Mechanical Extraction of Drying Oils

JOHN W. DUNNING, Research Department. The V. D. Anderson Company, Cleveland, Ohio

THERE are four methods of extracting animal and vegetable oils that are in most common usage in this country today. These four methods are: a) hydraulic pressing; b) mechanical screw pressing; c) solvent extracting; and d) a combination of mechanical screw pressing with subsequent solvent extracting. I should like to discuss with you the first two of these methods and briefly mention certain aspects of the fourth method.

J. W. Dunning

In a study of the extraction of oil from vegetable seeds two distinct phases of the extraction process present themselves. One phase concerns the mechanical equipment involved, the other phase concerns the mode of operating this equipment. Another manner of expressing this same idea is to state that one phase concerns the mechanics of oil extraction while the other phase concerns the chemistry, and particularly the physical chemistry, of oil extraction. These two phases are actually interdependent and inseparable in practice. However the mechanical equipment used in oil extraction varies widely for the different methods whereas the chemical aspects have much in common. We shall therefore discuss the mechanical extraction of oil from vegetable seeds with this distinction in mind.

It is difficult to appreciate modern oil mill equipment and present day modes of operation without some reference to oil mill practices of years ago. A century ago oil mill procedures in many respects paralleled in a qualitative way our procedures of today, but the recent developments in mechanical design, metallurgy, and instrumentation, coupled with the modern trend of "bigger and better," have enabled our plants of today to dwarf those of 100 years ago.

For example, until the first part of the 18th century, oil was extracted from some of the flaxseed and some of the other seeds by means of hand screw presses. These manual screw presses were superseded early in the 18th century by horizontal hydraulic presses, which in turn were soon displaced by vertical hydraulic presses. The seed in these early mills was handled entirely by manual labor. In fact, the first flaxseed plants in this country received their seed in bags rather than in carload bulk quantities. The seed was first fed to a pair of horizontal cast iron rolls to give it a preliminary crushing. The coarsely rolled seed were then shoveled, by hand, to "muller" stones. The coarsely crushed seed were finely ground between the mullers and the bed stones of these machines while water was added to the mass to keep it thoroughly wet. After reaching the proper condition of fineness and moisture, the meal was transferred to steam heated kettles in which the meal was cooked. It was then placed in woolen bags, which were laid in an envelope of woven hair and placed in the hydraulic presses. The cakes, after expression of oil, weighed eight or nine pounds each, and each press usually held six to eight cakes. The oil content of these pressed cakes was as high as 15% (1).

It is interesting to reflect on the procedures mentioned in the preceding paragraph. The procedures employed in an oil mill of 50 to 100 years ago parallel the procedures used today. Many refinements in control have been introduced, however, and the size of contemporary oil mills has necessitated mechanical handling of seed, larger equipment, and more rugged equipment.

ALTHOUGH the hydraulic press is disappearing from the American scene, many hydraulic installations are still used to recover oil from cottonseed and peanuts. Two types of presses are in common usage, the box press and the cage press. The box press, shown in Figure 1, is used extensively in the pressing of oil from cottonseed. It is called a box press because the individual spaces for receiving the meats or seeds are literally boxes. Some difficulty is experienced in using these box presses because the angle iron frame of the boxes tends to give under repeated use, thus permitting slippage of the meal exposed to pressure. The cage press is normally used on seeds of higher oil content. This press, in a great

FIG. 1. Hydraulic box press installation showing removal of slabs from press.

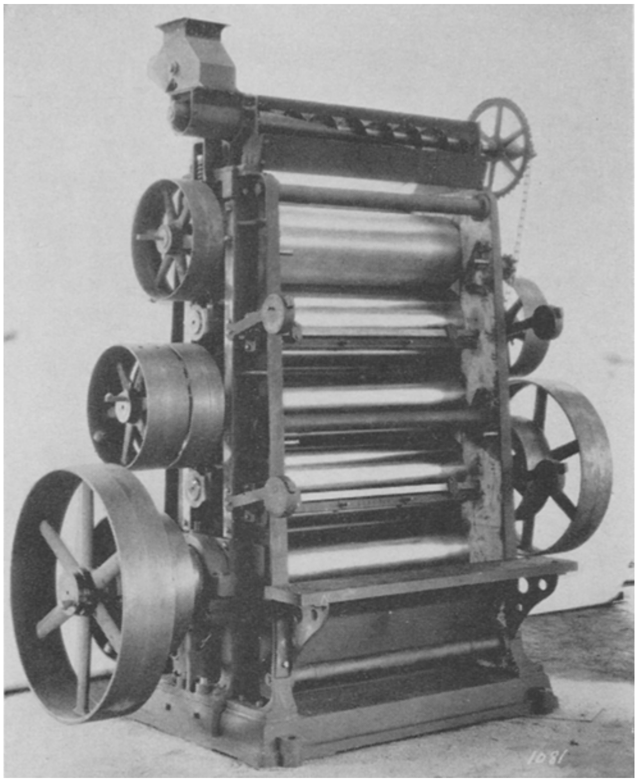

Fig. 2. French 5-High Rolling Mill.

measure, overcomes the spreading and escaping of meats from the sides of the cake under pressure as is experienced with the box type press.

A hydraulic press mill for processing flaxseed, as an example, is equipped with the usual seed handling, storage, and cleaning equipment. The cleaned seed are weighed to the oil recovery equipment. The weighed flax, in a steady stream, is rolled to particles of .005 to .010 in. thickness, usually in vertical roller mills. A set of five high rolls for this purpose is shown in Figure 2. The rolled meats are then "cooked" and dried before being delivered to the hydraulic presses. A type of cooker used for this operation, a 4-high stack cooker is shown in Figure 3. The "cooked" and dried seed are then transported to the hydraulic presses. In the case of the box press the cooked meats are formed into press cakes by a cake former, which is located below the stack cooker. Each cake, consisting of 20 to 25 pounds of seed, is formed in a press cloth which acts as a filter medium for the oil as well as a container for the seed. In the case of the cage press the cooked seeds are automatically layered in the cage presses between steel mats and press cloths. Pressure is then applied to the press to force the oil from the seed. There is voluminous literature concerning the operation of hydraulic presses. This literature concerns primarily the rate of application of pressure and the drainage time as these two factors influence capacity and residual oil in the cake. The chapter entitled "Cooking of Meats and Recovery of Oil" in the book "Cottonseed and Cottonseed Products" (2) gives a recent and excellent review of hydraulic press operations.

It is of interest to note that an average drainage or pressing time in a hydraulic mill of approximately 30 minutes is usual with a maximum pressure of approximately 5,000 pounds per square inch. Under these conditions the oil left in the cake will be something under 6%, depending on various efficiency measures in different plants.

As mentioned previously, the press cake from a box type hydraulic press undergoes some slippage during the pressing cycle. This part of the cake from an old press may amount to 6% of the total cake and may contain 10 to 15% oil. This softer part of the cake, after stripping of the cloths from the slab, is trimmed from the slab in specially designed cake trimmers. In some mills this high-oil part of the cake is returned to the stack cookers. In other mills small mechanical screw presses are employed to process this material. The press cakes are then sold as slab cake, or they are ground and sold as meal.

The oil from the presses is usually settled. One type of settling chamber or screening tank commonly used is shown in Figure 4. The oil is then filtered and ready for use as crude oil.

THE purpose of an oil mill, of course, is to express oil from oil bearing seeds. Given any set of equipment for this work, the efficiency of the operation and the value of the products are dependent upon the control of the several preparatory operations involved. The seed is cleaned to remove foreign matter that will contaminate the products, lower the mill capacity, and cause excessive wear of equipment. The seed is rolled to thin particles in order to permit a more uniform cooking of the seeds and to expose the oil bearing cells of the seeds. The rolled particles

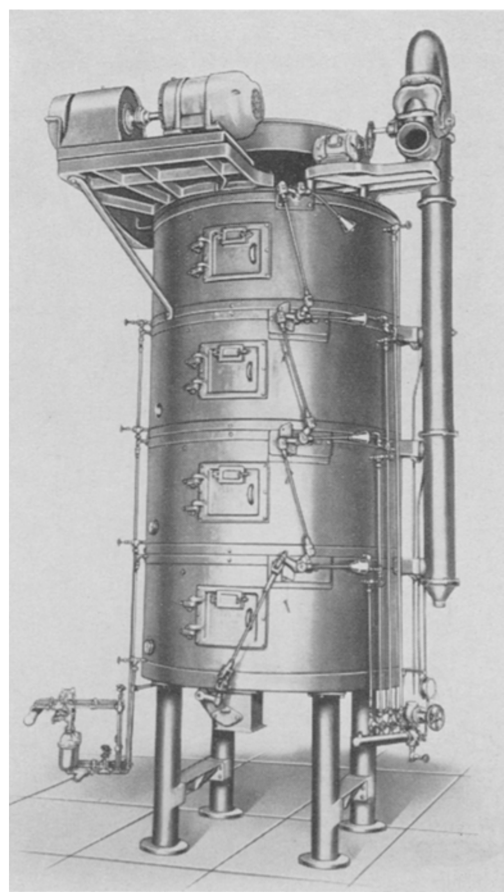

Fig. 3. French 4-High Stack Cooker.

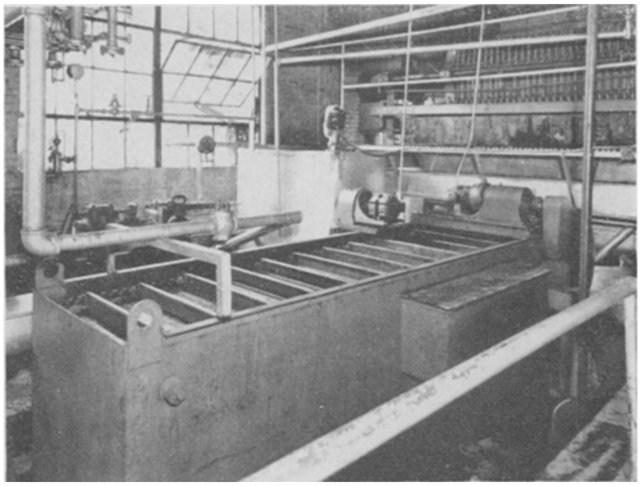

FIG. 4. V. D. Anderson Screening Tank Installation showing unfiltered oil storage tank and filter press in background.

are then cooked to coagulate or solidify fluid protein and phosphatide components of the seed, to rupture the oil cells, to increase the fluidity of the oil, and to remove the optimum amount of moisture for most efficient press operations. The actual conditions for cooking may vary from mill to mill. In an hydraulic operation on cottonseed the meats may be heated to a temperature of 190°F. as rapidly as possible and simultaneously adjusted to an initial moisture content of 11 to 12% in the top ring of the stack cooker. The temperature of the meats is increased during the passage through the stack cooker and over a period of 80 to 120 minutes time to a final discharge temperature of 230 to 240°F. At the same time the moisture content of the meats is reduced to a final value of 5 to 5½%.

The cooking of flaxseed, on the other hand, may involve the heating and drying of the flaxseed to a final temperature of 175 to 200°F. and to a final moisture content of 5 to 5½%. Flaxseed are normally retained in the stack cooker under the above conditions for a period of time ranging from 60 to 90 minutes.

In 1876 V. D. Anderson conceived the idea of a mechanical screw press for pressing oils from vegetable seeds. In 1900 the first successful press called an "Expeller" was manufactured. In 1906 the Expeller was used on vegetable seeds, and the first order of Expellers was delivered to a flaxseed mill. A picture of this Expeller, called a Model No. 1, is shown in Figure 5.

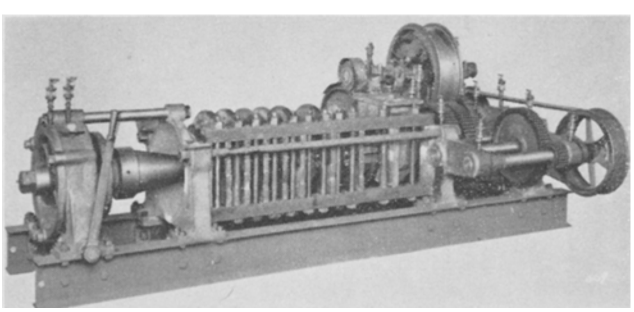

FIG. 5. Model No. 1 V. D. Anderson Expeller manufactured in 1906.

In the succeeding 44 years many improvements have been made in the design and operation of mechanical screw presses. At the present time the two leading manufacturers of mechanical screw presses in the United States are the French Oil Mill Machinery Company and The V. D. Anderson Company. Figure 6 is a picture of a modern Anderson Duo Expeller, equipped with 24″ tempering apparatus. Figure 7 shows the Anderson Twin Motor Super Duo Expeller equipped with a 36″ Cooker-14″ Conditioner Unit. Figure 8 shows a modern French 4-Section Mechanical

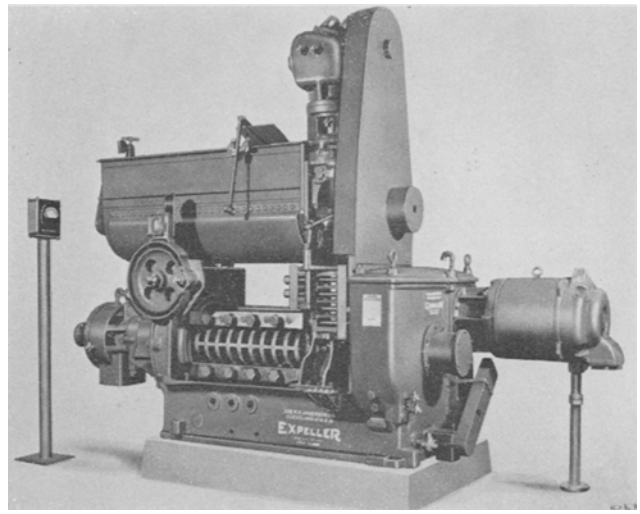

FIG. 6. Anderson Duo Expeller equipped with Tempering Apparatus.

Screw Press equipped with a four-high cooker-dryer. In the French four-section machine the material being pressed has a straight line flow through the machine, the feed section being operated at a higher speed than the main pressing section. This higher speed feed section applies an initial pressure to the material being processed which starts the flow of oil. In the Anderson Super Duo Expeller the feed worm which initiates the expulsion of oil is perpendicular to the main worm shaft.

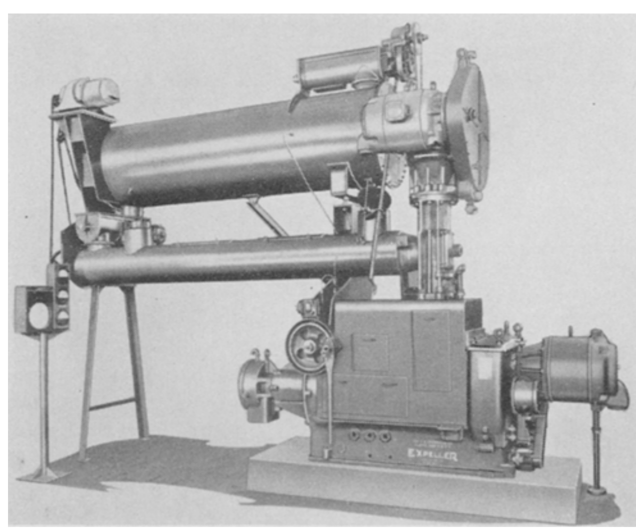

FIG. 7. Anderson Twin Motor Super Duo Expeller equipped with 36″ Cooker-14″ Conditioner Unit.

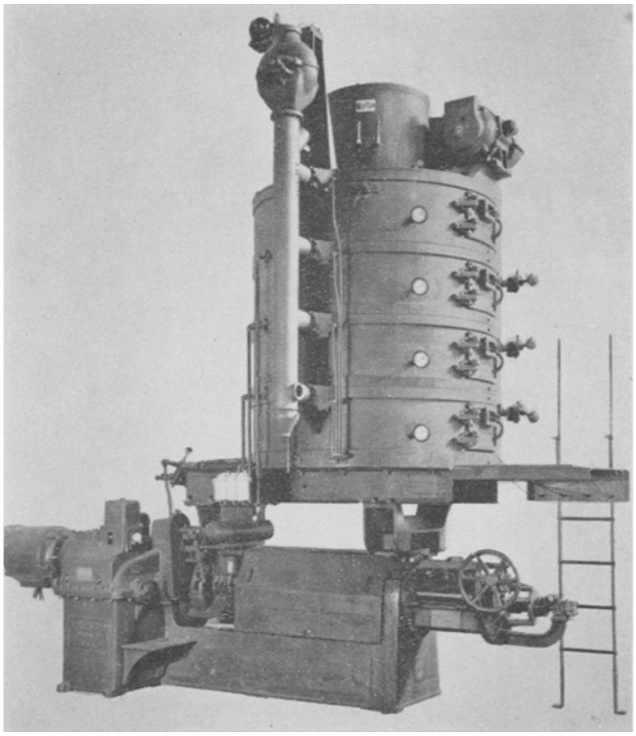

FIG. 8. French 4-Section Mechanical Screw Press equipped with 4-High Stack Cooker.

It would be difficult to estimate the number of mechanical screw presses that are 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 primarily because of the saving in press room operators and because of the increase in oil yield from the raw material. In addition, the inherent efficiencies of a mechanical screw press installation, with its relatively low installed cost, has made it possilbe 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 10,000 to 30,000 pounds per square inch 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 9. The top shaft illustrated has four carrying worms with a 4½″ shaft diameter at the feed section. The second shaft also has a 4½″ 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″ instead of 4½″ and the shaft taper is more gradual. The shaft illustrated at the top of the figure is used for pressing of oil from 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 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%. These values are calculated to an oil free basis. 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 9 may be used in the high capacity prepress machines.

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 drainage barrel is made up of rectangular bars which fit into a heavy barrel bar housing. The Anderson bars are 11″ long, and the French bars are 11$\frac{1}{16}$″ long. Therefore the main drainage barrel of an Anderson Expeller, which is approximately 33″ long, consists of three sections of bars. 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 flaxseed, may be .010″ in the feed section, .005″ in the center section, and .005″ in the discharge section. On the other hand, these same sections may have bar spacing of .030″, .020″, and .010″ when pressing copra. The spacing of the bars not only permits the drainage of oil from the material being pressed 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 sizes of these units

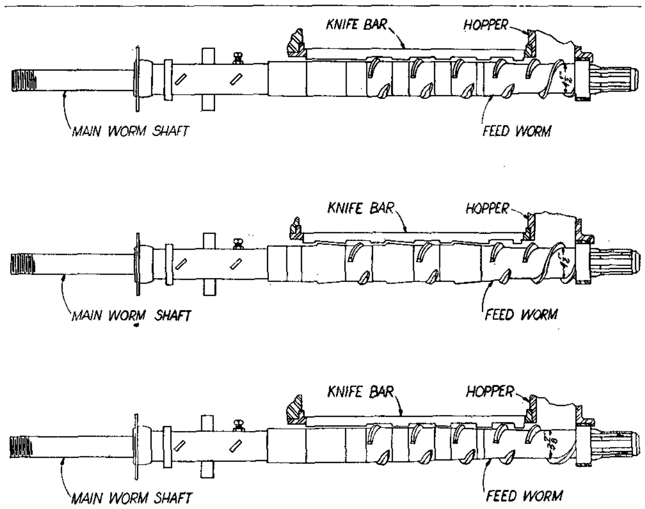

FIG. 9. Three typical horizontal worm arrangements for Anderson Expeller.

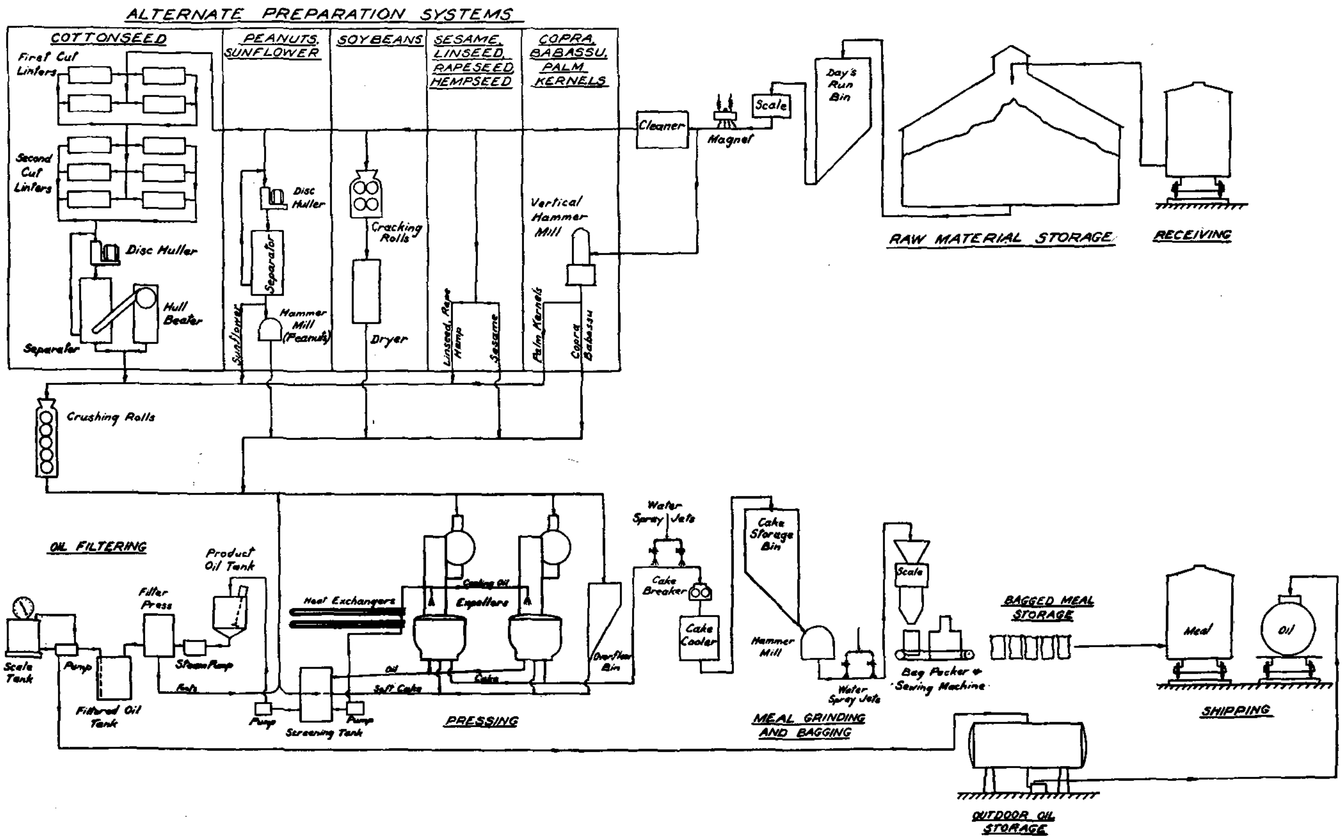

FIG. 10. Universal flow sheet for mechanical screw press operation on vegetable oil seeds.

connote the amount of work being done, which in turn indicates the necessity of rugged press construction. The main worm shafts of some screw press installations today are equipped with 50 HP motors. The maximum torque on a main worm shaft, when processing copra, for example, may be 16,000 foot pounds. The maximum thrust, when processing copra, 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.

On account of excess amount of this heat various cooling devices are necessitated 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.

This 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. It must be mentioned that rapid erosion of main worm shafts and barrel bars is quite often due to improper cleaning methods.

An unusual case of this type of erosion has occurred with crackling Expellers along about the Thanksgiving season. During this season there is an increase in turkey and chicken craws in the animal meats fed to the Expellers. If the fowl wastes predominate in the feed, sufficient sand and gravel may be present to wear out a main worm shaft in a few days.

THE general methods of preparing vegetable seeds for mechanical screw press operations are similar to those for hydraulic press operations. The same general manner of seed handling, storing, and cleaning may be utilized. Special attention, however, must be given to seed cleaning equipment in order that the erosion of screw press parts may not be excessive. The moisture content of the seed to be pressed must be reduced to a lower value (generally 3% or below) than for hydraulic operations.

The flow sheet in Figure 10 illustrates the auxiliary equipment used when processing different oil bearing seeds with a mechanical screw press. Of utmost importance is the continuous, uniform flow of seed to the presses. The steady flow of seed through the preparation quipment not only offers a greater possibility of uniformity of material to the oil extraction equipment, but also insures a continuous supply.

Of special importance in mechanical screw press operation is the cooking of the vegetable seed processed. If one were to imagine the pumping of a very thick slurry of mud to a screw press, he would expect that some of this slurry would be expelled through the barrel bars and the rest of it would be conveyed by the worms out the choke mechanism with very little separation of water and mud. On the other hand, if one were to imagine the conveying of bone dry dirt to a screw press, he would expect that this material would either immediately plug the press or would be conveyed on through with very little work done. It is apparent therefore that any material to be handled by a mechanical screw press must be in a specific physical condition to permit efficient operation of the press. It is true that a material like flaxseed may be handled by a screw press with no preparation other than cleaning. In fact, in the early days of screw press operations on flaxseed, cold press linseed oil was made in this fashion. However if the greatest yield of oil is to be obtained with a minimum of solids (foots) escaping through the barrel bars, the seed must be rolled and cooked to solidify the protein and phosphatide constituents of the seed.

The cake produced on a mechanical screw press is usually ground and sold as meal. The oil that flows from the presses is first settled, as in hydraulic operation, and then filtered, ready for sale as crude oil.

It is apparent from the foregoing that a mechanical screw press with a specific worm arrangement and bar spacing cannot handle, with equal efficiency, a high-fiber seed and a low-fiber seed, or a cooked material and a raw material, or a thoroughly cleaned seed at one instance and a high chaff seed at another instance. There are, in fact, more than 50 worm shaft and bar spacing arrangements in use for the many different materials being processed by mechanical screw presses. To obtain the maximum efficiency from a mechanical screw press therefore seed preparation methods must be controlled, seed cleaning procedures must be effective, and then proper worm arrangements with maximum effective bar spacings must be utilized.

In a subsequent paper F. P. Parkin will discuss the use of mechanical screw presses in combination with solvent extraction equipment for the extraction of oil from high oil content vegetable seeds. It should be indicated however that the generalities of the preceding discussion on expression of oil with the mechanical screw press are adaptable to the use of the mechanical screw press as a prepress machine. In order that this adaptation may be economical however the machines must be designed for high capacity. The residual oil content of the prepressed cake is, of course much higher than the 3.5 to 4% goal of single press operations.

The advances that have been made in the past years in mechanical screw press design and operation and the work that is presently being undertaken in the improvement of these machines indicate that the mechanical screw press will always have a utility in the processing of vegetable seeds. It appears that the mechanical screw press and solvent extraction and a combination of the two will go hand in hand to provide even more efficient production of vegetable oils for those engaged in this field.

Acknowledgment

The author wishes to thank The French Oil Mill Machinery Company and the National Cottonseed Products Association for certain pictures used in this manuscript.

REFERENCES

1. Ennis, W. D., "Linseed Oil and Other Seed Oils," D. Van Nostrand Co., New York (1909).
2. Bailey, A. E., "Cottonseed and Cottonseed Products," Interscience Publishers, Inc., New York (1948).

The Solvent Extraction of Drying Oils

F. P. PARKIN,* Minnesota Linseed Oil Company, Minneapolis, Minnesota

THE solvent extraction of drying oils is the application of modern science and engineering to the winning of oils from seeds and nuts. These oils through past history have found many uses in the preservation of documents and paintings. The first oils were very crudely obtained in wedge presses or by steeping the seeds and collecting the oil that floats on top. From this humble beginning in which only a small portion of the total oil in the seed was obtained, we have progressed to our present-day operations in which less than 1% extractable fat is left in the meal or residue from the seeds or nuts. The need for solvent extraction of drying oils has been brought about mainly by the economics imposed on the industry in general. That is to say, the percentage of total oil recoverable by solvent extraction as compared to mechanical pressing of the seeds is much smaller in the higher oil content drying oil seeds than will be found in the case of soybeans and other oil bearing materials that have a low oil or fat content.

F. P. Parkin

For purposes of comparison as to why solvent extraction has not been applied to the higher oil content seeds previously we may take the case of low oil content material, such as soybeans, and increase the yield of oil approximately 20% by solvent extraction over mechanically pressing the beans. In the case of flaxseed, which is considered to be a medium oil content seed, the yield of oil is increased by about 6% while in the case of the higher ranges of oil contents the oil yield is increased only about 3% by solvent extraction. Thus economics dictated that there must be high oil prices to warrant the additional cost of processing by solvent extraction.

Although our commercial experience to date has been mainly the solvent extraction of flaxseed to obtain linseed oil, the employment of solvent extraction for obtaining castor oil for treating to be a drying oil, has been used for years. Therefore, we should include oils that have been used, are now being used,

* Present address: 4815 Nokomis, Minneapolis, Minn.