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

Conclusion

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

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Solvent Extraction Including Seed Pretreatment

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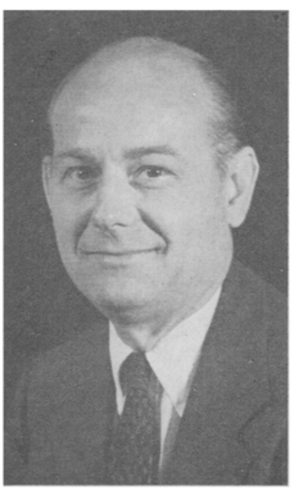
IN PREVIOUS SHORT COURSES the talks on solvent extraction have been centered chiefly on the design and operation of the various types of extractors in commercial use. As every short course speaker on this subject has emphasized, it is impossible to treat even such a limited area of the whole subject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



R. P. Hutchins

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

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

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

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

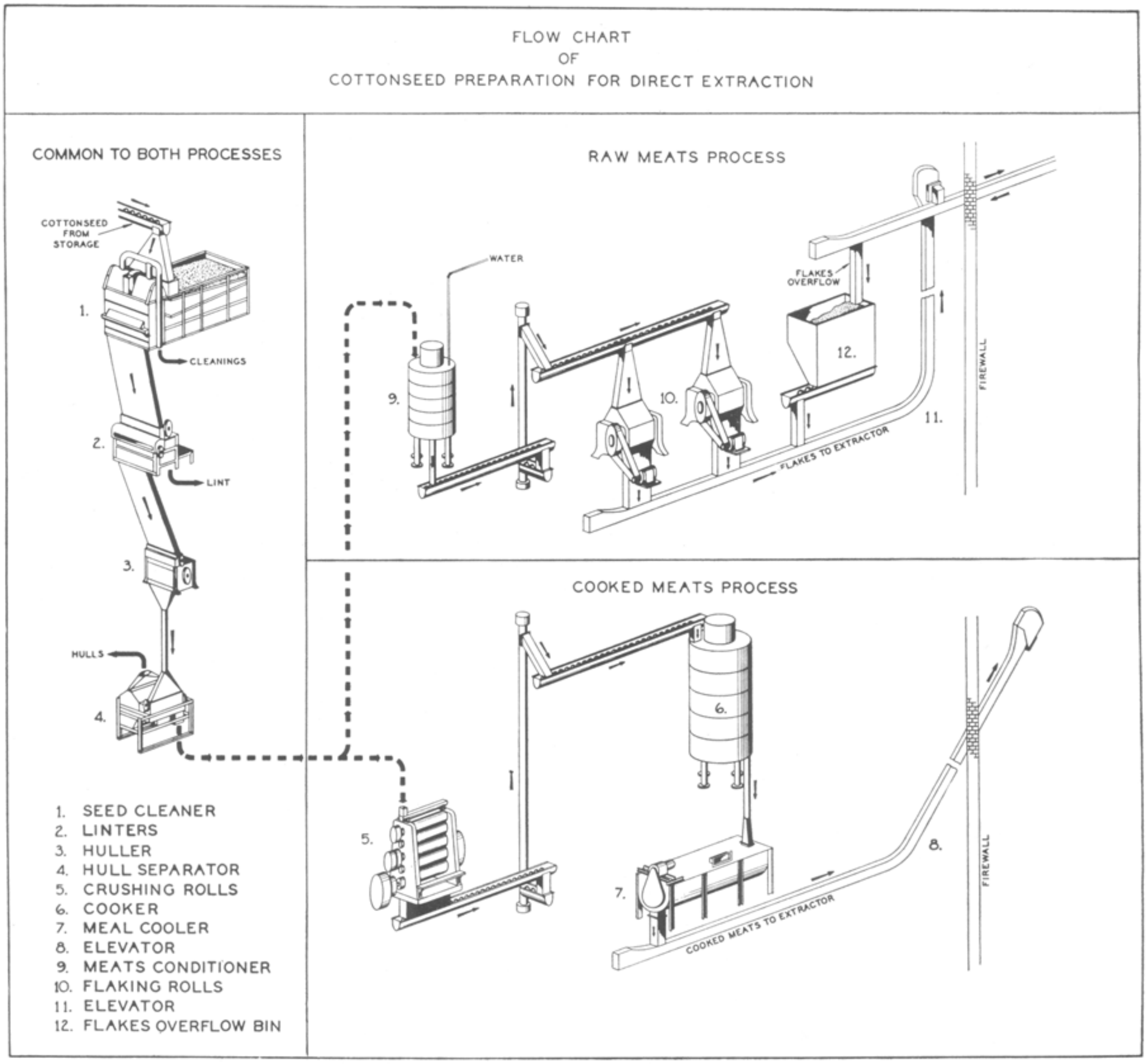


FIG. 1.

separation are increased capacity, especially through the flaking rolls, and reduced abrasion. Soybeans must first be cracked and then fine meats screened out on shaker screens before the remaining large-sized meats and hulls are separated by aspiration. The usual procedure is to aspirate heavily so that a number of meats are also picked up along with practically all of the hulls. This mixture of hulls and meats is then further separated by beating in cottonseed-type beaters or put across specific gravity tables or further treated to screening and aspiration.

The purified meats are then conditioned in a cooker type of meats-conditioner or a steam tube-dryer. The conditioning of raw meats for direct solvent-extraction is usually to a temperature of 160 to 170°F., for soybeans, with a moisture of 10 to 11%. Most other oil seeds which are to be processed by this flow are heated to a lower temperature of 120 to 130°F., particularly cottonseed, which is very sensitive to overheating so far as oil quality is concerned.

The flaking of seeds before direct extraction is a most important step requiring very careful operator control. Most meats are flaked to .010 or less before being sent to the extractor. In the flaking process and subsequent conveying to the extractor the meats will ordinarily lose 10 to 15° in temperature and 0.5 to 1.0% in moisture.

MATERIALS-HANDLING is a most important operation in the solvent-extraction process. It is involved not only in conveyors but in the design of many pieces of solvent-extraction equipment. Problems of corrosion and abrasion are intense with almost all oil seeds. Belt conveyors are almost universally used for whole soybeans and for most other oil seeds involving large-capacity conveying to and from storage. Screw conveyors and rotor lifts can be used for cracked soybeans and for most materials after hulls have been removed. Mass-flow type of conveyors are ordinarily considered necessary after the material has been flaked to prevent breaking down the material into too fine material. Screw conveyors are usually used for extracted meal although air conveying is getting to be popular. Bucket elevators are also used for elevating practically all types of materials from the unloading of raw material to the loading of the finished products.

In the direct extraction of such cooked materials as cottonseed, rice bran, and other materials including a number of high oil seeds, the material is usually first crushed in crushing rolls as shown by Item 5 in

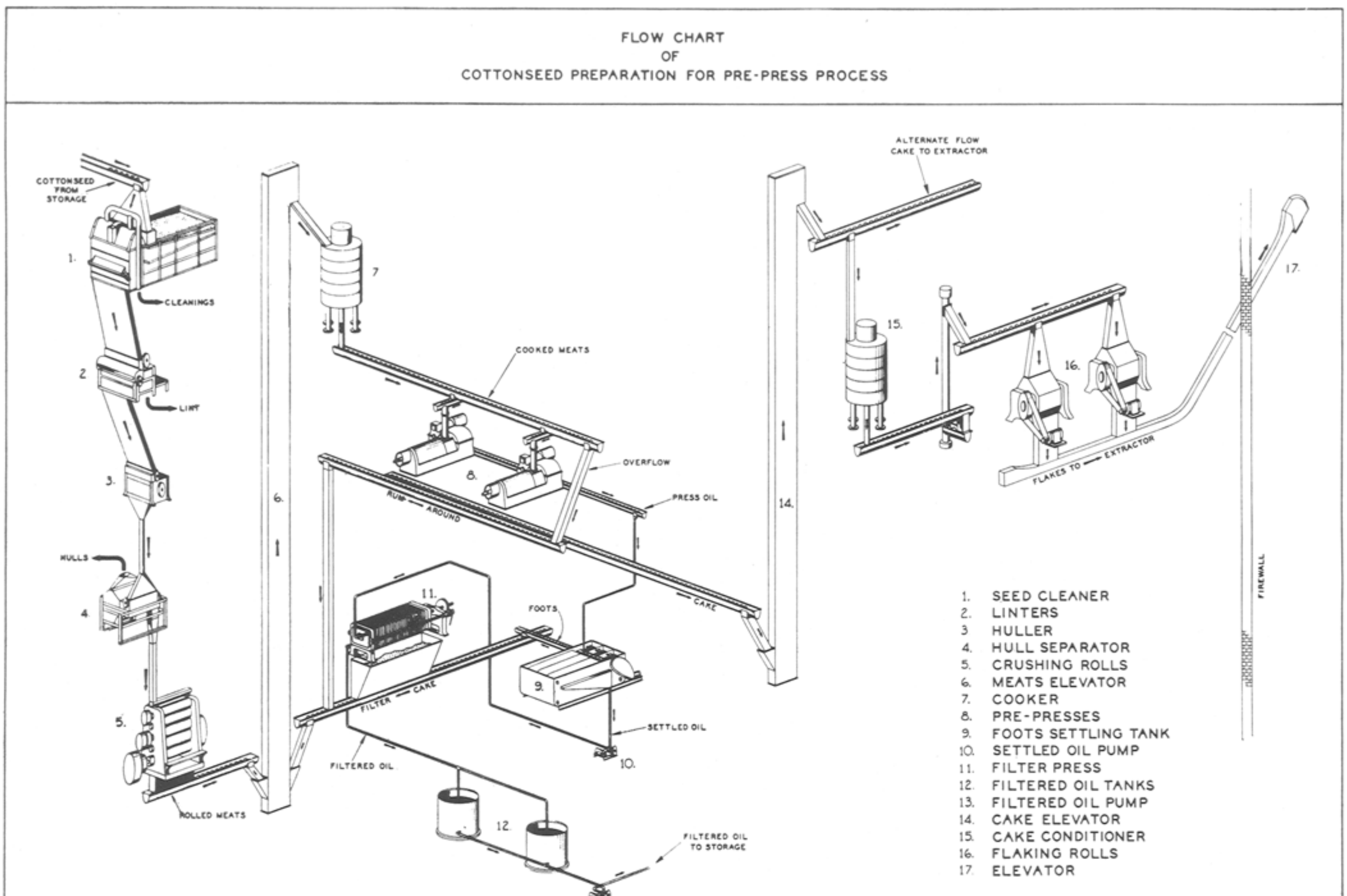


Fig. 2.

Figure 1. Adequate crushing should be to .010 thickness. The material is then cooked (4) to 220 to 230°F. for 30 to 45 min. with a maximum moisture of 15 to 25% and a finished moisture of 10 to 14%.

A most important further operation in processing cooked meats is the cooling and "crisping," which is necessary to surface-dry the particles and put them into a more granular state.

When cottonseed or other high oil seeds are prepressed, they are crushed and cooked (5) (6) before being pressed down to 8 to 18% residual oil in screw presses and expellers.

The cake from cottonseed and other oil seeds can then be extracted directly (5) very efficiently but other materials, including copra, palm kernel, and cold-pressed flaxseed, must be flaked in flaking rolls in order to get efficient extraction. Sometimes the cake is granulated after prepressing to permit easier desolventizing as well as to promote more uniform extraction (7).

The unit processes taking place in the extraction building or the extraction area are shown in Figure 3. They are: extraction, filtration, desolventizing, evaporation, stripping of oil, and solvent recovery.

The material prepared in the various ways described above is then conveyed through surge bins, sealed conveyors, or two-compartment filling devices to the various extractors which have been well described in previous courses and publications (8, 9, 10, 11). Extractors are divided roughly into the total immersion type, which are usually strictly countercurrent, and the percolation type, which usually have an initial concurrent and filtering section followed by a countercurrent section. Examples of the immersion types in this country are the V. D. Anderson (12) and the Allis-Chalmers (13) extractors. The percolation type of extractors in commercial use in this country are the French Basket Extractors (10), the Blaw-Knox Rotocel (9), and the Filtration Extractor (14).

Filtration is a unit process of varying importance, depending upon the type of extraction system used

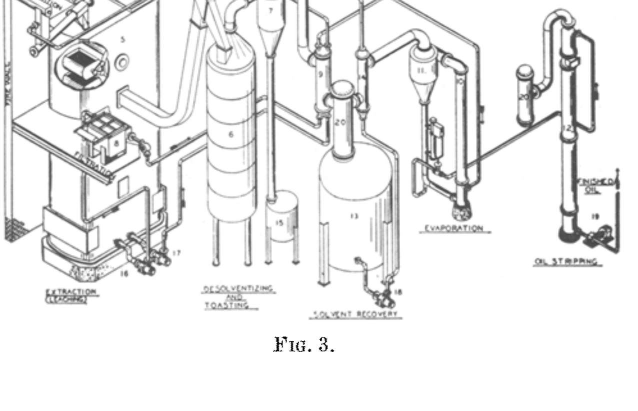


Fig. 3.

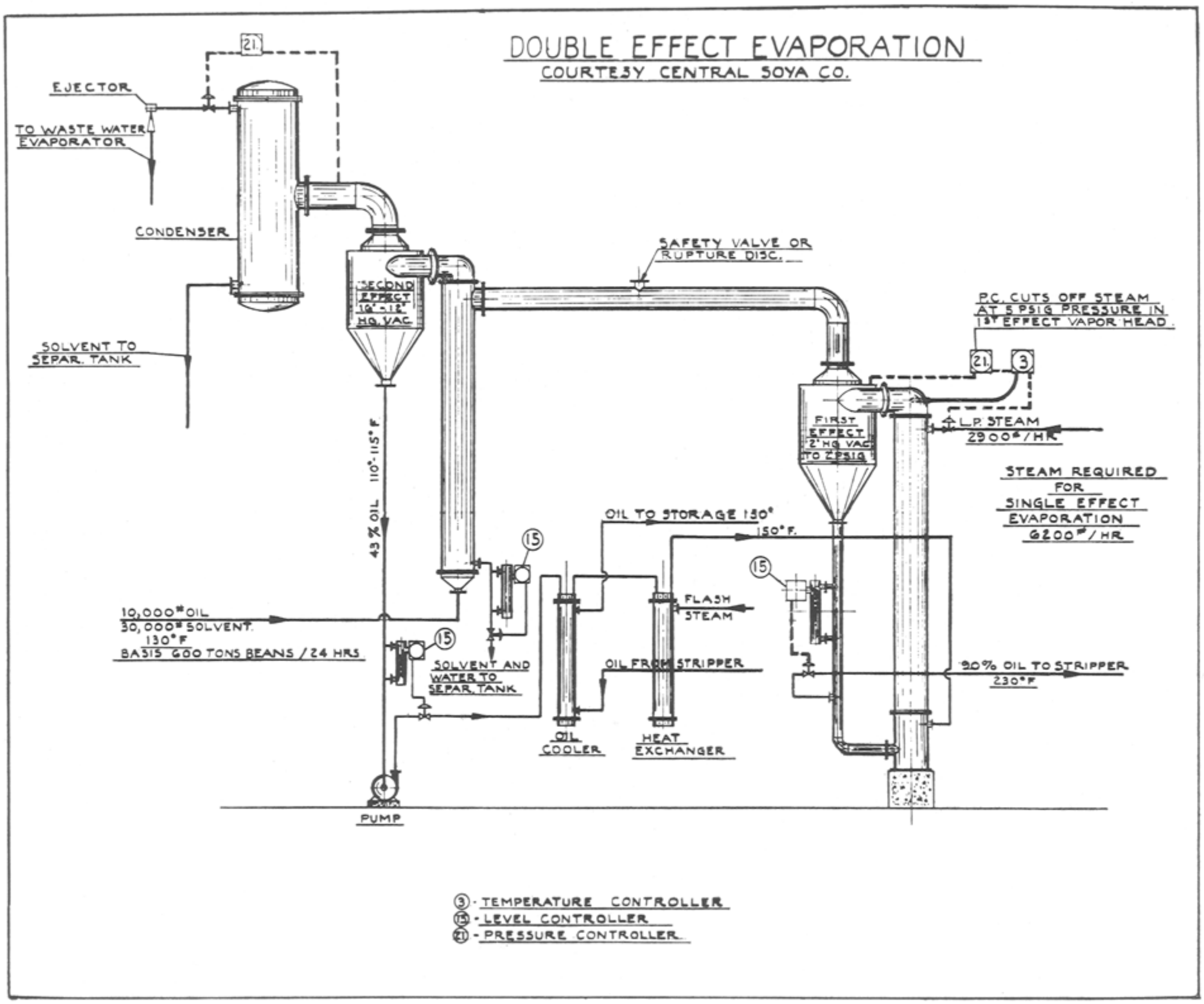


FIG. 4.

and the type of oil seed being processed. In some percolation type of extractors filters have been completely eliminated in view of the fact that completely polished miscella is obtained from the units. In other extraction systems filtration can be a major problem. For this reason the design of filters also varies greatly, depending upon the need for this operation.

THE DESOLVENTIZING OF FLAKES is an operation at least as important as extraction in the complete extraction cycle. Three methods of desolventizing currently are used extensively.

The oldest and traditional method involves steam-jacketed conveyor tubes called "schneckens," the term employed by German processors who first used them. The second is the vapor-desolventizing system used by Blaw-Knox (15, 16) and by Allis-Chalmers. The third system is the steam-desolventizing system of French (16), frequently combined with a toasting process.

The meal-conditioner tubes carried the flakes in multiple units over steam-jacketed surfaces, supplemented by some sparging steam. Dust control was a major problem in this system, and choke-ups in the tubes were not uncommon. Later design improvements in paddle and ribbon conveyor flights made this type of unit much more efficient. Possibly a third of the solvent plants operating in the country still have this type of meal-conditioning.

In the solvent vapor-desolventizing system hexane vapors are circulated through a steam heat-exchanger that superheats the hexane vapor which is then passed over the solvent-laden flakes. The super-heat in the vapor transfers to the liquid solvent in the flakes and vaporizes additional solvent. The recirculation cycle continues until sufficient heat is transmitted to the flakes to vaporize substantially all of the solvent. A final steam-stripping is required to separate the last traces of solvent from the flakes.

The French desolventizer shown in the flow chart uses open steam as the medium for vaporizing the solvent. For material such as soybeans and flaxseed the steam condenses on the flakes and transfers the heat of condensation of the steam vapor to apply to the heat of vaporization of the solvent. Solvent vapor replaces the steam, and water replaces the liquid solvent. Since the toasting process is a process of applying moisture and temperature to raw flakes, a good start in toasting is thus obtained. An added feature of this desolventizer is the scrubbing that the vapors get in passing through the material, which is wet with solvent before going to the collection system.

The evaporation of filtered or clarified miscella is ordinarily done in a long tube evaporator which recovers 90% of the solvent in a single unit. The oil is then passed through a stripping column, which can be either a packed column or bubble cap column or

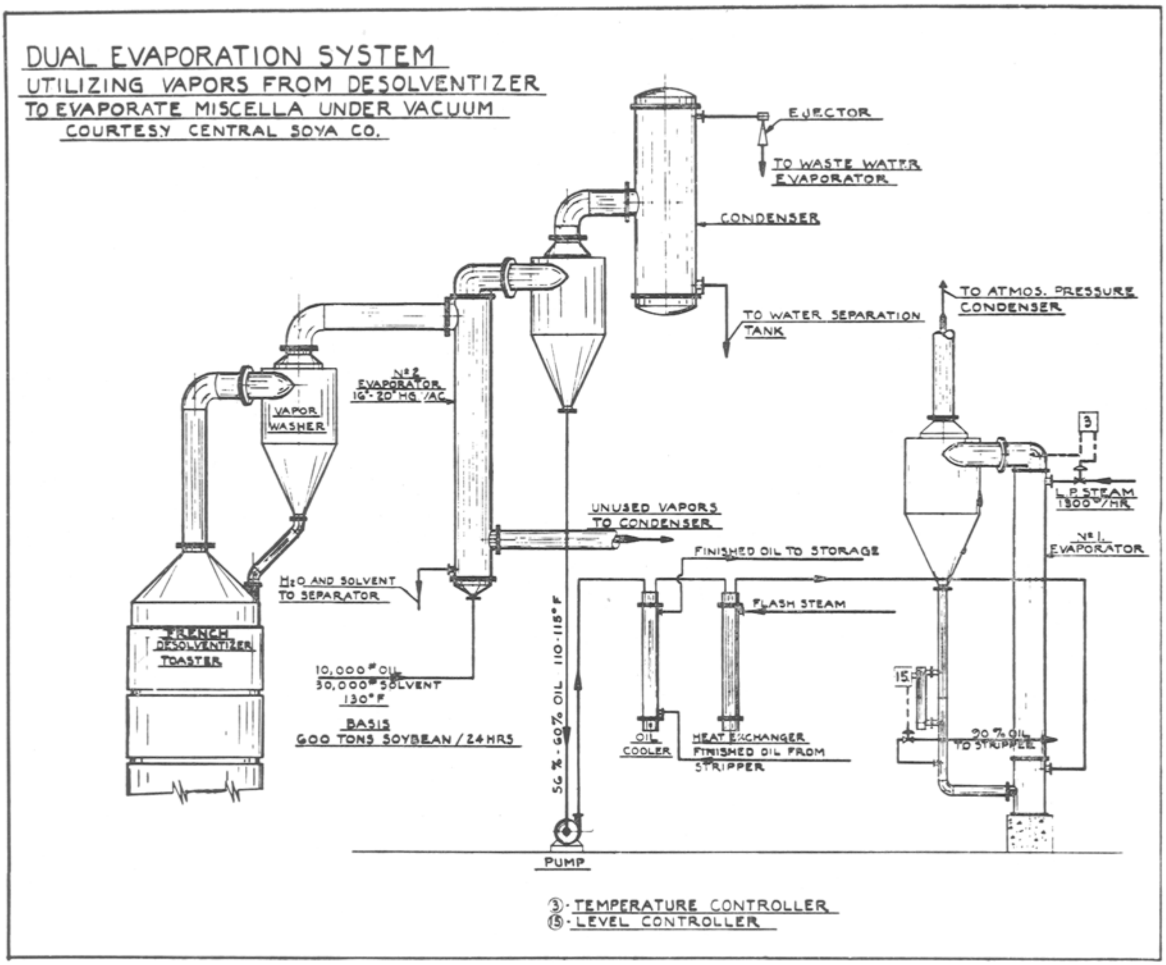


FIG. 5.

one with discs and doughnuts or perforated plates. Sparging steam is applied at the base of the column to assist in stripping out the last trace of the solvent.

This standard method of evaporation has the advantages of simplicity and lower capital investment. Some methods of improved evaporation efficiency have been successfully introduced by Central Soya Company (18) into their most recent plants. The first of these is shown in Figure 4, which is a double-effect evaporation system. The miscella is first evaporated under vacuum, with the vapors from the first-effect system in a traditional double-effect system. You can trace the miscella entering the second-effect evaporator, passing up through the tubes and taking up the heat from the vapors so that approximately half of the solvent is removed. This miscella containing about 43% oil is then pumped through a heat-exchanger, which takes up heat from the hot finished oil from the stripper and then goes through a further heat-exchanger to get to the atmospheric boiling point of the miscella and moves into the first stage evaporator, which uses low pressure steam. The steam required for a single-effect evaporation system, for a 600-ton per day soybean plant, is about 6,200 lbs. per hour. In the current system this steam usage is reduced to 2,900 lbs. per hour.

A further improvement is shown in Figure 5, which is a dual evaporation system, using vacuum for the No. 2 evaporator but using the vapors from the French desolventizer-toaster to evaporate about 75% of the solvent from the miscella. In this system only 1,300 lbs. per hour of low pressure steam is required for the miscella evaporation.

Since the processing of soybeans required about 1,000 lbs. of steam per ton of beans processed in normal operation, the reduction in miscella evaporation of 4,900 lbs. per hour is equivalent to nearly a 20% reduction in the over-all steam requirements. A substantial additional capital investment is involved in the dual evaporators required and the additional condenser capacity necessary for condensing part of this solvent under vacuum. The process is somewhat more complicated. It is difficult to determine exactly where such equipment is justified, but it seems that a capacity of possibly 500 tons per day of material to the extraction plant might be desirable for complete justification of a double-effect or dual-evaporation system.

The unit operation of solvent recovery is involved in all of the extraction equipment but is particularly a separate problem involving the recovery of solvent from the final discharge of vent gases. Refrigerated vent condensers are being used extensively for this final treatment of vent gases. Adsorption towers using activated carbon have been used as well as mineral oil absorption systems. Solvent recovery in modern plants has improved so that losses of less than 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.

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Unit Operations in a Mechanical Extraction Mill

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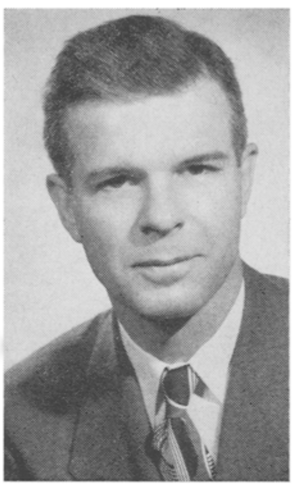
DURING THE LAST 20 YEARS there have been two industrial revolutions in oil milling in the United States. The first of these revolutions was the introduction and use of solvent extraction in the processing of vegetable seed. This introduction has been recognized and acclaimed as a great step forward in 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.



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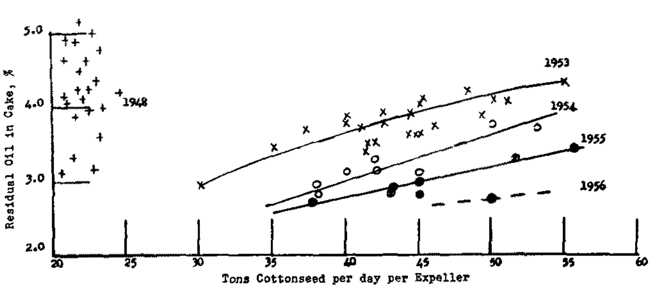

FIG. 1. Increase in capacity and decrease of oil in cake from Expellers over the years 1948–1956.

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