Edible Oil Deodorizing Systems[1]

ARNOLD M. GAVIN, EMI Corporation, Des Plaines, IL

ABSTRACT AND SUMMARY

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 oil 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 doedorizers.

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 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, semi-continuous, or batch units, consists of steam stripping the oil for FFA removal. The three operating variables which influence the deodorizer design are product throughput, stripping steam rate, pressure, and temperature.

The 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.

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 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 bleaching to occur.

MECHANICAL DESIGN

Figure 1 is a cut away view of a double shell deodorizer. The deodorization is conducted in a series of seven vessels all mounted within, but separate from, a single outer shell 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 2 is a schematic diagram of the 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 in the heating tank 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 next vessel.

In this third vessel, the prestripping tower, the oil is deodorized by passing over a series of stripping trays countercurrent to the flow of stripping steam, which is injected in the bottom of the section. This vessel is maintained under the same high vaccum 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.

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

---

[1] Presented at the AOCS Meeting, New York, May 1977.

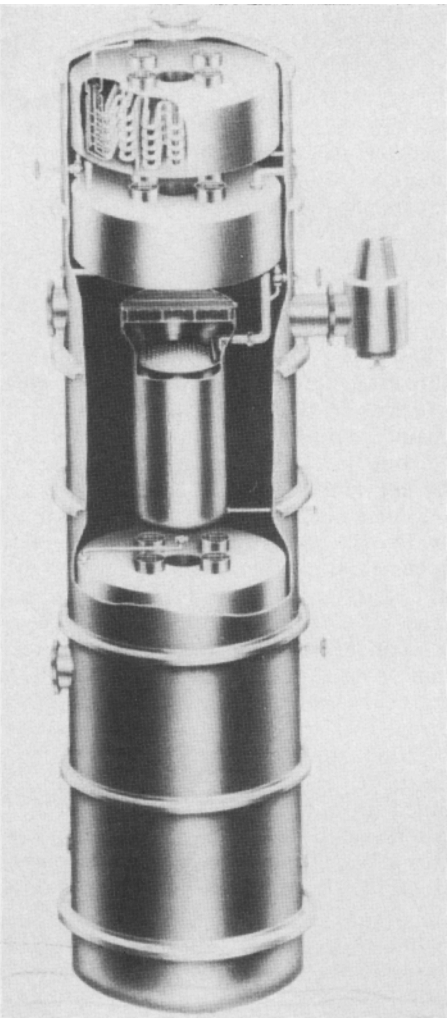
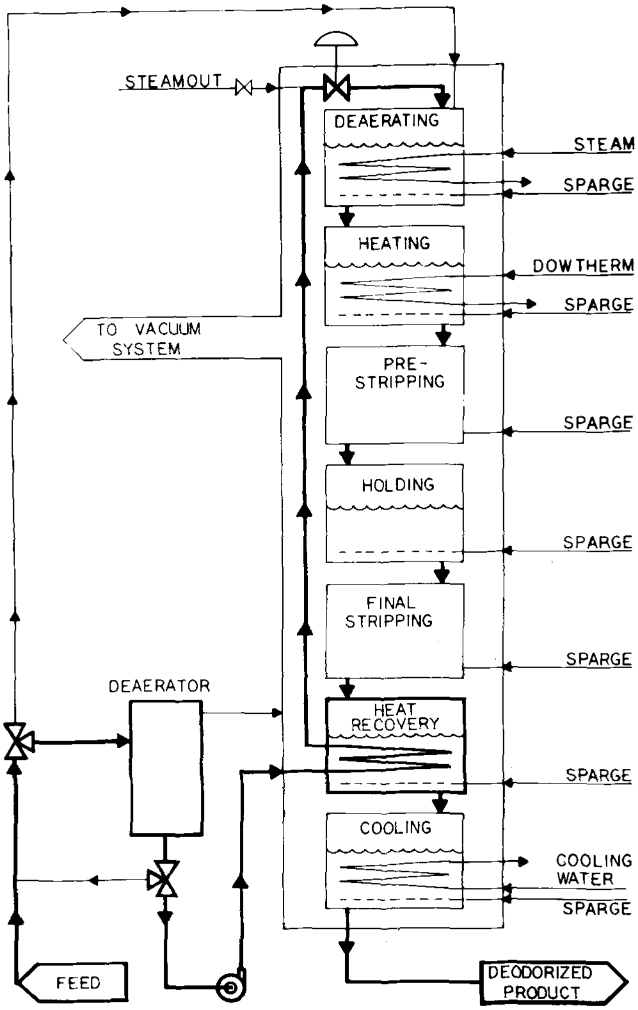


FIG. 1. Cut away view of a double shell deodorizer.



PATENT APPLIED FOR

FIG. 2. Schematic diagram of a double shell deodorizer.

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 them 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, 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 steam used in each tower.
4. Materials of construction: The seven tanks and all the interconnecting piping are made of type 304 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 doedorizing 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 3 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

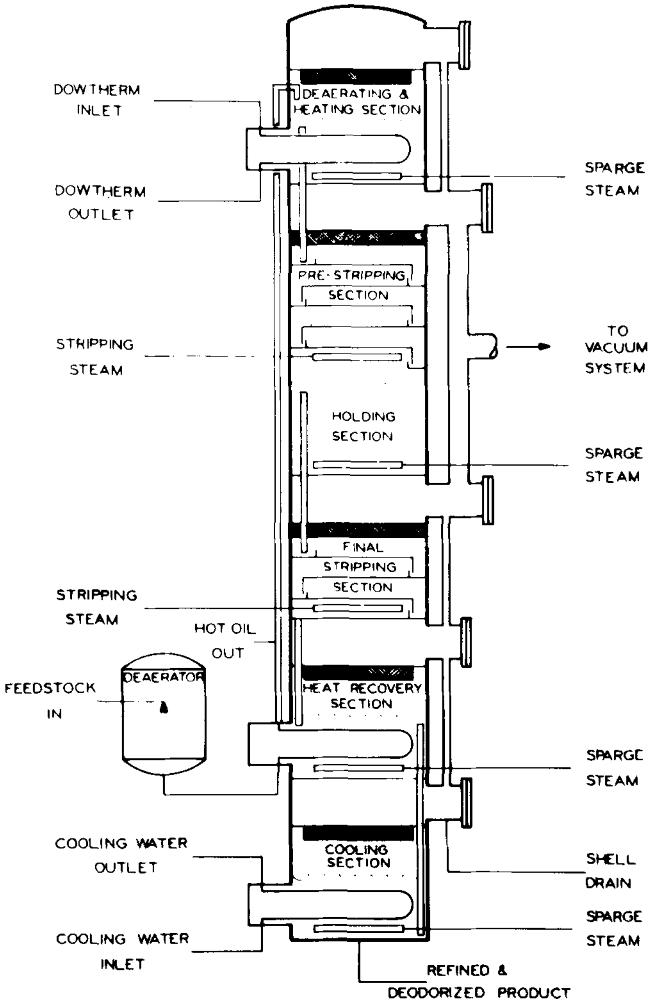


FIG. 3. Schematic diagram of a single shell deodorizer.

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.

The oil 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.

The oil next flows 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, pass from each section directly into the vapor take-off pipe and are 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 10 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 4 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 recovering 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 multistage countercurrent

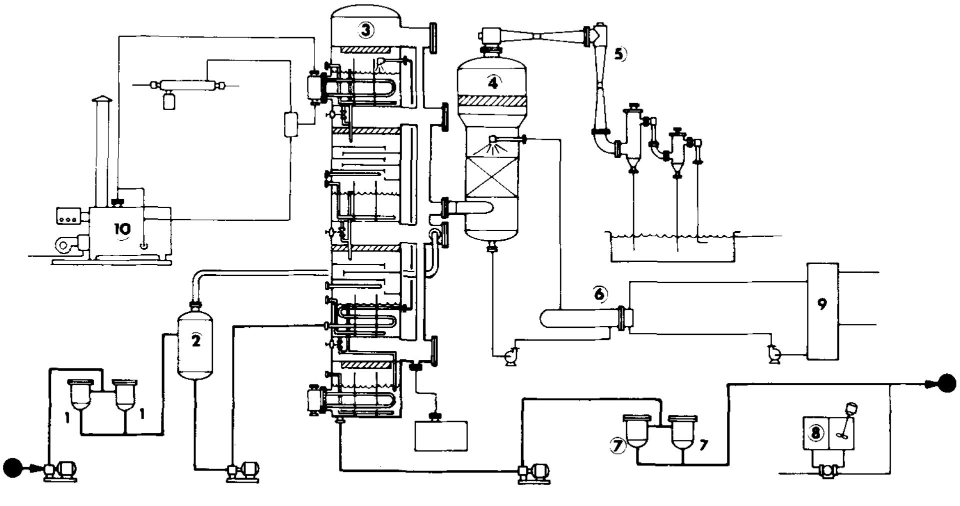


FIG. 4. Steam refining deodorizer flowsheet.

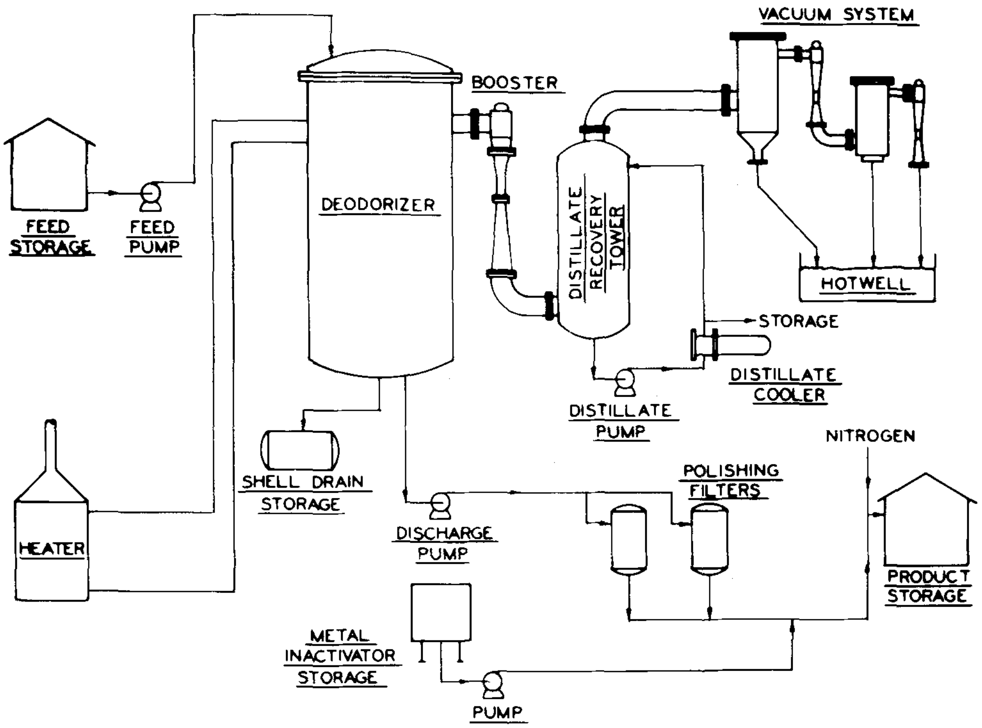


FIG. 5. Continuous deodorizer flowsheet.

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.

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 (*1*) and sprayed into the deaerator (*2*) 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 coils heated by vapor 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 temperature, type 316 stainless steel must be used for deodorizer fabrication. Either the double shell or single shell design can be furnished as a steam refining deodorizer in capacities from 5,000 to 60,000 pounds per hour. 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.

OPTIONAL EQUIPMENT

Change of feedstock: The single shell, double shell, and steam refining deodorizer systems include as standard equipment a manual stock changing system 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.

Antioxidant addition: A system is available for accurate addition of a metal inactivator to the feedstock, and of antioxidant to the product.

The deodorizer pollution control system: This optional system consists of three steps: the deodorizer distillate recovery system, closed circuit condensing water system, and the vapor scrubbing system. The vapors flow from the deodorizer vacuum booster into the bottom of the distillate tower and pass up through the internal contacting grid countercurrent to a descending stream of cooled liquid distillate which chills the vapors and condenses the distillate fraction from the steam. The liquid distillate flows out of the vessel and is pumped through a water-cooled heat exchanger, recirculated back into the tower, and sprayed on the top of the internal grid. Surplus distillate is automatically removed from the recirculating stream. Water for the cooler is provided by a tempered water recirculating system which is used to avoid solidification of the distillate in the cooler.

In the closed circuit condensing water system the condensing water is continuously recycled from the hotwell back to the barometric condenser through heat exchangers. Water from the cooling tower is used to indirectly cool the condensing water but remains free of fatty deposits. Noncondensables discharging from the vacuum system tailpipe are chemically scrubbed to eliminate disagreeable odors.

The advantages of the deodorizer pollution control system are:

1. Elimination of the build up of fatty material on the cooling tower and improvement in tower efficiency.
2. Elimination of disagreeable odors from the hotwell and cooling tower.
3. Automatic operation—requires minimal operator attention.
4. Designed to meet governmental regulations on odor
5. Operation proven in actual plant operation.

Figure 5 illustrates the auxiliary equipment normally supplied with deodorizing systems. Included are 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 bill of materials, piping and insulation specifications, start-up services, and operator training.

REFERENCES

1. Gavin, A.M., and R.W. Berger, JAOCS 50:466A (1973).
2. Gavin, A.M., and R.W. Berger, Ibid. 41:442 (1974).
3. Gavin, A.M., K.T. Teoh, and G. Carlin, Ibid. 54:312A (1977).

[Received June 6, 1977]