AMERICAN PEANUT SHELLERS ASSOCIATION

Handling and Storage of Farmer Stock Peanuts

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Chapter 1

I. FARMER STOCK WAREHOUSE – FOOD SECURITY

Introduction

All segments of the peanut industry have joined to produce wholesome peanuts of the highest quality. Growers', Shellers, food manufacturers and peanut warehousemen have each drawn a code of good practices for their particular segment of the industry and that code is available for distribution to industry members. It is in the best interest of the peanut industry as a whole for each segment to do its utmost to perform in the best possible manner. All recommendations in this manual should meet OSHA standards.

Security

Due to the increasing concern for food safety and food security, the following guidelines have been included. These are only a few of the major items to address concerning the safety and security of stored farmer stock peanuts in farmer stock warehouses. Each individual entity may choose to incorporate more precautionary steps in their system.

The scope of this section will address warehouse structure access, warehouse dump pit access, and perimeter access.

At the warehouse level, two major exclusion points exist:

1. Entry points are considered any point into which the warehouse could be accessed including top entry doors, sliding doors, roll up doors or bailout slide gate doors. Entry into farmer stock warehouses via top entry doors, sliding doors or rollup doors should be regulated by lock and key. A master key type system will help the simplicity of key distribution/hierarchy especially for large operations. For all drawdown slide gate doors, steps should be taken to secure entry or unwanted access of peanuts by either the same lock and key system or some type of numerically identified cable seal/tie system. The ID number should be logged, kept on file, and the log updated upon the bailout of the peanuts or an <u>authorized</u> removal of the cable seal.

2. Pit areas should be enclosed and securable by the lock and key system. If area is not enclosed, a pit cover should be placed over the pit opening at all times that the pit is not in use. This pit cover is to be fabricated of a solid material designed in such a way that removal is a deterrent to unauthorized persons.
   These steps will aid in ensuring that no hazardous items are introduced into the warehouse handling equipment and ultimately the peanut pile.

Controlled access to the perimeter of the facility grounds can be the first line of defense if applicable. Perimeter fencing is not always present at warehouse locations. If fencing is present, utilizing the previously mentioned lock and key system will compliment the warehouse security program. If feasible, installing perimeter fencing can be an investment by which some risk can be reduced.

Chapter

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II. BUILDING STANDARDS

Storage Types

There are several types of structures used for bulk storage of famer stock peanuts. The most common is a conventional metal clad post and beam structure. Most of the guidelines in this chapter pertain to the conventional metal warehouse. The conventional farmer stock warehouse is usually 80 feet wide with a 24 ft eave height. The length varies according to the desired capacity. The roof pitch is usually 12:12 (45 degrees). This allows enough room in the space above the peanuts to install belt conveyors and associated equipment to load peanuts in the warehouse. One variation of the conventional warehouse is to reduce the roof pitch to 9:12 (37 degrees) with a doghouse at the ridge to house the conveying equipment. These roof pitches will allow peanuts to flow at their normal angle of repose filling the warehouse to within 1 foot of the eave of the building and keep peanuts from contacting the roof panels or support structure. In a properly filled warehouse, peanuts will be 50-55 feet deep under the ridge of the building and 23 feet deep at the sidewall. A calculator to determine the storage capacity of a conventional farmer stock warehouse is available on the National Peanut Research Laboratory's website (www.ars.usda.gov/saa/nprl) and can be accessed on the American Peanut Shellers Association website.

A second type of farmer stock warehouse is a variation on the metal building in which the length and width of the building are approximately the same. The 'flat' storage facility generally has little or no peanuts in contact with the side or end walls of the structure. In a flat storage facility, peanuts are unloaded from trucks and placed in storage using telescoping conveyor belts. Peanut depth is usually very uniform throughout the storage with few peaks and valleys and no deeper than approximately 13 feet. Since peanuts are shallower and more uniform than in conventional farmer stock storage, the peanuts will cool and equilibrate faster than in a conventional warehouse. The disadvantage is that to ventilate the headspace at the recommended rates (See Chapter 3), considerably more airflow is required because the headspace volume compared to the peanut volume is much larger. Construction costs for a flat storage structure may be less than conventional storage because the roof structure does not have to support the weight of an overhead conveyor, nor do the side and end walls have to withstand the extreme lateral pressures exerted by peanuts in a conventional warehouse. Many flat storage structures are constructed so that trucks can be loaded and/or unloaded inside the building, allowing for loading/unloading during inclement weather.

A third type and fairly recent storage type is the monolithic concrete dome. It is a structure constructed in layers from the outside in. A vinyl skin is inflated into a hemispherical shape. High density polyurethane foam insulation is applied to the inside of the inflated vinyl skin. Steel reinforcing bar is tied to the foundation inside the foam insulation, and concrete is sprayed on in thin layers until the design thickness is achieved. Peanuts are typically loaded into the dome through a single spout located in the center of the dome. Peanuts are approximately 65-70 feet deep at the center. This makes it imperative that the aeration system be designed to fully aerate the pile by pulling air in through the inlets and down through the peanuts (See Chapter 3). The dome is much easier to maintain, sanitation is easier and less time consuming, and less time is required to seal the structure prior to fumigation. However, it is imperative that all peanuts be cleaned prior to loading because peanuts are usually loaded through a single opening at the center of the dome. Foreign material and loose shelled kernels will be concentrated directly underneath the opening and will severely restrict air movement.

The following comments generally apply to all three types of farmer stock storage structures.

Farmer Stock Warehouse Construction

1. Make sure all closure strips are installed correctly so that screws secure the strips.
2. Assemble putty tape on all laps.
3. White reflective roof and sidewall surfaces reduce heat inside the warehouses. This reduces deterioration of product and insect contamination.
4. Seal around shrouds on fans to prevent short-circuiting of air.
5. Use cushioned deadhead boxes on spouting. Install platforms to allow for maintenance.
6. Use belt conveyor in top of warehouse, with tripper, to load warehouse.
7. Put a concrete slab apron large enough to accommodate loading equipment at entrance doors to work on with loader, extending outward a minimum of 20 feet from each door.
8. Make all doors, hoods, fans, etc., accessible for sealing to fumigate.

9. Locate catwalk and belt in top of warehouse low enough to prevent overloading warehouse.

10. Incorporate cleaners and/or dirt screens to clean peanuts going into warehouse.

11. All wiring should be in conduit and on outside of building. No wiring should be between the wall and the stored peanuts. All lighting fixtures should be equipped with safety-type light bulbs.

12. Roof pitch of 12/12 will improve ventilation. Caution should be taken against over filling. A 12/12-roof pitch will allow for the elimination of a **doghouse**. A 9/12-roof pitch requires a doghouse in order to adequately fill.

Double Roof Warehouse Construction

CONCEPT

The addition of a second roof on a mechanically ventilated farmer stock warehouse provides a solution to a leaking roof as well as the advantage of stabilizing temperature variations within the warehouse. The costs associated with retrofitting a warehouse with a second roof can many times be less than replacing deteriorated roof sheets.

By spacing a second sheet of metal approximately two (2) inches above the existing sheet, and venting equally at the top and at the bottom to allow for a constant flow of air near ambient temperature, an insulating effect is created ***(Figure 1).*** The type purlin used should be such that upward airflow will not be restricted between the roof sheets. A thermal barrier is created by the air between the roof sheets, and a 15-20 degree temperature reduction within the warehouse is not unusual.

Venting so that outlet space at the top is at least equal to inlet space at the bottom is essential. A residential-type continuous ridge vent should be used on warehouses without doghouses (***Figure 2***). A warehouse with a doghouse should use a transition flash at the top to allow for adequate airflow (***Figure 3***). For a warehouse with a double wall doghouse, the transition should be the outer wall (***Figure 4***).

ADVANTAGES

A number of advantages are created with the installation of a double roof:

1. Condensation is reduced or eliminated due to the insulating effect.

2. Insect pressure is reduced due to lower inside temperatures during times of warm weather.

3. Leaks can be eliminated more effectively than with roof coatings and at less cost than replacing old roof sheets.

Note Additional information may be obtained from the USDA National Peanut Research Laboratory in Dawson, Georgia.

Figure 1.

Sheeting Detail of Double Roof

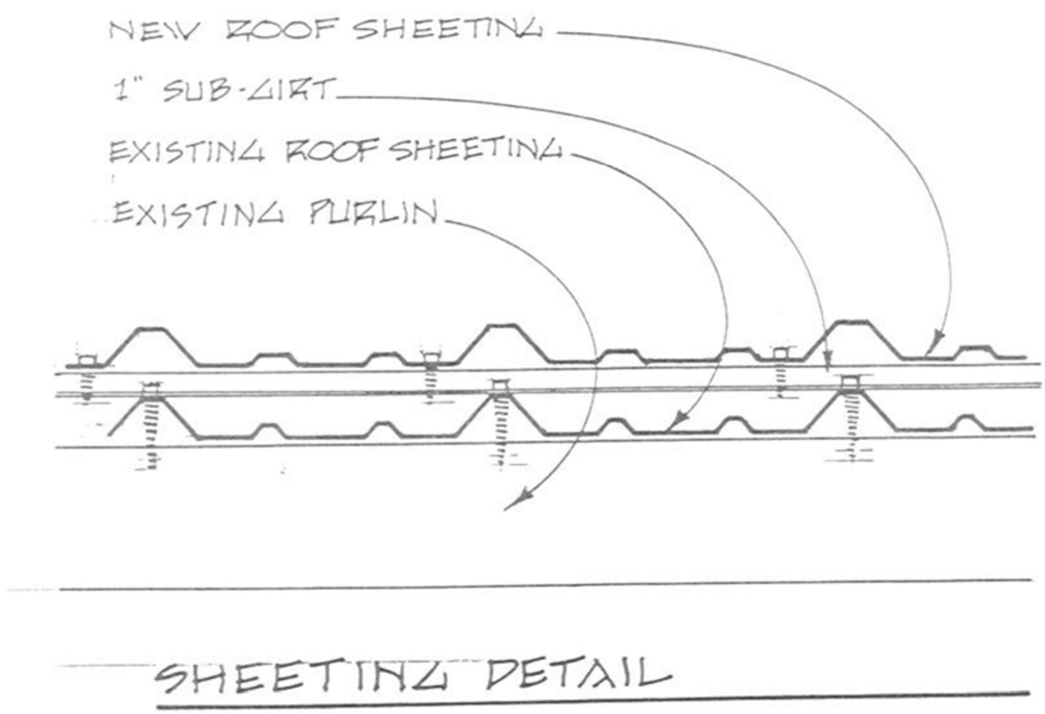


Figure 2. Continuous Ridge Vent of Double Roof

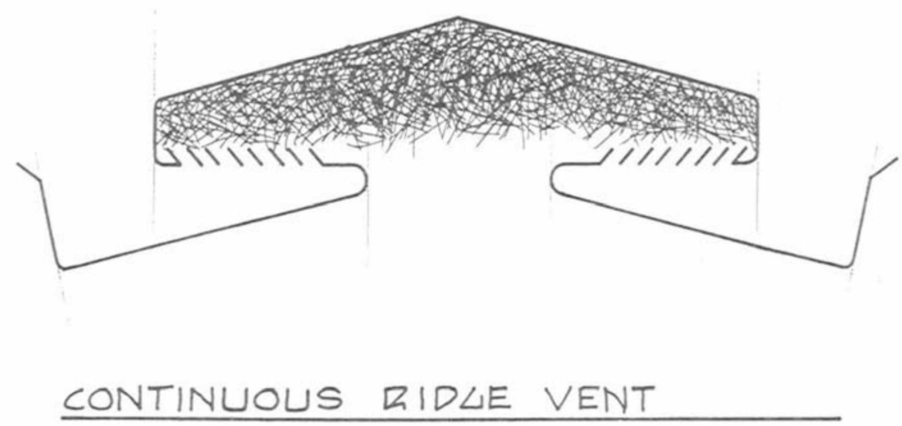


Figure 3.

Roof/Doghouse Transition

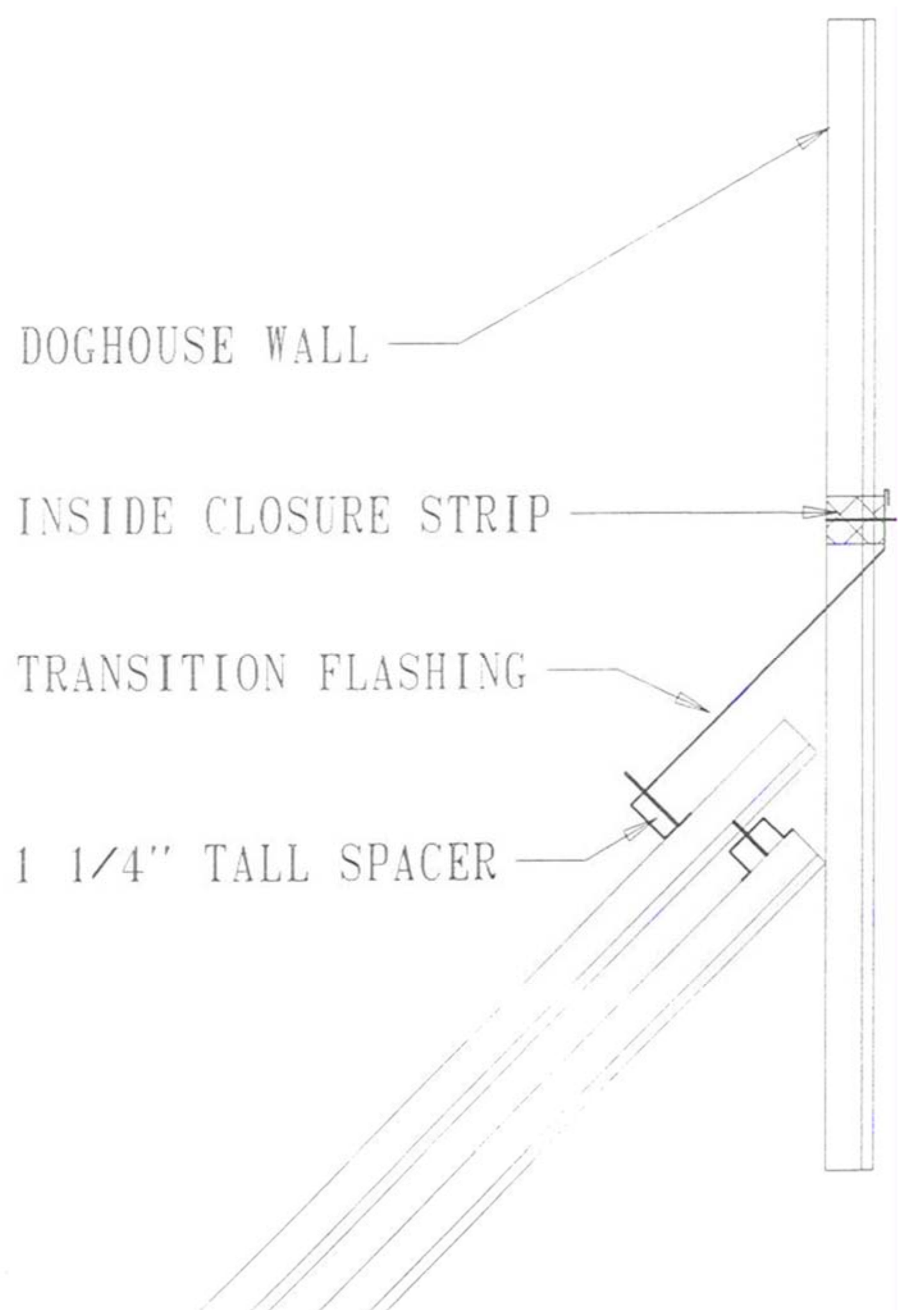
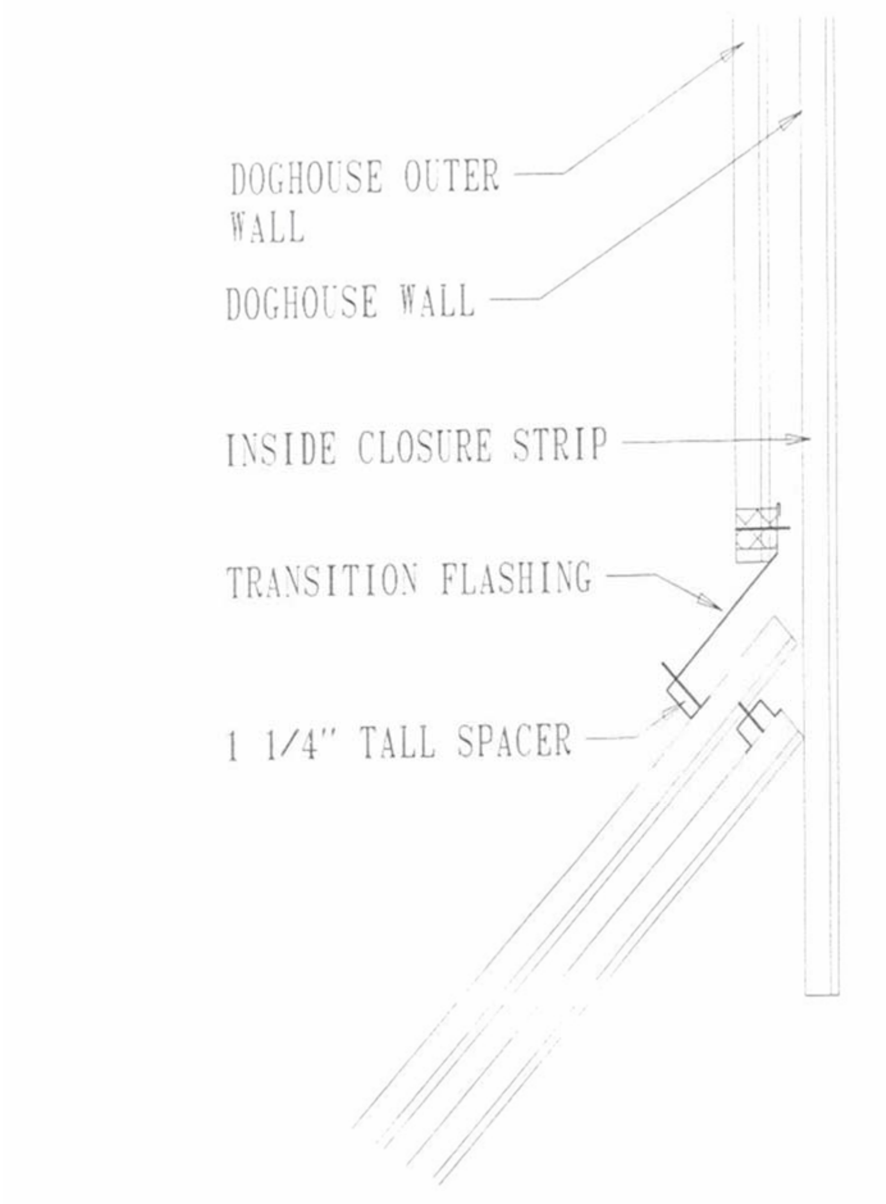


Figure 4.

Roof/Doghouse Transition - Double Wall



Chapter

3

III. WAREHOUSE VENTILATION AND AERATION

Introduction

Farmer stock peanuts are loaded into the storage structure shortly after curing and will continue to lose moisture and heat until they have reached equilibrium with their storage environment. The average moisture content of farmer stock peanuts is 8-9% when graded, and under typical weather conditions, will equilibrate to between 5 and 7% moisture. For a 5000 ton warehouse, that means that between 54 and 210 tons (13,700 and 53,700 gallons) of water must evaporate from the peanuts and be removed from the warehouse without condensing on the structure.

The purpose of a warehouse ventilation and/or aeration system is to remove the excess heat and moisture that leaves the peanuts from the structure with minimal condensation on the structure. An aeration/ventilation system that is properly designed and operated will not only remove the excess moisture, but cool the peanuts to a point where insect activity is minimized throughout the storage period.

A ventilation system is the part of the warehouse equipment and structure designed to remove the excess heat and moisture from the peanuts by pulling outside air through the headspace, the air above the peanuts and below the warehouse roof, and exhausting the moisture and heat laden air to the outside. This can be achieved by mechanically forcing air through the headspace or by relying on the natural tendency for warm air to rise. Both systems can work satisfactorily if designed properly.

An aeration system is a mechanical system designed to force air through the peanut mass absorbing moisture and heat as it goes, then exhausting to the outside. The aeration system can be designed to operate in conjunction with the headspace ventilation system or designed as the sole means of removing excess heat and moisture.

Design and operating guidelines are provided for mechanical and natural ventilation and aeration systems in the sections that follow.

Natural Ventilation

Naturally ventilated warehouses can be effective. However, insect controls through timer-released insecticide applications are less effective. Fumigation is also more difficult in naturally ventilated warehouses.

Generally, on a naturally ventilated warehouse, the inlet area at the eaves should be one (1) square foot per linear foot of warehouse, one half on each side. The exit area in the ridge should equal the inlet area.

Most naturally ventilated warehouses have been retrofitted with mechanical ventilation systems.

Mechanical Ventilation

The following guidelines on mechanical warehouse ventilation were developed in consultation with experts on the subject and with a review of available research. The field application of the research does not guarantee the achievement of optimum ventilation, but is simply a good method to realize that goal. The following guidelines were developed for a farmer stock warehouse filled to capacity. The ventilation system may not adequately control moisture and heat in the headspace if the warehouse is only partially filled.

Fans should be capable of exchanging the overspace or headspace air once every 2 to 3 minutes.

The velocity of the air through the inlets should not exceed 1,000 feet per minute (fpm). Ideally air entering the warehouse should not exceed 800 fpm to prevent water from entering the warehouse (***See*** **Figure 5**).

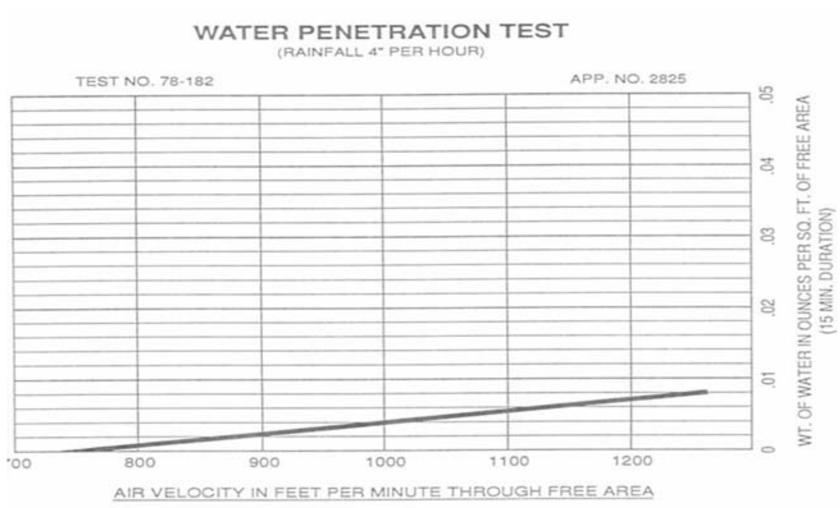


Figure 5. Amount of water carried into a test structure at various inlet air velocities

Fans should be located as high as reasonably possible in the gable, preferably in the leeward gable. Inlets should be located above the fill line for the warehouse in the gable opposite the fans. Some inlets (totaling 10-20% of inlet area) should be installed under the eaves and adjacent to bin walls at the inlet gable for good airflow across the peanut surface.

From a practical standpoint, the ventilation fans should run continuously while peanuts are in the warehouse, except when fogging or fumigating with chemicals labeled for use in farmer stock warehouses. However, if proper temperature and humidity sensors are used to determine dew point conditions, they should take preference in controlling fan operation after excess heat and moisture have been removed.

Generally, warehouses should be filled to within 1 foot of the roof at the eaves. DO NOT OVERFILL. Under no circumstances should the peanuts cover any inlet vents at this level as this will diminish the performance of the ventilation system.

All openings in the warehouse (seams, holes, etc.) not specifically used as inlets should be sealed, especially where they will short-circuit the air to the fans. From a ventilation standpoint, this is not necessary at the inlet end of the warehouse. Any openings may, however, present problems with insects and water entering or when fumigating the warehouse.

All inlets should be covered with ½" hardware cloth to prevent the entry of large insects and birds. Lower mesh size may restrict airflow.

Hooded vents will normally be used instead of louvers because of less air restriction, ease of sealing during fumigation, better water exclusion, and lower maintenance.

Belt slippage on ventilation fans is a common and serious problem, often resulting in a 50 to 75% reduction in airflow. This situation frequently occurs with minimal visual or audible indication of slippage, and requires the routine use of a tachometer to verify actual fan speed.

Whenever selecting a new fan drive or replacement belt, it is necessary to ensure that the sheave sizes and belts match. For instance, the drive sheave on the motor should match the sheave on the fan. If the drive motor has a B-sized sheave, then the fan sheave and the belt should also be a Type B. A Type "BX" belt will stretch less than a Type "B". Direct drives are available and eliminate the need for monitoring and replacing belts.

Replacing existing gravity louvers with hoods is suggested. If the louvers are utilized, care should be exercised to ensure sufficient free area is achieved. Once the needed free area for the opening is calculated, it should be determined that the louvered vent to be used provides the required amount of free area in square feet. The manufacturer specifications for the selected louver will provide amount of free area provided. The method for calculating required vent inlet space follows later in this chapter. It is also provided in the online ventilation calculator provided by the USDA, ARS, National Peanut Research Laboratory (Butts, 2004) at www.ars.usda.gov/saa/nprl.

In some cases, 45-degree hoods will be used to cover fan exhaust areas. A 90-degree hood can be used to reduce the possibility of rain blowing into the warehouse, but fan cfm (cubic feet per minute) must be increased to compensate for restricted airflow. 90-degree hoods should always be used to cover vent inlet areas to exclude water droplets from entering.

Generally, the entire ridge and all ridge vents should be sealed if the warehouse is mechanically ventilated. While the ridge vents at the inlet end of the warehouse may be used as inlets, they must be sealed whenever the warehouse is fumigated.

Calculating Mechanical Ventilation Requirements

The ventilation requirements are based on the headspace or overspace volume which is the difference between the total peanut volume stored in the warehouse and the total warehouse volume.

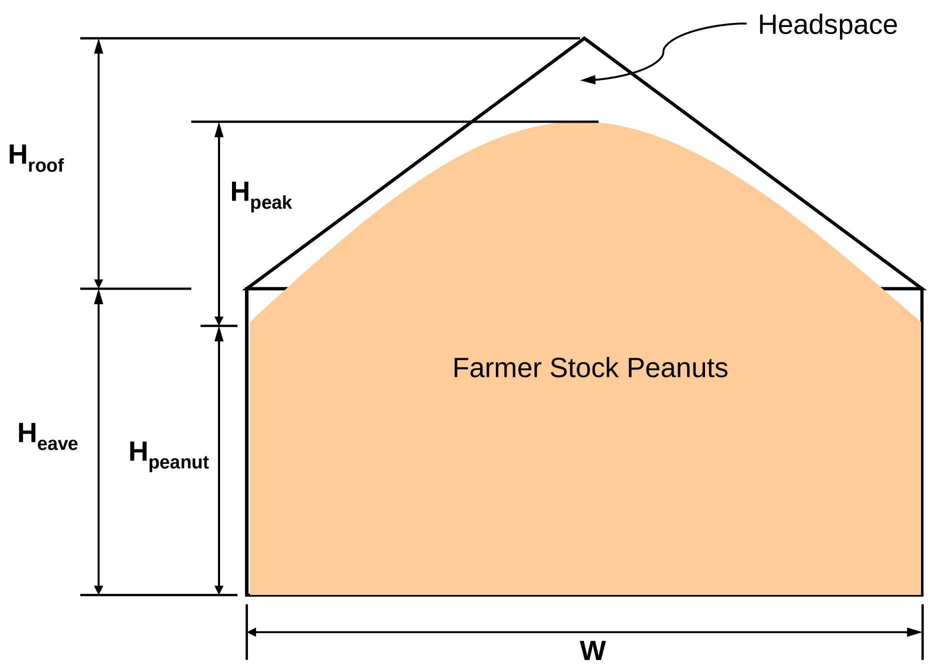


Figure 6. Typical farmer stock warehouse section for example calculations.

The following is an example calculation for a conventional warehouse that has a width (W) of 80 feet, a length (L) of 200 feet, an eave height (H_{eave}) of 24 feet and a 12:12 (45^o) roof pitch. We will first calculate the height of the roof peak above the eave (H_{roof}).

$$H_{roof} = \tfrac{1}{2} \text{ x } W \text{ x Roof Pitch} = \tfrac{1}{2} \text{ x } 80 \text{ x } \frac{12}{12}$$

$$H_{roof} = 40 \text{ ft}$$

The total warehouse volume ($V_{warehouse}$) is found by adding the volume below the eave and the volume above the eave.

$$\begin{aligned} V_{warehouse} &= (L \text{ x } W \text{ x } H_{eave}) + (\tfrac{1}{2} \text{ x } L \text{ x } W \text{ x } H_{roof}) \\ &= (200 \text{ x } 80 \text{ x } 24) + \tfrac{1}{2} \text{ x } 200 \text{ x } 80 \text{ x } 40 \\ &= 384{,}000 + 320{,}000 \\ &= 704{,}000 \text{ ft}^3 \end{aligned}$$

The next step is to calculate the height of the peanut pile peak (H_{peak}) above the sidewall fill level. The angle of repose of peanuts is between 30 and 33^o.

$$\begin{aligned} H_{peak} &= \tfrac{1}{2} \text{ x } W \text{ x } \tan(31^o) = 40 \text{ x } 0.6494 \\ &= 24 \text{ ft} \end{aligned}$$

The peanuts should be no higher than 1 foot below the eave on the sidewall, therefore
H_{peanut} = 23 ft. The peanut volume (V_{peanut}) is the sum of the volume from the sidewall depth and the peanuts above the sidewall to the peak.

$$\begin{aligned} V_{peanut} &= (L \text{ x } W \text{ x } H_{peanut}) + (\tfrac{1}{2} \text{ x } L \text{ x } W \text{ x } H_{peak}) \\ &= (200 \text{ x } 80 \text{ x } 23) + (\tfrac{1}{2} \text{ x } 200 \text{ x } 80 \text{ x } 24) \\ &= 368{,}000 + 192{,}000 \\ &= 560{,}000 \text{ ft}^3 \end{aligned}$$

As stated above, the headspace volume ($V_{headspace}$) is the difference between the warehouse volume and the peanut volume.

$$\begin{aligned} V_{headspace} &= V_{warehouse} - V_{peanut} \\ &= 704{,}000 - 560{,}000 \\ &= 144{,}000 \text{ ft}^3 \end{aligned}$$

The airflow, in cubic feet per minute (cfm), to exchange the headspace volume once every two minutes is calculated by:

$$\text{cfm} = V_{headspace} \div 2 = 144{,}000 \div 2 = 72{,}000 \text{ cfm}$$

The total open inlet area needed is:

$$\text{Inlet Area} = \frac{72{,}000 \text{ cfm}}{800 \text{ fpm}} = 90 \text{ ft}^2$$

Approximately 10% of the inlet area, or 9 ft^2, should be installed at the eaves on the end of the warehouse opposite the fans. If louvered vents are used, refer to the manufacturer's literature to obtain the free area provided by the vents to ensure there is adequate inlet space. As stated previously, the louvered vents are less efficient than hooded inlets with ½" mesh screen.

These calculations for headspace ventilation would apply to conventional warehouses as shown in the example that are filled to capacity. More problems may occur in partially filled warehouses due to the larger headspace volume. The headspace ventilation requirements for flat storage would be similarly determined by calculating the empty warehouse volume, the volume of peanuts stored, then subtracting the peanut volume from the warehouse volume to determine the volume of the headspace.

When selecting fans for warehouse ventilation, select the fans based on airflow (cfm) provided by the fans at 0.25 inch static pressure. Refer to **Table 1** for typical fan data provided by exhaust fan manufacturers.

Table 1. Performance data for typical exhaust fan used to ventilate farmer stock warehouse headspace.

Fan Diameter (in)	Static Pressure (inches of water)						Fan Speed (rpm)	Motor Horsepower (Motor speed=1725 rpm)
	0.125	0.250	0.375	0.500	0.625	0.750		
36	13200	11250	8250	3900	2350	----	600	1.5
	14800	1330	10700	8200	4100	2600	660	2
	17400	16300	14650	12500	10200	6000	760	3
	20600	19800	18800	17400	15200	13600	890	5
42	17900	16200	13000	10000	8100	6600	565	2
	20700	19600	17600	14400	11800	9900	645	3
	24900	24100	23000	21400	18900	16100	765	5
	28700	2811	27300	26300	24800	22800	875	7.5
48	25100	23400	21400	15000	9800	5000	535	3
	29800	28400	27000	25200	21800	15000	625	5
	34500	33500	32300	31100	29700	27700	720	7.5
	38400	37500	36800	35400	34200	32900	795	10
54	33500	31400	28400	21500	14400	10300	495	5
	38400	36900	34500	32100	26400	19100	565	7.5
	43100	41400	39600	37500	34900	29000	620	10
	49600	48300	46300	44100	43300	40600	710	15
60	46400	44100	41400	37500	30500	19600	505	7.5
	51100	48500	46300	43400	39000	32800	550	10

	59200	57400	56000	53400	50900	48200	635	15
	63100	61600	6000	58200	56100	53700	675	20

The ratio of horsepower to CFM varies greatly within fan types and sizes. A comparison of 42" and 48" commercial, medium and high volume fans reveals CFM per horsepower ranges from 3,750 CFM/hp to 10,300 CFM/hp. This is especially important because of the much higher electricity cost to operate the less efficient fan. Generally, low and medium volume fans deliver more airflow per horsepower than high volume fans and can lower energy costs by as much as several hundred dollars per warehouse per month.

Calculating Approximate CFM of Existing Fans

To estimate the airflow delivered by an existing fan, it will be necessary to locate the fan performance data. This can be obtained by reading the fan model number from the fan name plate on the fan housing. Fan performance data is available from the manufacturer for the fan model installed. Other data required from the field is the fan diameter, motor speed (RPM_{motor}), motor pulley diameter (D_{motor}), and fan pulley diameter (D_{fan}). Calculate the ratio of the fan pulley diameter to the motor pulley diameter.

$$\text{Ratio} = D_{fan}/D_{motor}$$

Calculate the fan speed (RPM_{fan})

$$RPM_{fan} = RPM_{motor}/\text{Ratio}$$

Using the fan diameter and the fan speed, locate the approximate CFM from the fan chart (See Table 1).

As an example, a 54" with a 9" diameter pulley is driven by 1745 rpm motor with a 3" drive pulley. The ratio is calculated as:

$$\text{Ratio} = D_{fan}/D_{motor} = 9/3 = 3$$

The fan speed is:

$$RPM_{fan} = RPM_{motor}/\text{Ratio} = 1745 \text{ rpm} /3$$
$$RPM_{fan} = 582 \text{ rpm}$$

A 54" fan shown in **Table 1** shows fan speeds at 565 and 620. The airflow at 0.25 inches static pressure at 565 and 620 rpm is 36,900 and 41,400 cfm, respectively. Interpolating between these two airflow rates, the airflow at 582 rpm is approximately 38,300 cfm.

Warehouse Aeration

Aeration systems have the same purpose as a headspace ventilation system: to control the heat and moisture in a bulk stored product. Cottonseed warehouses are typically aerated using evenly spaced tunnels in or on the storage structure floor (Wilcut *et al.*, 2008). Blankenship *et al.* (2000) conducted studies using aeration in a 10,000 ton warehouse in west Texas. Automated controls were used to manage fan operation based on the relative humidity of the outside air. In this study, shrinkage due to excessive moisture loss was less two out of three years normally observed in the southwestern U.S. (Smith and Butts, 1995)

Aeration systems for farmer stock warehouses is a fairly recent addition to the tools used to manage farmer stock storage. An aeration system design depends on how the system is intended to be used in managing the temperature and moisture of the peanuts in storage. The recommendations contained in this section are based on research partially funded by the American Peanut Shellers Association (Blankenship *et al.*, 2000; Butts *et al.,* 2006).

Aeration System Design

Farmer stock warehouse aeration systems may be designed and operated in one of two ways. The first system is designed to pull ambient air in through inlets located in the headspace and down through the peanuts. In this scenario, there is no headspace ventilation system and should be operated throughout the storage period using an aeration controller responding to temperatures and humidity measured outside the warehouse and in the peanut mass. **The design airflow rate for this scenario is 10 cfm/ton**. This is the recommended aeration scenario for the domes used to store farmer stock peanuts.

Another type of aeration system may be designed and operated in conjunction with an existing headspace ventilation system. In this scenario, the fan and air duct system is designed and installed to force air up through the peanuts during loading and the initial cool down and equilibration of the peanuts in storage. This type of system ***must*** be operated with the headspace ventilation system running. As air is forced up through the peanuts, it becomes laden with heat and moisture. If the headspace fan is not operating, the moisture laden air will come in contact with the metal roof of the building which may be well below the dew point temperature of the warm moist air causing it to condense and drip back down on the peanuts.

The fan(s) are operated after the entire length of the duct is covered during the cooler parts of the day to facilitate cooling during loading. This aeration system is operated throughout loading until the peanuts have cooled, and then turned off and the fan intake sealed.

Typically in this system a single duct is installed directly beneath and parallel to the ridge of the building. Another duct arrangement is to install two ducts parallel to the ridge of the building, but each offset from the centerline where they will be centered under the pile of peanuts loaded off each side of the tripper on the overhead conveyor. **The design airflow rate for this scenario is 3 cfm/ton per duct.** This scenario should ONLY be used in conjunction with a headspace ventilation system. If no headspace ventilation is available, then use the full aeration strategy discussed previously.

Aeration system specifications include airflow rates based on the amount of peanuts that can be stored in the warehouse, and the specifications of air distribution systems. The air distribution systems include the fans, motors, duct system, and inlet/outlet area. Aeration rates are based on the designed capacity of the warehouse. If the warehouse is partitioned, each bin should be aerated separately according to their individual storage capacity. Warehouse capacity can be calculated by multiplying the peanut volume calculated above by the peanut density (20 lb/ft^3 for runner peanut) then dividing by 2000 lb/ton. Warehouse capacity can also be determined using the online calculator (Butts, 2004). The warehouse capacity in the example above would be:

$$\text{Capacity} = \frac{V_{peanut} \text{ x } 20 \text{ lb/ft}^3}{2000}$$

$$= \frac{560{,}000 \text{ ft}^3 \text{ x } 20\text{lb/ft}^3}{2000} = 5{,}600 \text{ tons}$$

Airflow Rates

Total aeration requirements can be calculated using the equation shown below. The cfm/ton is selected based on the desired operating conditions discussed above.

$$cfm = T * \frac{cfm}{ton}$$

T is the capacity (tons) of the warehouse or bin to be aerated and $\frac{cfm}{ton}$ is the airflow rate recommended above. Airflow should be determined for the total amount of peanuts to be stored in the warehouse, and each bin aerated separately.

To fully aerate the 200 ft long warehouse in the example above, the desired aeration rate is 10 cfm/ton. Therefore, the fan should provide a total airflow of:

$$cfm = 5{,}600 \text{ tons x } 10 \text{ cfm/ton}$$

$$= 56{,}000 \text{ cfm}$$

If a single supply duct were to be installed in the warehouse to supplement the headspace ventilation system, then the airflow would be provided at a rate of 3 cfm/ton or 16,800 cfm.

Inlet/Outlet Area

There should be enough screened inlet/outlet area in the gables and the eaves of the warehouse to keep the air velocity less than 1000 fpm. This should be based on all of the air moved by the aeration and headspace ventilation systems combined. As mentioned earlier in this chapter, water droplets can be lifted and carried into the warehouse if the air velocity is 1000 fpm or faster. Therefore, a conservative design velocity is 800 fpm.

For the case of the fully aerated warehouse, the total amount of inlet area in the headspace would be:

$$\text{Inlet Area} = \frac{\text{cfm}}{800 \text{ fpm}} = \frac{56{,}000}{800} = 70 \text{ ft}^2$$

These should be 90° hooded inlets with ½" mesh screen to exclude birds. At least 10% of the inlet area should be located at the eaves.

Duct System Design

The purpose of the duct system is to deliver air uniformly throughout the mass of peanuts. A full perforated floor system would satisfy this requirement, but is not practical in a typical farmer stock warehouse. Duct systems may be formed into the concrete floor in new construction or existing warehouses. Retrofitting in-floor duct systems can be very expensive. Removable duct systems of perforated corrugated metal or plastic are suitable alternatives. Plastic would be relatively inexpensive compared to the corrugated metal pipe and would impart less damage on unloading equipment

Warehouses should be loaded by periodically moving the overhead tripper system so that peanuts are placed in the warehouse in layers the full length of the warehouse or bin. Therefore, the duct system should be installed parallel to the ridge of the warehouse. One duct should be installed down the center of the warehouse regardless of the aeration management scheme. Assuming that three tunnels are installed, place one tunnel down the center, and then place the other two on either side, approximately halfway between the center and the sidewall.

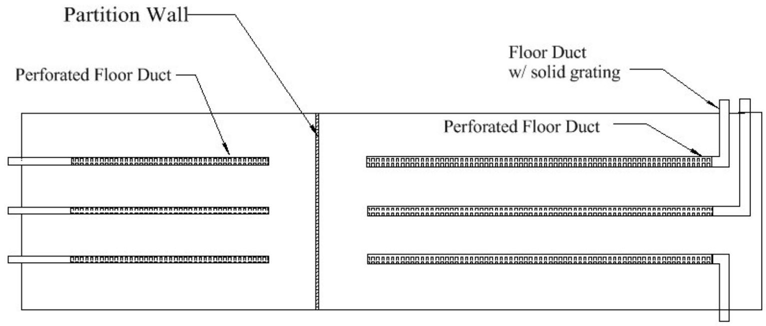


Figure 7. Typical farmer stock peanut warehouse with aeration floor plan.

There are two elements to duct design: cross-sectional area and duct open area. Maximum velocity in the duct should be 2000 fpm. Maintaining this velocity will minimize fan horsepower requirements.

Duct open area is the area of the duct through which air flows into the peanut mass. The average velocity of the air entering the peanuts should be 30 fpm to minimize pressure loss and to ensure uniform air distribution. The velocity (v) can be calculated by dividing the desired airflow rate (cfm) by the cross-sectional area (A) as shown in the below.

$$v = \frac{Q}{A}$$

Example:
Using the 200 ft long warehouse in the example above, an overspace ventilation system will be installed and operated according to recommendations contained in this chapter. An aeration system is desired to provide initial cool down of the peanuts and run up to 30 days into the storage period. The fan will then be turned off and sealed.

According to the on-line calculator, the warehouse capacity (T) is 5600 tons. The overhead fan should provide cfm at ¼ in. H_2O static pressure. Since the aeration system will be operated in conjunction with the headspace ventilation system, the design aeration rate is 3 cfm/ton and the total cfm is calculated.

$$Q = T * \frac{cfm}{ton} = 5{,}600\, tons * 3\frac{cfm}{ton}$$

$$= 16{,}800\, cfm$$

Since the aeration fan will be operated simultaneously with the overspace ventilation system, the fan(s) should be installed so that air will be forced into the duct system and up through the peanuts. The duct system will also be a single tunnel down the middle of the warehouse. Rearranging equation (2) and solving for the area, the cross-sectional area of the duct is determined by dividing the airflow in the duct by the maximum allowable velocity (2000 fpm).

If a single fan is used to force air the entire 200-ft length of the warehouse, the duct must have a cross-section of 8.4 ft^2. A rectangular duct formed into the floor that is 48 inches wide must be 25 inches deep.

If air is supplied by two fans, 8,400 cfm from each end, the duct size could then be 48 x 12 in. Using two fans offers the following advantages.

1. Air must travel only 100 feet instead of 200 feet.
2. Duct size is smaller.
3. Can begin aerating as soon as the first layer covers the first section of duct work instead of having to cover the entire length of the warehouse.
4. Smaller fans can be used.

Some disadvantages include the fact that the total electrical load using two fans may be more than using a larger single fan and there are two fans to service instead of one. For the purposes of this example, two fans will be used.

The open area of each duct must be determined. The perforated area of each duct should begin 10 ft from the end wall. Each duct should end 5 ft from the center of the warehouse leaving a 10-ft gap between the ends of the ducts in the center. Therefore, the length of the perforated section of the duct is:

$$\begin{aligned} L_{perforated} &= \frac{L_{warehouse}}{2} - d_{endwall} - d_{center} \\ &= \frac{220}{2} - 10 - 5 \\ &= 95\ ft \end{aligned}$$

The open area needed to achieve a velocity of air entering the peanuts, the total area should be:

$$\begin{aligned} A_{perforated} &= \frac{Q_{fan}}{v} \\ &= \frac{8400\,cfm}{30\ fpm} \\ &= 280\ ft^2 \end{aligned}$$

The percent open area of the duct grating is calculated by dividing the perforated area ($A_{perforated}$) by the total area of the duct exposed to the peanuts.

$$\% \, O.A. = \frac{A_{perforated}}{A_{duct}} * 100\%$$
$$= \frac{280 \; ft^2}{95 \; ft * 4 \; ft} * 100\%$$
$$= 74 \, \%$$

The perforated metal for the top surface of the in-floor duct should have a perforation pattern with 81% open area. This type of metal can be found, but may not offer the structural strength needed. To decrease the % perforation to 40%, the width of the tunnel would have to be doubled from 4 to 8 ft, which is not practical. If a 4-ft half-round duct were used, 52% open area perforation could be used which is more widely available. If less open area, i.e. 40%, is used the fan would have to be selected to account for the increased pressure loss.

The final calculation is the static pressure that the fan must overcome to supply the proper airflow. The pressure loss comes from the depth of peanuts, the foreign material in the peanuts, and the friction loss in the duct system. ASAE Standard, **D272.3-Resistance to Airflow of Grains, Seeds, Other Agricultural Products and Perforated Sheets** (ASAE, 2002), is the basis for determining the pressure loss through the peanut mass. The primary variable used in the calculation is the average air velocity through the peanuts and the peanut depth. The average velocity is calculated by dividing the airflow rate by the effective floor area. In this case, one duct down the middle of warehouse delivering air to one-half of the length of the warehouse, would deliver about 8400 cfm. Assuming that air would spread out approximately 10 ft to either side of the duct, the effective floor area is calculated as

$$A_{floor} = L * W = 100 * 20$$
$$= 2000 \; ft^2$$

The velocity or cfm/ft^2 is calculated by:

$$cfm/ft^2 = \frac{Q_{fan}}{A_{floor}} = \frac{8400}{2000}$$
$$= 4.2$$

Based on the curves for clean peanuts, the pressure loss per foot of depth (Δp/ft) is 0.002 in H_2O/ft. The maximum depth of peanuts in the center of the warehouse is approximately 50 ft. The total pressure loss through *clean* peanuts is:

$$\Delta p_{clean} = \Delta p \, / \, ft * depth$$
$$= 0.002 * 50 = 0.1 \, in \; H_2O$$

The LSK and fine-textured foreign material will tend to concentrate along the centerline of the warehouse and fill in the air space between the peanuts causing increased pressure loss. Typically, the foreign material will double or triple the pressure drop through the peanuts. Therefore, the total pressure loss through the peanuts will be about 0.3 in. H_2O. The friction loss in the transition from the fan and into the tunnel, along the tunnel, and through the perforated metal can be calculated. However, as a rule of thumb, the pressure drop in the air delivery system is about the same as through the peanuts. Therefore, the total pressure drop should be about 0.75 in. H_2O. **Table 2** summarizes the specifications for the example aeration system operating in conjunction with a headspace ventilation system.

Fan Operation

The purpose of the farmer stock warehouse aeration system is to control the peanut temperature and remove excess moisture. Excessive fan operation can dry peanuts to below the desired minimum of 7% causing excessive shrink. Therefore, fan operation is critical especially after the initial cool down and equilibration period.

Table 2. Aeration system specifications for example farmer stock warehouse

Number of Fans	2
Airflow (each fan)	8400 cfm @ 0.75 in H_2O
Duct Layout	2 ducts, one from each end of the building down the center
Duct dimensions	48” half round, perforated area 95 feet long, 10 ft between ends of ducts at the center of the building
Perforated area	52% O.A. beginning 10 ft from the end wall

Aeration fans should not be operated until the entire duct system supplied by the fan is covered. Turning the fan on before the duct is covered will cause the air to be forced out of the uncovered portion of the duct and not through the peanuts. Therefore, it is essential that proper loading practices that load the warehouse in layers are followed. Moving the tripper frequently will cover the tunnel quicker and will maintain a uniform depth of peanuts over the duct as the warehouse is loaded. Once the duct is covered, then fan operation can begin.

To achieve an equilibrium moisture content of 7%, peanuts must be stored at approximately 60% relative humidity. At 75% relative humidity, peanuts will equilibrate to about 9% moisture content (Young *et al.*, 1982). Therefore, to prevent over drying, fans should not be run when the relative humidity of the cooling air is below 60%. If drying still needs to occur for the majority of the peanuts in the warehouse, cooling air with slightly lower, e.g. 50%, relative humidity could be used for short periods of time. Running the fans when the relative humidity is greater than 75% increases the risk of wetting peanuts allowing for potential mold growth. If the aeration system is forcing air up through the peanuts, it will also increase the risk of condensation on the roof.

The second reason for aeration is to cool the peanuts. Therefore, run fans when the air temperature is cooler than the peanut temperature. These conditions would typically occur early in the evening, during the night, and early morning. However, during a portion of these times, the relative humidity may be unacceptable.

Automated aeration control systems are available and highly recommended because they are more reliable than manual operation.

Once the warehouse is loaded, then fan operation will continue until the peanut temperature has cooled sufficiently. This will usually occur within about 30 days. However, the cooler the peanuts the more stable the moisture and quality characteristics become. Once cooled, the peanut mass will maintain its temperature and will warm very slowly if the aeration system is not run. Again, temperature and humidity sensors in the warehouse will be very useful in managing the aeration systems.

Chapter

4

IV. ELEVATORS

Elevator Spouting

A 45-degree slope is necessary to allow for adequate flow of farmer stock peanuts, especially peanuts containing foreign material or high moisture, or if the spouting is rusty. However, a 45-degree slope over a long distance can result in too much velocity, causing damage to the peanuts. Deadheads and slow downs should be installed every 50 feet to slow down the flow of peanuts.

There are situations where damage can be lessened by reducing the slope to 38 to 40 degrees. To prevent clogging, caution must be exercised to prevent rusty spouting and handling of peanuts with high moisture or foreign material. Peanuts with low moisture and low foreign material can be damaged in spouts with 45-degree slope.

- Deadheads should always be installed when the angle of spouting is greater than 45 degrees, even for short distances. Deadheads should also be installed at the end of elevator spouts to slow velocity before exiting the spout.

- Deadheads should be accessible to personnel for cleaning. Platforms should be installed if necessary for safe access. Deadheads should be designed to allow for opening and cleaning.

Elevator Gate Openings

The width of the gate opening feeding the elevator should be 2 inches less than the width of the elevator cup. The elevator cup should extend one inch beyond the edge of the gate opening on each side. This will reduce spillage into the boot of the elevator where severe damage to the peanuts can occur.

Elevator Speed

Improper elevator speed results in tremendous financial losses to the peanut industry. The creation of loose-shelled kernels not only greatly reduces the value of farmer stock peanuts, but the threat of insect infestation is greatly increased.

Elevator handling of farmer stock peanuts to minimize mechanical damage should be considered when designing the elevator. Usual concern is only with the speed of the elevator belt. However, this is only one factor to consider minimizing mechanical damage.

Damage occurs when the centrifugal force of the peanuts exiting the elevator exceeds the force necessary to damage the peanut. The factors involved in calculating the centrifugal force are:

1. Weight of the Peanut Pod
2. Belt Speed
3. Head Pulley Diameter
4. Size of the Buckets

Calculating the Centrifugal Force Exerted by an Elevator

A formula can be used to calculate the damage resulting from changes in any of the above factors. Slay and Hutchinson determined that approximately 60% of the total damage inflicted on farmers stock peanuts by bucket elevators occurred at belt speeds above 200 feet per minute (fpm). They used an elevator with a head pulley diameter of 8 inches and buckets measuring 9 inches by 5.5 inches with approximately a 5.5-inch projection in their study.

The following formula is used to determine the force imparted to the peanuts in their 200-fpm belt speed:

$$S = \frac{WV^2}{3600\,g\,r} \qquad \textit{Equation \#1}$$

Where:

Where:	S	=	centrifugal force acting radially, lb.
	W	=	weight of elemental mass, lb.
	v	=	tangential velocity, fpm
	g	=	acceleration of gravity, 32.2 ft/s
	r	=	effective radius, ft.

The effective radius, r, is approximately equal to one-half the diameter of the head pulley plus one-half the depth of the bucket. For a head pulley diameter of 8 inches and the bucket size used by Slay and Hutchinson (9" x 5 & 1/2"), the effective radius would be 6 & ¾" (0.5625 ft.). The weight of a two-seeded pod for runner peanuts is approximately 0.005 lb. Substituting the appropriate values (W=0.005 lb.; V=200 fpm; g=32.2 ft/s; r=0.5625 ft) in equation #1, we obtain the following:

$$\mathbf{S = \frac{0.005\,(200)^2}{3600(32.2)(0.5625)}}$$

$$\mathbf{S = 0.003067}$$

$$\mathbf{S = 0.003}$$

Calculating the Safe Speed of an Elevator

Rearranging equation (1) and solving for the velocity, V, results in an expression for the velocity in terms of the centrifugal force, S, and effective radius, r. Substituting (S=0.003), and solving the first equation for the velocity in terms of the effective radius, we get:

$$\mathbf{V = \sqrt{\frac{3600\,(32.2)\,(r)\,(0.003)}{0.005}}}$$

$$\mathbf{V = 263.727\sqrt{r}}$$

$$\mathbf{V = 264\sqrt{r}}$$

$$\mathbf{V = 264\sqrt{.5625}}$$

$$\mathbf{V = (2.64)\,(.75)}$$

$$\mathbf{V = 198\ fpm}$$

Using equation (2) and assuming an average of 6 in. for the bucket projection, the following rpm's were determined for various head pulley diameters that resulted in the same centrifugal force imparted by the 8" pulley used in the study by Slay and Hutchinson. (***See Table 3, below***).

Table 3. Safe elevator speeds and head pulley rpm based on head pulley diameter.

Head Pulley Diameter (in)	Effective Radius, r (ft)	Velocity (fpm)	Head Pulley Speed (rpm)
8	0.58	203	97
10	0.67	217	83
12	0.75	230	73
14	0.83	240	66
16	0.92	253	66
18	1.00	264	61
20	1.08	275	52
22	1.17	285	50
24	1.25	296	47
26	1.33	304	45
28	1.42	314	43
30	1.50	322	41
32	1.58	333	40
34	1.67	341	38
36	1.75	349	37

Note the above belt velocity (fpm) and head pulley speed (rpm) are not absolute values since the peanut weight and the effective radius (r) have been eliminated. All speeds have been rounded to the nearest whole number. These velocities should be used only as guidelines. If belt speeds are with approximately 10%, the damage to the peanuts due to excessive speeds will be minimized.

The formula to calculate the centrifugal force was obtained from ***Agricultural Process Engineering*** by S. M. Henderson and R. L. Perry while the 200 fpm elevator speed was obtained from ***Handling Peanuts with Bucket Elevators – Rates of Conveying and Mechanical Damage*** by Whit O. Slay and Reed S. Hutchinson.

By using the formula above, if centrifugal force is too high, the elevator needs to be adjusted to lower the centrifugal force. Example: Increased diameter of head pulley decreases speed of belt.

Elevator Speeds Exceeding 200 FPM

Elevator speeds can be greater than 200 fpm, as long as the centrifugal force exerted on the peanuts does not exceed .003. This section illustrates that elevator speeds can greatly exceed 200 fpm without causing damage.

In the first calculation, S = 0.003067 in a scenario with an elevator belt speed of 200 fpm, peanuts with a pod weight of .005 lb., a head pulley of 8 inches, and bucket size of 9" wide x 5 ½" deep. S of 0.003067 should not be exceeded to keep damage to a minimum. The formula can be used to calculate S when any factor changes.

In a setup where the head pulley diameter is changed to 30 inches, bucket size remains the same, and belt speed remains at 200 fpm, S can be calculated as follows:

r = (30" head pulley x .5) + (5.5" bucket depth x .5)

r = 17.75" (1.479 ft.)

$$S = \frac{.005\ (200)}{3600\ (32.2)\ (1.479)}$$

$$S = \frac{200}{171{,}446}$$

$$S = .0011665$$

S is well below the critical point of .003067 where damage begins. How much can the belt speed be increased?

To solve for V, belt speed, the formula is rearranged with the new r of 1.479.

$$V = \sqrt{\frac{(3600)\ (32.2)\ (.003067)}{.005}}\ \sqrt{(1.479)}$$

$$V = (266.66)\ (1.216)$$

$$V = 324 \text{ fpm}$$

The elevator speed can be set at 324 fpm before S exceeds the critical point of .003067.

Calculating the Speed of an Existing Elevator

To obtain elevator belt speed, the following will be needed:

1. Head Pulley Diameter
2. RPM of Motor
3. Ratio of Reduction Box
4. Sprocket or Sheave Size on Head Pulley
5. Sprocket or Sheave Size on Motor

Example:

- 24" head pulley x 3.1416 (pi) = 75.40" (6.28 ft.)
- 1750 motor RPM / 9.2 reduction box ratio = 190 output RPM
- 60 teeth on head pulley / 17 teeth on motor = 3.53 ratio
- 190 / 3.53 = 53.82 head pulley RPM
- 53.82 RPM x 6.28 ft. = 338 fpm

Chapter

5

V. WAREHOUSE MAINTENANCE

General Cleanup

Proper sanitation is a year-round effort.

Prior to the storage season, the warehouseman should:

1. Thoroughly clean each building or bin included in the warehouse and surrounding outside areas.
2. Clean trash and oil remains or spillage of peanuts, grain, feed, or other prior contents. Pay particular attention to areas underneath loading platforms and underneath each building raised off the ground.
3. Clean out elevators, conveyors, elevator or conveyor wells, and any other location where old peanuts and refuse have collected.
4. Clean the walls, windowsills, rafters, beams, ledges, and other parts of the building where old peanuts, grain, dust, dirt, webs, and other debris can lodge.
5. Remove loose accumulations from cracks in wooden floors. If available, use a vacuum cleaner in this operation to prevent spreading filth and contaminants.
6. All refuse collected in these operations should be removed from the premises and discarded.
7. The six steps above should be carried on continuously as part of the regular housekeeping routine. Particular care should be exercised during and immediately following each delivery of peanuts from the warehouse and as often as practical during peanut receiving operations.
8. All elevator pits and conveyors should be checked following their use to see that all peanuts and related material are cleaned out.
9. Catwalks should continuously be kept clean and free of debris, trash, etc.
10. Keep all grass, weeds, trash and other items cleared to a distance of at least six feet away from the outside walls of the warehouse. All facility grounds should be mowed and kept in a sanitary condition.

11. A responsible employee conducting a regular inspection program should verify the foregoing conditions.

Insect, Rodent and Bird Control

Each facility should develop an IPM (integrated pest management) program to control insects, rodents and birds in warehouses. These programs have been sanctioned by regulatory agencies. Information is available from Colleges of Agriculture at land grant universities. An intensive insect inspection program of warehouses is essential. Maps should list locations of bait boxes around warehouses.

Contamination Prevention

Products that affect the storage life, quality, flavor, and safety of peanuts should not be stored in the same room or compartment with peanuts. For example, fertilizer, pesticides, gasoline or lubricating oils, and certain fruits and vegetables are objectionable.

Extreme caution should be taken with the use and handling of rodenticides to prevent contamination of the product. Pellets or any type of rodenticide that can be transported by rodents should be avoided.

Glass is a very serious contaminant of peanuts. Use of glass containers should be avoided and all light bulbs should be shatterproof.

Transportation or warehouse loading equipment should not be used for other commodities. If it is necessary to use for other commodities, equipment should be thoroughly cleaned and inspected before using for peanuts.

Good housekeeping practices should be in place to prevent contamination. Use of tobacco products should be avoided. Measures should be in place to prevent insects, rodents, and birds coming in contact with peanuts.

Mold Prevention

1. The peanut drying practices enumerated in the voluntary *Code of Good Peanut Drying Practices* should be followed.
2. All moisture collecting in elevator pits should be removed immediately following rains or seepage. All peanut buying points should be equipped with sump pumps or other type pumps to remove water from elevator pits.
3. Should loads of farmer stock become wet from rainfall prior to unloading, they should be examined and re-dried if necessary prior to dumping. All wet peanuts and trash should be removed from the premises and discarded. Such peanuts should not be placed with other peanuts either on trucks or in warehouses.
4. All conveyor buckets and belts should be checked, cleaned and dried following rain. They should be checked often for old peanuts, foreign material, etc., including during the off-season when such equipment is not being used. Caution should be taken to ensure that water is removed from conveyor cups. Immediately prior to load-out, elevator buckets and elevator

pits should be re-checked to make certain they are completely free of moisture, old peanuts, refuse and trash.

5. Peanuts in storage should be routinely checked for evidence of mold. If mold is evident, the reason for mold formation should be immediately determined and corrected. Moldy peanuts should be removed from edible use.
6. Warehousemen should check regularly for leaks in roofs, walls and around doors and ventilators. Such an inspection should also be made while rain is falling on the building.
7. All down spouts into buildings should be periodically checked to see that their points of spout entry are securely closed and sealed to prevent entry of moisture during and following rain.
8. Ventilation systems should be adequate. (See building Chapter 3 – Ventilation and Aeration.)
9. Moisture in any form other than surface spray applications for insect control should not be applied to peanuts in storage.
10. Special attention should be given to proper ventilation of tank type storage structures. Regular checks for condensation are extremely important.
11. Handling equipment should be checked regularly to see that it is properly adjusted to prevent the shelling, cracking or damaging of peanut hulls.

12. Peanut peaks should be knocked down to allow heat and moisture to exit the pile.

Loading Out Precautions

1. Exterior loading out of peanuts from the warehouse should cease during periods of precipitation.
2. Peanuts spilling in areas of loading operation should be immediately placed on truck or back in warehouse before such peanuts are damaged or begin to collect moisture. If this is not done, such peanuts should be completely removed from the premises and discarded.
3. Peanuts in transit should be protected from weather.
4. All trucks should be carefully inspected for undesirable odors or material residues that might affect flavor and quality of peanuts. They should be checked for weatherproofness and should be swept clean prior to use. Vehicles that are objectionable from these standpoints should be rejected.
5. Temporary storage facilities should be adequate to protect peanuts utilizing the standards in Chapter 5 of this document.:
6. Peanuts in drying trailers awaiting dumping or transport should be protected from inclement weather by shed, roof, tarp, or other cover.
7. When unloading or emptying the warehouse of peanuts, particular attention should be paid to moldy, wet, or hot spots that may have previously gone unnoticed. These peanuts should be separated from the balance of the good farmer stock and discarded.

8. When loading peanuts out of a warehouse, buying point operators should avoid overloading trucks, causing spillage.
9. Load out crew should use proper Personal Protective Equipment.

Summary

The warehouse must be constructed and maintained to prevent water leakage and moisture build-up but to allow adequate ventilation and air circulation through the peanuts.

- A good housekeeping program must be prepared, written, posted and followed at all times.
- An IPM program must be utilized.
- To maintain quality and food safety of farmer stock peanuts, the following should be practiced:
    a. Proper peanut drying techniques
    b. Regular building and equipment inspections
    c. Proper pesticide spray applications
    d. Effective ventilation techniques
    e. Regular peanut quality inspections
- A safe unloading program must be followed in minimize damage and handling.
- Good management practices should be followed at all farmer stock warehouses (American Peanut Council, 2009).

References

American Peanut Council. 2009. Good Management Practices For Farmer Stock Storage And Handling. [Accessed Mar 07, 2013]. http://www.peanutsusa.com/Information-For/Shellers-2

ASAE. 2002. D272.3 - Resistance to Airflow of Grains, Seeds, Other Agricultural Materials and Perforated Sheets. ASAE Standards: pp. 566-572.

Blankenship, P. D., G. M. Grice, C. L. Butts, M. C. Lamb, T. H. Sanders, B. W. Horn, and J. W. Dorner. 2000. Effects of storage environment on farmers stock peanut grade factors in an aerated warehouse in west Texas. Peanut Sci. 27:56-63.

Butts, C. L., J. W. Dorner, S. L. Brown, and F. H. Arthur. 2006. Aerating farmer stock peanut storage in the southeastern U.S. Trans. ASABE. 49(2):457-465.

Butts, C. L. 2004. Warehouse Ventilation Calculator. USDA, ARS, National Peanut Research Laboratory, [Accessed May 8 2009]. http://www.ars.usda.gov/Services/docs.htm?docid=7338.

Butts, C. L., and J. S. Smith, Jr. 1995. Shrinkage of farmers stock peanuts during storage. Peanut Sci. 22:33-41.

Henderson, S. M. and R. L. Perry. 1976. Agricultural Process Engineering, 3rd Edition. AVI Publishing Co., Inc. Westport, CT.

Slay, W. O. and Reed S. Hutchinson. 1973. Handling Peanuts with Bucket Elevators – Rates of Conveying and Mechanical Damage. U S Department of Agriculture, Agricultural Research Service, ARS-S-17. 15 pp.

Wilcut, M. H., W. D. Mayfield, and T. D. Valco. 2008. Cottonseed Storage. Cotton Inc. [Accessed May 8, 2009]. http://www.cottoninc.com/Cottonseed/CottonseedStorage.

Young, J. H., N. K. Person, J. O. Donald, and W. D. Mayfield. 1982. Harvesting, curing, and energy utilization. In Peanut Science and Technology, ed. H. E. Pattee and C. T. Young. Yoakum, TX: APRES.

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