Edible Oil Deodorization

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ABSTRACT

Deodorization of fats and oils is necessary to remove the disagreeable flavor and odors that are naturally present or created during processing. Steam stripping of the oils is used to remove these volatile flavor and odor components. This paper discusses the process specifications for deodorization and the mechanical design of edible oil deodorizers.

INTRODUCTION

Deodorization is the last major processing step in the refining of edible oils. It has the responsibility for removing both the undesirable ingredients occurring in natural fats and oils and those which may be imparted by prior unit processes such as caustic refining, bleaching, hydrogenation, or even storage conditions. It is this unit process that finally establishes the oil characteristics of "flavor and odor," which are those most readily recognized by the consumer when the shortening, lard, salad oil, cooking oils and margarine are used (1,2).

HISTORICAL

In the early stages of development of the edible oil industry as we know it today in America, there was little, if any, need for deodorization. Lard for edible use was consumed in essentially the same form as it was produced, and its natural flavor was considered an asset. Likewise, olive oil, one of the earliest known vegetable oils, the use of which dates back to antiquity, was highly prized for its distinctive flavor. However, as the cottonseed oil industry developed in the southern United States, the incentive grew to utilize this new oil for edible purposes. The discovery of the alkali refining process gave further impetus to the use of vegetable oils as food.

As a result, there grew up somewhat prior to the turn of the century the so called "lard substitute" industry. These substitutes consisted of blends of liquid cottonseed oil with harder, naturally occurring fats such as tallow and oleo stearine to which lard may or may not have been added. These substitutes, since they were made of cheaper materials in the main, enjoyed a price advantage over pure lard. The unpleasant flavor of the raw materials was so strong, however, that the product found little acceptance among discriminating buyers. Pure cottonseed oil also began to be used for cooking and salad oil purposes, but this product after alkali refining and bleaching with adsorbent materials likewise developed an undesirable flavor and odor. In addition, at about the same time, attention was being directed to the development for edible purposes of the newly discovered hydrogenation process.

Hydrogenated oils were perhaps the most disagreeably flavored of all and were practically inedible in their natural state. Hence, if the edible vegetable oil industry were to survive, some means of removing the odoriferous constituents had to be found.

European and a few American investigators attempted with but little success to remove the flavored constituents by chemical means or by masking the flavor with spices or other strong flavored ingredients. These attempts of course were foredoomed to failure, and better methods of deodorization were sought.

The first successful attempt at actually removing odor and flavor consisted in blowing a current of live steam through oil at elevated temperatures and atmospheric pressure. The flavor improvement was very marked, and this practice was soon adopted by many American refiners. As the process developed, batches ranged in size from 10,000 to 30,000 lbs., and deodorization time varied from five to ten hours. This development was attributed to Henry Eckstein, then superintendent of the N.K. Fairbank Company, which was later absorbed by the American Cotton Oil Company. The process was a considerable step forward and made the lard substitute and vegetable oil industries possible.

Improvements were made in the Eckstein process by Boyce, Cluff and others, including the addition of vacuum equipment and the use of superheated injection steam (3).

PROCESS REQUIREMENTS

Because of the many types of vegetable oils, it would be difficult to list all of the components of these oils which produce flavor and odor. These components have been identified in several types of oils as ketones, aldehydes, and free fatty acids. Their concentration is usually quite low, ranging from 0.1 to 1.0%. The odor imparted to a hydrogenated oil seems to be characteristic of the hydrogenation reaction.

Experience has shown that flavor and odor removal correlates well with the reduction in free fatty acid (FFA) content of the oil. If an oil has an FFA of 0.1%, it will have an odor that will be eliminated when the FFA is reduced to 0.01 to 0.03% assuming a zero peroxide value. In some commercial deodorizers, on occasion, reduction of the FFA will not correspond with deodorization of the oil, but in these cases there are usually other complicating factors.

All commercial deodorization, whether in continuous, semicontinuous, or batch units, consists of steam stripping the oil for FFA removal. The four operating variables which influence the deodorizer design are product throughput, stripping steam rate, pressure and temperature.

The amount of FFA removed from the oil is inversely proportional to the system pressure and directly proportional to the vapor pressure of the FFA and the sparge steam rate. Thus, the lower the system pressure at a fixed vapor pressure (or temperature) and sparge steam rate, the greater the FFA reduction. Since the vapor pressure of the FFA is directly proportional to the temperature, an increase in temperature as well as increased sparge steam rate both increase FFA reduction. The maximum temperature that can be used, however, is limited due to the detrimental effects on oil stability. The operating pressure and sparge steam rate are limited by economic considerations.

A useful relationship in the design of a commercial deodorizer, for a given FFA reduction and temperature, is: the ratio of the system pressure to the sparge steam rate is a constant, and a lower system pressure will allow a lower sparge steam rate.

There are three other principal factors which must be taken into consideration in the design of a deodorizer. The first is the type of materials used for its construction. Due to the deleterious catalytic activity of copper and iron on oils, modern deodorizers are fabricated from type 304 stainless steel where contacted by hot oil (Table I).

The stability of the oil will also be adversely effected if the oil is in contact with oxygen at deodorizing temperatures. Proper deodorizer design provides deaeration of the oil before heating and precludes the possibility of air contacting the hot oil in process.

The final factor to be considered in the process design of

TABLE I

Activity of Metals Toward Soybean Oil Oxidation, Temperature 100 C

Metal	Relative Catalytic Activity Toward Oxidation (Base-type 304 S.S. = 100)
Copper	389
Mild steel	140
Stainless steel (T.304)	100
Stainless steel (T. 316)	85
Nickel	75
Hastelloy B	66
Inconel	60
Aluminum	45

(Increasing activity ↑)

[a]This chart adapted from data in reference (4).

a commercial deodorizer is heat treatment. Experience has shown that certain reactions within the oil itself, and not related to FFA removal, are necessary to provide a stable oil after deodorization. This thermal treatment also will "bleach" certain oils to a much lighter color; this is particularly noticeable in soybean oil. These reactions and the heat bleaching are time and temperature dependent; therefore, commercial deodorizing systems should provide a retention period at deodorizing temperatures to allow these reactions and the heat bleaching to occur (2).

THEORY OF EDIBLE OIL DEODORIZATION

The deodorizers currently in use today are of three types, batch, semicontinuous (a series of batch deodorizations within a single vessel), and continuous. To understand the effects of operating variables such as temperature, pressure and stripping steam/oil ratio, a theoretical consideration of both the batch and continuous systems is given below.

Batch Systems

The detailed development of an equation relating the critical operating variables for batch deodorization has been presented several times in the literature. The final equation is

$$S = \frac{PO}{EP_vA} \quad (\ln V1/V2) \text{ or} \qquad \text{(a)}$$

where

$$\ln V1/V2 = \frac{EP\,vAS}{PO} = K\,\frac{Pv\,(s)}{P(O)} \qquad \text{(b)}$$

S = Moles of Steam
O = moles of oil
Pv = Vapor pressure of the FFA
P = Total system pressure
V_1 = Initial number of moles of FFA in the oil
V_2 = Final number of moles of FFA in the oil
E = The oil vaporation efficiency
A = Activity coefficient
K = Experimental constant

The evaporation efficiency, E, is a measure of the steam's ability to become saturated with the FFA as it passes through the oil and can be expected to vary depending on the concentration of the various compounds which make up the FFA fraction. The general range of values is 0.7 to 0.9.

The activity coefficient, A, is a necessary part of the equation since the theoretical development assumes an ideal solution, and vegetable oil-fatty acid solutions have been shown to be highly nonideal. Activities coefficients are usually determined experimentally.

Also, the vapor pressure of the FFA P_v, most often has to be determined experimentally or chosen based on experience, since the FFA stream is made up of more than one compound. Thus, in any commercial operation, a change in the type or source of oil may require a change in operating conditions to compensate for the new make up of the FFA material.

Continuous Systems

A batch system with "O" moles of oil must be steam stripped with "S" moles of steam to reduce the moles of FFA from V1 to V2. In a continuous system, these variables must be changed to time dependent ones. "O" now represent a flow of oil in moles per hour, while "S" is moles per hour of steam. V1 and V2 are now moles per hour of the FFA material. Thus for an oil entering with "O" moles per hour of oil containing V1 moles of FFA and leaving with V2 moles of FFA, the steam leaving must contain S=(V1-V2) total moles. The concentration of FFA in the outlet oil is

$$\frac{V2}{O + V2} \qquad \text{(c)}$$

Since the amount of FFA in normal commercial deodorization is always much less than the total oil from Equation (c), it may be approximated by

$$\frac{V\,2}{O} \qquad \text{(d)}$$

Similarily, the concentration in the outlet steam may be approximated as

$$\frac{V1\text{-}V\,2}{S} \qquad \text{(e)}$$

since in normal deodorization the steam quantity is greater than the FFA flow.

At system equilibrium the relationship between the mole fractions of equation (d) and (e) can be developed as follows. The partial pressure of the FFA over the solution is related to the liquid mole fraction by Raoults Law

$$P_a = X_aP_v \qquad \text{(f)}$$

where P_a = partial pressure
X_a = mole fraction

thus,

$$P_a = \frac{V\,2P}{O} \qquad \text{(g)}$$

Similarly, the vapor mole fraction is related to the FFA by Dalton's Law

$$P_a = Y_a\,P$$
Y_a = vapor mole fraction (h)

and

$$\bar{P}_a = \frac{V\,1\text{-}V\,2\,P}{S} \qquad \text{(i)}$$

Combining (5) and (7)

$$\frac{V1 - V2\,P}{S} = V2 \quad P_v \qquad (j)$$

Solving for V1/V2

$$\frac{V1}{V2} = 1 + \frac{P_v}{P}\frac{(S)}{(O)} \qquad (k)$$

As with elevation (b), an experiment constant K must be added to equation (k) since both Raoult's and Dalton's Law are only accurate for ideal solutions. Therefore,

$$\frac{V1}{2} = 1 + \frac{K P_v}{P}\frac{(S)}{(O)} \qquad (l)$$

Equations (b) and (l) are the basic design equations for any deodorizing system, since they relate the effect of the three major operating variables, system pressure, temperature and steam/oil ratio on the effectiveness of FFA removal. These relationships can be summarized as follows. For a fixed oil amount, O, and initial concentration, V1: (a) as the system temperature increases (P_v increases), the final concentration of FFA (V2) decreases; (b) as the system pressure, P, decreases, the final concentration of FFA decreases; (c) as the steam/oil ratio (S/O) increases, the final concentration of FFA decreases. The equations also show another useful relationship for an energy conscious industry. For a fixed FFA reduction and operating temperature, the ratio of the system pressure, P, to the steam rate, S, is a constant, and, therefore, a lower system pressure will allow a lower steam rate (4).

MECHANICAL DESIGN

Batch Deodorizer

Although many odd designs for batch deodorizers are described in patent literature, few of them have found practical use, and substantially all present batch deodorization is done in vessels of simple and quite uniform design.

The conventional batch deodorizer is a vessel in the form of a vertical cylinder with dished or cone heads; in modern installations the vessel is invariably welded and well insulated. The usual range of capacity is 10,000 to 40,000 pounds, with a capacity of about 25,000 pounds being perhaps the most common. Batch deodorizers are usually designed to hold 8-10 ft of oil and to have a similar amount of headspace above the surface of the oil; hence a 25,000 pound vessel may be about 8.5 ft in diameter and 17-18 ft high. The stripping steam is injected into the bottom of the vessel through a distributor, which usually consists of a flat "spider" of perforated pipes radiating from a central steam delivery line. A convenient method of controlling the flow of stripping steam is to maintain a fixed pressure back of an orifice of known size. As the steam pressure always falls to a low value beyond the orifice, the flow of steam will be proportional to the absolute pressure on the high side. In addition to the steam ejector system and means for heating, cooling and pumping the oil, necessary accessories include a thermometer or other device for indicating the temperature of the oil and a pressure gage designed to indicate accurately low pressures within the deodorizer independently of the barometric pressure.

To avoid excessive refluxing, it is desirable to make the vapor line leading from the top of the vessel to the booster or to an entrainment separator as short as possible. In some installations the top of the deodorizer and the vapor outlet are jacketed and heated. Entrainment separators are sometimes placed in the vapor line; in other installations separators of the centrifugal or "Venetian blind" type are placed in the upper part of the deodorizer proper.

With equipment operating at a high temperature and a 6-12 mm. pressure, about 8 hr is usually allowed for the complete cycle of charging, heating, deodorizing, cooling and discharging. Older installations operating at a higher pressure and/or a lower temperature may require a time cycle as long as 10-12 hr. Ordinarily stripping steam is injected at a rate of about 3 pounds per 100 pounds of oil per hr at 6 mm pressure, with the steaming rate being proportionately greater at higher pressures. The total amount of stripping steam used may vary from about 10 pounds to 50 pounds per 100 pounds of oil; the average is probably about 25 pounds.

Deodorization temperatures vary considerably in different plants. In the United States, hydrogenated vegetable oil stocks are generally deodorized in the range of 400-475 F. (204-246 C), and occasionally as high as 525 F. Many processors deodorize salad oil and cooking oils at somewhat lower temperatures than hydrogenated oils. Lard and similar animal fats are considerably easier to deodorize than vegetable oils and don't require such high temperatures, although a relatively high temperature is often used to permit deodorizing and steam refining in one operation. On the other hand, very high temperatures which cause some heat polymerization are undesirable for unhardened marine oils.

After deodorization is completed, the oil must be cooled before it is discharged to the atmosphere. Hydrogenated products which are relatively resistant to oxidation may be brought out of the deodorizer at a temperature as high as about 150 F. (66 C.) without appreciable injury to the flavor, but a temperature of 100-120 F (38-49 C) is generally preferred for oils. Some processors do not expose deodorized fats or oils to the atmosphere at all, but discharge them to nitrogen- blanketed tanks to fill all packages of the finished product under nitrogen. If the oil is not afforded the protection of an inert gas, it should be packaged as soon as possible, preferably within a few hours after deodorization, as even the more stable products will deteriorate slightly in flavor upon prolonged holding in storage tanks or upon being repeatedly melted and resolidified.

In batch deodorizers the oil may be cooled either within the deodorizer, by the circulation of water through cooling coils, or externally as it is pumped through a shell and tube cooler.

When cooling is conducted wholly within the deodorizer at 6 mm pressure, the temperature may be reduced to 130-150 F, depending upon the oil depth, before condensation of the stripping steam begins to occur. The practice of transferring the hot deodorized oil to a separate cooling tank is not to be recommended, unless the latter is, like the deodorizer, maintained under high vacuum and provided with stripping steam.

Theoretically, less hydrolysis of the oil should occur, and it should be possible to reduce the FFA to oil to a lower value when stripping is carried out in shallow layers than when the oil is in a deep layer and the average hydraulic pressure of the oil upon the injected steam bubbles is relatively high. Comparative results in which stripping is carried out in layers of oil varying from a few inches to several feet in depth do, in fact, reveal a slight trend toward lower acidities at the lesser oil depths. How-

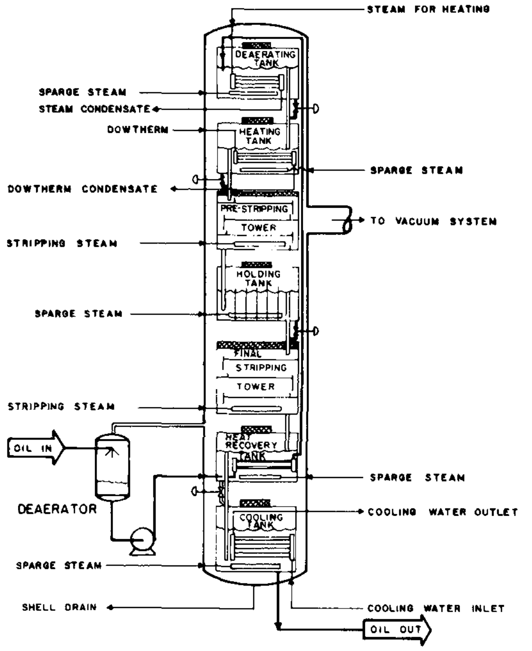

FIG. 1. Double shell deodorizer.

ever, the factor of oil depth is less important in this respect than is the absolute pressure above the oil. As mentioned previously, deodorization in efficient batch equipment at about 6 mm pressure can be depended upon to reduce the FFA of most oils to 0.015-0.030%.

If the deodorizer is so designed as to have extensive cool surfaces above the surface of the oil, upon which volatile materials may condense and return to the oil, the efficiency of stripping with respect to all volatile constituents may be seriously impaired (5). The principal advantage of a batch deodorization system is its simplicity. It can be operated for as long or as short a period as desired. However, the cost of utilities for the operation of a batch deodorizer is much higher than the cost of utilities for a semicontinuous or continuous deodorizer.

Semicontinuous Deodorizer:

The semicontinuous deodorizer consists principally of a tall cylindrical shell of carbon steel construction in which are placed five trays of type 304 stainless steel construction. Semicontinuous deodorizers operate on the basis of handling finite batches of oil in a timed sequence of deaerating-heating, holding-steam stripping and cooling, such that each quantum of oil is completely subjected to each condition before proceeding to the next step. These plants are normally automated and controlled from a central panel with time cycle controller and interlocks such that the sequence steps are interrupted in the event of insufficient batch size, improper drop valve opening or closing, or the oil not reaching the present heating or cooling temperatures in the allotted time.

The advantages and disadvantages of continuous and semicontinuous deodorizers, the two most widely used types, are important to our discussion. Continuous deodorizers provide uniform utility consumptions by not being subject to the peak loads attendant with batch type heating and cooling of semicontinuous operation. This permits smaller heating and cooling auxiliaries and the optimum in heat recovery through interchange between incoming and outgoing oil. Semicontinuous deodorizers ensure identical treatment for all of the oil and permit frequent stock changes with the minimum amount of lost production and practically no intermixing (1).

Continuous Deodorizer

In a double shell continuous deodorizer, the deodorization is conducted in a series of seven vessels all mounted within, but separate from, a single outer shall which is maintained under vacuum. The internal vessels are fabricated from type 304 stainless steel where in contact with the oil in process; the outer shell is carbon steel.

Figure 1 is a schematic diagram of a double shell deodorizer. Feedstock at 120 F is pumped into the external deaerating vessel, which is maintained under the same vacuum as the deodorizer to accomplish deaeration before heating. The deaerated feedstock flow is regulated by a liquid level controller and pumped into an internal heat recovery tank where it flows through pipe coils and is preheated by the hot oil surrounding the coils and moving countercurrent to the feedstock. This preheated, deaerated oil absorbs 50% of the heat normally required for deodorization by heat exchange with the hot deodorized oil prior to being pumped to the top tank in the deodorizer. This tank contains a series of baffles and pipe coils for steam heating. Steam heating is only required when a change is made in the feedstock. The oil then flows by gravity to the next tank.

The second vessel is the heating tank; it is also constructed with baffles to direct the flow of oil and provided with pipe coils for use with Dowtherm or other heating medium to raise the oil to the deodorizing temperature, usually between 400 and 525 F. This tank is sparged with steam to aid in heat transfer and to prevent pockets of oil from remaining in contact with the hot pipe surface. After reaching the desired deodorizing temperature, the oil flows, again by gravity, to the third vessel.

In this vessel, the prestripping tower, the oil is deodorized by passing the oil in a thin film over a series of stripping trays countercurrent to the flow of stripping steam, which is injected into the bottom of the section. This vessel is maintained under the same high vacuum applied to all sections since it is connected directly to the high vacuum system by means of passages which bypass the other sections. Thus, the highest temperature and highest vacuum are applied at the most advantageous stage of the process; and the low pressure drop-high efficiency stripping tray design assures maximum utilization of these optimum conditions. After prestripping, the oil continuously flows down to the holding tank, which contains a series of baffled passages with perforated pipe for steam sparging. This labyrinth effectively provides the required retention period for the thermal treatment of all of the oil.

In final stripping, the oil from the holding tank is again deodorized in another series of stripping trays to remove any additional odoriferous materials released during the holding period. Full vacuum is maintained on the final stripping tower by direct connection to the vacuum system through passages which bypass the other sections. The oil flows from the final stripping tower by gravity into the heat recovery tank where it preheats the incoming feedstock for maximum heat recovery. The oil flows from the heat recovery tank by gravity to the cooling tank. This tank is similar in construction to the heating tank except water is used in the coils to cool the oil to 150 F. Steam sparging is provided to aid in heat transfer. The cooled deodorized oil is then pumped from the vessel.

The steam used in sparging and stripping, along with the volatile impurities, passes from each vessel into the outer annular shell space and is removed through a single connection to the vacuum system. Wire mesh type entrainment separators are provided in the covers of the tanks and towers to remove entrained oil from the vapors leaving them. Any entrained oil not removed, together with any volatile materials that condense on the outer shell surfaces,

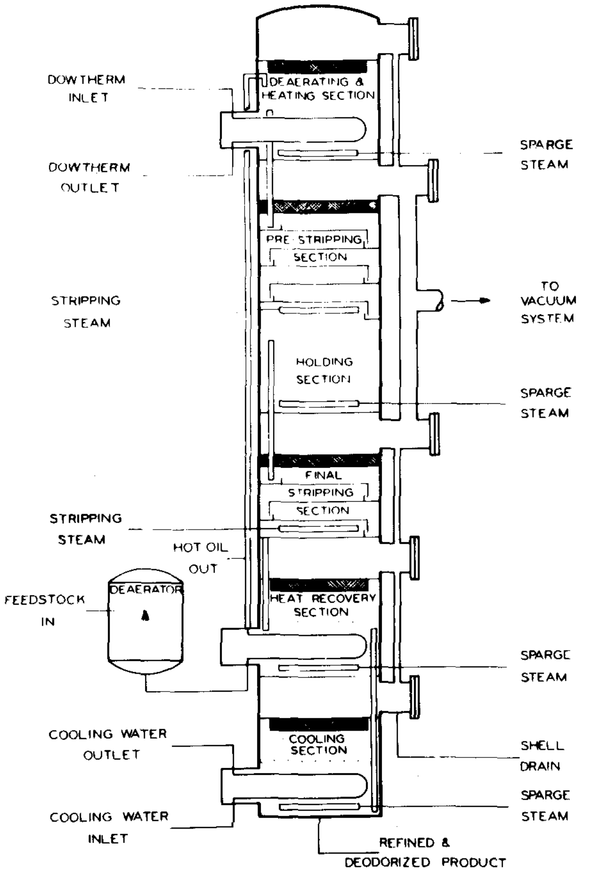

FIG. 2. Single shell deodorizer with heat recovery.

drains to the bottom of the outer shell and is removed periodically.

As previously discussed, the six principal factors considered in the design of a deodorizer are:

1. Pressure – Since the entire outer shell space is evacuated, all the deodorizing operations are conducted at the same low absolute pressure.
2. Temperature – The temperature of the heat transfer fluid flowing to the coils in the heating tank is controlled to maintain the desired deodorizing temperature. Agitation of the oil to provide a high rate of heat transfer is accomplished by sparging with steam.
3. Steam rate – The steam rate to each tower is metered and controlled individually, with fresh stem used in each tower.
4. Materials of construction – The seven tanks and all the interconnecting piping are made of type 203 SS. The outer shell is made of carbon steel since it does not come in contact with the oil.
5. Thermal Treatment – The holding tank provides the necessary retention time.
6. Protection from oxygen – The external deaerator removes dissolved and entrained oxygen from the oil before it is heated to the deodorizing temperature. In addition, if any air leaks through connections or seams in the outer shell, it will pass directly to the vacuum system without coming in contact with the hot oil.

The double shell deodorizing system is available in capacities of 15,000 to 60,000 pounds per hour; however, the single shell deodorizer is more economical to fabricate for lower capacities. Figure 2 is a schematic diagram of the single shell deodorizer. With this design we found it was less expensive to use Dowtherm for all of the heating instead of the steam-Dowtherm heating combination used in the double shell design. The single shell deodorizer consists of a type 304 stainless steel tower containing the same process elements as the double shell deodorizer. The carbon steel shell is replaced with a carbon steel vapor pipe manifold mounted alongside, with individual connections to each of the sections in the stainless steel deodorizer tower.

Feedstock at 120 F is pumped into the external deaerating vessel which is maintained under the same vacuum as the deodorizer to accomplish deaeration before heating. The deaerated feedstock flow is regulated by the liquid level controller and pumped through a U-tube heat recovery exchanger mounted inside the deodorizer where the oil is preheated by the hot oil surrounding the tubes. The oil then enters the top section of the deodorizer, which contains an integral U-tube type heating coil for use with Dowtherm, a series of passages and baffles for directing oil flow and a perforated pipe for steam sparging to aid in heat transfer. It flows by gravity into the second section of the deodorizer, the prestripping section, then flows by gravity into a holding section sparged by steam, then into a final stripping section. The two stripping sections have the same process design features as the double shell deodorizer. The oil then flows by gravity into the heat recovery section where it gives up heat to preheat the incoming feedstock, and next, by gravity, into the cooling section which contains an integral water-cooled U-tube coil to cool the oil to 150 F. The cooled oil is then pumped from the deodorizer.

The carbon steel vapor pipe connections to the stainless steel tower are located so that steam used in sparging and stripping, along with the volatile impurities, passes from each section directly into the vapor take-off pipe and is removed through a single connection to the vacuum system. Wire mesh type entrainment separators are provided in the top of each section. Manways, which are required for removal of the mist eliminators for cleaning, are mounted on the vapor take-off pipe in such a manner that any air leakage will flow directly to the vacuum system making it impossible for air to contact the hot oil in process. Both the single and double shell deodorizers, which have been proven in commercial operation for more than ten years, are supplied with the same process guarantee: they will produce a deodorized oil with a bland flavor, a maximum free fatty acid content of 0.03%, and a zero peroxide value.

STEAM OR PHYSICAL REFINING DEODORIZER

In Figure 3 the term steam refining refers to the removal of the free fatty acids from the oil by a distillation process instead of by reaction with an alkali. It has application to oils such as palm, palm kernel, coconut, soy, sunflower, corn oil and animal fats, from which all of the nonvolatile impurities can be removed by degumming, clay treating, or other means, so that only the FFA and other volatile impurities remain to be removed by steam refining. If such oils have a high FFA, steam refining has potentially lower losses and operating costs than alkali refining, particularly if it is combined with deodorizing. It also affords the possibility of recoverying the FFA in good quality and without the additional process of acidulation which is required for the soapstock resulting from alkali refining.

In this process the phosphatide-free oil from a pretreatment process is deodorized by three operations conducted under high vacuum at high temperature. First, the free fatty acids are removed by miltistage countercurrent contact with steam. Then the pigments are converted to a colorless form by retention of the hot oil for the required reaction time. Finally, the oil is deodorized by additional multistage countercurrent contact with steam.

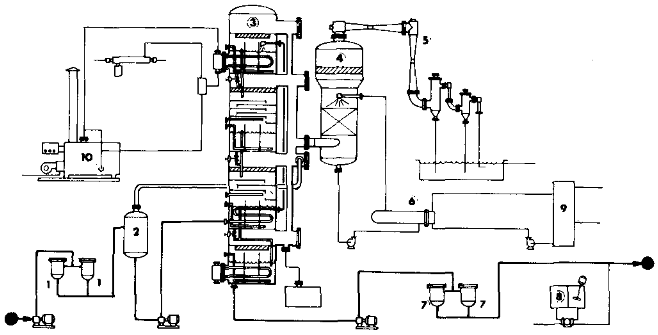

FIG. 3.

In order to achieve the full potential of the steam refining deodorizer, the process is designed with the following objectives: (a) reduction of the free fatty acids from 5.0% to 0.03% or less; (b) production of a fully deodorized product; (c) operation without substantially greater utilities consumption than a standard deodorizer; (d) recovery of the fatty acids from the sparge steam. In addition, the steam refining deodorizer must also be suitable for normal deodorization of the usual salad oils, shortening stocks and margarine oils without sacrifice of product quality or operation efficiency. The steam refining deodorizer is designed and operated in a manner similar to the single shell deodorizer.

The pretreated oil feedstock is continuously pumped through a filter, and sprayed into the deaerator, 1, under vacuum to remove entrained and dissolved air. The deaerated oil is pumped to the refining deodorizer, 3, in which it passes through coils in the heat recovery section and up into the heating section in the top of the deodorizer. In this section the oil is heated to the required processing temperature by vapor-heated coils from the Dowtherm vaporizer, 10, or by other suitable heating media. The oil then flows down to the refining section in which it passes over a series of trays countercurrent to the flow of stripping steam, which is injected below the bottom tray.

The refined oil flows down to the holding section which provides the retention time required for heat bleaching of the oil, after which it flows down to the deodorizing section. In this section the oil again passes over a series of trays countercurrent to the ascending stripping steam. The completely deodorized oil flows down through the heat recovery section to transfer its heat to the feedstock and then flows down to the cooling section. In this section the oil is cooled to the required discharge temperature and is pumped out through a polishing filter, 7. Metered quantities of solution from the antioxidant tank, 8, and nitrogen are injected as the oil is discharged to product storage.

Due to the corrosive properties of the large quantities of fatty acids at high temperture, type 316 stainless steel must be used for deodorizer fabrication. Either the double shell or single shell design can be furnished as a stream refining deodorizer in capacities from 5,000 to 60,000 pounds per hr. However, it is much more economical to fabricate the single shell deodorizer from type 316 stainless steel than it is the double shell deodorizer.

The steam refining deodorizer design achieves the objectives originally stated. (a) It removes the large quantities of FFA from high acid oils by means of additional stripping trays without the need for increased sparge steam in accordance with proven design principles. (b) It produces a fully deodorized product; and it is also suitable for the deodorization of normal feedstocks, because it is based on a deodorizer of proven performance to begin with. (c) It operates with only a moderate increase in utilities consumption. (d) It permits recovery of the distillate without further processing.

A comparison of utilities requirements per 1000 lbs. of feedstock for deodorizers and steam refining deodorizers is as follows (6):

Deodorizer	Refining	Normal
Steam 150 psig	300 lbs.	250 lbs.
Water 85 F.	4500 gals.	3800 gals.
Fuel Gas 1000 Btu/SCF	380 SCF	380 SCF
Electrical Power	1.5 KWH	1.5 KWH

OPTIONAL ITEMS

Heat Recovery

The high cost of fuel has made the deodorizer internal heat recovery system a standard part of deodorizing and steam refining deodorizing systems.Supplemental piping is provided to permit change of feedstock through the heat recovery system without intermixing. When it is necessary to change feedstock, the feed pump is stopped and oil in the deaerator is pumped through the heat recovery tank into the top section of the deodorizer. The flow is then reversed, and oil remaining in the pipe line and pipe coil is blown with steam into the top section of the deodorizer, thus completely emptying the system. This heat recovery system will save 125 lb. steam per 1000 lb. oil deodorized and is consistent with the principles of the original design, as hot oil is not piped or pumped outside the deodorizer vessel (7).

Change of Feedstock

The single shell, double shell, and stem refining deodorizer systems include as standard equipment a manual stock changing system remotely operated from the panel which is effective and convenient for occasional stock change. If feedstock is to be changed more than once a day, the deodorizer can be furnished with an automatic feedstock change system. With this system, a change of feedstock is accomplished from the control panel by simply pressing the start button for the automatic feedstock change system. By timed automatic integrated operation of the internal tank drain valves and the feed, discharge, and steam purge valves, the controller will automatically empty and fully drain the tanks and towers in sequence, and then refill the deodorizer with the next oil to be deodorized with one empty section between the new and old stock to eliminate intermixing. No operator attention is required for this operation, so the operator can direct his attention to operating the feed and product lines to and from storage for the feed and product polishing filters. A system is available for accurate addition of a metal inactivator to the feedstock, and of antioxidant to the product.

Deodorizer Distillate Recovery

Since deodorization involves the steam stripping of organic material from oil under vacuum, this organic material, commonly called distillate, passes into the vacuum system steam. Early deodorizer installations used once-thru water to condense this steam, with the discharge water returned to its source, such as a river or lake, or to a local water treatment plant. When governmental agencies began to restrict the discharge of organic material or charge high treatment fees, closed circuit water systems were introduced. In these systems the water from the vacuum system is cooled in a cooling tower and returned. However, quickly it was found that this organic material caused problems in the tower. It would collect on the tower fill, causing periodic shutdowns for cleaning. Between shutdowns it would decay, creating odor problems in the area around the tower. Wind currents would carry the odor beyond the plant boundaries, causing complaints from neighbors. A partial, though more costly solution, was attempted by the introduction of unfilled spray type cooling towers, but even these had maintenance problems, especially plugged spray nozzles, and did not completely eliminate the odor problem. Thus, it was necessary to develop a method of treatment of the deodorizer discharge vapor to reduce, as much as possible, its organic content.

In the late 1950's a direct contact cooling process was developed, and today almost every deodorizing system contains some version of this process. A typical flowsheet is shown in Figure 4. The deodorizer discharge vapor and vacuum booster steam flows into a tower where it is cooled by direct contact with a stream of circulating distillate. To provide for intimate contact between the vapor and liquid, some towers are partially filled with packing material while others spray the liquid into fine droplets, and still others contain a jet venturi. In all cases, however, the tower's purpose is to cool the deodorizer discharge sufficiently to condense most of the distillate. The tower bottoms are them pumped through a heat exchanger to remove the heat of condensation before being recycled to the tower. Automatic level control is supplied in the tower with excess distillate being pumped to storage. The location of the tower within the vacuum system and the operating conditions within the tower are selected to maximize distillate recovery, maintain a pumpable liquid in the tower and to prevent condensing of any of the vacuum system steam. In the early installations, the recovered distillate was returned to the crude oil or other location in the refinery for reprocessing.

With the introduction of Distillate Recovery Systems on large scale soybean oil deodorizers, it was found that this pollution control device actually produced a valuable by-product. The distillate was found to contain high quality sterol and tocopherol compounds which were in great demand for the production of natural vitamin E and other pharmaceuticals. During the 1960's and early 1970's, users of these raw materials actively campaigned to have all old and new deodorizer installations equipped with these systems to satisfy their raw material needs, and the value of good quality distillate skyrocketed. In 1974-75, however, a reduced market Vitamin E coupled with increasing quantities of synthetic substitutes caused a substantial drop in the value of the distillate. Only time will determine whether the Distillate Recovery Systems will return to a position of a "Profit-Maker" or remain strictly as a pollution control device.

Condenser Water Recycling

The Distillate Recovery Systems were very successful in substantially reducing the maintenance and odor problems in closed circuit water systems. However, because the operating conditions of the tower must be carefully controlled to allow the distillate to be pumped and to prevent steam condensation, some organic material still escapes it and ends up in the hotwell. Over a long period of time, the problems still develop with the cooling tower. With increasing emphasis on odor elimination by government agencies, the need of operating the cooling tower on only clean water was apparent. Thus, the condenser water recycling systems were developed.

The basic concept of such a system is shown on Figure 5. The dirty hotwell water is cooled in a heat exchanger with cooling tower water before being recycled to the vacuum system barometric condensers. There is no direct contact between the two water streams and, therefore, the cooling tower remains clean. This also allows the operator to start using the more efficient, lower cost, packed towers once again. The heat exchanger is specially designed, usually the plate type, to maintain high velocity through the passages to prevent the organic material from plugging the exchanger or fouling the heat transfer surface. This system then keeps the organic material in the hotwell water where a continuous bleed from the hotwell to the water treatment system prevents the building of this material.

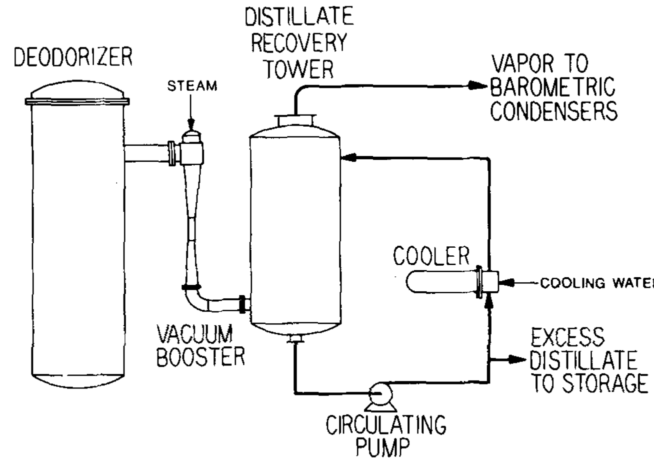

FIG. 4. Deodorizing distillate recovery system.

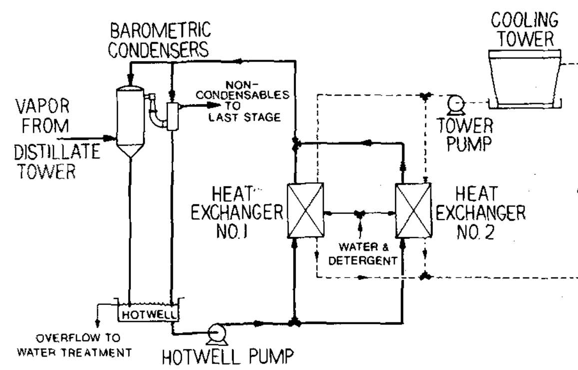

FIG. 5. Condenser water recycling system.

Despite the special design, the heat exchanger will eventually foul sufficiently so that the temperature of the water to the barometric will start to rise. To prevent the shutdown of the deodorizer due to erratic operation or loss of vacuum, a second heat exchanger is supplied. At a fixed timed interval or when the barometric water temperature starts to rise, the flow of the hotwell and cooling tower water is switched to the second exchanger. The dirty exchanger is then cleaned by backwashing with detergent in heated water and is ready for reintroduction into the system when it is needed. These types of systems are usually put under complete automatic control. Thus, at the appropriate time, the line valves switch, the hot water pump starts and runs for a special length of time, determined by actual operating experience to insure complete cleaning.

Vapor Scrubbing

Some of the low boiling compounds in the FFA continue the vapor phase through the barometric condenser and exit with the final vacuum stage discharge. Since a typical deodorizer vacuum system will have a noncondensing final stage, most installations pipe the discharge few inches

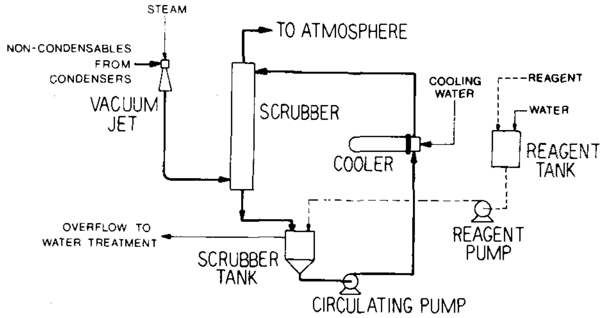

FIG. 6. Vapor scrubbing system.

below the hotwell water level. The volatile compounds dissolve in the hotwell water, and, where barometric condenser water recycling is not used, are reintroduced into the air in the cooling tower. Where recycling is used, they build up in the hotwell and can cause odor emissions around the deodorizer installation. Thus, in installation where this type of odor becomes a problem, a vapor scrubbing system such as that shown in Figure 6 is used to eliminate the volatile material. The vapor scrubber is a packed tower to provide sufficient contact time and area between the volatile materials and the scrubbing liquid. The bottom of the packed tower acts as a small hotwell to condense the vacuum jet steam and provide for some absorption of the volatiles. The remainder of the vapor then passes through the actual packed bed section. All the liquid collects in a small storage tank, is pumped through a heat exchanger for cooling and then is recirculated back to the tower.

To aid in the removal of the odor causing materials, chemical reagents are added to the circulating water stream to effectively oxidize all the organic compounds. Reagents such as sodium hypochlorite, calcium hypochlorite, or potassium permangante can be used with the secretion and concentration required, usually chosen based on actual operating experience with each installation (4). Auxiliary equipment normally supplied with deodorizing systems includes vessels, pumps, vacuum system, Dowtherm vaporizer with vent condenser, polish filters, control panel, instruments and controls. Engineering services include process flowsheet, equipment layout, structural steel design, detail piping layout, piping fill of materials, piping and insulation specifications, start-up services and operator training.

High Temperature Operation

Most commercial deodorizers operate at a temperature of 475 F to 525 F. If steam would be used as a heating medium, the pressure required would be ca. 900 psig. To reduce the cost and operating expenses associated with the generation of steam at this pressure, most commercial deodorizer installations use other heat transfer mediums. Mineral oil was one of the first mediums to be used, but the mineral oil is flammable, tends to break down at high temperatures, and there are considerable maintenance costs for the high temperature pump. The majority of the deodorizers use vapor phase heating with dowtherm A or therminol VP-1. Both are trade names for the eutectic mixture of diphenyl and diphenyl oxide, which boils at ca. 496 F at atmospheric pressure. Thus, to achieve a temperature required to deodorization of 500 F, only 16 psig is required. The typical system consists of a vaporizer (boiler), a burner complete with safety controls required by insurance regulations and a gravity return system for the condensate from the deodorizer. Thus, high temperature pumps are eliminated, but the heat transfer medium is flammable. Several years ago the therminol FR series of chlorinated biphenyl were popular as a heat transfer medium, as they are not flammable and are less expensive, however they are liquid phase transfer mediums and require high temperature pumping.

The heating of edible oils to deodorization temperatures has been the subject of considerable discussion, even to the extent of creating a bit of international intrigue. In 1973, contamination of rapeseed oil by a heat transfer medium resulting in illnesses and deaths was reported in Japan, with the blame being given to Dowtherm A. As a result, the Japanese government prohibited installation of new deodorization systems utilizing Dowtherm, and existing users were given two years to stop using the Dowtherm heating systems. When the smoke cleared, we found that only one-fourth of the 116 Japanese deodorizers were using Dowtherm A as the organic heating medium. Further, the refinery involved in the reported accident was using a mixture of 40% Dowtherm A and 60% KSK-260 oil. C. Imai et al. (8) reported that tests made by them and other laboratories on this rapeseed oil failed to detect any heat transfer medium. It can be concluded from their report that the usual deodorizer operating conditions are sufficient to remove Dowtherm A from the oil. The chlorinated biphenyl compounds, such as Aroclor and FR series Therminols, have been prohibited from use as heat transfer media in the processing of edible products in the U.S., but Dowtherm is permitted.

The prime emphasis, worldwide, seems to favor a shift to high pressure steam as the heat transfer medium. Over the years, European processors have been the more frequent users of high pressure steam. Their deodorizing temperatures of 210-240 C permit the use of 40-60 Kg/sq cm steam, whereas the higher temperatures of up to 275 C require steam pressures of 80-90 Kg/sq cm. A packaged type high pressure steam generator to handle the heating requirements of a deodorizer will cost about double that of a Dowtherm vaporizer unit (1).

Deodorizing Soybean Oil

In order to produce a quality product from soybean oil, careful attention must be paid to all steps in the refining process. As mentioned previously, deodorization is the last refining step before packaging and sale to the customer. Some refiners take the attitude that deodorization will produce a quality product regardless of the previous treatment of the oil. This simply is not true, particularly with soybean oil. The deodorizer will not make good quality deodorized oil unless the refiner sends good quality refined oil to the deodorizer. If the refiner is using the caustic process, he must treat the oil with the correct strength and amount of caustic to insure removal of phosphatides, he must water wash and bleach properly to insure removal of soaps, he should add citric acid to the oil before deodorizing and insure the deodorizer is operating at the proper temperature, pressure and with the required amount of stripping steam.

Citric acid or antioxidants and nitrogen should be added to the oil immediately after deodorization.

If the refiner is using the physical refining process, he must properly operate the degumming system to insure maximum removal of phosphatides, and monitor operating conditions of the pretreat-bleaching system to insure properly treated oil is fed to the steam refiner deodorizer, which should be operated under the same standards as outlined for the deodorizer in the previous paragraph.

Regardless of the refining method used, caustic or physical refining, the deodirized soybean oil should have less than 0.03% FFA, a zero peroxide, a color of 10 yellow 0.7 red and a bland taste.

FUTURE TRENDS

Twenty-five years ago semicontinuous and continuous deodorizers were supplied with capacities of 5,000, 7,500 and 10,000 pounds per hr. In 1964 the first 30,000 pound per hr continuous deodorizer was installed in the United States. This unit, twelve feet in diameter and forty-six feet overall in length, was the largest vessel which could be shop fabricated and shipped to site. Subsequent redesign would permit a capacity of 60,000 pounds per hr in a twelve foot diameter vessel. At present the world's largest capacity deodorizer 40,000, pounds per hr, is in operation in Brazil. The edible oil industry is expanding and in order to reduce operating costs, we expect that larger capacity deodorizers, up to 60,000 pounds per hr, will be built.

The resistance in the United States to the single shell deodorizer design has been broken by demonstration of the quality of products produced in a 15,000 pound per hr single shell deodorizer installed two years ago. Three single shell deodorizers will be in operation in the United States by the end of the year, and we foresee more in the future.

The physical or steam refining process has received considerable interest due to increasing supplies of palm and coconut oil. Elimination of soapstock acidulation and its inherent pollution problems has raised considerable interest in the physical refining of soybean oil. We do not expect the physical refining process to replace existing soybean oil caustic refining systems; however, we think any refiner planning a capacity expansion or a seed crusher wanting to become a refiner will install the physical refining system.

All new deodorizer and physical refining deodorizer systems will have a deodorizer distillate recovery system. Pollution regulations will require closed loop condenser water systems and scrubbing of the noncondensables.

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