Research Report 1020.

Smith, L.L., and S.T. Rayburn, Jr. 1977, Cotton seed Aera- tion and Storage. p. 72–79 *In* Cotton Ginners Handbook, USDA Agricultural Handbook 503, Washington, D.C.

Willcutt, M.H., and W.D. Mayfield. 1994. Cotton seed Handling and Storage. p. 195-214 *In* Cotton Ginners Handbook, USDA Agricultural Research Service, Washington, D.C.,

Willcutt, M.H., S.D. Filip To, P. Kradangga. 1996. A study in wall pressures in a flat clear-span cotton seed storage house, p. 1625–1630 *In* Proc. Beltwide Cotton Conf., Nashville TN. 9-12 Jan. 1996. Natl. Cotton Counc. Am., Memphis, TN.