Recommendations

As a result of the laboratory tests and their verification in a full-scale mill, the following recommendations are made for the benefit of hydraulic press mill operators:

1. The hull content should be kept low during pressing when the final output is sold as meal. If the cake is sold as a final product and the nitrogen content must be adjusted before pressing, this benefit cannot be realized. The addition of hulls to the cake during pressing is undesirable because it reduces the throughput of the mill and also reduces the oil yield.
2. The rate of application of pressure should be reduced below that customarily used. The experiments showed that the residual oil was reduced a measurable amount when the pressure was increased to its maximum during a 30-minute period instead of the customary 4 or 5 minutes. It is suggested that the pressure be built up over a 20-minute period in order to take advantage of this effect.
3. The total pressure on the cake need not be increased above 2,000 lb. p.s.i. unless the final cake thickness is greater than 1 in. The tests indicated that, for thin cakes, increasing the pressure had no effect on the residual oil.
4. The cake should be kept as thin as economical considerations and the throughput of the mill will permit. This is a matter which will necessarily be governed by local conditions at each mill.
5. The moisture content of the cake should be controlled carefully in order to obtain the minimum residual oil. Examination of Figure 14 shows a change in moisture content of a few tenths of 1% will increase the residual oil an undesirable amount.
6. Since the top and bottom cakes in the press are cooler than the middle cakes, it is desirable to raise their temperature by insulating them from the body of the press in any manner that may be feasible.
7. If possible, the entire press should be heated so that pressing could be carried on at a temperature of approximately 205°F. This may be accomplished by inserting strip heaters as was done for the tests, or possibly by steam passed through copper or other pipes embedded in the grates. It is probable that a jacket around the presses would be helpful, particularly in cold weather.

Acknowledgments

The tests described in this paper were carried out at the University of Tennessee during the period June 1949 to August 1952. The project was supervised by R. M. Dowd until November, 1950, at which time the project was taken over by Clyde L. Carter. The entire project was under the direction of the writer. The work was done under contract with the U. S. Department of Agriculture and authorized by the Research and Marketing Act of 1946. The contract was supervised by the Southern Regional Research Laboratory of the Bureau of Agricultural and Industrial Chemistry. Special acknowledgment is due to E. A. Gastrock, head, Engineering and Development Division, Southern Regional Research Laboratory, for his unflagging interest and helpful suggestions in the progress of the work.

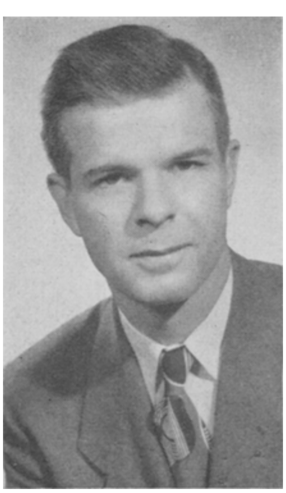
REFERENCES

1. Bailey, A. E., *et al.*, "Cottonseed and Cottonseed Products," Interscience Publishers Inc., New York, pp. 617-625 (1948).
2. Koo, E. C., *Industrial Research (China)*, *6*, 9-14 (1937).
3. Baskervill, W. H., *et al.*, Oil Mill Gazetteer, *51*, 56-63 (1947).

History and Latest Development in Expeller and Screw Press Operations on Cottonseed

J. W. DUNNING, The V. D. Anderson Company, Cleveland, Ohio

A DISCUSSION of the extraction of oil from cottonseed by means of mechanical screw presses may be divided into two broad phases. One phase concerns the mechanics of oil extraction while the other phase concerns the chemistry of oil extraction. Although these two phases will be discussed separately, it must be borne in mind that they are inseparable in practice.


J. W. Dunning

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 1), taken by Frank Anderson not many years ago, of an oil mill in the Orient. The basic unit of equipment 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. From the days of the Greek and Roman empires to the 17th century the stump press and its ancient equivalents were modified to impose more pressure on the seed being milled to give a better separation of oil from meal. The manual screw press (1) (Figure 2) may be cited as an example of this development. The vegetable seed was wrapped in some form of cloth and placed between the platens of the press. A single screw was then manually turned to impose a pressure on the seed, thus expressing some oil.


FIG. 1. Oriental stump press.

Many mechanical improvements in mill equipment appeared during the 17th and 18th centuries. It might be said that this early developmental stage was

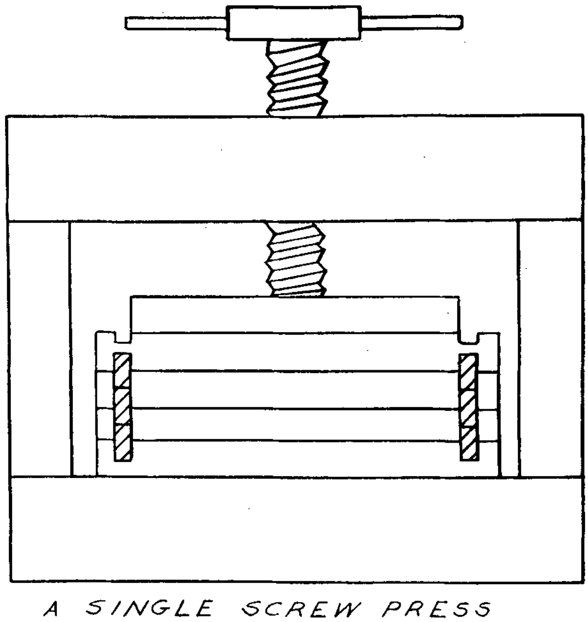


FIG. 2. Manual screw press, printed from Drachman (1).

culminated in 1795 when Joseph Bromah (7) 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 the 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 3.

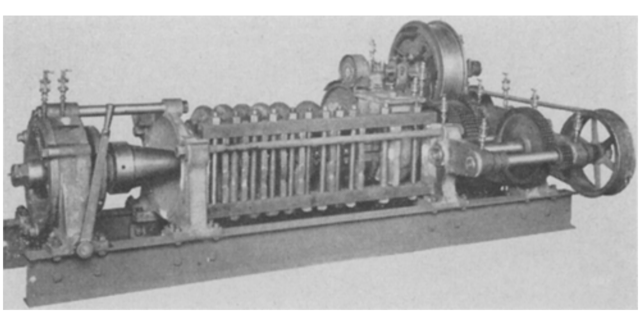


FIG. 3. Model No. 1 Expeller.

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 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 of . . . seed crushing on a small scale with a limited capital investment . . . at a relatively low manufacturing cost."

It is of importance 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.

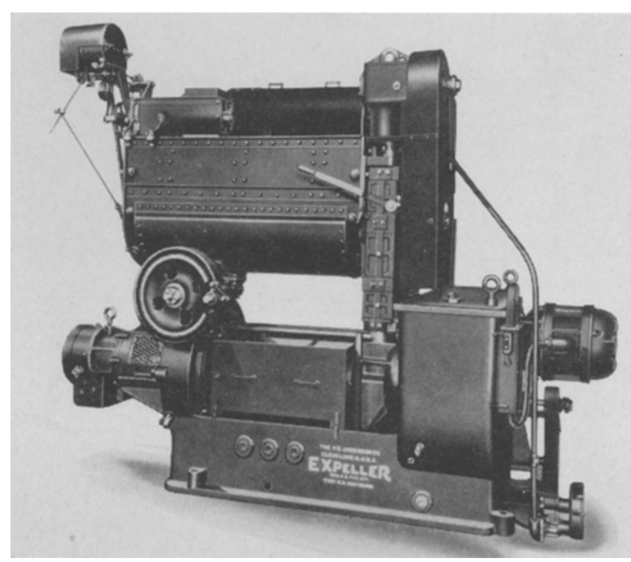


FIG. 4. Model "RB" Expeller.

In 1926 the model "RB" Expeller, shown in Figure 4, 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 "RB" Expeller.

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, The V. D. Anderson Company and the French Oil Mill Machinery Company. Contemporary screw presses manufactured by these two concerns are shown in Figures 5, 6, and 7. Figure 5 shows a Duo Expeller equipped with a tempering apparatus. Figure 6 shows a Twin Motor Super Duo Expeller equipped with a 14-in. conditioner. Figure 7 shows a French 4-Section mechanical screw press

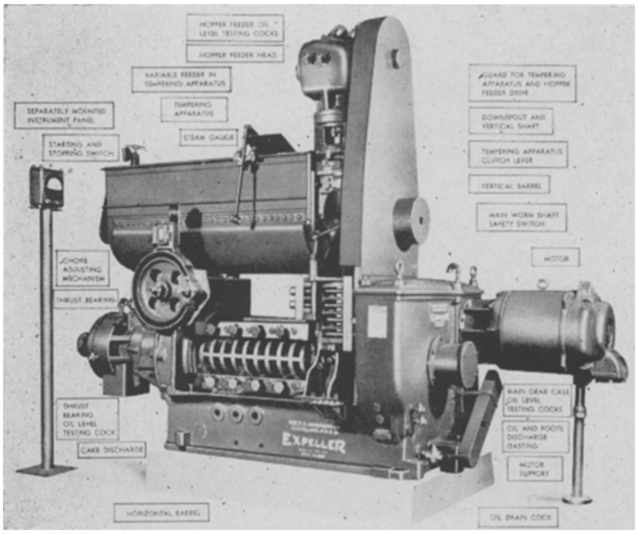


FIG. 5. Duo Expeller.

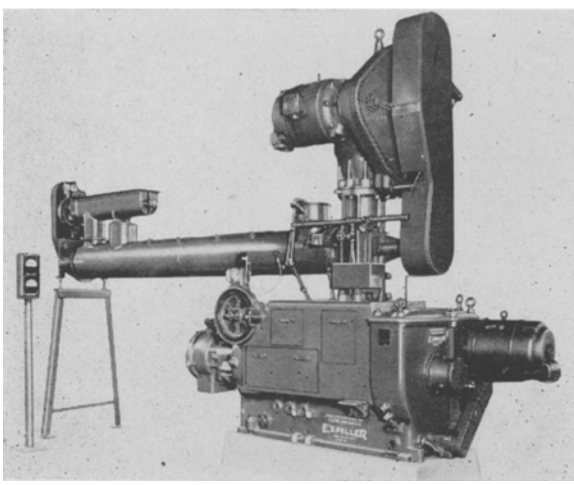


FIG. 6. Super duo Expeller with 14″ conditioner.

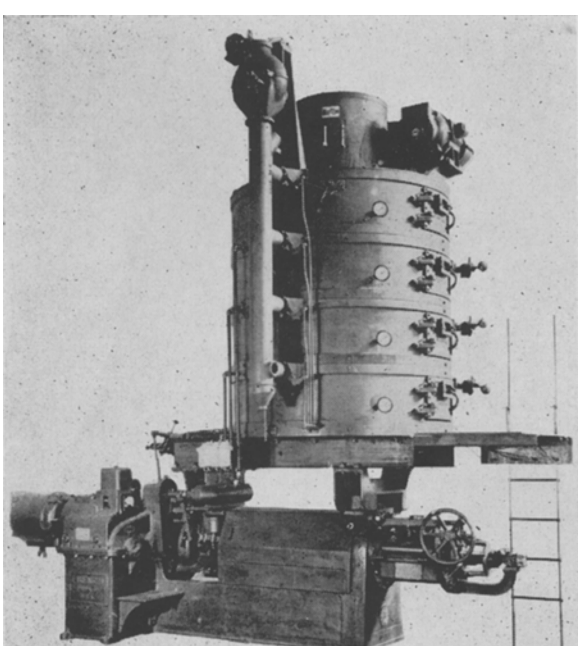


FIG. 7. Four-section French mechanical screw press.
Courtesy of French Oil Mill & Machinery Co.

equipped with a 4-high stacked cooker. 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 primarily because of the saving in 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. The 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 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 8. The top shaft illustrated has four

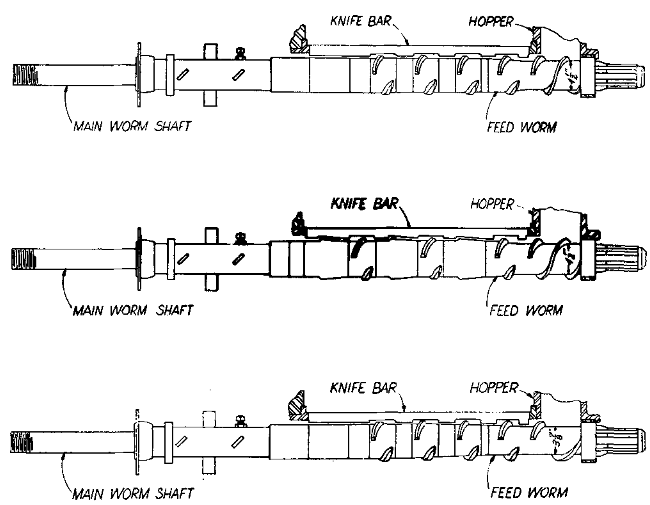


FIG. 8. Three different Anderson worm arrangements.

carrying worms with $4\frac{1}{2}$-in. shaft diameter at the feed section. The second shaft also has a $4\frac{1}{2}$-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 $3\frac{7}{8}$ in. instead of $4\frac{1}{2}$ in. and the shaft taper is more gradual. 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

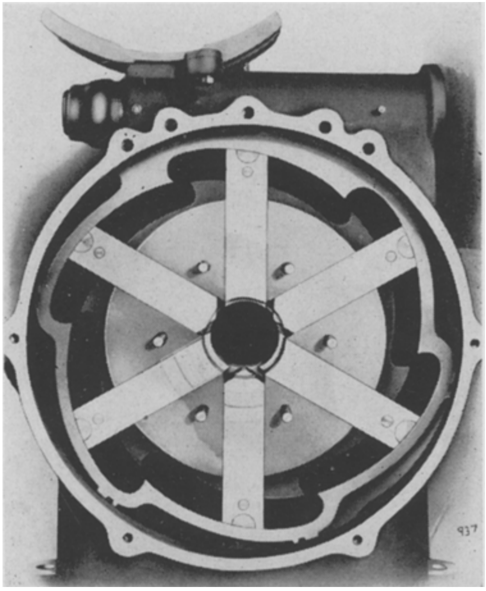


FIG. 9. Choke jaw mechanism for large Anderson presses.

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 8 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 3.5 to 9%, depending upon the shaft speed and the worm arrangement selected. The shaft arrangement shown in the middle of Figure 8 has a capacity of approximately 1.1 tons of cottonseed per day per RPM. At 30 RPM this shaft can process the meats from 33 tons of cottonseed per day. At 45 RPM this shaft can process the meats from 50 tons of cottonseed per day. At these speeds and these capacities this shaft will produce cakes containing 3.5 to 4.5% oil. The shaft shown at the bottom of Figure 8 has a capacity of approximately 2 tons of cottonseed per day per RPM. At 45 RPM this shaft has a maximum 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 9. 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 position the choke jaws to give a desired thickness of cake.

The drainage barrel, shown in Figure 10, 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. Therefore the main drainage barrel of an Anderson Expeller, which is approximately 33 in. 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 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 in., .020 in., and .010 in. 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 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 operating on copra, for example, are equipped with 50 H.P. motors. The maximum torque on a main worm shaft with this motor may be 16,000 foot pounds. 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.

Because of this heat, various cooling devises 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

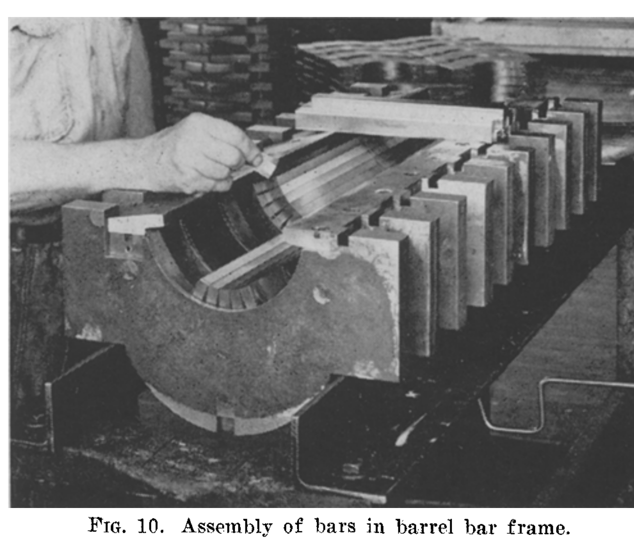


FIG. 10. Assembly of bars in barrel bar frame.

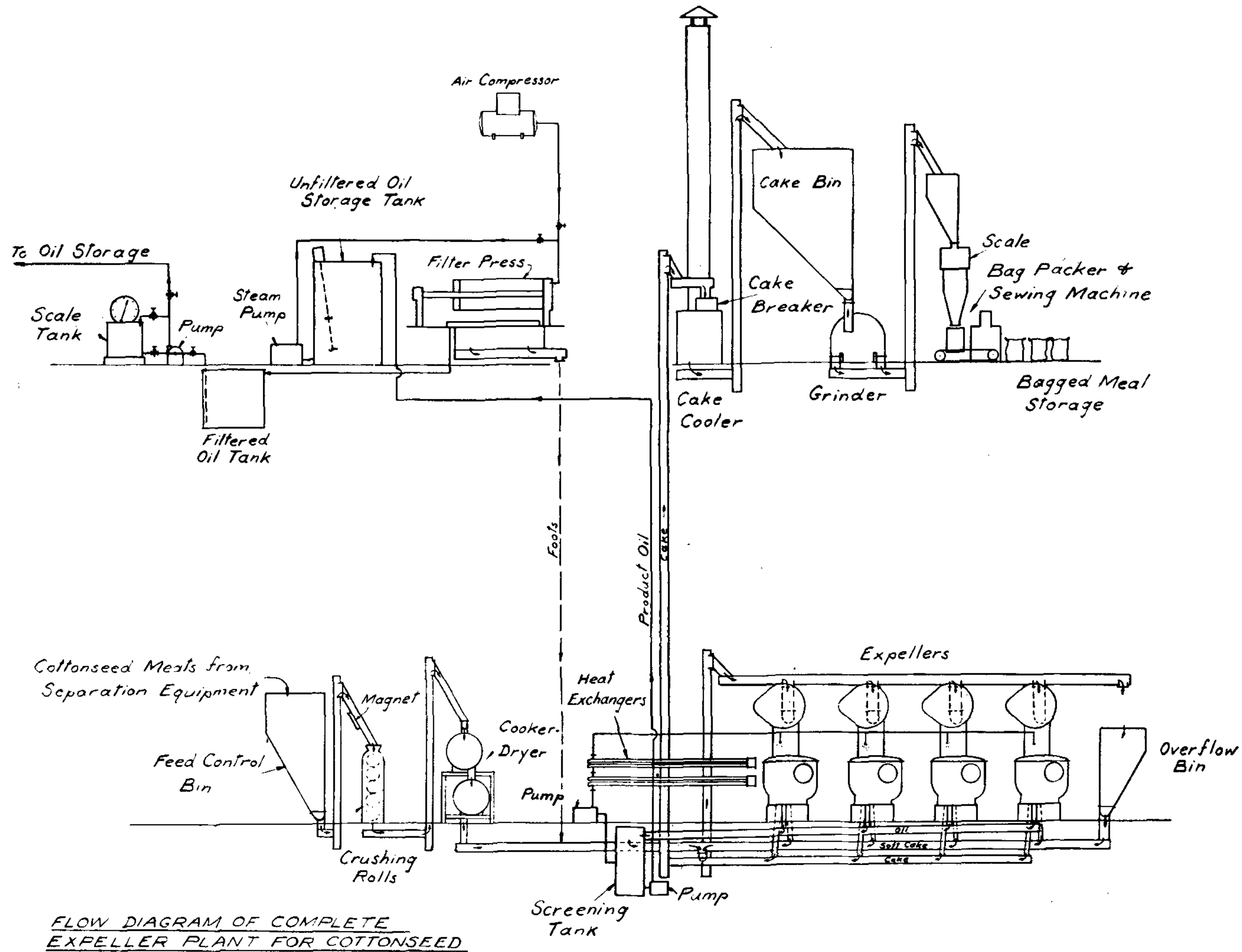


FIG. 11. Flow diagram of expeller plant for cottonseed.

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 seed cleaning methods.

Let us now turn to the composition of a contemporary mechanical screw press mill. Figure 11 is a general flow sheet of a cottonseed press room. The lint and separating equipment is not shown since this equipment is similar for the hydraulic, mechanical screw press, and solvent extraction plants. The cottonseed meats from the separating room are rolled either through conventional 5-high rollers, which are shown in Figure 12, or through a flaking roll shown in Figure 13. The rolled meats are then conveyed to a cooker. The two standard cookers employed in the United States today are the stacked cooker, illustrated in Figure 14, which is manufactured by the French Oil Mill Machinery Company and the Davidson Kennedy Company, and the horizontal cooker shown in Figure 15, which is manufactured by The V. D. Anderson Company. The cooked meats are then dried to approximately 3-4% moisture content and conveyed to the mechanical screw press. In an Anderson installation the oil from the presses flows to a screening tank, shown in Figure 16. The screening tank removes the bulk of the foots from the oil and continuously returns them to the Expellers. About 50 GPM of oil from the screening tank is pumped to the barrels of each Expeller in the plant. This oil is passed through heat exchangers to reduce its temperature to approximately 120°F. This oil maintains a uniformly low temperature of the Expeller barrel and at the same time flushes the foots from the barrel. The settled oil from the screening tank is filtered and pumped to storage. The filter cake at the end of a filter cycle is slowly conveyed to the Expellers. The Expeller cake is conveyed to the meal room where it is ground and bagged.

Having studied the layout of a mill, what is the most efficient mode of operating this mill equipment? During the years from 1906 to 1948 the capacity of the Expeller on cottonseed was more than doubled, and the residual oil in press cakes was cut in half. The screw presses and Expellers in 1948 were capable

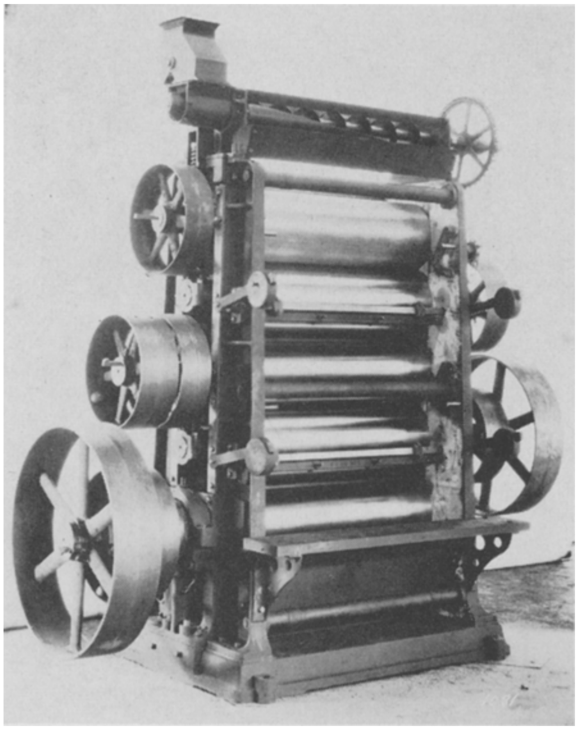


FIG. 12. Five-high roller mill.
Courtesy of French Oil Mill & Machinery Co.

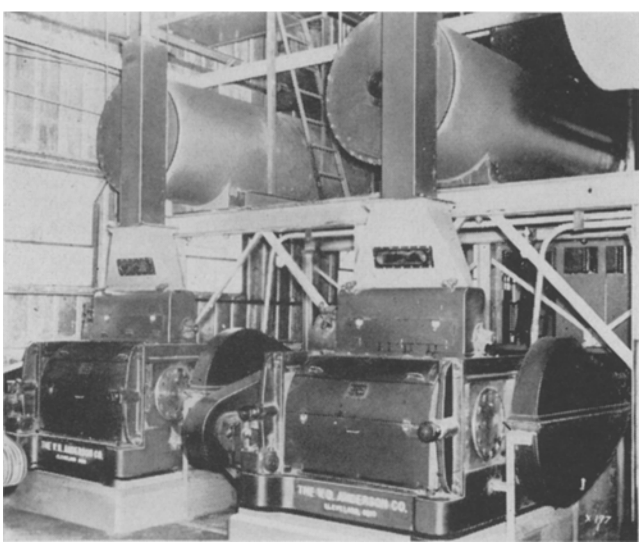


FIG. 13. Flaking mills used for rolling of cottonseed.

of handling the meats from 20-25 tons of cottonseed per day. The meats were usually rolled and cooked in some manner prior to pressing. The cooking normally consisted of moistening the meats either ahead of or in the first part of the cooker to 10-11% moisture. The moisture was then dried from the meats by heating the meats to a temperature of 235-245°F. The final moisture content of the meats was 2-3% just as they entered the downspout of the Expeller. The data in Table I obtained from a cottonseed mill in 1948 are exemplary of the practice and results of an Expeller mill at that time.

Another great stride was made in Expeller operation between 1948 and 1952. Data from one Expeller installation in 1952 is compared with the 1948 data in the same table. Again, the capacity of the Expeller has been doubled so that now an Expeller can handle the meats from 45-50 tons of seed per day. The increase in capacity has not resulted in an in-

TABLE I
Cottonseed Processing Data

	1948	1952
Expeller capacity, T/D	23	46
Residual oil in cake, %	4.2	4.1
F.F.A. in seed, %	0.4	0.4
F.F.A. in product oil, %	1.2	0.6
Refining loss		
"Expeller" method	7.5	
"Slow Break" method	12.5	3.8
Refined red color	4.3	4.5
Bleach red color	2.1	1.4

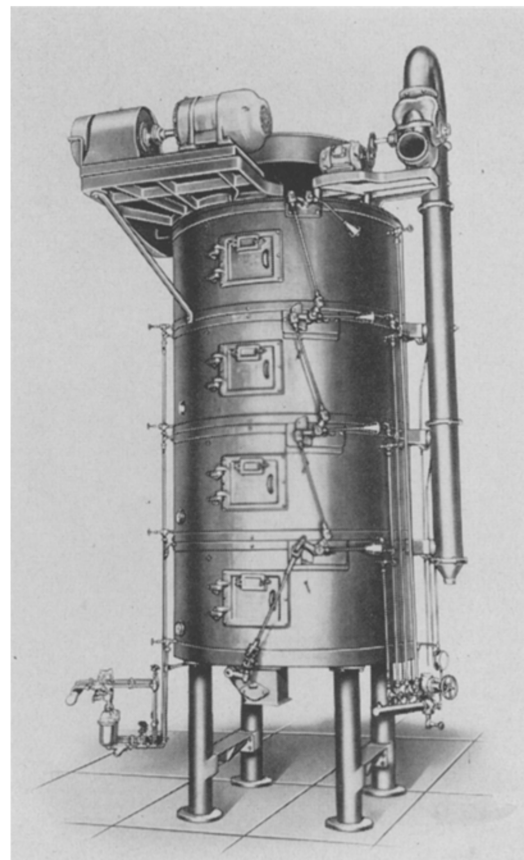


FIG. 14. Four-section stacked cooker.
Courtesy of French Oil Mill & Machinery Co.

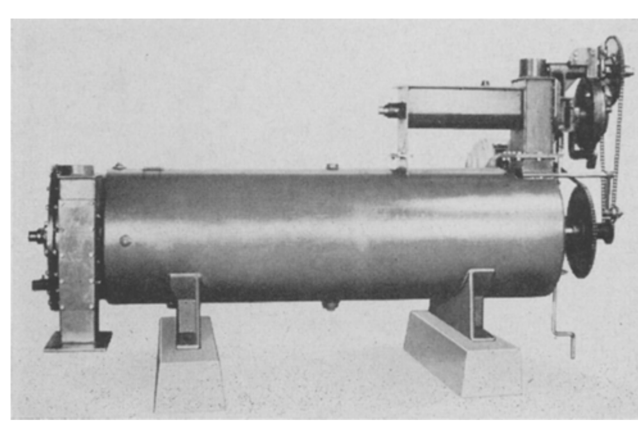


FIG. 15. Horizontal cooker.

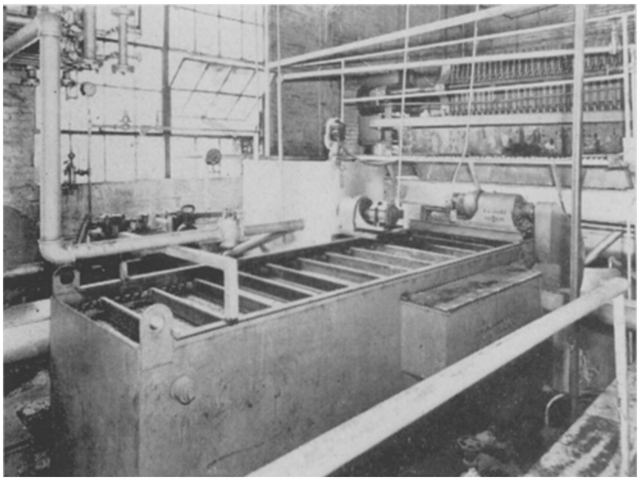


FIG. 16. Oil screening tank with filter press in background.

crease in residual oil so that Expeller cakes from high capacity machines will be approximately 4%. Not only has the Expeller capacity been doubled in the last five years, but there has been a great improvement in the quality of the oil. It will be observed in Table I that the FFA rise from the seed to the product oil was .8% in the 1948 mill. The FFA rise from the seed to the product oil in 1952 was .2%. In addition, the refining loss of the 1952 oil by the "hydraulic" method was lower than the refining loss of the 1948 oil by the "Expeller" method. The bleach color of the oil is also reduced.

A minor deviation in discussing the processing of cottonseed meats should be made in order to clarify the situation with respect to the refining loss of cottonseed oils as expressed by the "Expeller" and the "regular" or "hydraulic" methods. The refining loss methods expressed in the Trading Rules refer to the regular method, the slow break method, and the cold pressed or "Expeller" method. In the early 1900's some cold pressed oil was made in hydraulics. Most of the oil made in Expellers however was cold pressed oil. The name "Expeller method" or "Expeller oil" is therefore actually a colloquialism as a result of producing the bulk of cold press oil in the early Expellers. Even in 1948 the bulk of the cottonseed oil prepared in Expellers and screw presses was refined by the "Expeller" method. The high capacity Expeller installations, along with the necessary mode of preparation, however, has changed the situation with respect to "Expeller" oil *vs.* "hydraulic" oil. One can now make a hydraulic type of oil; that is, an oil that refines by the "hydraulic" methods, in an Expeller and a screw press. Therefore the terminology, "Expeller oil" or "Expeller method," as well as "Hydraulic" method is, today, a misnomer. When one purchases a tank car of cottonseed oil labeled "hydraulic oil," the terminology means that the oil refines by one of the "hydraulic" methods and not that the oil was produced in a hydraulic press, since it may have been produced in an Expeller. This terminology of cottonseed oil specification has caused considerable confusion and may well be a subject for consideration by the Rules Committee of the A.O.C.S.

In order to increase the capacity of the Expeller, as has been done in the last five years, and to produce hydraulic quality oil, careful attention must be paid to the preparation of the meats prior to pressing. Several articles (2, 3, 4, 5) have been recently written on this subject. It is well however to review the essential elements of this preparation.

The meats must be rolled to a thinness of .010 in.-.012 in. With dry meats it is preferable to moisten the meats to 9-10% moisture prior to rolling. The meats then should be cooked at a moisture content of no less than 12% at a temperature of 185-195°F. for 15-20 minutes. This cooking 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 FFA rise 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; to detoxify the free gossypol by rupturing the gossypol glands and causing this material to diffuse or to become absorbed into the proteinaceous material. Although the word "cooking" in reference to preparation of cottonseed meats has been used for many years, not all mills appreciate the value of establishing cooking conditions and maintaining those conditions throughout the cooking time of 15 to 20 minutes. The meats after cooking are then dried to 3-4% moisture content before entering the downspout of the Expeller. The contemporary Expeller press room therefore consists of rolls, cookers, and Expellers as has been the common practice for some years. However by the increase of the speed of the shafts of the presses and by a more careful control of the operating conditions, a present-day press can handle the meats from 40-50 tons of cottonseed per day and produce an oil that refines like hydraulic oil.

Twenty centuries of development and use of oil mill equipment evolved the hydraulic press. In another century the mechanical screw press was invented. During the following forty years of development and use the capacity of the Expeller was quadrupled. In the last five years the capacity of this machine has been doubled, and a radical improvement in oil and meal quality has been realized. It is the goal of the manufacturers of this equipment to continue their developmental program so that in the years to come the capacity of the mechanical screw presses and the quality and yields of products will be further increased.

REFERENCES

1. Drachman, A. G., "Ancient Oil Mill Presses," Levin and Munksgaard, Copenhagen, 1932.
2. Dunning, J. W., Oil Mill Gazetteer, *55*, 21-2 (1950).
3. Dunning, J. W., Oil Mill Gazetteer, *56*, 64-8 (1951).
4. Dunning, J. W., Terstage, R. J., J. Am. Oil Chem. Soc., *29*, 153-55 (1952).
5. Dunning, J. W., Keahey, H. P., J. Am. Oil Chem. Soc., *29*, 627-28 (1952).
6. Ennis, W. D., "Linseed Oil and Other Oil Seeds," p. 181-6, D. Van Nostrand, New York, 1909.
7. Goss, W. H., "History of Oil Seed Processing," Proceedings of Am. Oil Chem. Soc. Short Course," 1948, p. 52-59.