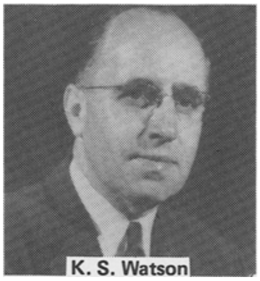
SESSION VI – OIL PROCESSING WASTES AND BY-PRODUCTS

Use or Disposal of By-Products and Spent Material from the Vegetable Oil Processing Industry in the U.S.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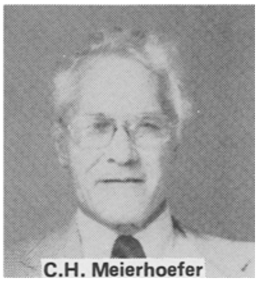
C.H. Meierhoefer

KENNETH S. WATSON, Director of Environmental Control, Kraftco Corporation, Glenview, Illinois, and **CURT H. MEIERHOEFER**, Vice President–Engineering, Humko Products Operation, Kraftco Corporation, Memphis, Tennessee, USA

ABSTRACT

During processing of vegetable oils, certain by-products and waste materials are generated. Where and how the by-products are recovered and used and how the solid wastes are handled and disposed of are considered. Several suggestions for the future are explored.

INTRODUCTION

Wastewaters generated by vegetable oil processing plants are most generally discharged after removal of floating fats, oils, and greases into a municipal sewer system. The miscible organic materials contained in this wastewater are of vegetable origin and are completely biodegradable. Some plants, not conveniently located for municipal service, treat their wastewaters using the biological treatment approach and discharge them directly into a water course.

The treatment of plant wastewater discharges is outside the scope of this discussion of by-products and spent materials. Further, the manufacturing operations of the industry are touched upon only to the extent necessary to give proper attention to the by-products and waste materials produced. It is considered pertinent, however, to address the in-plant handling of wastewater because this action contributes both by-products and waste materials.

In developing this paper, no effort was made to consider the practices employed in any one particular plant. Rather, the approaches and techniques available to the total industry are summarized in a "state of the art" manner.

As a result of today's emphasis on environmental control, recovery of by-products from materials originally construed to be wastes has taken on new significance. Obviously, if by-products can be recovered on a break-even or a profitable basis, such action represents a sounder approach than spending money, which does not contribute to the profitability of the business, on waste treatment. For this reason, the preparation of this paper summarizing the by-product and spent materials areas for the edible oil refining industry appears particularly timely.

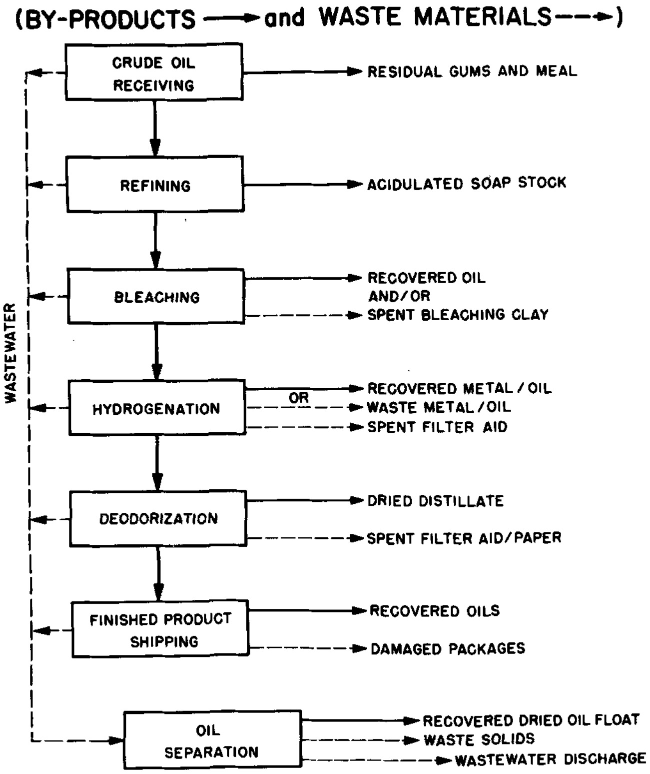

FIG. 1. Typical vegetable oil processing plant.

SECONDARY MATERIALS PRODUCED

Since the thrust of this paper is to consider the secondary products or materials of consequence in the manufacturing of edible vegetable oil products, the processes from which such materials originate are illustrated in Figure 1. This represents an abridged diagram of a typical plant, omitting many process details and variations which are not considered essential or necessary in this discussion.

Since very large amounts of oil are handled throughout the operation, some oil is lost and is picked up in the wastewater flowing from the sites. In view of the present emphasis placed on pollution control in the U.S., steps must be taken to recover as much of this oil as is feasible and within economic practicabilities. At the same time, this must produce a wastewater quality that protects the

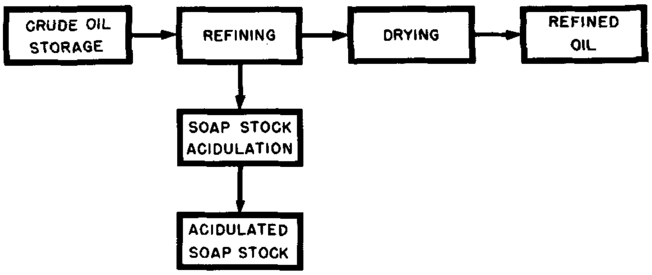

FIG. 2. Refining.

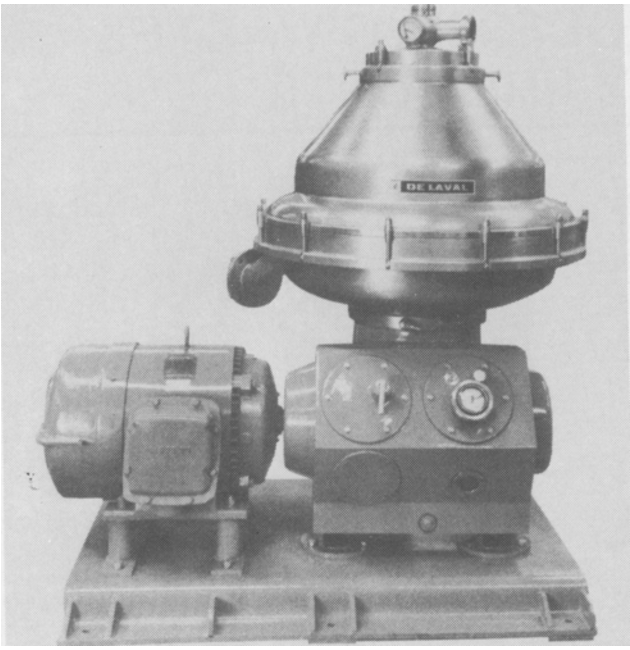

FIG. 3. De Laval centrifuge SRPX:317 (The De Laval Separator Co.).

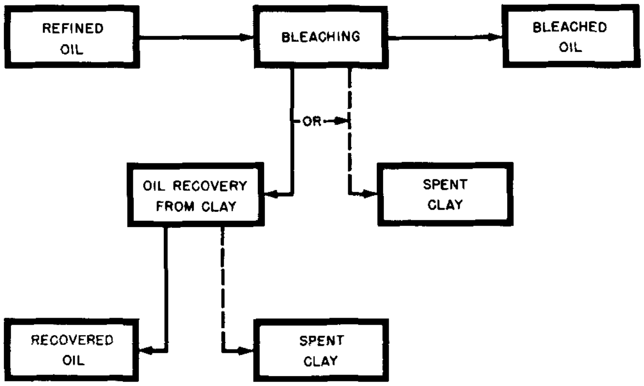

FIG. 4. Bleaching.

nation's water resources. Thus, the importance of cost reduction is extended to the wastewater area, and the optimum recovery of oil from wastewater serves as one means of offsetting the financial impact of environmental control. Handling of the wastewater within the plant to reduce the amount of oil being discharged will be considered in some detail later.

It can be noted from Figure 1 that in carrying out certain operations, such as crude oil receiving and refining, only a single by-product of consequence is produced. On the other hand, the hydrogenation step could be carried on in such a manner that two spent materials are generated, or alternatively with the production of a by-product and a waste material. This illustrates the fact that under some circumstances and conditions a material could be a by-product, while under other conditions it could be a waste material. Therefore, the exact mode of operation is generally established by the economic, geographic, and other factors affecting a particular refiner. It is obvious that wastewater has its origin in each section of a vegetable oil processing plant; therefore, such a train is also shown.

Refining

Following the normal continuity of oil flow, the initial refining process (Fig. 2) will be considered in this discussion as a continuous, centrifugal alkali refinery using mechanical equipment for soapstock separation when processing such oils as soybean, cottonseed, corn, and coconut. It is recognized that other methods of refining are sometimes practiced, such as hydration for gum removal, steam refining, batch alkali refining, and batch acid refining. To consider these other methods of refining is a redundant exercise not justified in the time allotted for this paper.

In such a processing plant, there are two by-product and associated wastewater streams—from soapstock separation and refined oil washing. After saponification of the free fatty acids of the crude oil with caustic or soda ash, the soapstock is separated from the neutral oil in a centrifuge; the soapstock is accumulated in a separate vessel while the refined oil flows continuously through mixing equipment where clean water is added. The amount of water added to the refined oil is ca. 10% of the crude oil fed into the system. From the water mixing zone, the refined oil-water mixture then passes through a second centrifuge, where the water plus residual water-soluble impurities are separated from the refined oil. The refined oil is then dried in a vacuum chamber.

The wash water, containing ca. 0.2% total fatty acids by weight, is normally added to the soapstock for those refiners that acidulate their soapstock. For others, this water is accumulated in a decanter, where the emulsion is broken and the oil portion recovered for recycling to the refinery.

Soapstock from the refining centrifuges is usually diluted with water to reduce the viscosity for pumping into the acidulation process. Two methods of acidulation are common, batch and continuous. In each process, the diluted soapstock is treated with an inorganic acid, normally sulfuric, to convert the soap into a fatty acid. Other fatty and nonfatty materials are also included in the soapstock, such as neutral oil, phosphatides, meal, and solid debris derived from the crude oil.

During acidulation, the oil component is separated from the water phase by centrifugation in the continuous system or by gravity settling in the batch process. Figure 3 shows a photograph of a centrifuge typical of those used in this separation step. The oil phase is then dried by settling and drawing off the water, or it is pumped through a vacuum chamber. This material, depending on the market demand and the origin of the crude oil, is sold to fatty acid producers, soap makers, and foundries. A major portion of the acidulated soapstock goes to the animal feed industry, where it serves as a high energy feed ingredient.

Wastewater resulting from acidulation must be neutralized and constitutes the major wastewater disposal problem in the edible oil processing industry. The miscible organic materials, mainly glycerine, cannot be removed by normal gravity separation. The wastewater can be subjected to gravity separation for optimum removal of the immiscible components, and they in turn are included with other fatty by-products collected in the plant and sold for animal feeds.

Acidulated wastewater, properly treated to adjust pH and remove the immiscible materials, however, is readily biodegradable and does not present a problem in a properly designed secondary treatment facility.

A minor source of by-products and wastewaters results from equipment cleaning, oil drips, and area cleanup. The recovery of these fatty materials is normally accomplished by the use of catch basins.

Bleaching

Bleaching, as defined for this discussion, is achieved through the use of an absorbent material such as bleaching clay and activated carbon for the removal of color bodies and residual traces of soap or impurities contained in the refined oil.

The refined oil is pumped (Fig. 4) into a vessel where the bleaching materials are added. The vessel can be either at atmospheric pressure of under a vacuum. Present-day opera-

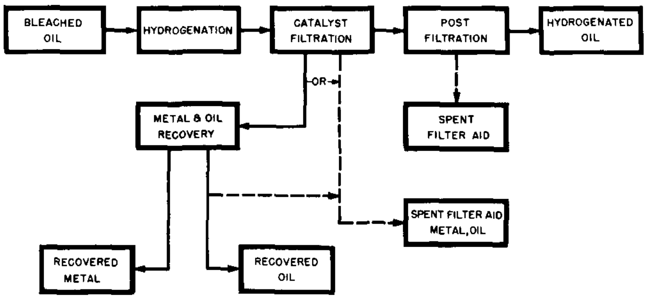

FIG. 5. Hydrogenation.

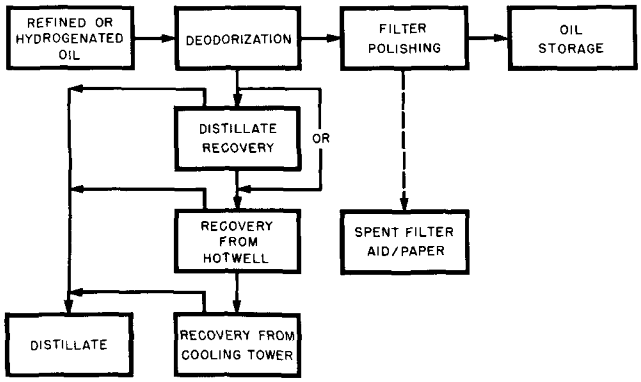

FIG. 6. Deodorization.

tions tend to favor vacuum bleaching, which has been practiced for many years, mainly to reduce product oxidation and, secondly, to improve the efficiency of the bleaching materials. Both batch and continuous systems are used.

Water use in a bleaching operation is normally confined to that used for vacuum generation and cleanup of the filtration equipment. Since water from a cooling tower system is generally used on the vacuum equipment, overall requirements are minimal.

The spent bleaching clay is removed from the oil with filters. This clay represents a substantial amount of solid waste material. The amount of bleaching clay used depends, of course, on the type of refined oil processed and the color reduction desired.

Spent clay removed from the filter contains 20-25% oil by weight. Recovery of oil from spent clay has been done by water separation and solvent extraction. As a result of present-day restrictions, imposed by environmental control laws, disposal of wet clay has discouraged use of the water phase method. Because solvent extraction, using hexane, presents a tremendously hazardous situation, it is not, to the best of our knowledge, at present being practiced in the U.S.

The normal disposal method now used for spent bleaching clay is to dump it in a landfill. However, this method is not without problems and concern. As an example, clays containing unsaturated oil will rapidly oxidize to the point of causing spontaneous combustion, creating an odor condition as well as a fire hazard if not properly blanketed for air exclusion. The availability of satisfactory landfill area is another concern. The waste clay should be covered with soil as soon as possible to exclude air and minimize spontaneous combustion hazards.

One independently owned oil reclaiming plant near Richmond, California, is using the water phase method. It is recovering oil from the spent clays generated by vegetable oil processors on the West Coast. It is reported that a second plant using the same process has just been placed in operation near Barstow, California. After recovery of most of the oil, the spent clay still needs to be taken to a landfill. Economics have not been very favorable for recovery recently, but the situation could change.

Hydrogenation

The hydrogenation of vegetable oil is the chemical combination of hydrogen and oil in the presence of a metallic catalyst—usually finely divided nickel, although other metals have been used.

Figure 5 illustrates the bleached oil being pumped into the hydrogenation equipment, which is a closed vessel equipped with an agitator and heat exchanging facilities for heating and cooling the product. Water use in the hydrogenation process is mainly for controlling the exothermic reaction and cooling the oil after hydrogenation. Cooling water circulated through cooling towers is normally used in this process, so the generation of wastewater is insignificant.

After hydrogenation, removal of the catalyst from the oil is accomplished by filtration. The filtrate contains minute quantities of objectionable, metallic substances which are derived from the catalyst. Therefore, diatomaceous earth is mixed into the oil, and a second filtration is performed. Filter presses used for catalyst filtration or post filtration are quite similar to those used in the bleaching process. The metal-free oil is now acceptable for further processing.

Two secondary materials are thus generated. The spent catalyst, which in most cases has previously been used in two or more batches, is recovered from the filter. It will contain 30-35% of oil by weight and 10% nickel, and the remainder consists of diatomaceous earth.

Depending upon the economic conditions, the spent catalyst can either be processed for metal recovery or sent to a landfill. If the metal is recovered for recycling back into new catalyst, a certain amount of the oil portion is likewise recovered, while the diatomaceous earth portion is disposed of on a landfill. Catalyst recovery may in some cases be performed at the plant, while in other cases the material is reprocessed by catalyst manufacturers. The spent filter aid from the post filtration step is taken to the dump. The quantity is considerably less than from the bleaching process.

Deodorization

The final processing step in the vegetable oil processing plant is represented in Figure 6. Edible oils must finally be made palatable for human consumption after the refining and processing steps previously covered are accomplished. The deodorization process, which can be of either the batch or continuous type, removes odoriferous materials by steam distillation.

Stripping steam is injected into the oil, at a temperature of ca. 250 C, and under a high vacuum. The odoriferous materials, free fatty acids, and small quantities of triglycerides are carried by the stripping steam through the primary steam ejector of the vacuum generating system and are finally condensed along with the stripping and motive steam within the barometric condenser. Scrub coolers are often installed in this train before the barometric condenser to remove as much as practicable of the distillate and fatty acids so they will be kept out of the recirculating cooling water. Figure 7 is an illustrative sketch of such a scrub cooler.

The large quantities of cooling water necessary to condense these vapors in the barometric condenser are normally supplied from a cooling tower. Previous to the present environmental regulations, one-pass water was used on many installations and the wastewater discharged into streams. This practice has since been generally abandoned due to the small fat content of the cooling water, even though the bulk of the distillate is captured in the hotwell. Stream pollution control practices in the U S. now forbids this type of stream contamination.

In recent years, distillate recovery equipment has been developed that will remove 80-90% of the distillate from

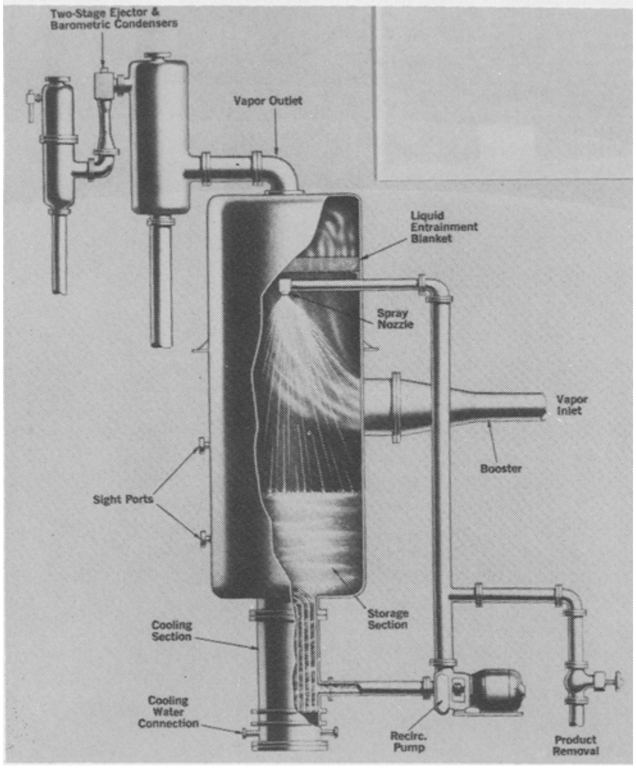

FIG. 7. Elliott swirl-jet scrub cooler (Elliott Division of Carrier Corporation).

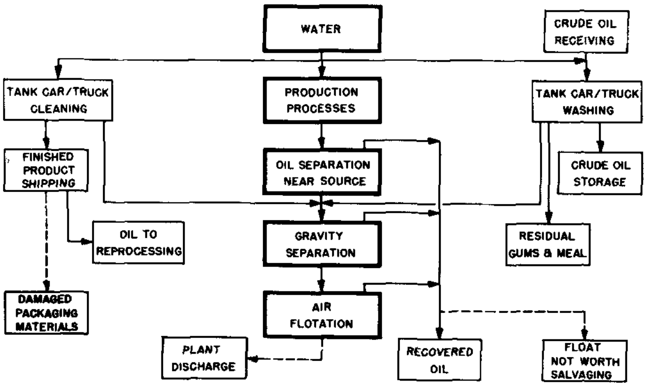

FIG. 8. Recovery of oil from wastewater vegetable oil processing plant.

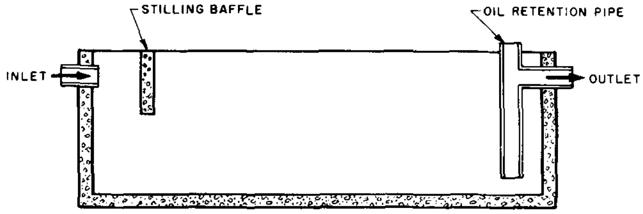

FIG. 9. Simple trap tank for removing immiscible oils from water.

the steam train before it reaches the barometric condenser. The material is collected in dry form and is sold for tocopherol recovery, fatty acid production, well drilling, and animal feed supplement. A certain fraction passes through the recovery unit—mainly the short chain fatty acid fractions, which are deposited in the hotwell and recovered.

With the constant circulation of cooling water to and from the cooling tower, the water attains a certain concentration of fatty materials, which are deposited on the fill material in the cooling tower and in the tower basin. Removal of this material is required on a maintenance type schedule to prevent air blinding of the tower and clogging of the water pumps.

By-products are derived from three points in the deodorization step: the distillate recovery unit, if this equipment is used, the hotwell, and the cooling tower. The amount of distillate produced varies in accordance with the type of equipment used, the variety of oil deodorized, its free fatty acid content, the vacuum employed, deodorization temperature, and the mechanical condition of the equipment. As a general rule, 0.5% of the feedstock would approximate the amount of distillate produced.

After the oil has been deodorized, it is passed through a polishing filter to remove small particles of polymerized material and any other small, inert debris that if left in the oil would produce an objectionable appearance. A filter aid, such as a diatomaceous earth, is coated onto the paper sheets of the filter. These spent materials are conveyed to the land disposal area.

WATER AND WASTEWATER

The water supply for vegetable oil plants in the U.S. is typical of such supply for many industries operating sizable plants in this country. Many have their own ground or surface source of supply, and some use a combination of both. Some of these plants are also connected to city water systems for drinking and high quality water and sometimes as a second source for fire protection purposes. Further, there are numerous plants which use city water as their major source, but some of these may also have secondary ground or surface sources.

Since we are now operating in the environmental control era in the U.S., the plants of this industry, as well as other industries, are giving more attention to water conservation, recirculation, and reuse, thus reducing overall water requirements. In many cases, such action also represents a sound cost reduction step. Further, such water management reduces the volume of the single most massive quantity of spent material for which the plant must devise a method of disposal. The practice of sound water usage also, in many cases, reduces the size of the waste treatment facilities which must be provided. A later paper will be concerned with methods of disposal for this wastewater being used in the U.S.

As indicated in Figure 1, there are many points of water use in a vegetable oil refinery. In this paper, however, only the principal areas where water comes in contact with materials being processed and thus becomes wastewater will be emphasized. Water usage for area and equipment cleanup is recognized as an essential part of good plant operation, but due to the relative low volumes involved, it will not be given much emphasis in these discussions.

This constant water to wastewater conversion process (Fig. 8) is in effect whenever the plant is in operation. Water is required in the crude oil receiving area to wash the tank cars and trucks transporting the crude. In some operations, designated tank cars and trucks are assigned only to crude service and require less cleaning with water. Others use the transporting vessels for both crude and finished product hauling and, therefore, must be cleaned before each finished oil shipment. The residual oil, gums, and meal removed with the water stream from cleaning vessels carrying crude are partially recovered by a gravity separator and combined with other oil by-products for use as an animal feed supplement. The wastewater containing certain dissolved and suspended organic materials flows to the primary processing area before discharging into a biological treatment plant.

At the other end of the process, tank cars and trucks used solely for finished product transportation are washed before each trip. The residual oil from those tanks is first removed with clean, hot water, and the oil is separated in a decanter for reprocessing as an edible product. Then a

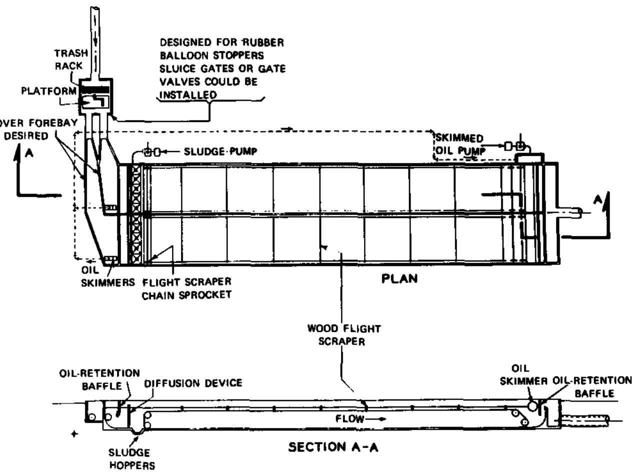

FIG. 10. API oil-water separator (Reproduced from The American Petroleum Institute's *Manual on Disposal of Refining Wastes).*

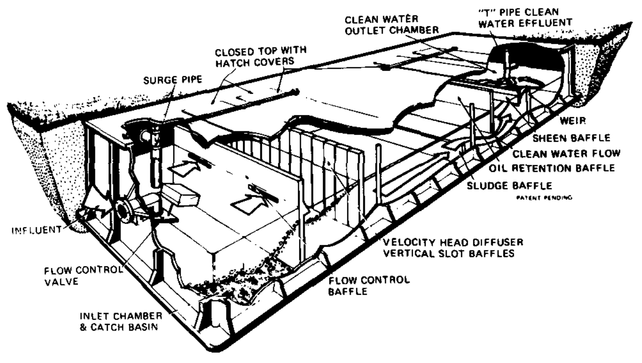

FIG. 11. Schematic of a packaged separator for the removal of immiscible oil from an industrial effluent (AFL Industries, Inc.).

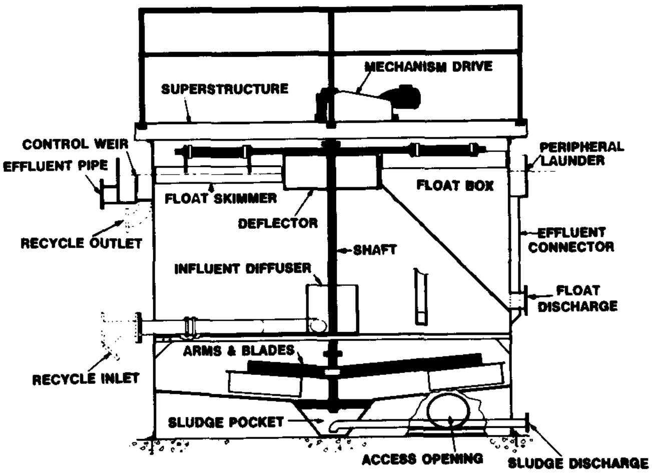

FIG. 12. Schematic of flotator clarifier used to remove oils and greases from effluents prior to discharge (Envirotech EIMCO BSP).

circulating detergent solution is used, followed by a clean water rinse and a hot air blast for drying.

We can see that there are major process water requirements for a vegetable oil plant. Hot water is used in the continuous refining process to remove small quantities of soap from the refined oil. Some refiners combine this wastewater with soapstock prior to acidulation, while others who do not acidulate soapstock collect the floatable oil in a gravity separator for reprocessing. Water is used in soapstock acidulation for dilution to permit pumping and proper mixing with an inorganic acid, usually sulfuric. The acid wastewater generated by this process is then discharged through a gravity separator for residual oil removal and pH adjustment and is finally discharged to a biological treatment facility.

Deodorization requires the use of large quantities of water in the vacuum generating equipment. The stripping stream carrying odoriferous material is combined with the motive steam and is condensed in the barometric condensers. Most refiners now use cooling towers for their condensing water. A major portion of the fatty materials removed from the edible oils is collected in distillate recovery units and the hotwell. The remainder is contained in the cooling water and returned to the cooling towers, where the water is cooled by large volumes of air moved by motor driven fans.

The air exhausted from the towers carries objectionable odors (a waste material) into the surrounding atmosphere. As a result of operating in the environmental control era in the U.S., considerable effort is made to keep these odors under control through feeding various oxidizing agents and even activated carbon into the circulating water. The blowdown from these cooling towers is piped to the plant wastewater treatment facilities for removal of the oily residues.

The center wastewater train of Figure 7 outlines in appropriate sequence the principal steps taken to recover lost oil from the plant wastewaters. It will be noted that wastewater from washing of tank vehicles for hauling crude and similar vehicles for shipping finished products are shown tied into the central train for control of oil loss. In actual plant operation, these cleaning steps are usually followed by trap tanks located adjacent to the point of water use in order to remove oil at the source before discharge into the common plant effluent line. It is most important to minimize commingling of different fatty waste materials while in the water phase. As an example, crude oil will contain phosphatides which are emulsifying agents while refined oil does not. If these waste materials are mixed, the amount of oil which can be recovered from the water is diminished due to unnecessary emulsification.

These trap tanks, or initial gravity separators, one of which is also shown immediately after the production process block in the major wastewater train of Figure 8, also have the function of removing oil after a minimum contact period with the water conveying it. Use of the recovered by-product depends, of course, upon the processing source. The spent materials are the wastewater discharged and at times solid materials that settle to the bottom of the trap tank which must be removed and hauled to a landfill.

The gravity separation concept (Fig. 9) is the simplest type of oil trapping tank employed by the industry. These facilities come in a variety of forms and sizes, but their main purpose is to slow the velocity of the discharge flow sufficiently that unemulsified oil rises to the surface to be retained. This oil is then removed from the surface of the water by action extending from manual dipping or pumping to the use of sophisticated skimming equipment (Fig. 10).

The next step in removing oil from wastewater in many plants, and shown in the center train of Figure 8, is that of one or more gravity separators through which the total plant discharge passes. These are usually larger separators of a configuration generally following that designed by the American Petroleum Institute (Fig. 10).

A number of manufacturers, with the general use of API concepts, are fabricating separators which can be purchased as an integral, packaged unit. Such a packaged unit being fabricated by one manufacturer is illustrated in Figure 11.

After the full utilization of gravity separation, the final step in oil removal for most plants is that of flotation clarification, as shown in Figure 8. This final step, sometimes looked upon as a polishing operation, removes the remaining immiscible oil before the wastewater is passed to a biological treatment facility. The equipment in which this step is achieved is illustrated in Figure 12.

The floating oil layer removed from the three separation steps just described is dried by first settling for maximum water drain-off, then submitting the remaining water-oil mixture to drying equipment. This equipment can be simply a tank with heating coils to boil off the water, a heat exchanger and vacuum chamber, or a wiped film evaporator. The dried oil is then sold to producers of animal feeds or fatty chemicals processors, depending on the quality.

Since higher quality oils are recovered in the first separation step and the poorest quality in the last step, their end uses, therefore, can be different, depending also upon market conditions. The sludge or solids recovered in each separation step, consisting mainly of inert materials and nonusable components, is disposed of on a landfill. As mentioned previously, the wastewater from which the oil is removed also represents a plant waste material, and this is discharged to some type of biological treatment process.