Deodorization 1975

CALVIN T. ZEHNDER, Director of Engineering, Votator Division, Chemetron Corporation, Louisville, Kentucky, USA

ABSTRACT

Current deodorization equipment available worldwide is reviewed with a general discussion of process innovations, operating conditions, and process-quality control problems. Flavor, color, odor, and stability of finished products are considered as affected by deodorization.

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 the 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 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, margarine, etc., are used.

The charter for suppliers of deodorization process equipment is to deliver a commercially salable top quality deodorized oil at the most favorable economic compromise of capital investment to operating costs. Since the deodorization process is essentially steam distillation, the efficient removal of the undesirable materials is dependent upon (a) the vapor pressure of the materials to be removed, (b) the absolute pressure under which deodorization is done, (c) temperature, (d) holding time at elevated temperature, (e) quantity of stripping steam per quantity of oil, and (f) efficiency of the apparatus used in contacting the steam and the oil. Of these variables, the last one, "efficiency of the apparatus," is that which offers the prime challenge to the ingenuity and creativity of the equipment suppliers' engineers.

DESIGN CONSIDERATIONS

The basic deodorizer system design must include equipment and auxiliaries capable of providing the operating conditions required to satisfy the process variables, mentioned above, for the specific oils. Table I is a tabulation of ranges of the commercial operating conditions generally accepted by the industry.

The operating absolute pressure, within the range of 1-6 mm Hg, is usually determined by agreement between the equipment supplier and his client. No commercial data are available to absolutely prove quality advantages of the finished product at 1 mm Hg as opposed to 6 mm Hg operation. The prime considerations are initial capital investment vs. ongoing operational costs. Current energy conservation awareness and the rising costs of fuel have resulted in most processors favoring minimum steam consumption at the penalty of higher capital costs. With usual utilities of 25-30 C water and 8-15 kg/sq cm steam, the most economical steam consumption will be obtained with a four stage ejector system designed for 6 mm Hg operation (Kinema, Inc., private communication, 1975).

TABLE I

Commercial Deodorization Conditions

Absolute pressure	1 -6 mm Hg
Deodorization temperature	210-274 C
Holding time at elevated temperature:	
Batch type	3-8 hr
Continuous and semicontinuous types	15-120 min
Stripping steam: wt % of oil	
Batch type	5-15%
Continuous and semicontinuous types	1-5%
Product free fatty acid:	
Feed, including steam refining	0.05-6%
Deodorized oil	0.02-0.05%

The deodorization process being time-temperature dependent explains the rather wide ranges shown for these variables. Even though it seems to be changing, European oil chemists and processors generally prefer the lower temperature–longer holding time operation whereas the U.S. has accepted high temperatures and shorter times.

The variation in amount of stripping steam required by the various equipment suppliers is both a function of the absolute operating pressure and the mechanical mixing efficiency of the equipment. Effective steam stripping is dependent upon volume; therefore, 1 mm Hg operation will require a lower wt % of stripping steam than 6 mm Hg operation. Oil depth is the primary factor requiring both increased stripping steam and extended holding time for batch deodorizers.

The oxidative effects of metals on the oils have been eliminated with the generally accepted use of 18-8 type stainless steel for all parts in contact with the oil at elevated temperatures.

During the past several years, deodorization losses have received considerable attention both from governmental agencies and oil processors. Environmental regulations controlling stream and air pollution, coupled with more stringent limits on the amount of fat permitted in metropolitan sewers, have resulted in the design of more efficient distillate recovery systems and a greater emphasis on overall fat recovery from refinery effluents. What initially appeared to be an "albatross" to many refiners resulted in maintenance savings and a very profitable by-product. With the installation of distillate recovery systems, the cleaning of closed loop cooling tower condenser water systems became less frequent. Also, for those refiners processing large volumes of soybean oil, the recovery of high quality tocopherols and sterols provided an extremely marketable by-product. Unfortunately, during 1974 and 1975, reduced sales of Vitamin E, coupled with an oversupply of both natural and synthetic Vitamin E, have resulted in a sharp decline in the price and a rather curtailed and selective market. It is believed that the worldwide inflation-recession has made its mark on the sale of Vitamin E. A quality distillate has a current value of only 25% of the 1973-1974 value.

Heat recovery, or heat interchange, has taken on increased importance as a result of the energy crisis and skyrocketing fuel costs. Equipment suppliers have all been challenged to provide such systems as a normal accessory of their deodorizer system.

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

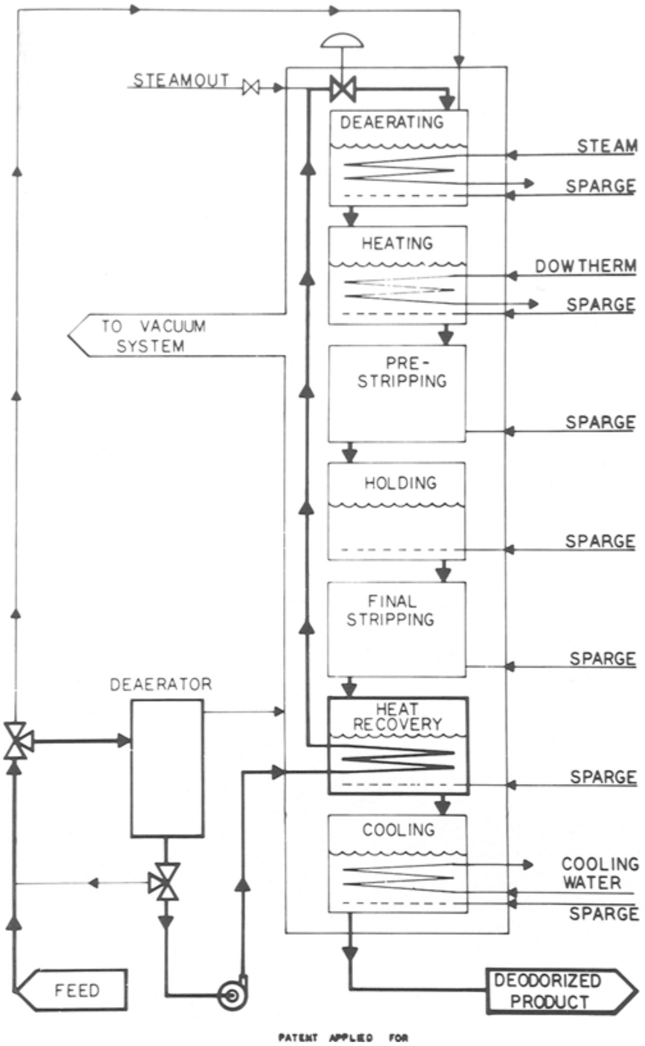


FIG. 1. Schematic diagram of double shell deodorizer (EMI Corporation).

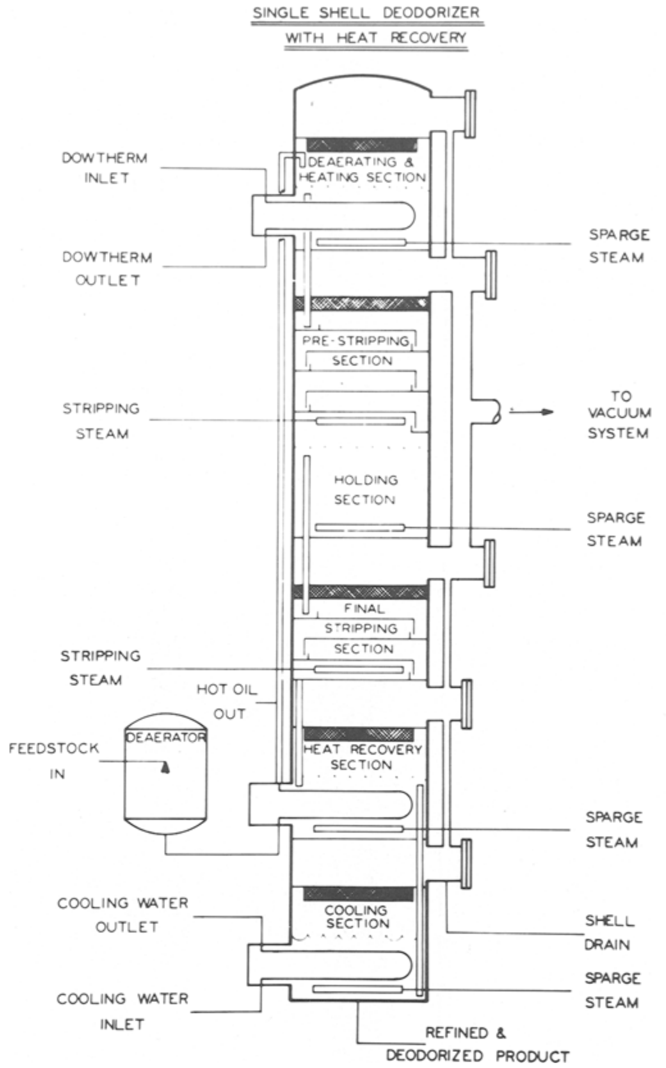


FIG. 2. Schematic diagram of single shell deodorizer (EMI Corporation).

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 2 years to stop using the Dowtherm heating systems. When the smoke cleared, we found that only 25% of ca. 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. (1) 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 media. 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.

DEODORIZATION EQUIPMENT TYPES

Deodorization equipment in use today can be classified into three principal groups: batch, continuous, and semicontinuous.

The batch deodorizer is self-descriptive in that a desired size vacuum vessel is fitted with heating and cooling coils and a means for injecting stripping steam into the batch of oil. The oil is charged into the vessel under vacuum, heated to deodorizing temperature, and stripping steam is supplied to the oil for the required holding time. The deodorized oil is then cooled to the desired temperature and discharged through a polishing filter to storage. Many batch deodorizers are still in use even though the economics of labor and utility costs strongly favor the semicontinuous and continuous units. Some refiners continue to operate batch deodorizers for handling small specialty lots of oil and thus minimize interferences with their major production schedules. These circumstances, however, are usually those in which a refiner has batch units prior to installation of more modern equipment.

Continuous deodorizers operate so that the oil flows continuously through the heating, holding, and cooling phases of deodorization with the retention times controlled by overflow weirs and pipes. Various designs are utilized in attempting to ensure that all of the oil is subjected to the same deodorization conditions of time, temperature, and stripping steam, i.e., no short circuiting.

Semicontinuous deodorizers operate on the basis of handling finite batches of oil in a timed sequence of deaeration-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

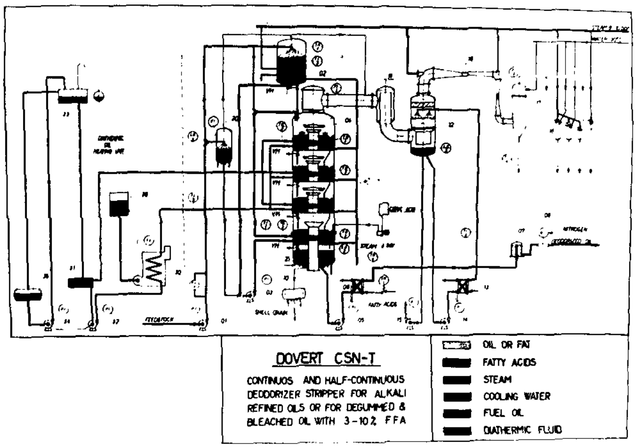


FIG. 3. Continuous-semicontinuous deodorizer flow diagram (Fratelli Gianazzo SpA).

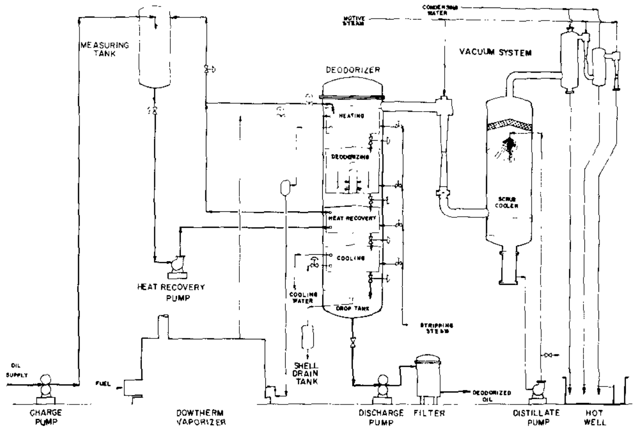


FIG. 5. Semicontinuous deodorizer flow diagram (Votator Division, Chemetron Corporation).

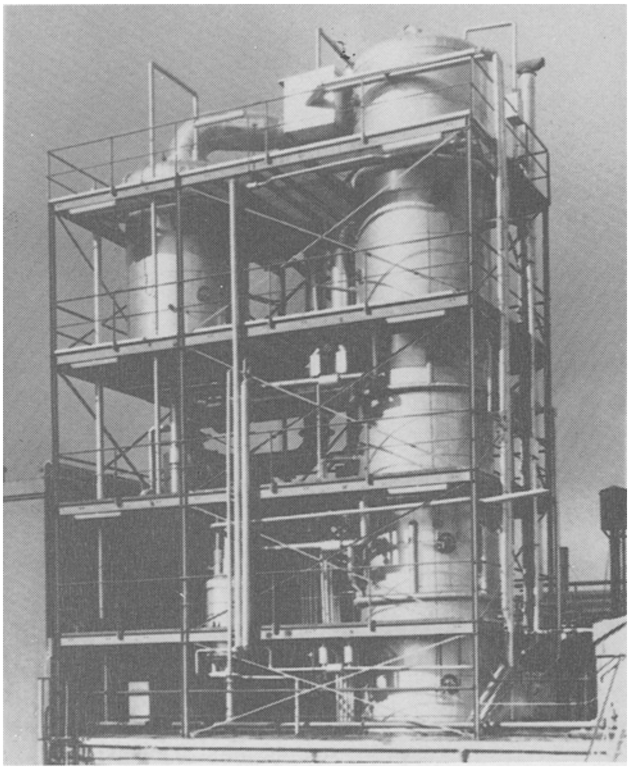


FIG. 4. Semicontinuous deodorizer installation (Lurgi Apparate-Technik GmbH).

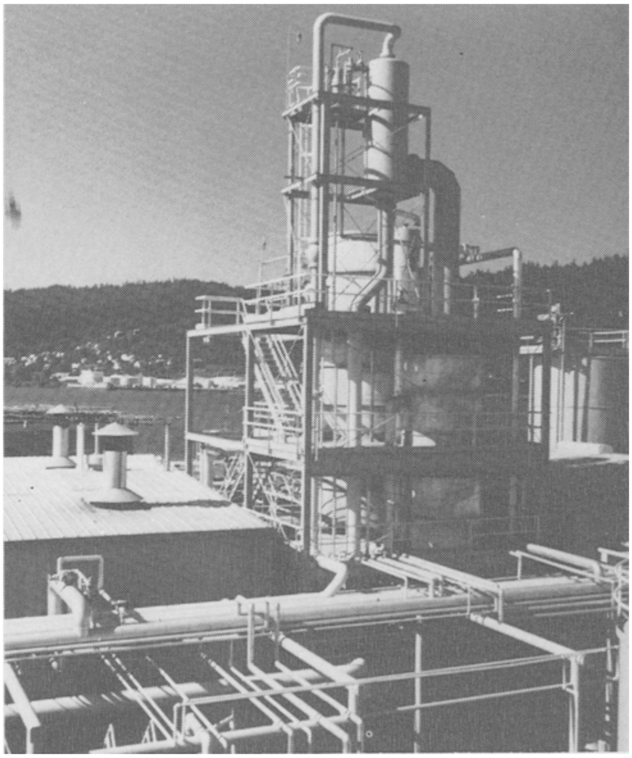


FIG. 6. Semicontinuous palm oil steam refining deodorizer (Votator Division, Chemetron Corporation).

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 preset 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 oils. 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 contamination or intermixing. Refiners processing basically one type of oil or involved in very infrequent stock changes will be more suited to continuous deodorizers, whereas the rather typical U.S. refiner who can be faced with several stock changes per day should definitely consider semicontinuous operation.

Regardless of equipment type, the common trend for all deodorizers is toward larger capacity units. As recent as 8-10 years ago, the average capacity was 10,000-15,000 lb/hr. Today, especially in the U.S., a 30,000 lb/hr unit is the order of the day. Capacity limitations are primarily related to design and shipment problems.

COMMERCIAL EQUIPMENT REVIEW

Time will not permit a detailed review of each manufacturer's designs. Therefore, general descriptions follow, with emphasis given to the salient features.

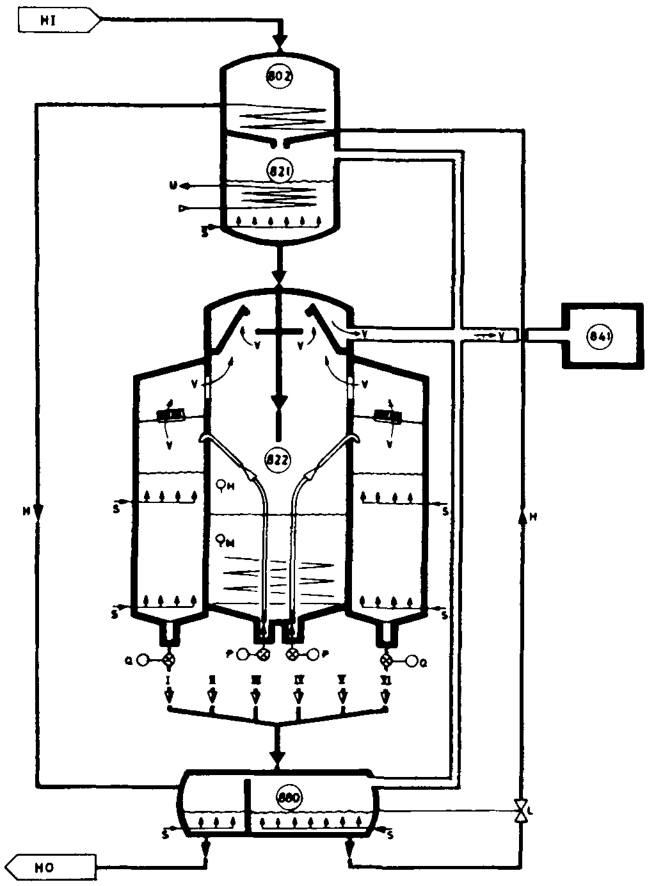
The EMI Corporation (Des Plains, Illinois, private communication, 1975) Model A deodorizer is a continuous type, "Double Shell" design (Fig. 1), which eliminates any possibility of product degradation due to contact between air and hot oil. All deaerating, heating, stripping, and cooling is accomplished under vacuum within the outer shell or vessel. Feedstock changes are accomplished by the proper manipulation (fully automatic if desired) of drain valves located between various internal sections of the deodorizer. Heat recovery between incoming and outgoing oils is available with the addition of an external deaerator, pump, internal heat recovery tank, and piping between the heat recovery tank and the deodorizer deaerating section. A new concept for edible oil deodorizers (2) is a single shell unit (Fig. 2) designed for the same processing advantages at lower capital cost than the "Double Shell." Specific attention is given to locating a carbon steel vapor header on the outside of the stainless steel deodorizer tower, with the connections to the tower being between the processing sections. Access manholes to the tower are located in the vapor take-off pipe so that any air leakage is directly into the vacuum system suction.

Gianazzo (3; private communication, 1975) manufactures both the continuous and semicontinuous type units. The Dovert-CS, continuous, is single shell construction with radially compartmented sections, each containing several stripping steam "special funnels" and the necessary heating, heat interchange, and cooling coils. The Dovert-T, semicontinuous or "timerized" unit, is of the same general design as the continuous unit except that it is the tray-within-a-shell design and completely automated. A third type unit, Dovert CSN-T (Fig. 3) is a fully continuous unit that may also be operated semicontinuously. This allows the continuous advantages of optimum heat recovery and uniform minimum utility consumptions and the semicontinuous advantages of uniform oil treatment by batch processing and minimum lost time during stock changes. The additional equipment required for this dual type operation is a second vessel serving as combination deaerator-surge-measuring tank, a supplementary receiver-drop tank built into the vessel bottom, and the usual drop valves and sequence automation for semicontinuous operation. The batch size is determined by drop valve open time.

The Krupp Conti Crossflow Deodorizer (Fried. Krupp GmbH, Hamburg, West Germany; private communication, 1975) is the single shell continuous type with multiple stripping trays partitioned in a circular manner with the oil flowing from outside to center of each tray where the vapor outlet is located. The base of each tray consists of a perforated plate and a solid plate which forms a steam chamber from which steam is injected into the flowing oil. With the exception of heat interchange, all heating and cooling is accomplished in external heat exchangers.

G. Mazzoni (4; private communication, 1975) "DAG-D" deacidifying-deodorizing distillation plant is a continuous process utilizing external preheating deaerating, heat interchange, and cooling. Internal heating and steam stripping is accomplished with the oil flowing through a labyrinthic course. The deodorizer vacuum and deaeration of water for stripping steam is maintained by mechanical vacuum pumps with refrigerated precondensers. This plant appears to be more suited to the deacidifying of oils with high percentage free fatty acid (FFA) consisting of lower mol wt fatty acids than to the deodorization of the usual variety of oils requiring very low FFA in the final product. It is the writer's opinion that these systems with mechanical vacuum pumps would be limited in throughput capacity much below the current average refinery requirements.

Lurgi (5; private communication, 1975) supplies continuous and semicontinuous deodorizers of the single shell design. Figure 4 is a photograph of a Lurgi semicontinuous deodorizer with vapor scrubber. The units consist of multiple internal stages with each stage equipped with steam spargers and oil circulators that operate in accordance with the airlift pump or vomit tube principle. Heating and cooling can be provided in various ways: all within the vacuum vessel; preheating, heat interchange, and cooling external with internal heating to deodorization temperature; or all internal with indirect heat interchange. All internal heating and cooling are normally supplied with



HI = Oil feeding
HO = Finished oil outlet
802 = Oil deaerator-exchanger (in continuous operation)
821 = Oil heater (in continuous operation)
822 = Semicontinuous deodorizer
S = Live steam injection
H = Oil circuit
QH = High level indicator
QM = Low level indicator
P = Steam jet remote valve
Q = Oil drain remote valve
V = Vapors to vacuum system
L = Oil level regulating valve
U = Heating fluid
841 = High vacuum device
880 = Oil cooler buffer tank

FIG. 7. Deodorization flow diagram (N.V. Extraction De Smet).

semicontinuous units, whereas the latter two methods are associated with continuous units. Internal precooling is normally supplied as indirect cooling whereby condensate is recycled through the last stage cooling coils and the heat rejected via an external plate-type cooler. This is done to prevent build-up of hardness salts in the last stage cooling coils. Lurgi connects the first of the deaerating-preheating-drying stages to the downstream side of the booster ejector. This results in an operating pressure of 20-50 mm Hg depending on the condenser water temperature and is intended to eliminate possible vacuum fluctuations in the deodorization stages due to entry of a wet product.

Wurster & Sanger (Chicago, Illinois; private communication, 1975) markets a continuous deodorizer,

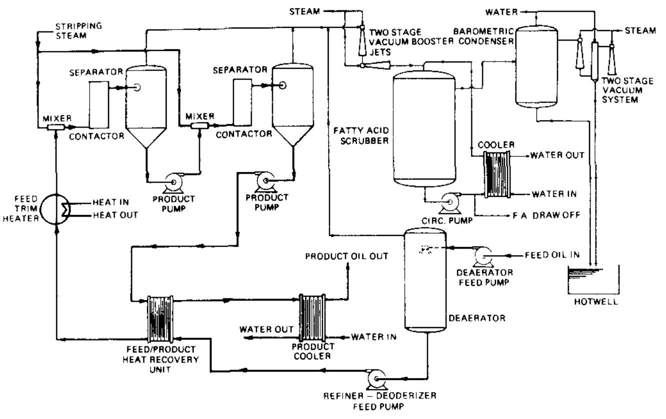


FIG. 8. Deodorization-steam refining flow diagram (Parkson Corporation).

single shell design, with countercurrent flow between steam and oil achieved by the oil flowing over Dowtherm heated bubble cap trays. With the potential air leakage problem through flanged connections and valve stuffing boxes on single shell units, Wurster & Sanger has developed a special design whereby these points are pressurized with nitrogen to prevent air entry. All sections of the deodorizer retaining oil are provided with air operated drain valves to assist in changing feed stocks.

Votator Division (Chemetron Corporation, Louisville, Kentucky), through the efforts of Bailey (6), was the original developer of the tray-within-a-shell design and still utilizes this design in the deodorizers which it markets. Both continuous and semicontinuous type units are available. However, the semicontinuous unit continues to receive the broadest acceptance because of its ability to accept frequent stock changes. Figure 5 depicts the current design with heat recovery and distillate recovery systems. Development work and patents by Lineberry and Dudrow (7) resulted in an improved stripping steam to oil contactor which reduced the long (60 min) deodorizer holding time to 15 min. This has helped to reduce the size of units and minimize cost increases for units with larger throughput rates desired by refiners. Figure 6 is a photograph of a newly designed deodorizer being used for the steam refining of palm oil. The unit is of standard design, except that two deodorizing trays are included to allow 30 min holding time to reduce the FFA from 5% to 0.02-0.05%. Votator designed deodorizers are also marketed through its licensees Simon-Rosedowns (Hull, England) and Extraktionstechnik (Hamburg, West Germany). Extechnik has been obliged to furnish modified Votator deodorizers to accommodate the lower temperature-longer holding times required by some German and European processors. Further, they have designed a single shell unit around the new Votator stripping concept to meet the needs of a lower cost market.

The author wishes to acknowledge the fact that there are deodorizer manufacturers other than those discussed in this paper. The exclusion is not intentional but results from lack of knowledge, oversight, and/or inability to obtain data on their units. Companies which should be recognized are CMB Costruzioni Meccaniche Bernardini, SpA (Rome, Italy), EBE Eisenbau Essen (Essen, West Germany), and N.V. Extraction De Smet, S.A. (Edegem, Belgium) (Fig. 7).

RECENT INNOVATIONS

The following discussion relates to two of the most recent new deodorizer designs being offered to edible oil processors.

The Parkson Corporation (Fort Lauderdale, Florida; private communication, 1975) markets their VSS Deodorization and Steam Refining System (Fig. 8) as the only continuous, low hold-up, short residence time unit

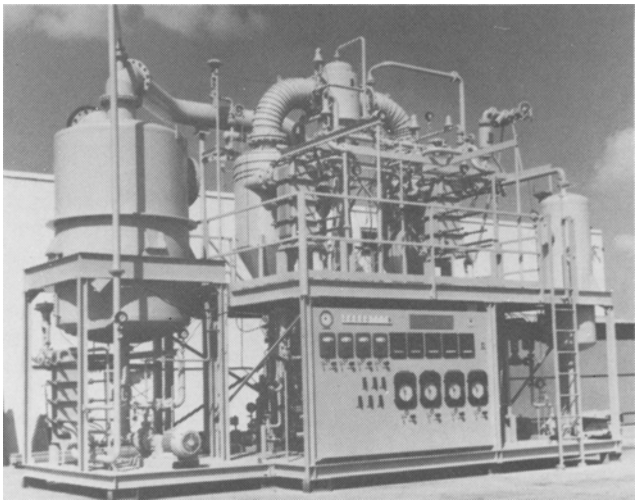


FIG. 9. VSS deodorization and steam refining skid mounted system (Parkson Corporation).

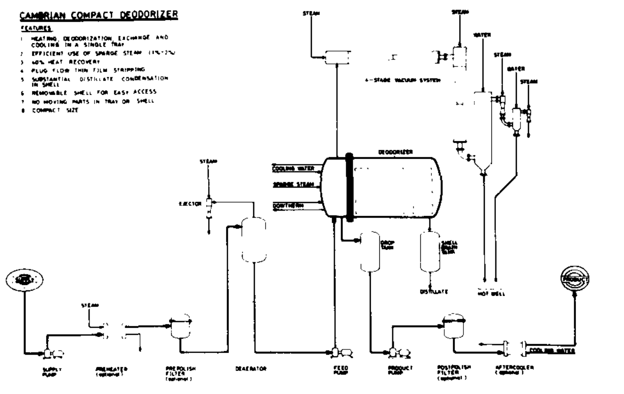


FIG. 10. Schematic flow diagram of Cambrian compact deodorizer (The Cambrian Engineering Group Ltd.).

available to the industry. A special high surface to volume ratio, tortuous path contactor brings about intimate exposure of the oil to stripping steam, as a two phase mixture, resulting in high mass transfer rates which reduce deodorization and steam refining holding times to a few seconds. Figure 9 shows a Parkson skid mounted VSS System which incorporates the standard process steps of deaeration, heat interchange, heating, and cooling. Upon leaving the contactor, the high velocity, two phase steam-oil mixture discharges into a highly efficient cyclone separator with the vapors exiting overhead into vacuum system boosters or a distillate scrubber. Some of the claimed advantages are improved product yield, negligible oil hydrolysis, high heat recovery, and lower total installed cost.

The Cambrian (Cambrian Engineering Group Ltd., Mississauga, Ontario, Canada; private communication, 1975) Campro Deodorizer is a continuous tray-in-shell unit embracing a design which combines plug flow with a unique thin film steam stripping concept. All of the usual deodorization steps (Fig. 10) are contained in a single rectangular stainless steel tray enclosed in a horizontal vessel. Access to the internals is made by horizontally retracting the shell. The oil flows in a serpentine manner around heat transfer coils, overflowing from one section to the next. In the deodorizing section, sparging steam propels the oil as a thin film through a number of distillation stages. Cambrian claims the time required for effective deodorization is reduced to only a fraction of that necessary for standard types of equipment. Heating and cooling sections, which have levels maintained by overflow baffles, are emptied by means of a steam lift. Low investment and maintenance costs, efficient use of sparge steam (1-2% of feedrate), and low neutral oil losses are among the advantages claimed for the unit.

REFERENCES

1. Imai, C., H. Watanabe, N. Haga, and T. Ii, JAOCS 51:495 (1974).
2. Gavin, A.M., and R.W. Berger, JAOCS 51:442 (1974).
3. Fratelli Gianazzo SpA, Milan, Italy; Bulletins GOG 17a and GOG 27b, 1975.
4. G. Mazzoni SpA, Busto Arsizio, Italy; Bulletin "DAG-D," Physical Refining, 1975.
5. Lurgi Apparate-Technik GmbH, Frankfurt, West Germany; Bulletin T1090/8.73, 1975.
6. Bailey, A.E. (National Cylinder Gas Co. [now Chemetron *Corporation*]), U.S. Pat. 2,691,664 (1954).
7. Lineberry, D.D., and F.A. Dudrow, U.S. Pat. 3,693,322 (1972) and applicable patents in other countries.