a gallon of solvent per ton of material processed are now common. This is less than 0.3% loss.

The engineering improvements in the oil-seed solvent-extraction industry in the past 10 years have been very extensive. Every one of the 14 unit processes touched on in this paper has been stepped up in efficiency by at least 100% in this time. Plant costs have been held almost steady for 15 years in spite of skyrocketing costs of labor and material. The urge for improvement which characterizes private competitive enterprise is very much in evidence in the oil seed industry.

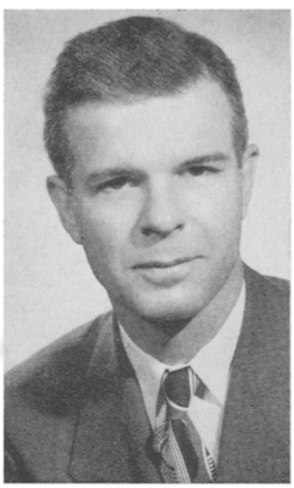
REFERENCES

1. Hutchins, R. P., Oil and Soap, *22*, 165–168 (1945).
2. Bailey, A. E., "Cottonseed," Interscience Publishers, New York (1948).
3. Kenyon, R. L., Kruse, N. F., and Clark, S. P., Ind. Eng. Chem., *40*, 186–194 (1948).
4. Spadaro, J. J., Vix, H. L. E., Gardner, H. K., D'Aquin, E. L., Eaves, P. H., and Gastrock, E. A., J. Am. Oil Chemists' Soc., *32*, 160–163 (1955).
5. Hutchins, R. P., "Extraction of Cottonseed by Prepressing and Extracting Prepressed Cake," Oil Mill Gazetteer, August (1955).
6. Moore, N. Hunt, "Exsolex Process in the Solvent Extraction of Cottonseed," Cotton Gin and Oil Mill Press, April (1950).
7. Anderson, E. T., and McKubbin, Keator, J. Am. Oil Chemists' Soc., *31*, 475–477 (1954).
8. Hutchins, R. P., "The Practice of Solvent Extraction," A.O.C.S. Short Course, 1948.
9. Karnofsky, George, "The Mechanics of Solvent Extraction," A.O.C.S. Short Course, 1949.
10. Hutchins, R. P., J. Am. Oil Chemists' Soc., *30*, 535–537 (1953).
11. Moore, N. Hunt, J. Am. Oil Chemists' Soc., *30*, 538–539 (1953).
12. Dunning, J. W., Oil Mill Gazetteer, *56*, 64–68 (1951).
13. Bilbe, C. W., Oil Mill Gazetteer, *52*, 39–41 (1948).
14. Gastrock, E. A., Spadaro, J. J., Gardner, H. K., Knoepfler, N. B., and Molaison, L. J., "Current Status of the Filtration-Extraction Process," Oil Mill Gazetteer, August (1954).
15. Leslie, U. S. No. 2,571,143.
16. Karnofsky, George, U. S. No. 2,691,830.
17. Hutchins, R. P., U. S. No. 2,695,459.
18. Kruse, N. F., and Witte, N. H., Central Soya Company, personal correspondence.

Unit Operations in a Mechanical Extraction Mill

JOHN W. DUNNING, The V. D. Anderson Company, Division of International Basic Economy Corporation, Cleveland, Ohio

DURING THE LAST 20 YEARS there have been two industrial revolutions in oil milling in the United States. The first of these revolutions was the introduction and use of solvent extraction in the processing of vegetable seed. This introduction has been recognized and acclaimed as a great step forward in oil-milling practices. The second revolution that has taken place within the last 10 years has not been recognized as such. This revolution concerns the advancement in mechanical expression of vegetable oils, which may be summarized by referring to the data plotted in Figure 1. In 1946-47-48 cottonseed mills, as an example, were usually pressing the meats from 20 to 23 tons of cottonseed per day per Expeller. Oil in cake ranged from 3+% to 5% on a 41% protein basis, with most mills in the range of 4 to 4½%. The oil was refined by the cold-press method, normally using 18–20° Baumé caustic.



J. W. Dunning

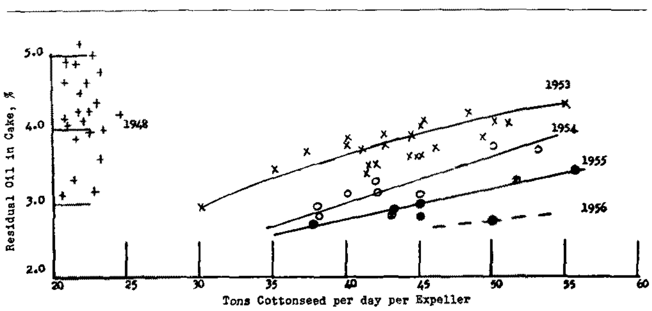


FIG. 1. Increase in capacity and decrease of oil in cake from Expellers over the years 1948–1956.

Today many mills are pressing the meats from 45 tons of cottonseed per day per Expeller, producing cakes containing 2.7 to 3.5% oil on a 41% protein basis. The graph indicates that in the last three years the trend has been toward lower and lower oil in cake. In addition, the oil made in these mills refines by the hydraulic method, using 12 to 14° Baumé caustic. The through-put and yield accomplishment in this revolution is in itself amazing. But there is perhaps an even more spectacular accomplishment. The capital investment required for the milling equipment from the meats bin to the cake and filtered oil is less today than in 1948. Just consider a moment, the oil producing equipment all combined, that is, the Expellers, screening tank, pumps, elevators and conveyors, filtered oil tank, etc., for a 90-ton per day cottonseed mill costs $11,500 less today than in 1948. In addition, this 90-ton per day mill of 1956 can produce, on the average, 800 more pounds of oil than it did in 1948, a reduction in capital investment with a gain in yield and an improvement in quality. This is an accomplishment of which oil millers can be rightfully proud and an accomplishment probably not attained by any other industry in the United States.

This accomplishment was realized primarily by studying the process variables and the unit operations in an oil mill and by applying the results of these studies to the operation of the mill.

Today an oil mill is not composed of a number of isolated independent arts. Rather, it is composed of a group of inter-related and dependent chemical engineering unit operations. As an introduction to these unit operations, reference is made to Figure 2, which is a general flow sheet of a vegetable oil mill, concerning the processing of 11 different commodities, which characterize the preparation conditions employed for the hundreds of commodities processed in screw presses over the world. Copra, because of its relatively tacky nature, is cleaned of scrap iron, disintegrated, preferably in a vertical hammer mill, dried, and pressed. Linseed is processed in a cleaner, then rolled, cooked, dried, and pressed. Soybeans likewise

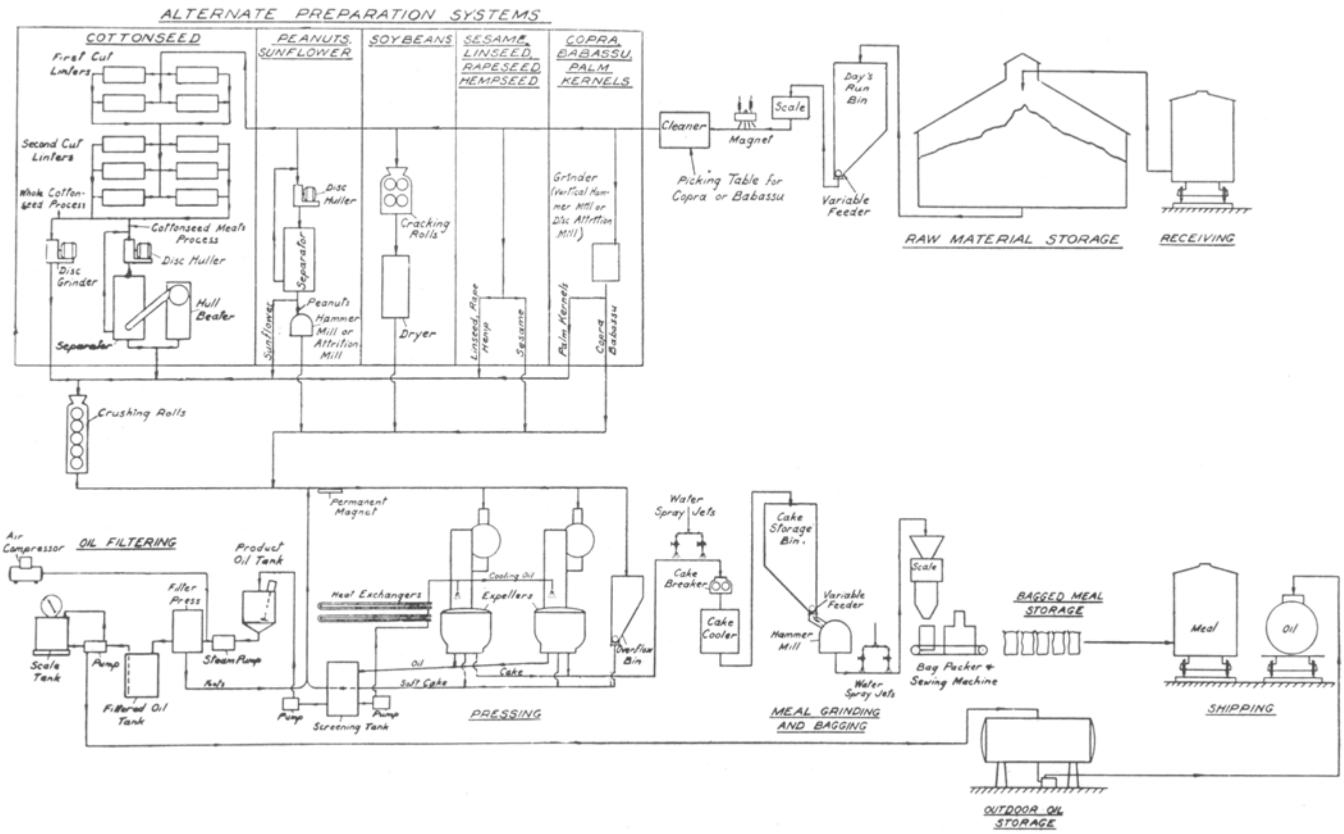


FIG. 2. General flow sheet for vegetable oil expeller mills

are cleaned, cracked, dried, and pressed. Peanuts are first cleaned, then dehulled. The kernels are broken, preferably in a vertical hammer mill, cooked, dried, and pressed. Cottonseed are cleaned and delinted. Blackseed from the delinting operation are dehulled, the meats are rolled, cooked, dried, and pressed.

In the United States there are perhaps 20 or more commodities processed in mechanical screw presses. The most important of these commodities are flaxseed, peanuts, copra, packing and rendering materials, and cottonseed. As examples of the importance of mechanical screw presses to these industries, there are approximately 750 Anderson Expellers employed in the packing and rendering industries alone. In the seven major cottonseed producing states there are more than 600 mechanical screw presses in operation. It is amazing to realize that in any one of these many different oil mills there may be 11 separate chemical engineering unit operations. These operations will be discussed in relation to the flow of the commodity through the oil mill, with particular reference to cottonseed.

Materials Handling

In an oil mill pneumatic conveyors, screw conveyors, drag chain conveyors of various types and designs, bucket elevators, etc., are employed. Some commodities and products are free-flowing, for example, flaxseed, soybeans, and delinted cottonseed. These materials may be conveyed and elevated by a wide variety of units. Other materials are tacky, for example, cooked cottonseed meats. These lend themselves to conveyance by means of a screw conveyor, a perfect discharge elevator, or certain types of drag-chain conveyors. Because of the difference in physical nature of these different materials, the proper selection of conveying equipment is highly important in order that subsequent unit operations are not shut down as a result of failure of materials-handling equipment.

Screening and Aspirating

Most commodities must be effectively cleaned prior to pressing in mechanical-extraction equipment. This cleaning removes not only stones, sand, dirt, and trash from a raw material but in many instances also removes undesirable foreign seeds from the raw material. Since the service life of mechanical-press parts, roller mills, and conveyors themselves is a function of the cleanliness of a raw material, it is highly important to have these materials properly cleaned.

In addition to cleaning, many raw materials are preferably decorticated prior to pressing, for example, soybeans, sunflower, castor, and cottonseed. A specific reference to cottonseed in this connection is worth noting. After the delinting of cottonseed, the blackseed may contain approximately 28% protein. Cottonseed meal however is normally sold at a 41% protein content. In order to produce 41% protein cottonseed meal the hulls are cracked and separated from the meats in equipment, as illustrated in Figure 3. Just a few years ago there was a question whether or not a mill could effectively press cottonseed meats of 45 to 46% protein content on the cake basis instead of the usual 41% protein content. Today many mills are running at this higher protein content, and many are processing cottonseed meats that contain as high as 50% protein. One of the primary reasons for operating at higher protein levels is to produce a cake

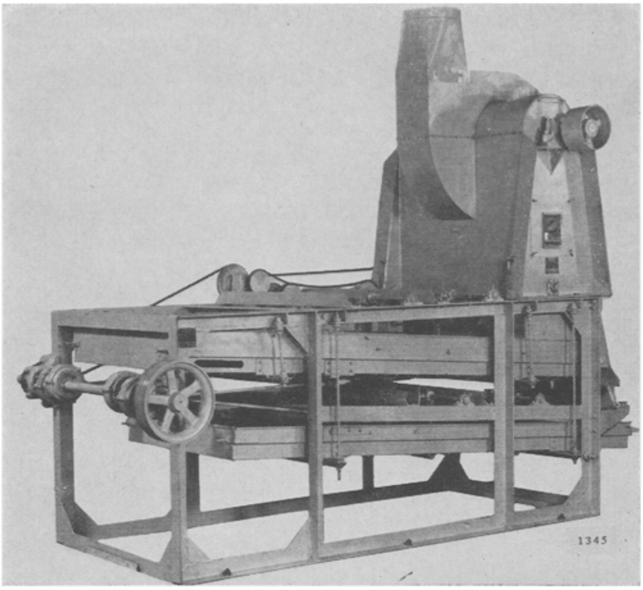


FIG. 3. Cottonseed huller and aspirator equipment. (Courtesy Bauer Bros. Co.)

of, say, 50% protein and 3+% oil content, which may be blended with hull bran at approximately .5% oil content to end up with a finished meal containing a lower oil than that in the cake. The theory is that the addition of .5% oil hull bran to cake will permit the production of a lower oil meal than if these same hulls were run through the press and permitted to have an oil content the same as that in the cake. Under these conditions many mills obtain a higher yield of oil per ton of seed than would be possible if they were processing 41% protein cake.

Another advantage in running the higher protein cake concerns the increased capacity thus realized in the presses. Mathematically, if one were pressing the meats from 40 tons of seed per day per machine at 41% protein, the same machine would have a little over 48 tons per day capacity at 50% protein. Although this mathematical relationship is not borne out completely, mill data do indicate that an increase in protein content of cake permits an increase in capacity of the press just because the volume of material through the press is thereby reduced.

There is evidence also that the maintenance required for a press is slightly reduced by the pressing of higher protein meats. This would at least be reasonable because the hulls in cottonseed, as well as in most vegetable seeds, are more abrasive than the meats themselves. As an example, high capacity Expeller mills pressing 45 to 50% protein cottonseed cake report barrel bar life of 7,000 tons of seed. Shaft life in these mills may be as long as two or three years with the processing of 15,000 to 18,000 tons of seed. On the other hand, a flax mill pressing improperly cleaned seed or a cottonseed mill located in a sandy, windy area may have a barrel bar and shaft life one-half the above. Irrespective of the specific reasons for pressing high protein meats, many of the cottonseed mills today are following this practice. It should be mentioned that because of the variation in protein content of the cakes from different mills, it is necessary to compare the efficiency of these mills on a single basis. Although the practice of converting a 50% protein cake to a 41% protein basis is sometimes frowned upon, it is at least one method of reducing oil in cake to a common factor for comparing the work of one mill operated under different conditions as well as comparing the work from different mills.

Disintegration

Most vegetable seeds and nuts and meat products must be ground, rolled, or cracked prior to mechanical pressing. This is necessary if for no other reason than the fact that the mechanical press is designed for pressing and not for disintegration. It is standard practice to grind copra in a vertical hammer mill to approximately ⅛-in. particles; to crack soybeans in a corrugated roll of a 12–14 LePage cut; and to roll cottonseed to approximately .010-in. thickness. Sesame seed is one commodity, because of its physical nature and high oil content, which is preferably not disintegrated prior to pressing.

It is classically stated that cottonseed meats should be rolled to .008 to .010-in. thickness in a 5-high roller mill, as shown in Figure 4. Most mills seriously attempt to roll their meats to this degree. Some mills however, by treatment of meats prior to rolling, roll them even thinner than this classical specification. As an example, when meats are moistened to approximately 11% moisture content and warmed to 140 to 145°F. and then rolled in a single pair roller mill (Figure 5), the hulls can be rolled to the size of nickels. By flattening and reducing the thickness of the hulls, the meats, of course, may be rolled to much thinner sections. Although there is some evidence of cell rupture during the rolling operation, the consensus is that the rolling actually presents thinner sections of meats for the subsequent cooking and drying operations.

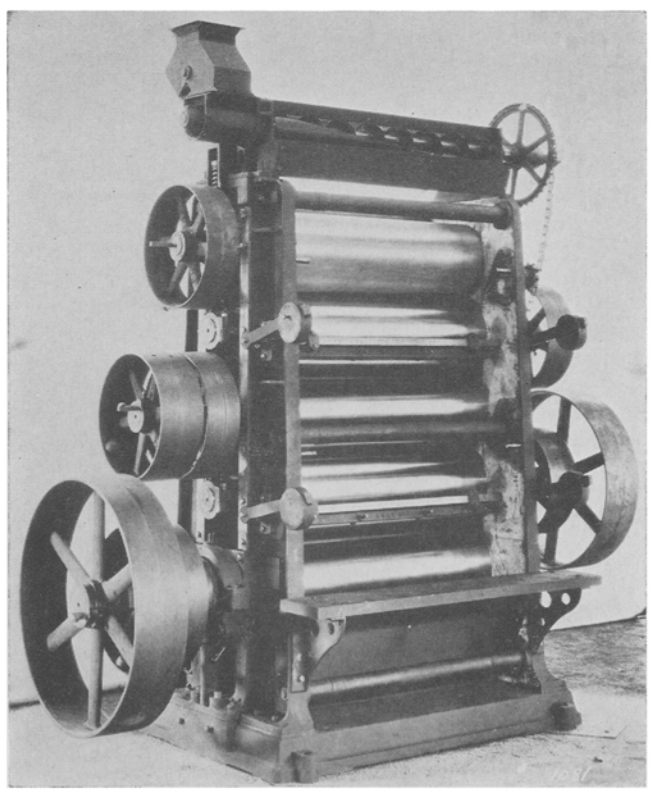


FIG. 4. 5-high roller mill. (Courtesy French Oil Mill Machinery Co.)

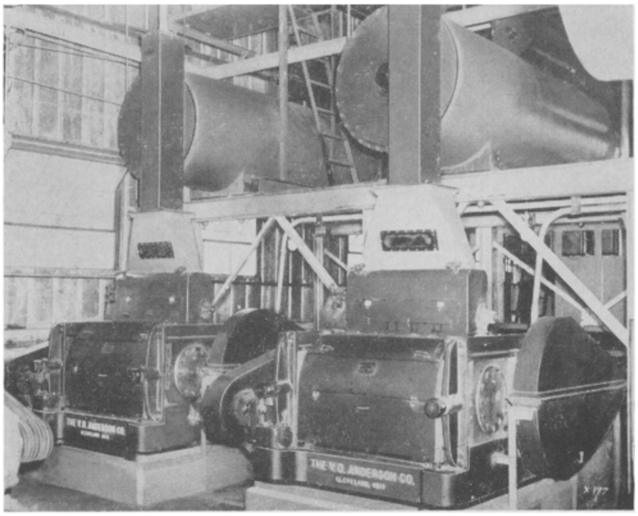


Fig. 5. Single pair roller mills with conditioners.

With respect to rolling, pilot-plant data obtained in our Cleveland pilot plant have indicated that the rolling of soybeans prior to mechanical expression is more effective than cracking of the bean. It is assumed that rolling is more effective with soybeans than cracking solely because rolling presents much thinner sections of material for drying so that a more uniform moisture may be obtained throughout the bean particle as a result of rolling, rather than cracking. For the same reason, a thinner section of material is exposed to pressure in the mechanical press, thus requiring less energy on the part of the press to rupture the physical structure of the cracked bean and compress this structure to yield oil.

Humidification

The control of moisture in mechanical pressing is one of the most important operations in the mill. Too much stress on the control of moisture cannot be made. The amount of moisture in vegetable material governs the screening efficiency, the disintegration efficiency, the cooking, the drying, the press operation, the settling of foots, and the filtration of the oil. Sometimes I am inclined to feel that the appreciation by oil mills for control of moisture is responsible for the industrial revolution in mechanical press mills. This may be an extreme statement, but those who have operated mills or studied the operation of mills are keenly aware of its importance.

The necessity for the control of moisture begins in the seed storage house, where it is recognized that excess moisture in stored vegetable seeds permits a fermentation and decomposition reaction, which has a deleterious effect on the ultimate products from these seed.

Some mills humidify delinted cottonseed prior to decortication by the blowing of live steam onto these seed as they travel along a conveyor. Some mills have humidified delinted cottonseed in black seed storage tanks. This operation is followed in order to get some additional moisture into the meats to aid the subsequent rolling and cooking operations and slightly to moisten the hull and remaining lint in order to aid the subsequent separation operation.

Most cottonseed mills practice some manner of moistening of meats prior to rolling. This practice is followed in an attempt to get as much moisture into the meats as possible before the meats enter the cooker and to condition the meats themselves for the rolling operation. A few mills have gone so far as actually to condition the meats with moisture and temperature prior to rolling (Figure 5). This practice is said to give very good results.

Most vegetable seed are preferably rolled at moisture contents between 9 and 11% moisture. At lower moistures the seed tends to fracture into dust particles. At higher moistures the seed tends to become soft and tacky and thus to overload the disintegrator.

As mentioned above, many vegetable seeds are preferably cooked and dried prior to mechanical pressing. Although several articles (1), (2), (3), (4) have been written on this subject, it is well to review the essential elements of the cooking process. The cooking process has the following purposes: to rupture the oil cells, thus making the oil readily available for extraction; to increase the fluidity of oil by increasing the temperature of the meats and the oil; to destroy the molds, bacteria, and enzymes in the meats, which otherwise might increase the F.F.A. rise

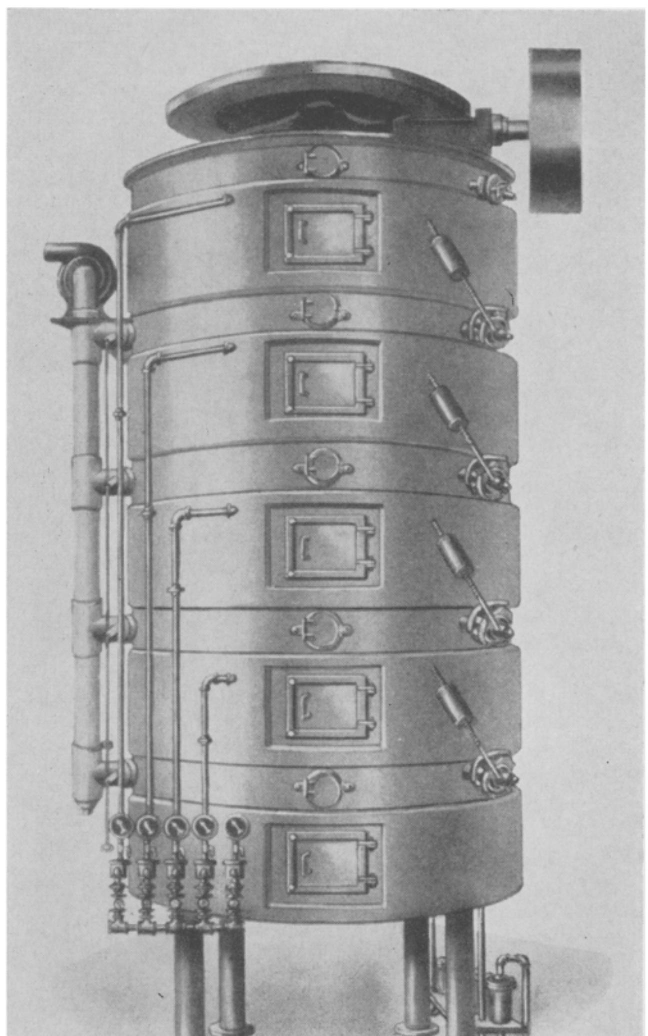


Fig. 6. 5-high stacked cooker.
(Courtesy Davidson-Kennedy Company)

of the oil as well as harm the meal; to coagulate, set, or precipitate the fluid protein fraction of the meats (Some of the proteins in the cottonseed are in a fluid state; unless they are transformed to a more or less solid state by the cooking process, these proteins will be extracted with the oil, thus increasing the refining loss of the oil.); to coagulate or precipitate the phosphatides; in the case of cottonseed to detoxify the free gossypol by rupturing the gossypol glands and causing this material to become diffused or absorbed into the proteinaceous material.

Briefly the cooking operation consists of exposing the rolled meats at a minimum of 12% moisture content to approximately 190°F. under conditions of agitation for approximately 20 min. Many mills recognize the necessity of cooking meats at 12 to 13% moisture, but seldom is it appreciated that water is actually fulfilling a chemical and physical function in the cooking process. Water acts as a heat transfer medium to conduct heat into the meats mass. At low moisture contents this heat transfer is very slow. As the H_2O increases, the heat transfer increases. In addition to the moisture acting as a heat transfer medium, water itself actually takes a place in the chemical and physical reactions occurring during the cooking procedure. Water reacts with the phosphatides and the proteins to bring about a coagulation reaction. Water diffuses into the cells of the meats and physically ruptures these cells, making the oil available for pressing and dispersing the color bodies and detoxified gossypols into the meal. From a physical and chemical point of view therefore, water is an essential material in the cooking process. Without water, cooking, as we know it today, cannot be achieved. Because of the importance of water as a heat transfer agent and as a chemical reactor in the cooking process, it is essential that this water diffuse uniformly throughout the meats mass before the cooking procedure can be completed. For this reason it is highly advantageous to have the meats conditioned with moisture prior to their entering the cooker.

Two types of cookers in use today are the stack cooker, shown in Figure 6, and the horizontal cooker, shown in Figure 7. Although the word "cooking" in reference to the preparation of vegetable seeds or meats has been used for many years, not all mills appreciate the extreme value of establishing cooking conditions and maintaining those conditions throughout the cooking time of 15 to 20 min.

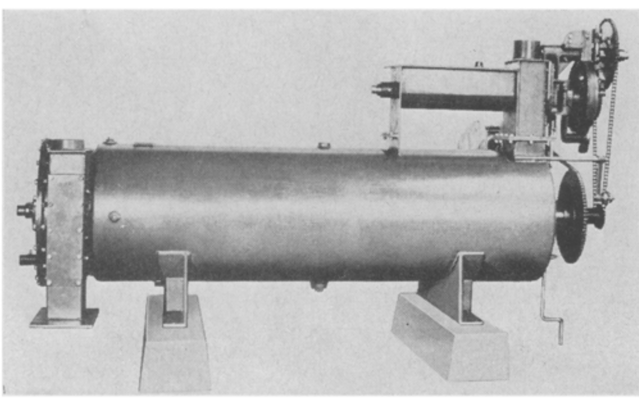


FIG. 7. Horizontal cooker manufactured by The V. D. Anderson Company.

Drying

After the water has played its part in the cooking process, it is then to be removed in order that the cooked meats may be effectively pressed. In most mills the drying of the meats is carried out at final temperatures of 245–270°F. so that the dried meats ahead of the press are at approximately 3% moisture. In the case of copra and sesame seed this moisture content should be in the range of 2%. It must be stated that some mills press at higher moistures and some mills press at slightly lower moistures with equal results, depending upon the specific conditions within the mill. A variation in final temperature is permissible, provided the final water content is low enough to permit the degree of pressing desired.

Pressing

Before discussing contemporary mechanical screw presses, let us briefly review the development of this machine. The mechanical screw press oil mill of today is quite unlike the oil mill of centuries ago when the ancient Egyptians, Phoenicians, and Chinese produced some form of crude oil and meal. These early mills were very primitive and are illustrated by a photograph (Figure 8), taken by Frank Anderson

FIG. 8. Stump press.

not many years ago, of an oil mill in the Orient. The basic unit of equivalent in this mill is called a stump press. It consists of a burned-out stump with a heavy pole driven by an ox to macerate the seed and thus free some of the oil.

Many mechanical improvements in mill equipment appeared during the 17th and 18th centuries. It might be said that this early developmental stage was culminated in 1795 when Joseph Bromah (6) obtained an English patent for a hydraulic press. Many improvements were made in the first hydraulic press so that it was the major mechanical oil extraction unit until the early 1900's. The idea of a mechanical screw press was conceived by V. D. Anderson in 1876. In 1900 the first successful press, called an Expeller, was made. In 1906 the first order for Expellers was delivered to a flaxseed mill. In 1908 the Expellers were first used for pressing of oil from whole cottonseed. A picture of this Expeller, called "Model No. 1," is shown in Figure 9.

In 1909 W. D. Ennis in his book entitled "Linseed Oils" (6) states that "the first practical mechanical press for continuous extraction of . . . oil was built about five years ago. Several of these presses are now in successful operation . . . for expressing oil from

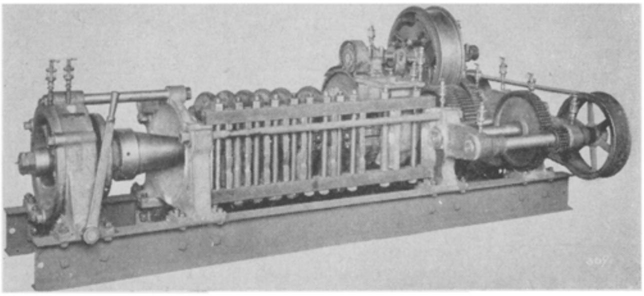


Fig. 9. V. D. Anderson Company, Model No. 1 Expeller (1906).

linseed and cottonseed. The Anderson machine subjects the whole or ground seed to the end-thrust of a powerful worm. All seeds can be pressed cold and without grinding, but the best results are obtained by flattening and breaking up the seed in a mill, composed of two rolls, and then slightly warming the meal (to 140°F.) in a tempering apparatus before introducing it into the Expeller. In this way is obtained the maximum yield of oil. Besides the saving in labor, the Expeller uses no press cloths. Its prime feature is that it permits . . . seed crushing on a small scale with a limited capital investment . . . at a relatively low manufacturing cost.''

It is important to remember that less than 50 years ago the Expellers were used as cold-press machines primarily on whole seeds and in many instances were the only mechanical device in the press room.

About 1910 the Krupp Works in Germany was licensed by The V. D. Anderson Company to manufacture a mechanical screw-press. The press in Germany was called an ''Andersonpresse'' and later a ''Schnekenpresse.'' This machine was used primarily in Europe as a forepress unit ahead of hydraulic presses. The Expeller would forepress a considerable amount of oil. The cake would then be heated and finally pressed in the hydraulic presses. Thus was initiated in Germany, as well as in the United States, the use of a mechanical screw-press as a prepress machine ahead of hydraulics and later ahead of solvent-extraction plants. In Europe screw-presses were developed mainly to forepress. In the United States, on the other hand, the first Expeller was developed and improved for the expressing of nearly all the oil from a seed in one operation.

In 1926 the model ''RB'' Expeller, shown in Figure 10, was first manufactured. As one can observe, the ''RB'' is a much-heavier-built machine than the original ''Model No. 1.'' In addition, the ''RB'' was equipped with roller bearings, thereby its name.

In 1933 the French Oil Mill Machinery Company introduced a mechanical screw-press into the field so that at the present time there are two leading manufacturers of mechanical screw-presses in the United States. Contemporary screw presses manufactured by these two concerns are shown in Figures 11, 12, and 13. Even though these contemporary presses are far more efficient than the original Expeller, it is interesting to note that many old No. 1 Models are still in use.

It would be difficult to ascertain the number of mechanical screw-presses that are now in operation in the world today. It can be stated however that these presses, during the last 50 years, have displaced many hydraulic presses. This displacement has occurred

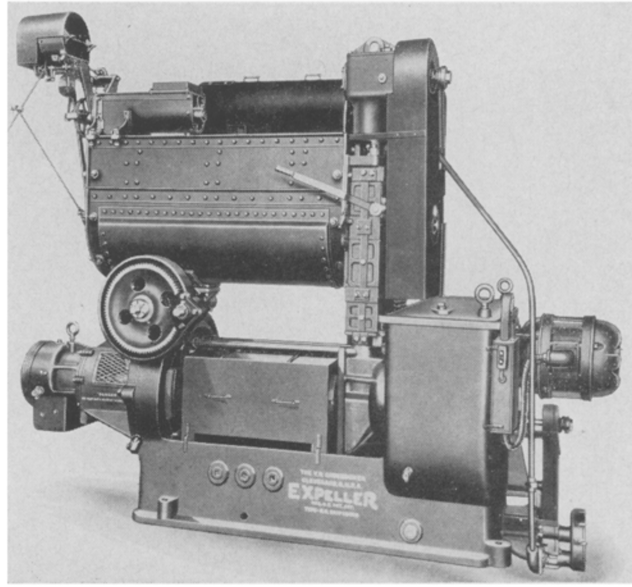


Fig. 10. RB Expeller manufactured by The V. D. Anderson Company (1926).

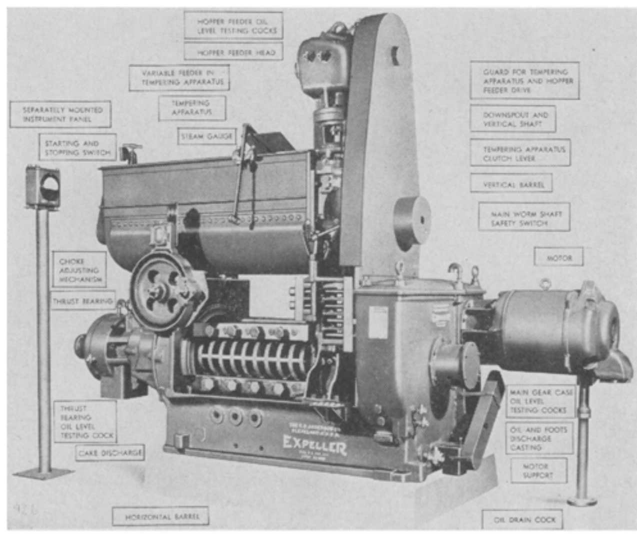


Fig. 11. Duo Expeller manufactured by The V. D. Anderson Company.

primarily because of the saving in cost of press-room operators and because of the increase in yield of oil from the raw material. In addition, the inherent efficiencies of a mechanical screw-press installation with its relatively low installed cost has made it possible for many small-scale operators to process vegetable seeds who otherwise could not have done so.

The mechanical screw-press has five essential elements that must be understood and appreciated if efficient work is to be done with one of these machines. These essential elements are: the main worm shaft and worms; the choke mechanism; the drainage barrel; the motors, transmission, and thrust bearings; and the cooling mechanism.

The main worm shaft and worms are designed to exert a pressure of 5 to 15 tons p.s.i. on the seed being processed and at the same time to convey the seed through and out the pressure chamber. To illustrate some of the differences in worm arrangements, three different Anderson main worm shafts are shown in Figure 14. The top shaft illustrated has four carry-

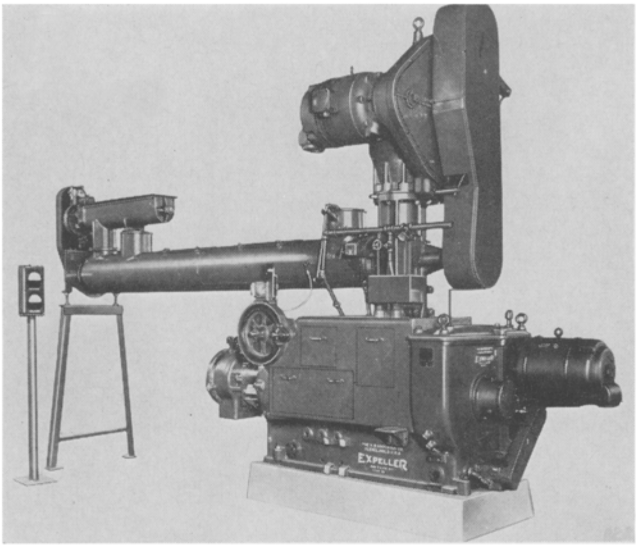


FIG. 12. Twin motor Super Duo Expeller with conditioner manufactured by The V. D. Anderson Company.

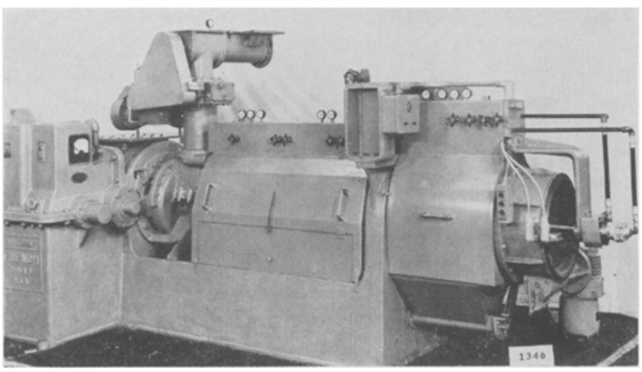


FIG. 13. Contemporary screw-press manufactured by French Oil Mill Machinery Co.

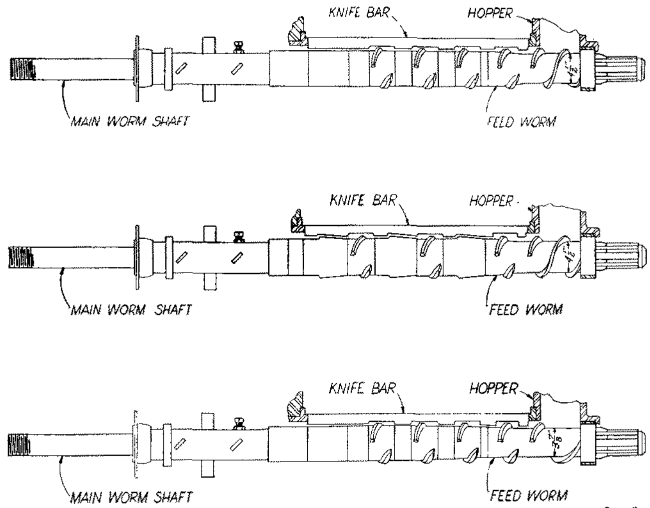


FIG. 14. Three V. D. Anderson Company main worm shaft arrangements.

ing worms with 4½-in. shaft diameter at the feed section. The second shaft also has a 4½-in. feed shaft diameter, but it is equipped with only three worms and, in addition, three cone collars. This shaft, by inspection, is a more severe shaft than the one above and exerts more pressure on a given material than the preceding shaft. The bottom worm arrangement is the same as the top one except that the shaft diameter at the feed section is 3⅞ in. intsead of 4½ in. and the shaft taper is more gradual. The shaft shown at the top of Figure 14 may be used for pressing whole cottonseed. The shaft illustrated at the middle of the figure may be used for pressing of oil from dehulled cottonseed or flax. In the former case, on an oil-free basis, the crude fiber content of whole cottonseed is approximately 28% and the protein content 24% whereas the crude fiber content of dehulled cottonseed is approximately 10% and the protein content 45%. The top shaft illustrated therefore is designed to process a high crude fiber material, which builds up considerable friction between the worm shaft and the barrel housing. On the other hand, the second shaft illustrated is designed to handle a material of lower crude fiber content, which does not build up as high a case friction as whole cottonseed. The shaft illustrated at the bottom of Figure 14 may be used in the high capacity prepress machines.

The capacity of a screw press is a function of the shaft arrangement and the shaft speed. For example, one Expeller can process the meats from 25 to 100 tons of cottonseed per day, yielding cottonseed cakes ranging in oil content from 2.7 to 9%, depending upon the shaft speed and the worm arrangement selected. The shaft arrangement shown in the middle of Figure 14 has a capacity of approximately 1.1 tons of cottonseed per day per r.p.m. At 30 r.p.m. this shaft can process the meats from 33 tons of cottonseed per day. At 45 r.p.m. this shaft can process the meats from 50 tons of cottonseed per day. At these speeds and these capacities this shaft can produce cakes containing 2.7 to 3.5% oil. The shaft shown at the bottom of Figure 14 has a capacity of approximately 2 tons of cottonseed per day per r.p.m. At 45 r.p.m. this shaft has a capacity of the meats from 100 tons of cottonseed per day. At this capacity cottonseed cakes containing 8 to 10% oil may be produced.

In general, the main worm shaft is selected to exert the proper pressure on the type of seed being processed. Screw presses however are equipped with a choke mechanism that permits a final adjustment of this pressure. This choke mechanism also permits adjustment of the pressure to counteract slight variations in the conditions of preparation of the seed.

The choke mechanism employed on larger Anderson presses is shown in Figure 15. The choke jaws, which are stationary with respect to the movement of the shaft, are guided by a grooved outer ring. This outer ring, in turn, is moved by means of a worm mechanism. By manually turning the worm mechanism, the outer grooved ring is turned to permit the choke jaws to give a desired thickness of cake.

The drainage barrel, shown in Figure 16, is made up of rectangular bars, which fit into a heavy barrel bar frame. The Anderson bars are 11 in. long and the French bars are 11$\frac{1}{16}$ in. long. The individual bars in the drainage barrel are separated by bar-spacing clips. Here again the specific spacing of the bars depends upon the type and preparation of the material being processed. For example, the spacing of the bars in the main barrel, when processing cottonseed, may be .010 in. in the feed section, .0075 in. in the center section, and .010 in. in the discharge section. On the other hand, these same sections when pressing copra may have bar spacings of .030, .020, and .010 in. The spacing of the bars not only permits the drainage of oil from the material being pressed

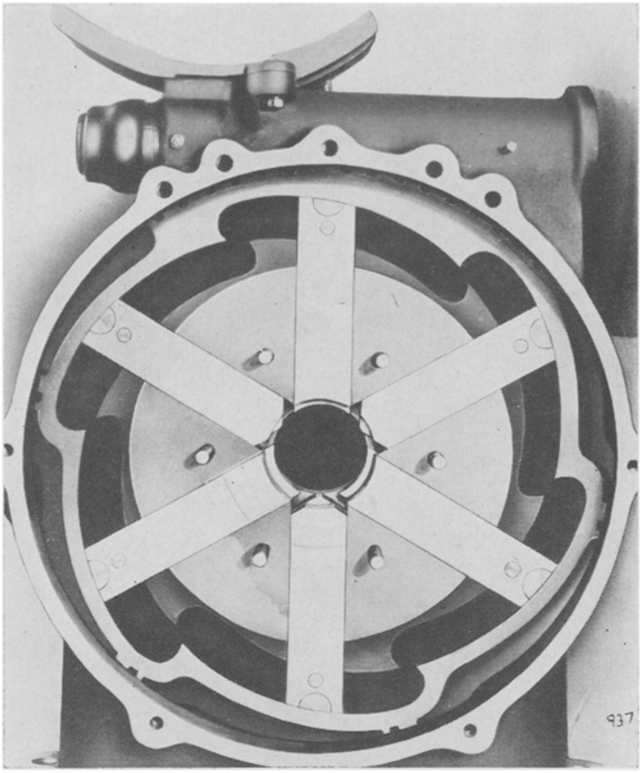


FIG. 15. V. D. Anderson Company choke jaw mechanism.

but also acts as a coarse filter medium for the solids.

The motor, transmission, and bearings are, for sure, essential elements of any motor-driven unit. In various screw-presses however the size of these units connotes the amount of work being done, which in turn indicates the necessity of rugged press construction. The main worm shafts of some screw-press intallations today operating on copra, for example, are equipped with 50 h.p. motors operating at 20 r.p.m. The maximum torque on a main worm shaft with this motor at 20 r.p.m. may be 16,000 ft. lbs. The maximum thrust may be as high as 110 tons. All of this work, of course, is not spent in merely conveying a raw material through a mechanical screw-press. Some of this work is required to compress the solids being processed. Of major importance, a good deal of this work exhibits itself in the form of heat because of the friction between the material being pressed and the encasing elements of the machine.

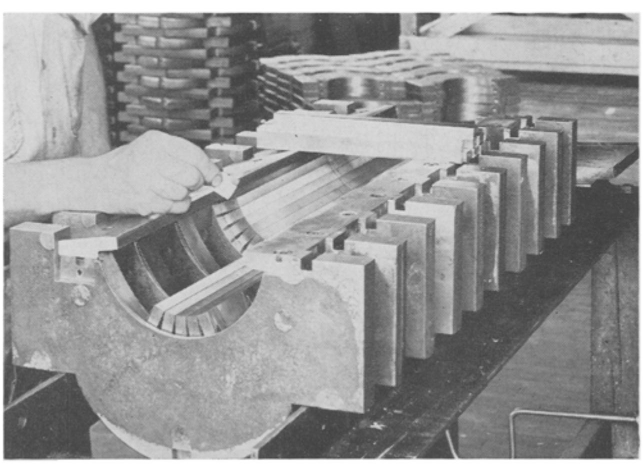


FIG. 16. V. D. Anderson Company horizontal barrel showing lining of barrel with barrel bars.

Because of this heat, various cooling devices are required for use with a mechanical screw-press. Machines built by the French Oil Mill Machinery Company are equipped with water-cooled shafts and water-cooled ribs in the bar cage. Machines built by The V. D. Anderson Company are equipped with an oil-cooling mechanism and may be equipped with water-cooled shafts for particular seeds. In either case the purpose of the cooling device is to dissipate the heat evolved, thus preventing the deterioration of the vegetable oil produced.

The same friction in a mechanical screw-press that evolves heat also presents an erosion problem. During the years emphasis has been placed upon the development of special alloys of fabrication for screw-press parts and the development of metal heat-treating methods to keep stride with increased pressures employed in the presses.

Heat Transfer

Although heat transfer and the unit operation, drying, are closely associated with humidification, the specific application of heat transfer to oil cooling may be mentioned. In cooling the horizontal and vertical barrels of an Anderson Expeller, process oil as stated above is pumped over these barrels at a rate of 50 g.p.m. of oil per Super Duo Expeller. With water at 70°F., 10 g.p.m. of water are required to cool the process oil from the Expeller, in the case of cottonseed, to 120°F., for recirculation to the Expeller bed. A fintube heat exchanger of 202 sq. ft. of surface per Expeller unit is suitable. In the case of a water-cooled shaft, approximately 3 g.p.m. of water at a temperature under 100°F. are pumped through the shaft for reducing the skin temperature between the shaft and the material being pressed.

In a French screw press, which utilizes water cooling in the rib cage, approximately 10 g.p.m. of water at 72° are required per press.

Fluid Flow

Water and vegetable oil are the two materials transported in the fluid state in oil mills. Fluid flow characteristics of water may be obtained from many handbooks. Fluid flow characteristics of vegetable oils depend primarily upon the solids or foots content of that oil. The product and cooling oil flowing from an Expeller at approximately 55-g.p.m. rate is preferably transported to the screening tank in a screw conveyor or an inclined trough. After settling the oil in the screening tank, the oil that is cooled and recirculated to the Expeller is relatively free of foots. This recirculated cooling oil can be pumped at 70 p.s.i. head with 3.75 h.p. at at rate of 50 g.p.m. per Expeller.

Sedimentation

The oil from the mechanical press is first settled to remove the bulk of the vegetable seed solids, which are called foots. A screening tank, illustrated in Figure 17, may be used for this purpose. The vessel is so designed that the product oil, before filtering, passes through a settling zone at a velocity of .001 ft. per second. Although the screening tank is an effective means of separating the bulk of the foots from

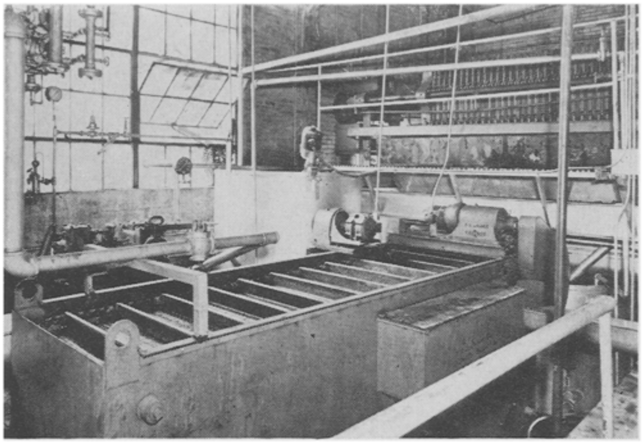


FIG. 17. Screening tank showing filter plate and frame filter press in background.

the process oil, the degree of settling is greatly dependent upon the degree of cooking. Using cottonseed as an example, if the cottonseed meats are processed at too low a moisture or at too high a temperature, so that actual cooking does not take place, many fine particles will accumulate in the screening tank with the oil and will ultimately be pumped to the filter press. Two qualitative indications of the correctness of the cook are the amount of foots on the screening tank and the texture of these foots. If the foots are relatively small in amount and soft and mealy, the cooking has not been completed. If the foots are of a nominal amount (approximately 2% by weight of the meats being pressed) and of a flinty texture it can be assumed that the cooking conditions are more or less right.

Filtration

After settling, the oil must be filtered ahead of storage. Normally one 36 x 36 x 36-in. plate filter press will be suitable for an 18-hr. filter cycle in a mill processing, for example, 100 tons of cottonseed per day. Again the rate of filtration and the length of filter cycles are highly dependent upon the control of the cooking and drying operations.

Mixing

After the cake from a mechanical-press mill is ground in the meal room, it is customary when pressing certain vegetable seeds to mix hulls back with the ground meal in order to adjust the protein content. This is quite often accomplished by proportioning a predetermined stream of ground hulls into a predetermined stream of ground meal. The mixture is then conveyed, preferably in a cut-flight type of conveyor, for a distance of several feet in order to obtain a uniform blending of the components. Some mills use a standard dry-solids mixer for this operation.

During the last 10 years oil millers have accomplished the industrial revolution in mechanical pressing by studying the above unit operations and by applying the results of those studies to the operation of their mills. As stated earlier, probably the one operation that has had the greatest influence on this oil-milling revolution has been the control of moisture. It is interesting to ask, "are the above conditions of seed preparation necessarily the best and optimum conditions for preparation in order to obtain the highest yields of oil and the best quality of oil and cake?" For example, in the rolling of cottonseed meats, is it possible that these meats should be conditioned with more moisture and some heat prior to rolling and that rolling should be conducted at 11% moisture instead of 9%? In other words, are we positive that the conditions that we are employing today in our oil mills are the ultimate, or do we believe that in one, three, or five years further great strides in meats and seed preparation may be realized to further increase the efficiency of an oil mill?

By a study of the data in Figure 1 it is apparent that the work of the miller, the researcher, and the manufacturer is not completed. A further study of the process variables and of the optimum conditions of these different variables is necessary so that through their control the oil mill of five years in the future will be more efficiently operated than the oil mill of today.

To aid in this increase in efficiency of oil mills, Anderson has designed and installed a larger Expeller that has a longer bed casting. This longer bed casting is designed for a 55-in. horizontal barrel instead of the standard 33-in. horizontal barrel. On start-up of this machine in a cottonseed mill the Expeller processed the meats from 50 tons of cottonseed per day, producing a cake which contained 2.8% oil on a 41% protein basis. In spite of the increased capacity the residual oil remained at the low value of 2.8%. By combination of the endeavors of the machinery manufacturers further to improve their equipment and by a study of processing conditions in the oil mills, mechanical press mills should in the future operate at higher capacities per press yet obtain the same or lower residual oils in the cake and continuing to improve the quality of products.

REFERENCES

1. Dunning, J. W., Oil Mill Gazetteer, *55*, 21–22 (1950).
2. Dunning, J. W., Oil Mill Gazetteer, *56*, 64–68 (1951).
3. Dunning, J. W., and Terstage, R. J., J. Am. Oil Chemists' Soc., *29*, 153–155 (1952).
4. Dunning, J. W., and Keahey, H. P., J. Am. Oil Chemists' Soc., *29*, 627–628 (1952).
5. Ennis, W. D., "Linseed Oil and Other Oil Seeds," p. 181–186, D. Van Nostrand, New York, 1909.
6. Goss, W. H., "History of Oil Seed Processing," Proceedings of Am. Oil Chemists' Soc. Short Course, 1948, p. 52–59.