Chapter 15

ADVANCES IN PEANUT HANDLING, SHELLING AND STORAGE FROM FARMER STOCK TO PROCESSING

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INTRODUCTION

Raw peanuts are living seeds and therefore a semi-perishable crop. They are subject to quality loss during handling and storage through microbial activity; mechanical damage; bird, insect, and rodent infestation; physical changes (shrink, weight loss, etc.); biochemical changes (flavor, rancidity, dormancy, germination, etc.); and absorption of odors and chemicals. Milling quality and shelling outturns are greatly affected by many of the above quality losses.

STORAGE OF FARMERS STOCK PEANUTS

"Farmers stock peanuts" means picked and threshed peanuts which have not been shelled, crushed, cleaned, or otherwise changed (except for removal of foreign material, loose shelled kernels, and excess moisture) from the form in which customarily marketed by producers (Peanut Administrative Committee, 1993). There are approximately 700,000 ha of peanuts presently harvested in the U.S. each year with an average yield of approximately 2.8 t/ha. Peanuts are grown and stored mainly in the Southeast (Alabama, Florida, and Georgia), Southwest (New Mexico, Oklahoma, and Texas), and the V-C area (Virginia and North Carolina). Most farmers stock peanuts must be stored in some type of structure for a period as short as a week to as long as 10 months. Only a small amount of peanuts is transferred directly from the buying point to the shelling plant during harvest. Farmers stock peanuts placed in storage are usually dormant and the germ respires at a low rate.

Woodroof (1973) noted that clean peanuts can be stored for several years when subjected to suitable storage environments. The primary aim in storage of most agricultural products is to maintain quality. Decreases in temperature and moisture in the storage environment generally reduce the rate of product quality deterioration. However, high losses in milling quality result when peanut kernels are dried below 7% wet basis (w.b.) kernel moisture content or if kernel temperature is below 7 C when the peanuts are shelled (Beasley and Dickens, 1963; McIntosh and Davidson, 1971). Thus, the best storage conditions for normal dry-bulk storage of unshelled peanuts are about 7.5% kernel moisture content w.b. and 10 C. If these conditions are maintained, good quality farmers stock peanuts can be stored without significant loss in quality for a 10-month storage season (Davidson *et al.*, 1982).

Most farmers stock peanuts are stored in flat-type storages (height of storage is less than the width or diameter). However, during seasons with bumper crops, they can be found stored in almost any type of structure that will provide weather protection. Although flat-type storage is the most common, sizeable amounts of peanuts are stored in round metal bins and concrete silos which are common to the grain industry.

There are basically three types of flat-storage warehouses. The conventional (Fig. 1) with a 37 (9/12) or 45 (12/12) degree roof slope, the conventional with doghouse (Fig. 2) and a 37 degree roof slope, and the muscogee with doghouse (Fig. 3) with a 37 degree roof slope. Typical steel bin storage and concrete silo storage facilities are shown in Figs. 4 and 5, respectively.

The muscogee type warehouse utilizes lighter framework than the conventional warehouse because (a) it does not have as great end-wall pressures and (b) the horizontal conveyor is not as long as in the conventional warehouse. Methods of ventilating the muscogee are more limited than other warehouse types and these will be discussed in detail under **Ventilating Systems.**

The circular tanks or bins are identical to those used in the grain industry. They are erected on a circular reinforced concrete slab with a vapor barrier. The walls generally consist of formed corrugated galvanized steel bands that are bolted or riveted together on site, and usually form a self-supporting wall

Fig. 1. Mechanically ventilated conventional flat-type storage warehouse for farmers stock peanuts with a 45 degree roof slope (12/12).

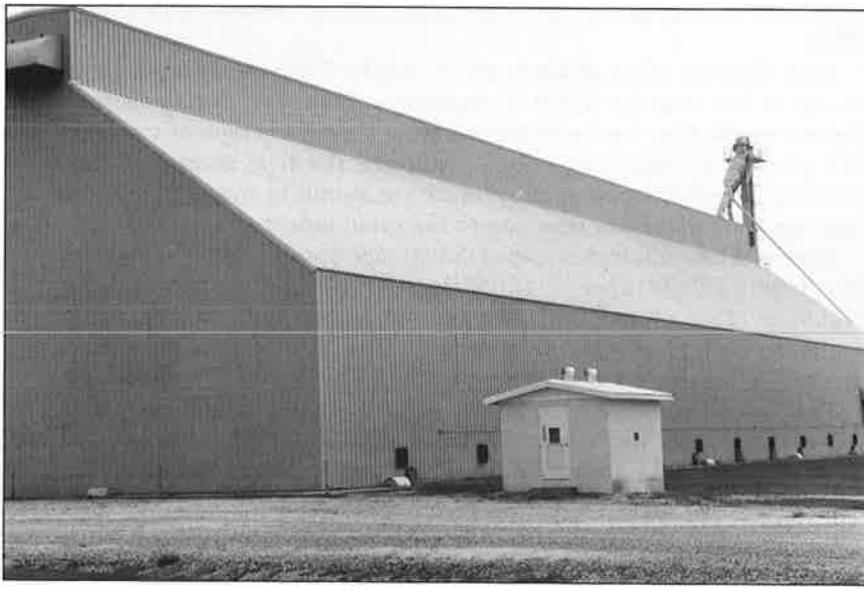

Fig. 2. Conventional flat-type storage warehouse for farmers stock with "doghouse" structure on top and a 37 degree roof slope (9/12).

Fig. 3. Muscogee flat-type storage warehouse for farmers stock peanuts.

Fig. 4. Steel bins used to store farmers stock peanuts.

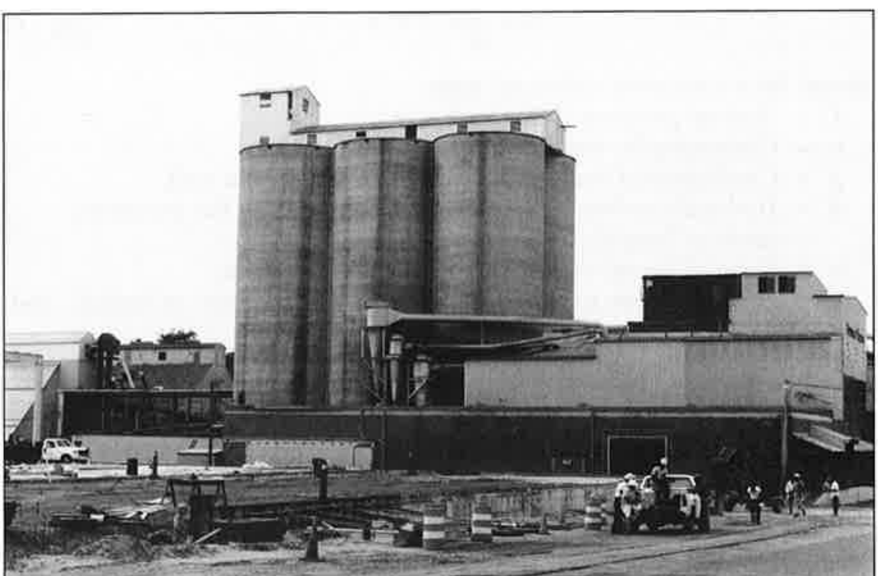

Fig. 5. Concrete silos used to store farmers stock peanuts.

without additional steel columns and girts.

Another version of the flat storage is tilt-up construction where the concrete sidewalls are formed in sections with reinforcing steel in place and the concrete is poured using the floor as the form bottom. When the panels are cured, they are raised to the vertical position and secured in place with mastic sealing the joints between the panels.

A semi-underground warehouse model with concrete walls and floor has been constructed and tested against conventional warehouse models (Smith, 1986; Smith and Sanders, 1987). There has been interest in building a full sized warehouse of this design but none are known to have been built.

Flat-type peanut warehouse design has been based mainly on the procedures used to design grain storages (Stahl, 1950) as well as the design for circular type storages (ASAE, 1993b). The basic considerations for design are static peanut pressures, wind, snow, and dead loads (conveyor, catwalk, tripper, etc.); allowable stresses of the building materials; and the dynamic pressures (loading and unloading, starting and running loaded conveyor and tripper, etc.). Since peanut warehouses have been designed using grain storage structure procedures, peanuts are considered to be semifluid. Storage structures have been generally classified as shallow bins or deep bins (Stewart and Britton, 1973). A shallow bin has a depth less than the least lateral dimension of the bin while a deep bin has a depth greater than the least lateral dimensions of the bin. Static pressure load on the warehouse wall is generally calculated with Janssen's equation based on the deep bin as follows:

$$L = \frac{wR}{\mu'}\left(1 - e^{\frac{-k\mu' h}{R}}\right) \qquad \text{Eq. (1)}$$

where, for a consistent system of units:

- L = Lateral pressure (force/unit area),
- w = Grain specific weight (weight/unit volume),
- μ' = Coefficient of friction between peanuts and bin wall,
- R = Hydraulic radius: Area of bin floor divided by the perimeter (units of length),
- k = Ratio of lateral to vertical pressures in the grain,
- h = Depth of grain to point under consideration (units of length), and
- e = 2.718

Samples (1966) determined μ' values for peanuts contacting steel, plywood, and concrete to be approximately 0.45, 0.56, and 0.55, respectively. Others have developed theories and resulting equations to predict pressure in deep bins, but Janssen's equation is the most widely used in bin design. Coulomb and Rankine (cited by Dunham, 1953; Stewart and Britton, 1973) developed theories and equations to determine pressure against retaining walls which should apply to shallow bins or most flat type storages. Dynamic pressures due to loading and unloading a bin are often referred to as overpressures and are usually determined by multiplying the static load by 1.4 (ASAE, 1993b). Snow and wind loads for various locations can be obtained from ASAE

(1993a). The mean bulk densities of leading varieties of farmers stock peanuts from measurements made at the National Peanut Research Laboratory are listed in Table 1. Bulk densities may increase by an estimated 10% due to typical warehouse loading (Davidson *et al.*, 1982).

The typical flat storage is an uninsulated steel building with a sheet metal covering that is 24.4 m wide with eave heights of 3.7 to 7.3 m and length from 24.4 to 91.4 m in multiples of 6.1 m. Roof slopes are usually 37 (9/12) or 45 (12/12) degrees with most newer warehouses having the 45 degree roof. Most are single-wall constructed; that is, the sheet metal is fastened to the exterior of "Z"-bar girts which are attached to the exterior of the supporting columns. In most instances, 26-gauge sheet metal is used. Some warehouses have the sheet metal attached to both sides of the girts and are referred to as double-wall warehouses. The inside sheet metal makes it easier to clean with water or air after warehouse unloading, as long as the metal covering has not been punctured. If holes have been made through the metal, peanut material gets between the inside and outside wall and this material is practically impossible to remove without removing the sheet metal. This material in the wall creates an attractant for insects and rodents. These warehouses are erected on a poured, reinforced concrete slab with a preferred north-south orientation if the prepared site will accommodate this arrangement. The slab area should be well drained to prevent water from accumulating around the warehouse. A vapor barrier is placed beneath the slab to prevent moisture from penetrating the warehouse floor and wetting the peanuts. Table 2 is a revised table from Davidson *et al.* (1982) listing some desirable features for farmers stock warehouses.

Clean farmers stock peanuts form a 33 degree angle of repose (Davidson *et al.*, 1982). For good air movement through the peanut mass, the warehouse should be filled to a minimum distance of 0.3 m between the peanut mass and the roof at the eaves. With a 9/12 roof slope and a 33 degree angle of repose

Table 1. Bulk density of farmers stock peanuts.

Cultivar	Normal range[a]		Average	
	kg/m^3	lbs/ft^3	kg/m^3	lbs/ft^3
NC 7[b]	214-221	13.38-13.80	218	13.64
Florunner[c]	304-344	18.38-21.48	327	20.41
Starr[d]	288-336	17.98-20.98	316	19.73

[a]Values were obtained by measuring the weight and volume of peanuts poured into a 30.48 x 30.48 x 60.95-cm container (loose fill).

[b]NC 7 is the most widely grown cultivar of the virginia-type peanuts.

[c]Florunner is the most widely grown cultivar of the runner-type peanuts.

[d]Starr is one of the most widely grown cultivars of the spanish- type peanuts.

Table 2. Some desirable design features for farmers stock warehouses.

Component	Desirable characteristics	Function
Site	Clean, elevated, graded, well drained	To prevent water entry and eliminate insect-rodent haven
Building orientation	North and south	To provide uniform sun exposure and minimize condensation
Approach and exit to dump pit and doors	Concrete or asphalt paving sloped away from dump pit and doors	To prevent water and additional foreign material from entering the pit and warehouse
Foundation and floor	Steel reinforced concrete with vapor barrier underneath 15.24 cm minimum thick floor	To support the weight of the building, peanuts, the loading unloading vehicles and to maintain a dry floor
Exterior walls and roof	Steel or concrete adequately designed for integrity and strength with no crevices or cracks and reflective exterior finish or coating	To withstand peanut, wind, ice and snow loads, while preventing leaks, entry by rodents, insects, and birds and to reflect solar radiation
Interior	Open floor space with no beams or obstructions. No partitions if mechanically ventilated	To provide easy removal of peanuts and unrestricted overspace ventilation
Loading equipment	Dump pit, elevator, and overhead conveyor or mobile conveyor loader	To provide for rapid but gentle loading at minimum cost
Unloading equipment	Tunnel with under floor conveyor, draw ports and front end loader or mobile conveyor unloader	To provide for rapid but gentle unloading at minimum cost
Precleaning equipment	Conventional precleaner or belt screen or cleaning equipment on elevator down spouting	To remove foreign materials that restrict air movement during storage and/or that add additional moisture, and/or take up storage space
Ventilation system	Overspace ventilation that will provide at least one air change every 3 min	To remove excess moisture and heat, to minimize condensation and to reduce overspace temperatures
Insect control system	Designed for fumigation, automated surface treatments and/or automated spraying of peanuts as loaded	To provide good insect control with a minimum risk of adding to the moisture problems

for peanuts, the distance left between the peanuts and the roof at the eaves is about 1 m or more because of the tripper location. To fill a warehouse with this roof slope, it is necessary to "cutback" or move the peanuts to the eaves by shovel, requiring a tremendous amount of labor and damages a large amount of peanuts. Eliminating the "cutback" is an advantage of the doghouse warehouse design. The doghouse is usually 2.4 to 3.7 m wide and 2.4 to 3.7 m high at the eaves and extends the length of the warehouse. The roof of the doghouse is usually relatively flat, with enough slope for good water flow. The conveyor, tripper, and catwalk are located in the doghouse. This allows the warehouse to be filled to the roof at the eaves; however, the 0.3 m minimum distance should be maintained between the peanuts and the roof at the eaves for air movement and inspection. Although good warehouse fill can be achieved with the doghouse type warehouse, the distance left between the roof and the peanut mass greatly limits the ability to inspect the peanuts during storage for insect activity and moisture accumulation from condensation or leaks.

HANDLING FARMERS STOCK PEANUTS

Increasing financial demands due to quality loss during all phases of peanut processing are requiring close scrutiny of any damaging factors in the system. Current handling equipment for peanut warehouses is causing or contributing to peanut quality loss or damage (Slay and Hutchison, 1973; Dickens and Hutchison, 1976; Davidson *et al.*, 1982).

Equipment for loading and unloading peanuts from warehouses usually consists of two separate systems. Warehouse loading commonly employs the use of a hoist or hydraulic lift to empty peanuts from a transporting vehicle into a dump pit. A bucket elevator then lifts the peanuts to a horizontal belt conveyor with mobile tripper which distributes the peanuts in the warehouse (Fig. 6) (Davidson *et al.*, 1982).

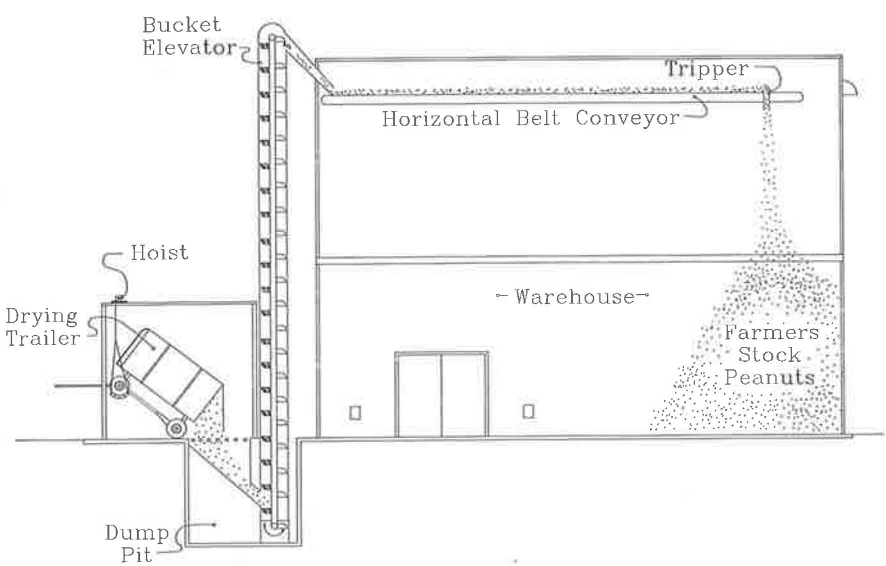

Fig. 6. Schematic of typical loading system.

The elevator is usually located at one end of the warehouse. The peanuts are elevated and discharged onto the horizontal belt conveyor located in the apex of the warehouse roof and runs approximately the length of the warehouse. This belt conveyor is sized to handle slightly more peanuts than the elevator can deliver when the conveyor is operated at a belt speed not in excess of 61 m/min to prevent excessive peanut damage when discharged from the belt. The tripper is a mechanism through which the horizontal conveyor passes to discharge the peanuts at the desired location in the warehouse. A catwalk is usually located on one side of the conveyor and extends the length of the warehouse. The tripper is usually manually positioned although some can be motor driven to the desired point of discharge. The conveyor and catwalk system must be located a minimum distance below the roof ridge to allow the tripper adequate clearance to pass beneath the structural steel framework supporting the roof. This structural steel also supports the tripper track, catwalk, and conveyor system with steel beams attached to the structural steel to form the base of an isosceles triangle at each structural steel location (usually 6.1 m).

Slay and Hutchison (1973) determined that approximately 60% of the damage done to farmers stock peanuts when handled by a bucket elevator occurred at belt speeds above 61 m/min. Their results were based on an elevator with approximately 22- by 14-cm buckets spaced 18 cm apart and a 20.3-cm diameter head pulley. The centrifugal force, S, acting radially on the peanut can be determined by the following equation from Henderson and Perry (1976).

$$S = WV^2/(3600\ gr) \qquad \text{Eq. (2)}$$

where: W = Weight of elemental mass, kg,
V = Tangential velocity, m/min,
g = Acceleration of gravity, m/sec^2, and
r = Effective radius, m.

The elevator belt speed and head pulley revolutions per min (rpm) can be calculated for different diameter head pulleys to produce the same approximate force on the peanut pods that was produced in the study by Slay and Hutchison (1973). An average size two-seeded runner-type peanut pod weighs approximately 2.3 g. Substituting the 61 m/min belt velocity and the pod weight in Eq. (2):

$$S = (0.0023)\ (61)^2/(3600)\ (9.8)(0.1715)$$

$$S \simeq 0.0014\ \text{kg}$$

Solving Eq. (2) for V in terms of r:

$$V = \sqrt{3600grS/W}$$

$$V = \sqrt{3600(9.8)(0.0014)r/0.0023}$$

$$V = 146.5\sqrt{r} \qquad \text{Eq. (3)}$$

Using Eq. 3 the belt velocity can be determined for the effective radius of various head pulley and bucket configurations. Results from Eq. 3 were used to develop Table 3 which gives the elevator belt velocity and head pulley rpm that will produce the approximate force that Slay and Hutchison (1973) experienced when they determined the maximum belt velocity for acceptable damage to farmers stock peanuts by bucket elevators. However, for minimal damage, elevators should not be operated any faster than necessary to properly empty the buckets.

The most common unloading system consists of a front-end loader and an inclined conveyor (Fig. 7). In this procedure, the bucket of the front-end loader is lowered against the warehouse floor and forced into the pile thus filling the bucket. The loader is then backed out of the pile and maneuvered to dump the peanuts into a large hopper located over the low end of the conveyor. The peanuts are gravity fed onto the conveyor and elevated until they are dumped onto a wagon or truck positioned under the elevated end of the conveyor.

Although mechanically proficient, the conventional loading and unloading systems have some disadvantages. Foremost, dirt from the peanuts concentrates immediately underneath the conveyor in the warehouse during loading. This concentration of dirt prevents needed moisture movement during storage by inhibiting ventilation for a large part of the warehouse. This

Table 3. Maximum belt velocity recommended for farmers stock peanut elevators[a].

Head pulley diameter	Head Pulley	Belt velocity
m	RPM	m/min
0.203	97.2	61.7
0.254	82.7	66.0
0.305	73.1	70.0
0.356	66.0	73.8
0.406	60.7	77.4
0.457	56.3	80.8
0.508	52.8	84.2
0.559	49.7	87.3
0.610	47.2	90.4
0.660	45.0	93.3
0.711	43.1	96.2
0.762	41.4	99.0
0.813	39.9	101.8
0.864	38.5	104.4
0.914	37.3	107.0

[a]Elevator buckets assumed to be 15.2 cm wide. If bucket width differs, add 1/2 bucket width to head pulley radius to determined effective radius for calculations of belt velocity and head pulley rpm.

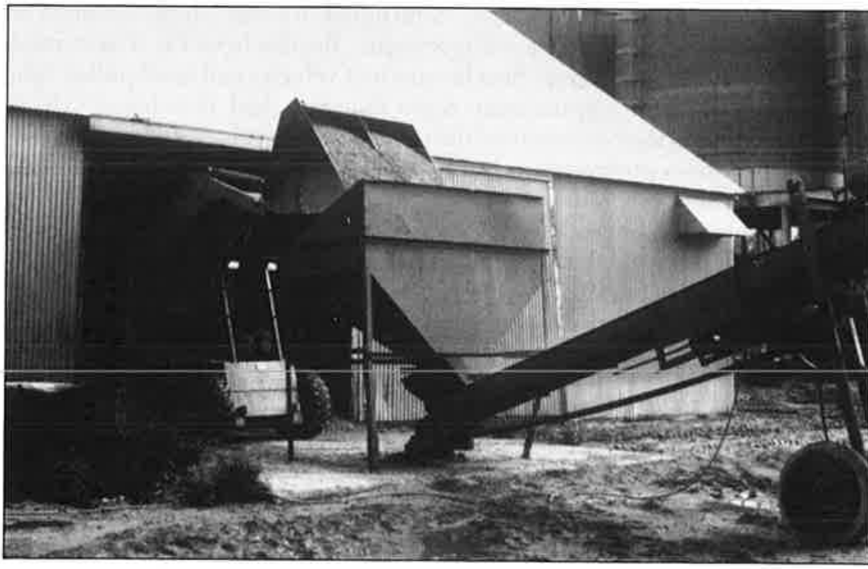

Fig. 7. Front-end loader and inclined belt conveyor.

restriction of air movement through the peanuts causes general peanut quality deterioration and increases risks for aflatoxin contamination during storage. Peanuts are also mechanically damaged by the loading and unloading components of warehouse handling systems.

Bucket elevators used in warehouse loading systems shell or generate loose-shelled kernels (LSK) during operation (Slay and Hutchison, 1973). Shelling peanuts through handling prior to the shelling operation increases risk of kernels to greater quality deterioration. Peanuts are also damaged or shelled during warehouse loading by the length of drop from the tripper to the warehouse floor or peanut pile. During unloading, peanuts are destroyed or LSK are generated by the front-end loader running over peanuts or pressing peanuts into the peanut pile during bucket loading. During warehouse unloading, the concentrated dirt located underneath the belt conveyor prevents normal peanut flow or causes bridging and subsequently an increase in safety risk for employees operating the unloading equipment.

New Loading and Unloading System

A possible alternative to conventional peanut systems for loading and unloading warehouses has recently been introduced into the peanut industry from equipment originally designed to handle potatoes. The potato handling equipment is currently being evaluated in a limited number of peanut warehouses and by the USDA, ARS, National Peanut Research Laboratory (NPRL). The equipment appears to provide solutions to many of the peanut handling problems discussed above. A photograph of the potato handling equipment is shown in Fig. 8. This equipment consists of several belt conveyors which are mechanically linked to convey peanuts into or out of the

Fig. 8. Potato handling system.

warehouses. Peanuts are collected onto the system by a pickup unit which can be modified to receive peanuts for warehouse loading or unloading. The attachment for warehouse loading of peanuts from drying trailers or hopper bottom trailers is shown in Fig. 9. Mechanical damage to the peanuts is greatly reduced during loading because the bucket elevator is removed from the loading system. Also, the conveyor section discharging peanuts in the warehouse starts near the floor and is elevated as the height of the peanut pile increases, preventing excessive drop. Concentration of dirt in the peanut mass is prevented because the discharge conveyor can be moved during loading to various locations in the warehouse, preventing accumulation of dirt in any specific warehouse location. For warehouse unloading, the loading attachment is removed and the pickup unit is driven into the peanut pile (Fig. 10). Peanuts are then conveyed and loaded into trailers and transported to shelling and processing. Since peanuts flow directly from the pile onto the conveyor during loading, the physical damage to the peanuts normally caused by operating front-end loaders is reduced.

Although not fully evaluated, some preliminary tests have been conducted comparing quality damage during unloading. Loads of peanuts were alternately removed from a warehouse with conventional and potato handling equipment. Peanut samples were then extracted and graded. Smaller percentages of loose shelled kernels and splits from the graded samples suggest a more gentle handling with the potato system (Table 4). The potato equipment provides solutions to some of the problems related to peanut damage caused by conventional loading and unloading systems; however, one disadvantage with the potato equipment is the maximum height that the equipment can load is 6.1-6.7 m. With this limitation, less than two-thirds of

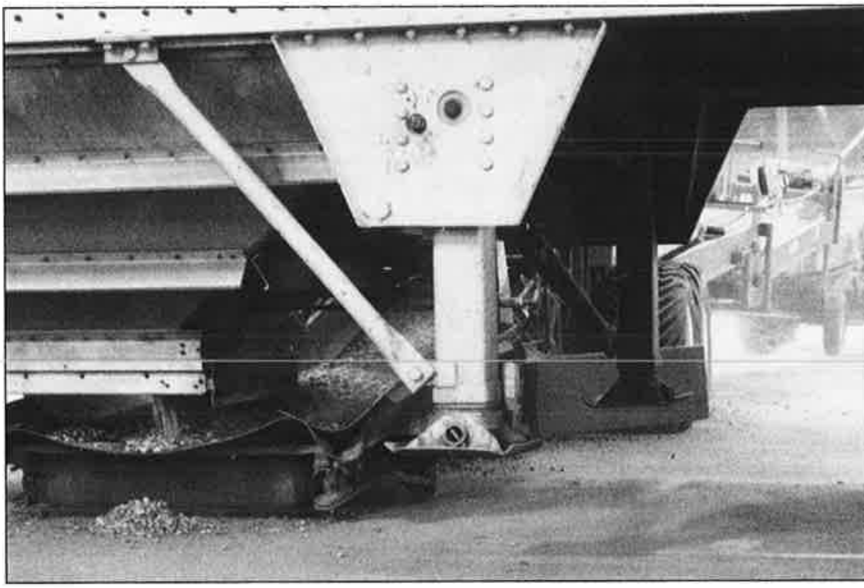

Fig. 9. Attachment for unloading drying trailers or hopper bottom trailers.

Fig. 10. Pickup unit for unloading warehouses.

Table 4. Comparison of official grade, loose shelled kernels and splits from samples form peanuts unloaded from a warehouse with conventional and potato handling systems.

Test lot	Loose shelled kernels: Conventional unloading system	Loose shelled kernels: Potato handling system	Split kernels: Conventional unloading system	Split kernels: Potato handling system
	%	%	%	%
1	7	5	4	6
2	4	5	5	3
3	6	3	6	6
4	5	5	7	7
5	5	4	8	7
6	7	3	5	5
7	5	3	7	4
8	8	5	4	3
Avg	5.9	4.1	5.8	5.1
S.D.	1.4	1.0	1.5	1.6

a typical warehouse can be loaded. However, if considered for use, warehouse designs could be altered to more adequately approach limits of the potato equipment and to approach more conventional steel frame, metal clad structures. Although requiring more floor space for the same tonnage, the height of the structure would be reduced by more than 40% and the size of the steel frame for the warehouse probably could be reduced. Even with the limitation of partial loading of conventional warehouses, the potato equipment should be considered for unloading warehouses because of the reduction in handling damage.

The Belt Screen

One common technique utilized in the separation of peanuts and accompanying materials is screening with vibratory, perforated screens. These screens divide a flow of materials into two components by allowing smaller particles to fall through the perforations as larger materials flow across. Although providing acceptable separations, vibratory screens have the two major disadvantages of (a) relatively low flow rates and (b) occasional clogging or blanking of perforations which prohibit material separation.

Beginning in the early 1980's, development of a new type of screening device (named the "belt screen") was begun by the USDA, ARS, South Atlantic Area (SAA), NPRL, Dawson, Georgia, and the U.S. peanut industry. The belt screen utilizes multiple, parallel belts (double-vee or round), spaced apart at specific distances, which rotate continuously around appropriately positioned sheaves (Fig. 11). Materials with smaller diameters fall through the spaces between the belts as materials are carried across the separation area of the screen (Fig. 12). The belt screen overcomes the two major disadvantages of vibratory screening by (a) providing a much higher flow rate per unit of screen width and (b) avoiding essentially any type of blanking.

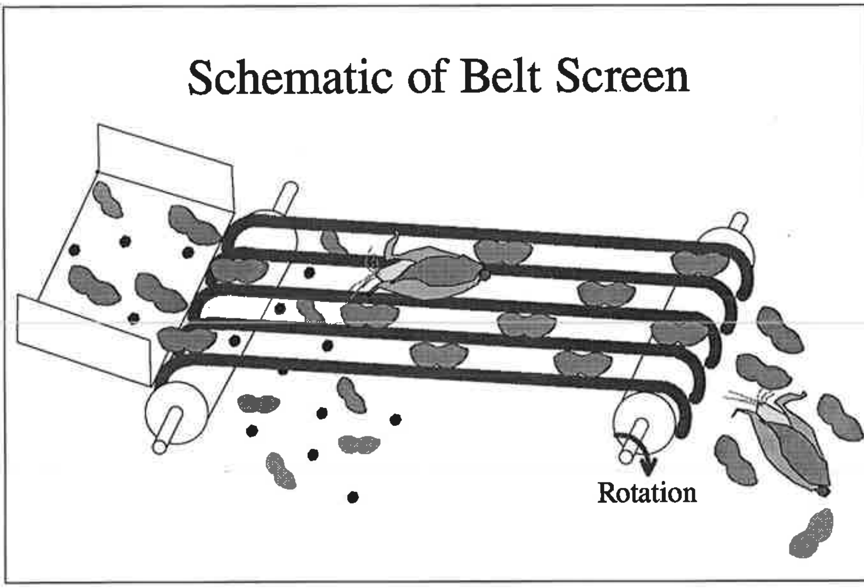

Fig. 11. Belt screen schematic.

Fig. 12. Belt screen separations.

The operation of the belt screen was examined in the "Peanut Quality Enhancement Project" (PQEP) where eight belt screens were installed at peanut buying points with two in the Virginia-Carolina area, four in the Southeast area, and two in the Southwest area (Blankenship *et al.*, 1988). Most types of commercially grown peanuts were screened during the tests. A summary of the peanut types, screen openings, flow rates, and average weight of material separated from the peanuts (THRUS) is presented in Table 5. Average weights of test lots varied from 3.13 to 4.31 t between locations and flow rates varied from 5.68 to 8.9 t/hr/m of screen width. For a market type and screen size, THRUS averaged 3.22 to 13.60% of the original test material.

Commercial versions of the screen have been produced by at least two U.S. equipment manufacturing companies. Belt screens are currently being used as both stationary and portable farmers stock peanut screens for cleaning and sizing unshelled peanuts prior to shelling.

Ventilating Systems

Warehouse ventilation is an absolute necessity if peanut quality is to be maintained during storage. As previously noted, farmers stock peanuts are bought based on a 7% w.b. kernel moisture content; however, they can be legally warehoused up to 10.49% w.b. kernel moisture content. Peanuts this high in moisture content will mold in a few days if not properly ventilated. Diener and Davis (1977) concluded that the optimal conditions for *A. flavus* growth include temperatures from 25 to 35 C, relative humidity of 85% or higher, or peanut kernel moisture contents in excess of 10% w.b. Ventilation is necessary to remove the excess moisture and heat from peanuts being warehoused (Sanders *et al.*, 1981; Smith and Davidson, 1982).

The two types of ventilating systems used in warehouses are mechanical and natural (Smith *et al.*, 1983, 1984). The mechanical system have a fan(s) in one gable and air inlet area in the opposite gable. Prior research and

Table 5. Average initial weights of test lots, peanut flow rates and amounts of THRUS separated by belt screening.

Peanut type	Screen opening		Initial wt of test lots	Flow rate/m of width	Wt	Amount of THRUS separated less foreign material wt		
	mm	in.	t	t/hr	t	%	t	%
Spanish	8.73	22/64	3.45	7.83	0.19	5.51	0.10	2.95
	9.53	24/64[a]	3.83	6.52	0.29	7.57	0.17	4.44
Runner	9.53	24/64	4.31	7.20	0.25	5.80	0.13	3.02
	9.53	24/64	4.17	6.58	0.34	8.15	0.25	6.00
	9.53	24/64	3.91	7.26	0.32	8.18	0.24	6.14
	10.32	26/64	4.00	6.46	0.54	13.50	0.44	11.00
	10.32	26/64	4.23	8.90	0.35	8.27	0.30	7.09
Virginia	9.53	24/64[b]	4.00	6.46	0.13	3.25	0.05	1.25
	10.32	26/64	3.13	5.68	0.15	4.79	0.10	3.19
	11.11	28/64	3.32	7.11	0.24	7.23	0.15	4.52

[a]Data for 13 lots.
[b]Data for 24 lots.

experience (Dickens and Hutchison, 1976; Smith *et al.*, 1985) have shown that an exchange of the overspace air once each 2 to 3 min will generally prevent condensation problems while exhausting excess heat and moisture. Fans are usually located on the end opposite the prevailing wind to take advantage of the wind pressure. The fan capacity is usually determined by using a free air static pressure of approximately 0.64 cm of water and making the selections from fan capacity tables. Earlier mechanical ventilation systems generally had a fixed louver type air inlet area and a gravity type louver over the fan. However, new mechanical ventilating systems are using a 90 degree hooded-type inlet to exclude water from entering the warehouse while providing a relatively obstruction-free inlet covered with hardware cloth, 1.27- x 1.27-cm mesh, to exclude large insects and birds (Fig. 13). The fixed louvers required a much larger opening in the warehouse to obtain the same amount of effective inlet area. The gravity louvers over the fans are being replaced by 45 or 90 degree hoods (Fig. 13) which are virtually maintenance free. The hooded-type inlets are much easier to seal if warehouse fumigation is needed.

Mechanical ventilation requires that the warehouse be as air tight as possible to provide the proper ventilation. The fan shroud and housing should be sealed to prevent air from short circuiting around it. Closure strips need to be correctly fitted along the rakes of the gable containing the fan(s) as well as the ridge and eaves. In reality, there will be some air leaks where the sheet metal laps; however, as much of the air as possible should enter the warehouse from the end opposite the fan to give a good exchange of the overspace air. It is desirable to have as much as 10% of the air to enter the

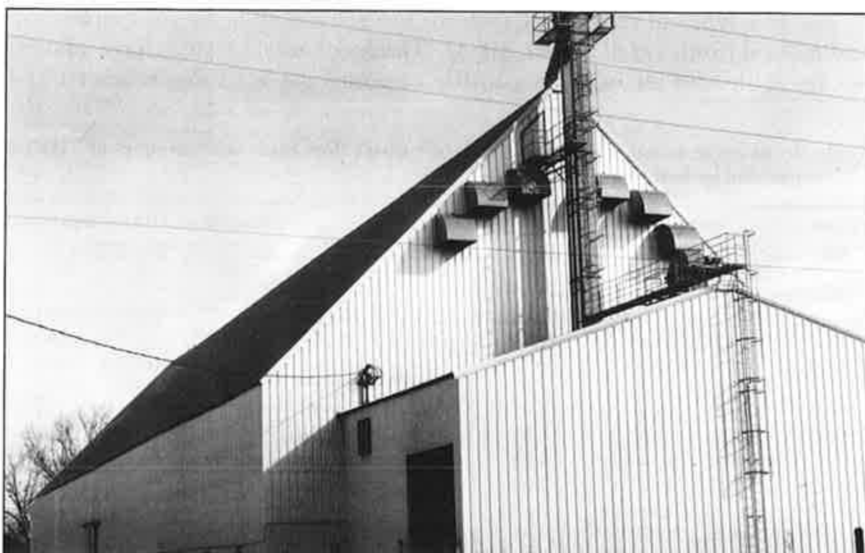

Fig. 13. Typical air inlets in a mechanically ventilated farmers stock peanut warehouse.

warehouse through inlets under the eaves at the inlet end of the warehouse to prevent stagnant air pockets. Partitions in a warehouse cause air flow problems, especially when they extend to the roof from the eaves up to the catwalk level. This often creates dead air areas with condensation and insect problems. As mentioned earlier, the muscogee warehouse design creates additional concerns when planning mechanical ventilation because of the sloping roof on all four sides and the short doghouse on the top. The muscogee design requires a loose fit of the sheet metal under the eaves all around the warehouse for air entry, as well as an inlet in the end of the doghouse opposite the fan, to allow air flow over the entire peanut mass.

A naturally ventilated warehouse (Fig. 14) depends on convection currents, the "chimney or stack effect", for air exchange in the warehouse. Continuous ridge and eave vents are preferred. Many naturally ventilated warehouses have individual roof and eave vents installed that effectively open only half the effective length of the ridge and eave. Esmay and Dixon (1986) stated that the greatest air flow/unit area of total opening is obtained by using inlet and outlet openings of nearly equal areas. Therefore, a typical 24.38 m wide warehouse has a 0.30 m wide ridge exit opening with a 0.15 m wide eave inlet for each eave.

A filled warehouse similarly reacts to the natural surroundings as does an opened top chest-type refrigerator or freezer. That is, if the ambient temperature is at or above the peanut mass temperature, air being drawn into the warehouse by the fan(s) passes through the overspace with little effect on the peanut mass except for the surface peanuts. However, if the air is at a temperature lower than that of the peanuts, the air drops into the peanuts

Fig. 14. Typical naturally ventilated farmer stock peanut warehouse.

displacing the warmer air and cools and possibly lowers the moisture content of the peanuts by replacing the former ambient air (Fig. 15). Virtually the same process takes place in the naturally ventilated warehouse except by naturally occurring convection currents (Fig. 16).

Modification

Roof and sidewall colors effect the storage conditions of peanuts in a number of ways. Most warehouses use galvanized sheet metal for the roofs and sidewalls. The galvanized sheet metal absorbs much of the solar energy falling upon it and transfers it to the peanuts by conduction and radiation, especially in poorly ventilated warehouses. With higher than ambient overspace temperature, the overspace air can contain large amounts of moisture. This warm moist atmosphere encourages insect activity. Condensation usually occurs at night or in the early morning when the roof is cooled to the dew point temperature of the overspace air due to sky radiation (Smith and Davidson, 1982). The condensation collects in sufficient quantities at the purlins to drip. This wets the surface peanuts in the "drip lines" beneath the purlins and increases insect activity and mold growth. It is not uncommon for warehouse wall and roof surface temperatures to be 26 to 32 C above the ambient air temperature on a clear day. Light colors can reflect much of this solar energy. White is especially effective in reducing the surface temperature to levels which seldom exceed 8 C above ambient air. Peanut quality can be maintained for a long period at lower temperatures.

Double roofing or installing a second roof over an existing, deteriorating

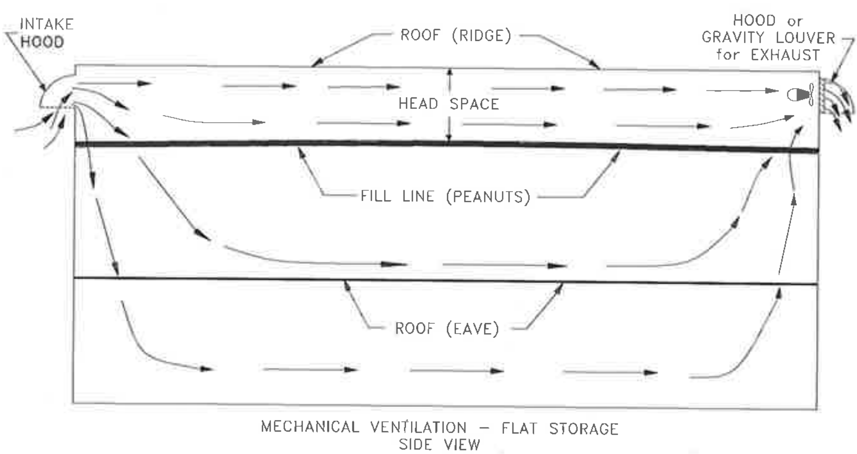

Fig. 15. Schematic of air flow patterns in a typical mechanically ventilated farmers stock peanut warehouse.

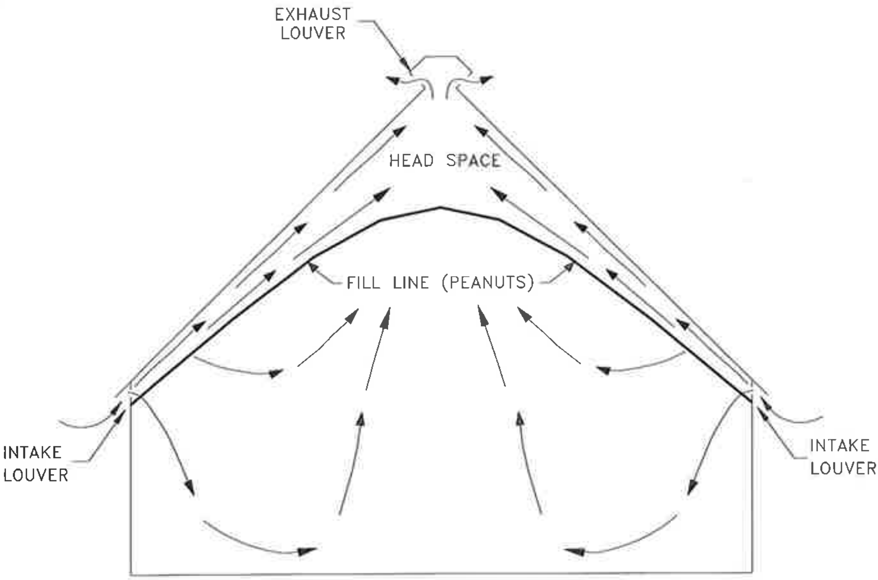

Fig. 16. Schematic of air flow patterns in a typical naturally ventilated farmers stock peanut warehouse.

one has gained popularity in the Southeast in recent years. This procedure provides several advantages over replacing an existing roof. The costs involved in removing and disposing of an existing roof are usually more than the additional materials and labor needed to install the new roof. New purlins or mini-purlins are installed on top of the existing roof at the existing purlin locations. These purlins range from approximately 2.5 to 10 cm deep, thus positioning the new roof approximately 5.5 to 13 cm above the old roof. The air flowing between the roofs serves as an insulator thereby keeping the lower roof nearer the ambient air temperature. At purlin locations, the air flow is restricted to approximately a 3-cm deep passage (the distance between ridge and valley of formed sheet metal). The air velocity between the roofs is relatively low because of the convection flow or "chimney effect". The air velocity increases at each purlin due to decreased open area, but since this restricted distance is very short, the overall effect of the purlins on air flow is very small.

Advantages of the double roof concept include (a) major reduction or elimination of condensation, (b) cooler peanuts due to lower mean overspace temperature, (c) reduced insect activity due to lower overspace temperature, (d) longer and better peanut quality maintenance, and (f) effective leak control. Figure 17 presents a schematic view of how the double roofing is accomplished.

Insect Control

Insect control is becoming a greater problem in peanut warehouses. Presently, the limited number of EPA approved insecticides for use on

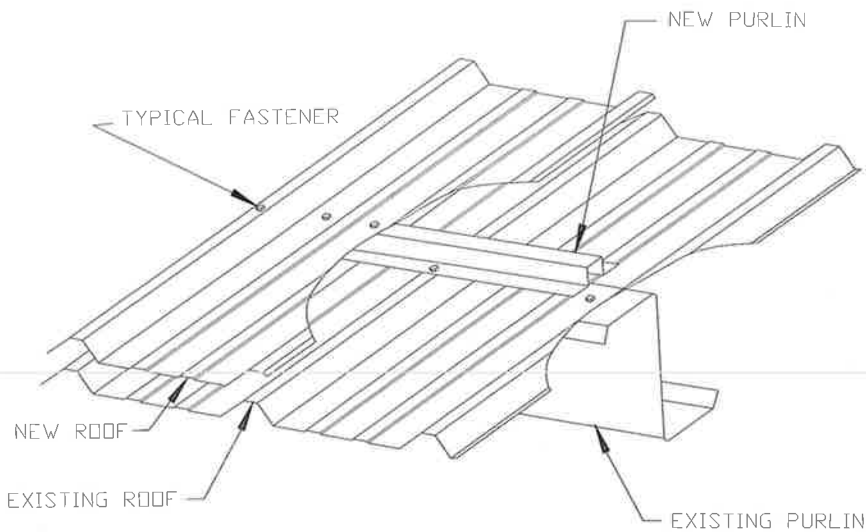

Fig. 17. Schematic showing the double roofing concept.

peanuts include malathion, dichlorvos, synergized pyrethrins, and *Bacillus thuringiensis*. Many manufacturers refuse to buy peanuts that have any malathion residues; however, malathion is rarely used because it is ineffective in controlling most peanut insects. Dichlorvos is labeled as a space rather than contact treatment and most often is dispensed through timed controlled aerosol systems. The synergized pyrethrins are also used mainly in an aerosol system. There is no set tolerance for them on peanut hulls but a zero tolerance has been set for kernels. *Bacillus thuringiensis* is mainly used as a surface treatment because of relatively high costs and because it is only effective on moth larvae, *Lepidoptera* spp. Presently, two fumigants remain registered for use on farmers stock peanuts, phosphine and methyl bromide. Fumigants do not offer any lasting protection and they are costly; however, they are very effective when properly used.

Use of the aerosol-type insecticides are ineffective in naturally ventilated warehouses because of the open area necessary for the ventilation system to function effectively. Generally, the fan(s) should be timed to stop at dusk-dark, the aerosol system activated, and fan(s) back on in about 4 hours (Redlinger and Davis, 1982). Therefore, the hooded-type air inlets and outlets on the mechanically ventilated warehouses are preferred over the fixed slotted louvers. By having the fans off in the early part of the night, there is a lower probability of reaching the dew point temperature of the overspace air than at later times. Also, adult insects usually reach peak activity about dusk.

With only a few approved insecticides available for use in controlling insect infestations in warehouses, it becomes very important to use preventative measures. Warehouses should be cleaned as soon as they are unloaded to remove all old peanut residue that could harbor insects and/or provide suitable breeding and development areas. Recently, a new pyrethroid insecticide, cyfluthen (Tempo®) has been approved for use as a cleanup and a pre-loading spray for farmers stock warehouses. This insecticide is very effective in controlling peanut insects when properly applied.

The area around the warehouse should be kept clear of tall grass and weeds, especially close to the building. This can be done by a concrete or asphalt apron around the warehouse or by using a herbicide. Removal of all old peanut (or other crop) residue from the area, as well as trash or other material that could provide a breeding place and haven for insects and rodents is important (National Peanut Council, 1971, 1972; Dickens and Hutchison, 1976; USDA-ASCS Handbook, 1978; Southeastern Peanut Association, 1992).

SHELLING ADVANCES

Precleaning, Shelling and Gravity Separation

Advances in precleaning, shelling and gravity separation during the past 10 to 12 years mainly involve techniques and processes that utilize existing equipment. Some shellers use belt screens to presize peanuts by pod size before shelling. This results in higher shelling efficiencies in each stage of shelling. It also allows better stick removal because the material falling through each belt screen can be removed by using smaller round holes or louvered openings on stick machines.

Improvements have been made in gravity separation due to higher shelling efficiencies resulting from presizing which reduces the load of unshelled pods on the gravity separator. Gravity deck designs have improved because (a) better guides for air direction and distribution on the underside of the deck, (b) adjustable weirs for lights discharge, and (c) larger capacity gravity separators with automated adjustments are being used.

A density separator has been designed to make more accurate density separations than conventional gravity separators. The density separator has been used previously to clean small grains, and preliminary tests have been conducted with peanuts. Additional testing will be needed to determine the precision of the machine for various peanut separations.

Some shelling plants utilize statistical process control (SPC) charts to determine when the plant or a particular piece of equipment is functioning properly. Critical points in the process are identified and samples are taken at specified time intervals (hourly, every 2 hours, twice each shift, etc.). The sample size depends on the amount of defects (damage, foreign material, unshelled, sound whole kernels, count/oz, etc.) and flow rate. Averages, upper control limits and lower control limits, are established after 40 or more data points have been collected with the equipment operating under normal conditions. Once the SPC charts have been developed, data is continually collected at specified intervals and plotted. A glance at the chart will indicate whether the equipment is operating normally or if something has happened to change the makeup of the product feeding the machine.

Electronic Sorting

Several advances have been made in electronic sorting equipment and techniques in the past 10 to 12 years. Bichromatic machines have been designed that can remove damaged and sound whole kernels from splits in one pass. Automatic cleaning devices have been designed that clean the viewing chamber continuously or at set intervals. Electronics allow product run through the machine to be rejected or accepted with automatically adjusted settings. Settings for sorting several different products can be stored in the machine's memory and recalled when desired.

Several companies have developed sorting machines that use a camera to view a single layer of peanuts as it passes on a belt or as it discharges from the belt. Ejectors (utilizing compressed air) remove the defective peanuts. These machines appear to be very effective in removing most types of foreign material. Each manufacturer's machine has specific features. Therefore, each should be evaluated before choosing one for a particular application. Capacities of these machines vary from 2.27 to 9.07 t/hr, depending on the width of the belt and the product being sorted. Belt widths vary from approximately 25.4 to 101.6 cm. These machines are used on red skin, blanched and in-shell peanuts.

Electronic sorting machines are used to remove splits from small whole kernels and vice versa. This technique is effective at low flow rates when separation with screens is not possible.

Packaging

There have been few advances in packaging. A machine is available that will automatically fill, close, and palletize peanuts in paper bags. Presently, there is no shelling plant known to be using the machine on peanuts, although there have been some test shipments of paper bags.

Some of the larger manufacturers have increased their use of bulk rail cars and bulk trucks to ship peanuts to realize savings in labor, packaging material and freight. However, initial costs for leasing or purchasing rail cars or bulk trucks and the necessary handling equipment is expensive.

Future Considerations

In the future, shellers must consider the environmental impact of their operation. These should include air, noise, and groundwater pollution and energy consumption.

Precleaning equipment should be designed that is quieter, requires less air flow and horsepower and that utilizes baghouses to control dust. Future designs may require completely different approaches than the industry is now using.

Equipment should be designed for safety, sanitation and worker comfort. Belt guards should be installed which can be easily removed for servicing and that can be easily replaced. Screens or covers should be easy to remove to clean the machinery. Controls and adjustment points should be clearly marked and convenient to reach.

SHELLED STOCK STORAGE

Shelled peanuts are more susceptible to deterioration than unshelled peanuts due to the removal of the protective hull, possible damage to the seed coat, broken kernels, bruised kernels, and weight of kernels in the mass inflicting additional bruising. Peanut oil does not become semisolid until the ambient temperature drops to about 5 C. Therefore, when kernel damage occurs above 5 C, oil tends to creep from the damaged cells in breaks and bruises and gives the peanut a darker, wetter look, especially if the seed coat is still attached (Woodroof *et al.*, 1947).

Refrigeration

Peanut quality can be maintained in shelled stock for at least a year at temperatures of 1 to 5 C and moisture contents of 7% w.b. or lower. By further reducing the moisture content to 6% w.b. and the temperature to minus 18 C, acceptable quality can be maintained from 2 to 10 years (Davidson *et al.*, 1982). In commercial refrigerated storage, it is desirable to maintain the temperature between 1 and 5 C at 55 to 70% relative humidity for a kernel moisture content of 7 to 7.5% w.b. The refrigerated space needs to have good air movement to prevent areas where the relative humidity could exceed 70% and foster mold growth. Peanuts in bags or boxes should be stacked at least 0.5 m from the walls, ceiling, equipment, other lots, and raised on pallets above the floor for good air circulation. The area should be odor free and void of other products with distinctive odors, since peanuts readily absorb odors and tastes from other products. Insects are not normally a problem in refrigerated storage because most insects become inactive at temperatures below approximately 13 C for a sustained period of time. However, rodents can be a major problem in refrigerated space and control measures are often necessary. Frequent inspections are necessary for rodents, operating parameters, and general storage conditions.

Perhaps the biggest changes in refrigerated storage of shelled peanuts in recent years has been the decline in rented commercial refrigerated storage space. Most of this can be traced to the decline in the small, locally owned shelling plant and the consolidation of the shelling industry to a relatively small number of large shellers who have built their own refrigerated storage facilities at the larger shelling plants. This has greatly reduced odor and flavor problems that were at times prevalent in the commercial facilities where different commodities were stored. Other improvements in newer storage facilities have been the use of more efficient insulating materials, improved control systems, and more efficient refrigeration equipment.

Raw shelled peanuts can only be kept for a few weeks at room temperature before a noticeable decline in quality occurs, especially in color and taste (Woodroof *et al.*, 1947; Holaday *et al.*, 1979; Davidson *et al.*, 1982). During the winter months, this time can be extended by storing shelled peanuts in unheated warehouses. The use of low oxygen atmospheres shows promise of maintaining peanut quality for an extended time without the aid of refrigeration (Slay *et al.*, 1980, 1982, 1985). These low oxygen atmospheres also limit insect damage.

Tempering

Tempering is the process of equalizing the temperature of the peanuts removed from cold storage to the ambient temperature of the new surroundings in order to prevent, or at least greatly reduce the potential for condensate to form on the peanuts. The tempering area needs to be well ventilated and yet give full protection to the peanuts from the weather, birds, rodents, and insects. Bags and small containers should be positioned for good air flow around them to insure that they quickly reach an acceptable temperature. Large bulk containers should be only one container deep and high to assure good air circulation and heat transfer. Tempering is much more important in warm, humid climates than in cooler, drier areas. Mold growth also occurs more quickly under warm conditions, especially *Aspergillus flavus*.

Transporting

When shelled peanuts are transported from the shelling plant to storage or to a buyer, they are usually moved by bulk, fiberboard box, nylon tote bag, or burlap bag, depending upon the destination. Transporting vehicles should be clean, dry, weatherproof, and adequately sealed to prevent moisture, insects or rodents from contacting the peanuts (National Peanut Council, 1976). Care should be exercised in handling the containers to prevent damage to the peanuts or the containers. Bulk handling in both rail and truck carriers has become popular, especially with larger manufacturers. Refrigerated and insulated carriers are helping to maintain better storage conditions than in the past by reducing wide temperature fluctuations between day and night that were responsible for many condensation-related problems. However, at present, these carriers are helping but not eliminating these problems. In warm and hot weather, fairly tight carriers increase in temperature because of (a) the high outside ambient temperature and (b) the additional heat and moisture released from kernels resulting from increased respiration rates. Quality can be greatly decreased if these adverse conditions are not corrected immediately. Many of the refrigeration systems used on truck carriers have been designed for transporting fresh produce at low temperatures but at high relative humidities which can create peanut quality problems.

Good air circulation is necessary in refrigerated carriers to prevent areas with high moisture and/or high temperature levels. Carriers should not be used for storage once the destination is reached. They should be emptied and the peanuts placed into proper storage where their condition can be easily monitored until they are utilized. Further research is needed to develop better bulk handling methods for shelled peanuts. Most of the preceding criteria pertaining to peanuts being transported in bulk also pertains to peanuts being transported in fiberboard boxes and burlap bags. Assumptions are that peanuts are being transported from and to good storage conditions, and the carrier needs to meet these conditions as economically possible in a short time. Because raw shelled peanuts are a semi-perishable commodity, they should be handled properly during transit in order to maintain good quality.

RESEARCH NEEDS

During the past 10 years, there have been few new recommendations for improved warehousing and storage; but there have been considerable efforts made to follow the existing recommendations. This has been the result of increased quality consciousness in the peanut industry. Research needs to be conducted to improve methods for loading and unloading warehouses to minimize peanut damage and thus limit loss of quality. Concepts used in the potato industry in loading and unloading potato storages show much promise for the peanut industry. Modification of existing potato handling equipment may be satisfactory or it may be necessary to design and build all new equipment employing these concepts. Some warehouse modification will be necessary to use this equipment for loading and unloading peanuts. Perhaps the biggest change for new warehouses would be reduced initial costs since the tall, steep roofed warehouse with the high elevator, overhead conveyor belt with tripper and associated heavy construction would no longer be necessary. The new warehouses would not require a heavy super structure, but would have relatively flat roofs, 1/12 to 4/12 roof slope, with eave heights of perhaps no more than 6 m and the resulting peanut mass being relatively flat across the top and being homogeneous in content.

Ventilation necessary for these new warehouses needs to be determined because of the reduced overspace volume and the more uniform peanut mass. Continual research is needed to develop a good, simple, and reliable control system for warehouse ventilation. With new and better types of insulating materials available and changes in warehouse designs, studies are needed to determine the economic value of full or partial warehouse insulation. The initial moisture content of peanuts going into storage is greater than the moisture content that peanuts can safely be stored. However, the kernel moisture should not be allowed to drop below 7% w.b. or a weight loss below purchase weight will be realized. Improved controls to maintain an optimal warehouse environment will help prevent kernel weight loss while maintaining quality. These and other research studies in handling, storing, and shelling peanuts will lead to reduced losses, better quality, and more wholesome peanut products.

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