Lectures of the 1956 Short Course on Unit Processes in the Fatty Oil, Soap, and Detergent Industries

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Part I

Handling, Shipping, and Storage of Oilseeds

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DISCUSSION WILL BE LIMITED to the basic problems involved in the handling and storage of cottonseed and soybeans, the basic answers to the problems, and some of the equipment and procedures used.

The Basic Problems

There are only two fundamental problems for processors in the handling and storing of oilseeds. First, the seasonal nature and rapidity of the crop movement, and, second, the deterioration of the oilseeds in storage.

Crop Movement. In the case of cottonseed there is almost no on-the-farm storage, and the capacity for seed storage at cotton gins is limited. It is doubtful that farm and gin storage account for more than two weeks during the peak harvesting season. In a normal year approximately 90% of the crop in a given area moves in a 120-day period. Depending on weather, daily receipts at the oil mill increase rapidly to a peak around the 30th day and diminish slowly to the end of the receiving period.

In the Mississippi Delta farming areas the crop moves to the gins about as shown in Table I.

TABLE I

Percentage of Cottonseed Ginned by Ginning Periods

Period	% of Total for Period	% of Total Cumulative
Before September 1	4.4	4.4
September 2 to September 16	11.1	15.5
September 17 to October 1	18.5	34.0
October 2 to October 18	21.5	55.5
October 19 to November 1	14.3	69.8
November 2 to November 14	8.2	78.0
November 15 to December 1	7.7	85.7
December 2 to December 13	3.7	89.4
December 14 to January 16	3.4	92.8
After January 16	7.2	100.0

Obviously the mills must be prepared to receive and store seed at a much greater rate than they can crush it. Based on a typical crushing schedule, the storage requirements in terms of annual crush and crushing period have been generalized in Table II.

TABLE II

Cottonseed Storage Requirements

Length of Operating Season (Months)	Storage Requirements % Annual Crush
6	31.3
8	44.1
10	52.3
12	57.7

The rapidity of the soybean crop movement differs in degree from cottonseed. One outstanding factor is the large amount of storage capacity ahead of the processors on farms and in elevators. Another is that soybeans are actively traded on the commodity market, and a season's crop is bought and sold several times. These things control the position of the beans in storage and obviously affect the rate of receipts at the mill. The positions by quarters in the four main storage categories are shown in Table III for the year 1952.

TABLE III
Stocks in Various Positions by Quarters, 1952
(Thousand Bushels)

	January 1	April 1	July 1	October 1
On Farms	103,380	59,603	5,847	1,947
Count y Elevators	44,390	21,858	4,704	296
Terminals	9,760	5,457	3,809	710
Processors	61,852	42,708	30,838	610
Total	219,382	129,626	45,198	3,564

The total crush for the 1952 crop year was 244,000,000 bushels. An average processor therefore reached a storage inventory of something more than 25% of his crush. In spite of this lower storage requirement for soybeans many mills must take receipts at five to ten times their crushing rate during the peak of the movement.

In order to assure receiving a large enough portion of the crop to allow crushing until the following season, the processor must have a substantial amount of storage for either cottonseed or soybeans; but storage *per se* is not sufficient.

Deterioration in Storage. Deterioration can occur to a serious degree in both cottonseed and soybean storage. Under conditions intermediate between dry dormant cottonseed and wet germinating seed there quite often is deterioration due to enzyme activity with a gradual digestive breakdown of oil, carbohydrates, and protein in the kernel. Gossypol and like pigments are released and undergo reactions which tend to set the color of oil produced. The accepted measure of this breakdown is the free fatty acid content of oil in the seed. The rate of increase in free fatty acid rise varies with the moisture of the seed, the initial free fatty acid of seed put in storage, and the temperature of the seed.

Typical effects of variations in free fatty acid of seed put to storage are shown in Table IV.

It may be seen that the neutral oil available in the seed decreases much more rapidly in seed which is stored initially at high free fatty acid. Data collected from different qualities of seed stored under oil mill storage conditions for a period of several years at various temperatures and moistures have also shown the effect of these variables. Aside from the effect of deterioration of oilseed on neutral oil quality the oil mill suffers a very real loss in yield.

To illustrate more specifically the loss in oil yield/ton of seed, assume that a hydraulic mill received and stored seed at .9% FFA. After four months in storage the seed is crushed when the free fatty acid content is 1.3%, assuming 10% rise/month in storage. The free fatty acid rise in milling would remain about constant at this level. The rise in refining loss due to free fatty acid rise of seed in storage would be .84%.

TABLE IV
Rise in Free Fatty Acids During Storage

Seed Moisture	FFA Content Before Storage	Average Seed Temperature	Rise in FFA per Month in Storage
%	%	°F.	%
10–11	1.0	50	Less than 0.1
10–11	2.5	50	About 0.2
10–11	5.0	50	About 0.5

Since the premium or discount amounts to .75 of 1% for each percentage of refining loss under or over 9%, the real loss would be .75 × .84 × 330 lbs. oil/ton of seed = 2.1 lbs. oil loss/ton. Consequently a rise of .8% over an 8-month storage period would result in a 4.2 lbs./ton oil loss. From this it may be seen that losses to a mill because of the free fatty acid rise in storage can reach enormous proportions.

Similarly the factors which determine the rate of deterioration or keeping qualities of soybeans are: moisture of beans going into storage, temperature in the storage unit, the quantity and type of foreign material, the quantity of sprouted, frosted, immature, or heat-damaged beans, and the quantity of physically damaged beans.

In some cases, depending upon the quantity, type, and localization, foreign material may be a more critical factor than moisture in determining bean condition in storage units. Only a small percentage of the oil mills clean beans before putting them into storage; and in nearly every case the foreign material is concentrated in spots or sections of the unit. This is caused by the foreign material's tendency to stick at the point of discharge from the distributor while the clean beans roll. This concentration of dirt, sand, and weed seed is so tightly packed that cooling air channels around this area and spontaneous heat cannot be readily dissipated. Heat damage eventually spreads from the core of the high percentage of foreign material to adjacent areas of cleaner beans. Once the beans reach a certain degree of heat damage, they cake, thereby forming a mass through which cooling air will not flow. The only recourse after this condition has developed is to move or turn the affected section of the storage unit. Heat damage originating in the regions of high foreign material is common when the average moisture of beans in the unit may be 12% or under.

A significant characteristic of beans in storage is the seasonal movement of moisture even when moisture contents are low enough for safe storage. This

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movement during the fall and winter months causes accumulations of moisture in the upper layers that may become sufficiently high to cause damage from molds. Clean soybeans near the walls and upper surfaces cool more rapidly than those at the center of the bin. Convection currents are created with cool air moving downward near the walls and upward as it becomes warmer upon coming in contact with the comparatively warm mass of beans near the center of the unit. This warmer moist air moves upward, and some moisture condenses as it reaches the cooler, upper layers of beans. The moisture content increases in the surface layers in a lenslike mass.

The direction of air currents reverses as the mass warms in spring and summer, but the dispersion of the accumulated moisture is much slower during the warming portion of the cycle than is the accumulation. Beans in the upper portion of storage units have reached moistures exceeding 25% when original moistures were below 12%. This moisture migration partially explains why beans in the upper layers heat after having kept well all the fall and winter.

The Basic Answers

Recognizing the problems of fast-moving crops and deterioration in storage, the processor can theoretically equip himself to handle almost any situation he can expect to face. Unloading and conveying equipment and combinations of them are available at any capacity desired. As mentioned earlier, he can calculate the total amount of storage necessary to assure year-round operation. Adequate dryers are available for both cottonseed and soybeans so that the damaging effect of moisture on storage oilseed can be reduced to a very low minimum. The same dryers may be used effectively to cool seeds which are received hot, and seed in storage may be effectively cooled by fans which pull air through them. Safe moisture and temperature storage limits are very easily determined. Should the crusher face any temperature rise in storage, he can detect it by means of thermometers or thermocouples placed in the cottonseed or soybeans and overcome it either by additional air cooling or by transferring the oilseed to other storage at a rate fast enough to prevent serious damage. Nothing can be done to improve seed and beans which are high in free fatty acids or are otherwise inferior on receipt; but they can be either milled at once or very satisfactorily segregated on the basis of their analyses, assuming sufficient unloading, conveying, and storage facilities are available to do this. The effect of foreign material on soybeans can be eliminated by installation of cleaning equipment of sufficient capacity to equal the maximum unloading rate.

As can be seen, the handling and storage problems are rather easy to solve with sufficient capital. Unfortunately the processor has some desire to make a profit from his operations. Faced with the investment costs necessary to give him sufficient flexibility to preclude any handling or storage problems, he would be unable to compete with the operator who invested sufficiently to handle a "normal" season, realizing that no one season is entirely typical of another. He must balance the advantages of high-capacity unloading and storage units against the better segregation and turnover found in smaller units. He must weigh the cost of increased cooling and temperature control in storage against possible losses in yields and quality. The cost of operating and maintaining modern mechanized units relative to manual handling must be considered.

In short, the crusher, just like any other processor, must consider the rate of return of each of his investments if he is to maintain a satisfactory return from his over-all operation. Because of unpredictable fluctuations in market conditions, weather conditions, crop yields and quality, he must make his decisions with some degree of uncertainty.

Equipment and Operation

Next the flow of the cottonseed and soybean crops may be followed to their ultimate storage and some of the types of equipment and methods of operation discussed, which are available to use. As mentioned previously, farm and elevator storage plays an essential part in the soybean marketing system.

Storage Prior to Oil Mill Storage. Farm storage is comprised of steel grain bins, overhead bins in combination corn cribs and granaries, or Quonset huts. Portable or permanent elevating and conveying equipment is used to fill the units, depending upon the type of farm storage employed. Farm storage units other than overhead bins with grain chutes are emptied by means of drag or screw conveyors into elevators equipped with loading spouts. The soybeans move from farm storage either to the mills or the elevators.

The grain storage bins utilized by elevators are ordinarily of the silo type, having a height several times their diameter. Reinforced concrete, steel, tile, and brick bins with hopper bottoms to facilitate emptying are most commonly used. The hopper bottoms are built with somewhat greater slope than the angle of repose of the grain to be handled. An angle of approximately 35° will shed soybeans satisfactorily. The storage capacities of elevators have been greatly increased since the introduction of the combine and transportation of the crop by truck. Many elevators which once had holding capacity for only a few carloads of beans now receive and store several thousand bushels per day.

Cottonseed storage ahead of the oil mill usually consists of no more than a few days storage in seed houses at the gins.

Receipt at the Mills. In the case of both cottonseed and soybeans, soon after the harvesting season begins, the oilseeds start their rapid flow to the mills in trucks, box cars, hopper cars, barges, and ships. More than 80% of cottonseed receipts at oil mills arrive by truck while most of the remainder comes by rail. At the smaller soybean crushing mills most of the receipts are also by truck while at larger units the majority of the beans arrive by railroad or barge. Regardless of the method used to transport the oilseed to the mill, the first operation in every case is to sample the receipt according to methods specified by the Department of Agriculture. A portion of this sample is used for grade determination as a basis for settlement. This sample is also used in most cases to determine whether the oilseed should be dried, should be milled immediately, or should be segregated from seed of different quality. Moisture is the primary consideration in determining the quality of soybeans for storage. The sample is checked for moisture in a suitable moisture meter, and the load is directed to the unloading station for proper segregation. The same is true of segregation of cottonseed on the basis of moisture. Free fatty acid in cottonseed is also an important factor in their segregation, but there is no practical method for determining this from the receipt sample soon enough to direct the unloading of the seed. Previous free fatty acid analyses from the same shipper are used for routing and unloading of seed.

Methods of Unloading. The most common methods of unloading oilseeds are with forks and shovels, with power shovels, with pneumatic unloaders, with truck and car dumpers, and with large movable elevators. Seed is pulled out of a truck bed with a power shovel into a pit where the carry-away conveyor is located. The operators lower the truck end-gates, unhook the cross chains, sweep out the bed, and replace the end-gates. The shovel itself is a steel or aluminum plate about 30 x 30 in. with handles attached to a steel cable on a revolving drum. The operator pulls the shovel to the forward end of the bed and engages a rotating drum, which winds up the cable that pulls the seed out of the truck. The main advantages of this method are the low operating cost and the low installation cost. The chief disadvantage is the low unloading rate for the number of operating personnel. The rate is about 30 tons/hour/shovel. A similar arrangement is used for box cars of soybeans, and a mechanized unit using this principle allows an operator to unload a car of soybeans from a station outside the car.

The typical pneumatic unloader consists essentially of a fan, a movable suction nozzle, a collector, a feeder, and a conveyor linked with the distribution system. The principal advantage for this type of unloader for trucks is that it is not necessary to remove and handle tail-gates. A similar unit is used quite successfully for unloading box cars of cottonseed. The movable suction nozzle is placed on the floor of the car, and seed is fed to it in this adaptation. The unloading rate for a pneumatic unloader is approximately 30 tons of seed/hour.

For a number of years the truck dumper has been used successfully at grain elevators to unload grain from trucks and wagons. In comparatively recent years it has been adapted to unload cottonseed at oil mills. Because of cottonseed's greater angle of repose, it is necessary to chain the truck to the platform and incline it to an angle of 40–45° from the horizontal. A similar unit is used for unloading soybeans. The installation cost of the dumper is very high compared with that of other unloading methods. Its main advantages are its speed of unloading and low operating cost. Dumpers are also available for the unloading of box cars of soybeans. These cars are elevated to one side and vibrated so that the beans flow out of the door of the car. Dumper stations can be operated at capacities well in excess of 100 tons/hour, provided adequate take-away conveying and distribution are available.

There are a number of soybean oil mills which are convenient to navigable streams where economical transportation by water is available. Barges and ships are used to transport beans to these mills. Ship cargoes can be in excess of 4,000 tons. The ships lie alongside unloading docks at the mill, and beans are removed at rates up to 700 tons per hour.

Drying. Except for mills that employ cleaning equipment before storage, the next step in handling the soybeans and cottonseed is that of drying high-moisture receipts to improve the quality and storage ability. Several types of dryers are available. In some the combustion gases are blown either through perforated cells containing the oilseed or laterally through flowing ribbons of the oilseed. Other dryers employ fans and coils which heat air instead of using the products of combustion. Oilseed from dryers must be cooled before being sent to storage, or heat damage will occur.

Cottonseed dryers have been used for a number of years to reduce seed moisture before going to storage. The cost of drying depends upon drying rates, power costs, steam costs, and labor. The capacity of an individual unit depends upon the initial moisture of seed and the amount of moisture being removed. This variation in capacity is seen in Table V for a typical cottonseed mill dryer installation.

TABLE V
Cottonseed Drying Capacity vs. Moisture Reduction

Initial % H_2O	Dryer 2%	Capacity (tons) for Various Reductions in H_2O			
		4%	6%	8%	10%
1.2	528				
14	590	302			
16	653	334	228		
18	708	362	247	190	
20	761	391	266	204	168

Storage. The oilseed now is conveyed to the storage unit which has been selected for it. The most commonly used types of storage at oil mills are old-type houses, Muskogee-type houses, silo-type storage units and tanks, and outside storage. The old type of seed houses are wood structures composed of a series of bins or lateral sections each having a capacity of 100–1,000 tons. Total house capacity may range from 1,000–5,000 tons. They are built both with and without air cooling systems. These houses are usually equipped with elevators and a screw conveyor for filling. A drag belt in the tunnel through the center of the house is used for feeding out the seed. In the old type of seed house, columns supporting the roof structure were subject to damage when seed caved. Roof truss construction in the new houses, such as the Muskogee type, eliminate the need for columns. Air-cooling headers run through the tunnels in the center of the house, and lateral cooling ducts spaced at 8-ft. intervals are connected. Selective cooling, where hot spots have developed, is possible by closing or opening slides in the laterals coming off of the trunk line.

The Muskogee roof has a slope of 45°, which is near the angle of repose for cottonseed. These houses range from 90–120 ft. in width and 100–300 ft. in length so that there is a wide range in size to meet specific capacity requirements.

Silo-type storage units are constructed of tile, brick, concrete, or steel. The smaller capacity units of 1,000–2,000 tons are usually tile, brick, or concrete. Other larger ones with capacities up to 6,000 tons are steel. These units are filled either by blowing seed through a 10-in. line to a distributor in the top of the tank or by troughing belts and trippers. A belt conveyor in the tunnel is provided for emptying the tank.

In some areas, particularly at western mills, where the average rainfall is low during the storage period, seed and beans are stored in piles on the ground.

Temperature in Storage. With the oilseed now in storage the crusher must concern himself with the protection of a sizable investment. He watches the temperatures of the cottonseed or soybeans throughout all of the storage units very carefully. The temperatures are obtained through the use either of thermocouples spaced at proper intervals inside the unit or through the use of grain thermometers placed in pipes which have been driven into the stored seed at proper intervals. He will use his cooling fans to pull air through the storage unit to help control any temperature rise which may develop at any spot in the unit. If he is unable to control it, he must then turn the cottonseed or soybeans to another storage. During the cool nights he will use his cooling systems to reduce the average temperature of the seed in storage so that deterioration will be checked and his yields will not be reduced. If he has been careful in his selection of capital equipment and in handling and storing the seed, he will be spared a loss on his investment as a result of deterioration.

Conclusion

The rapid crop movement has been discussed, also the problem of deterioration in storage, and some of the procedures and equipment which the crusher may use to solve his problems. In a few weeks the oil seeds will start their flow to the mills. No one season is entirely typical of another, and the crusher will soon be faced with new problems relative to unloading, storage allocation, and segregation day by day and hour by hour. Each problem is demanding of solution and cannot be deferred or referred. The success of the mill's year-round operation may depend in large measure upon the initiative, hard work, imagination, and judgment with which an unloading season is handled. The crushing industry is looking forward to this season and to every season with an unique interest that is hard to describe. The interest is so much a part of processors that oil mill men could never, and would never want to lose it.

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Solvent Extraction Including Seed Pretreatment

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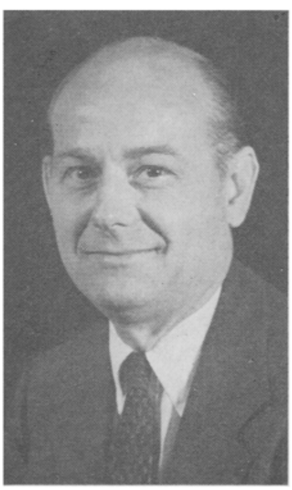
In previous short courses the talks on solvent extraction have been centered chiefly on the design and operation of the various types of extractors in commercial use. As every short course speaker on this subject has emphasized, it is impossible to treat even such a limited area of the whole subject in detail. The other very important unit processes involved in the complete solvent-extraction process, particularly those of seed preparation, have had to be passed over quickly and possibly superficially because of the severe time limitation. In the present paper we propose to emphasize seed preparation and other auxiliary unit operations at the expense of a more complete discussion of extractors and extraction.



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The unit operations of seed preparation are seed cleaning, hulling or cracking, hull separation, meats conditioning or cooking, flaking or crushing, cooling and "crisping," pre-pressing, and materials handling. Three preparation flows are shown in Figures 1 and 2. Practically every type of oil seed or nut is or can be processed in one of the three ways described. Cottonseed is processed in all three ways, and the flow charts refer to cottonseed. Every other oil seed can be prepared for solvent extraction in one of the three ways shown with only minor variations.

The following discussion refers to both Figures 1 and 2. Seed cleaning is a most important operation in the preparation of seeds for extraction and is probably neglected more than any other operation. Proper seed-cleaning will increase capacity, reduce maintenance, and improve oil quality. The effect on oil quality of dirt, trash, and weed seeds is frequently startling (1). Many processors have a great hidden dollar loss every year because of inadequate cleaning.

The comminution of seeds and nuts includes hulling, cracking, and shredding as well as crushing or flaking. Cleaned cottonseed is first delinted, usually in two steps (2). It then must be hulled. This is done in either a bar huller or a disc huller, which seem to be best able to cut the hulls and release the meats with a minimum of pulverizing of the meats. Soybeans are cracked in cracking rolls, which are corrugated rolls running at high differential speeds and which are either 2-pair or 3-pair high (3).

The next operation for many oil seeds involves hull separation. The separation of hulls from cottonseed meats has been developed to the highest degree of efficiency probably because the problem was the most difficult. For soybeans the process is much simpler but has been developed much less completely. The soybean processors could learn a lot about separation from the cottonseed processors (2). The removal of hulls from soybeans is getting to be more and more of interest because of the appeal of special high protein meal. Additional advantages of hull