Reference # 7 Section 5.15 Soaps
& Detergents (August 1992)
1 copy

AIR POLLUTION
ENGINEERING MANUAL

SECOND EDITION

Compiled and Edited
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COUNTY OF LOS ANGELES

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A large-scale plant using a Raschig ring-packed tower followed by three gas coolers was built. Overall phosphorus pentoxide recovery exceeded 99.9 percent, but the process was eventually abandoned because of the excessive rate of corrosion of the gas coolers.

This same process, with a second packed scrubber or glass fiber-packed filter unit for acid mist removal replacing the gas cooler, is used by a number of phosphoric acid producers throughout the country. These plants routinely operate with phosphorus pentoxide recovery efficiencies in excess of 99.8 percent. A visible phosphoric acid plume still remains, though the phosphorus content has been reduced to less than 0.1 grain per scf. A plant such as this is in operation in Los Angeles County and is shown in Figure 568. The plume contains a large percentage of water vapor and does not violate local air pollution prohibitions. Stack analyses of emissions from this plant are shown in Table 200.

The packed scrubber must be thoroughly and uniformly wetted with either water or weak acid and must have uniform gas distribution to achieve high collection efficiency. Good gas distribution is also mandatory for glass fiber filter units, and a superficial gas velocity of less than 100 fpm is recommended.

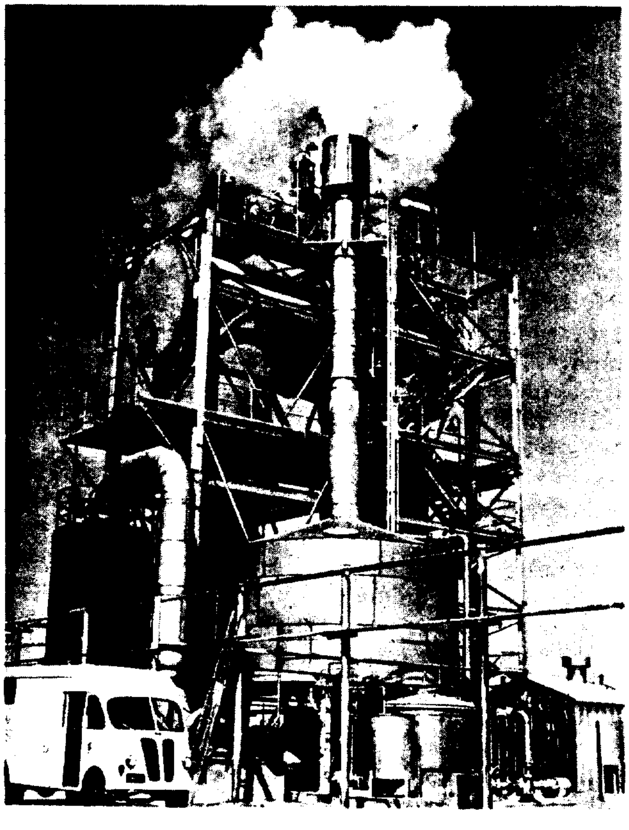


Figure 568. Phosphoric acid plant with a Raschig ring-packed scrubber.

The Brink (1959) fiber mist eliminator is a relatively new type of collector that has been used successfully on sulfuric acid mist, oleum, phosphoric acid, ammonium chloride fume, and various organics. Collectors of this type have been discussed in the preceding section of this chapter.

At one plant owned by Monsanto Chemical Company, the stack plume was very persistent and visible. Thirty milligrams of fine sulfuric acid mists per standard cubic foot and 80 to 200 milligrams of phosphoric acid particles per standard cubic foot were emitted from the stack. To correct the situation, a gas absorption apparatus followed by a fiber mist collector was installed. Collection efficiencies of 99 percent on particles less than 3 microns in diameter and of 100 percent on larger particles were achieved. The stack plume, which consists of 15 percent water vapor, disappears within 40 to 50 feet of the stack on dry days and within 150 feet on wet days. No maintenance problems or changes in pressure drop through the apparatus have been encountered.

SOAP, FATTY ACID, AND GLYCERINE MANUFACTURING EQUIPMENT

INTRODUCTION

Soap for washing and emulsifying purposes has been manufactured and used for over two thousand years. Traditionally, soap has been manufactured in batches by saponifying natural oils and fats with a solution of caustic soda, salting out the soluble soap formed, and drawing off the dilute glycerol produced. Shortly before World War II, major changes started to occur in the industry. Pretreatment of the fats and oils was introduced and changes were made in plant procedures and in finishing of the soap. Since World Was II, with the advent of synthetic detergents, soap use has declined precipitously until its production today constitutes less than 20 percent of the combined production of soaps and detergents (Silvas, 1969). Figure 569 illustrates the vast change in relative production of soap and detergent since 1944. The manufacture of detergents is discussed in another section of this manual.

When the direct neutralization of fatty acids by soda ash and/or caustic soda was introduced as a soap-making process, fat splitting, or hydrolysis, became a basic operation of the soap industry. Prior to 1955, the soap industry generated its own supply of fatty acids for use in soap making by splitting of natural fats and oils and provided fatty acids to other chemical process industries. Since 1955, however, fatty acids have also been synthesized from petroleum products, so that today fatty acids are produced synthetically in greater quantities than by splitting natural

Table 200. STACK ANALYSES OF EMISSIONS FROM A PHOSPHORIC ACID PLANT WITH TWO RASCHIG RING-PACKED SCRUBBERS

	Report series No.	
	C-167 A	C-167 B
Phosphorus burning rate, lb/hr	1,875	895
Gas rate, stack outlet, scfm	12,200	3,420
Gas temperature, stack outlet, °F	175	162
Diameter of first packed scrubber,ft	8.5	8.5
Height of first scrubber's Raschig ring packing, ft	12	12
Diameter of final packed scrubber, ft	20	20
Height of final scrubber's Raschig ring packing, ft	3	3
Final scrubber's superficial velocity, fpm	47	13
P_2O_5 emitted, gr/scf	0.095	0.108
P_2O_5 emitted, lb/hr	9.9	3.2
Emissions as % of phosphorus burned	0.23	0.16

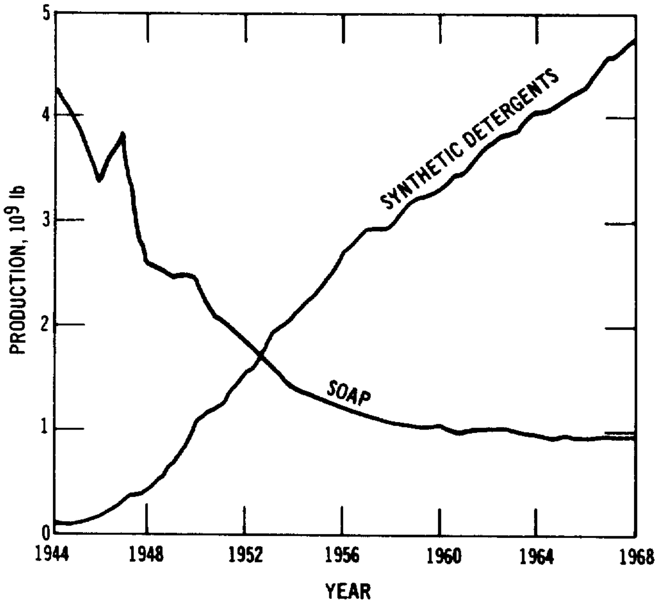


Figure 569. Production of soap and detergents in the United States, 1944 to 1968 (Chemical Week, 1969).

fats and oils. The soap industry, however, still uses fatty acids produced almost exclusively by splitting natural oils and fats, and still supplies a significant amount of fatty acids to other chemical process industries. The soap industry had been the principal supplier of glycerine to chemical process industries. However, glycerine is now produced synthetically, and presently the soap industry supplies only about one-half of the total glycerine consumed in this country.

Metallic soaps have uses entirely different from those for ordinary soaps, so that theyare not in direct competition. These soaps are alkaline earth, metal, or heavy-metal salts of fatty acids. They are made either by heating fatty acids with metallic oxides, carbonates, etc., or by the reaction of soluble ordinary soap with solutions of heavy-metal salts. Their manufacture will not be discussed in this section.

RAW MATERIALS

The soap industry applies the term "oil" to those natural fats which are liquid at ambient conditions, excluding hydrocarbon oils obtained from petroleum. "Fats," in the soap industry, refers to all natural oils and fats, liquid or solid. Soap is produced almost exclusively from these natural fats and oils.

Ordinary soluble soaps are classifiable in a number of ways. They may be generally classed as toilet soaps, household soaps or industrial soaps. Traditionally, sodium soaps have been called hard soaps, and potassium soaps called soft soaps. Today such classification is no longer meaningful, as the hard or soft quality of soap is much more dependent on the type and quality of fats and oils used to make the soap.

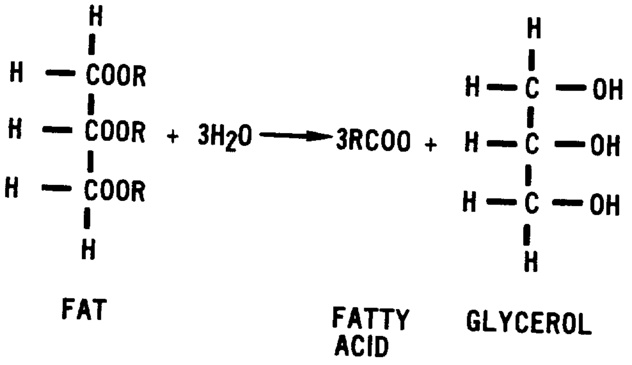
The properties of soaps are directly related to the type of fatty acids used. The most desirable fatty acids are lauric, myristic, paluitic, stearic, and olsic, which are acids having 12 to 18 carbon atoms. These acids constitute the bulk of the fatty acids found in tallow and coconut oil. As a result, many soaps are combinations of these two oils, usually in ratios of 3 or 4 parts of tallow to 1 part coconut oil. Because of its favorable acid content, availability, and low price, tallow is the most predominant fat used for soap making. It constitutes 80 percent or more of the total fats used by the soap industry. Greases, the rendered fats from hogs and other small domestic animals, are the next most often consumed fatty material (Shreve, 1967). Other natural oils, including marine oils, may also be used in the soap making processes. Many of the marine oils are used in special applications. They represent only an insignificant portion of the total fats used.

Sodium hydroxide is the saponifying alkali used for most soap manufacture. Potassium hydroxide still is used to some degree, and because potassium soaps are more soluble than the sodium soaps, they are used, or blended with sodium soaps, for making liquid soap solutions. Minerals, including soda ash, caustic potash, sodium silicate, sodium bicarbonate, and trisodium phosphate, are used extensively as builders or fillers. Used in smaller quantities, but of exceeding importance as synergetic soap builders, are tetrasodium pyrophosphate and sodium tripolyphosphate. Carboxylmethylcellulose (CMC) also is an additive for most heavy-duty soaps.

Finished soaps also may contain small quantities of chemicals used as preservatives, pigments, dyes, and perfumes, as well as antioxidants or chelating compounds. Bar toilet soaps and powder or granular laundry soaps may be manufactured as a combination of synthetic detergents and the neutralized fatty acid soluble soaps. Detergents used are either anionic or nonionic, but not cationic.

FATTY ACID PRODUCTION

Fatty acid production from natural fats may be performed by any one of several processes. The processes all result in "splitting" or hydrolysis of the fat. This may be represented as:



$$\begin{array}{l} \quad H \\ \quad | \\ H-COOR \\ \quad | \\ H-COOR \\ \quad | \\ H-COOR \\ \quad | \\ \quad H \end{array} + 3H_2O \longrightarrow 3RCOO + \begin{array}{l} \quad\ H \\ \quad\ | \\ H-C-OH \\ \quad\ | \\ H-C-OH \\ \quad\ | \\ H-C-OH \\ \quad\ | \\ \quad\ H \end{array}$$

Three current processes for splitting or hydrolyzing fats to produce fatty acids and glycerol utilizing either batch or continuous processes are detailed and compared in Table 201. Several older process methods, such as panning and pressing procedures, fractional distillation, and solvent crystalization, no longer are used. Of the three current processes, the continuous high-pressure hydrolysis process is the one most often used by the soap industry. A flow diagram of the process is shown in Figure 570.

In the continuous high-pressure hydrolysis process, fat and water, both in liquid phase, are heated in contact with each other to temperatures in excess of about 400 °F, and some of the water becomes dissolved in the fatty matter. The proportion of water that becomes dissolved in the fatty layer increases rapidly with rise in temperature, causing a reduction in the aqueous layer. At temperatures approaching 550 °F, depending upon the type of oil used, the aqueous phase merges into the fatty phase, leaving but a single liquid phase (Ittner, 1942). In practice, the equipment is operated at temperatures and pressures where the two components show considerable mutual solubility but below the temperatures where only one phase exists. The glycerine formed is continuously removed in the water stream, and at the same time the product fatty acids are removed as a separate stream.

The equipment used for this process is a vertical column (Figure 570). The fats, in liquid form, are first vacuum deaerated, which prevents darkening, and then pumped into the bottom of the column through a sparge ring. Deaerated, demineralized water is pumped at high temperature and high pressure into the top of the tower. High-pressure steam, at pressures of 700 to 750 psi, is introduced into the tower either along with the oil or directly into the reaction zone at the center of the tower, or, in some cases, at both the top and bottom of the tower. Tower operating pressures are usually 650 to 800 psi, and temperature of the fats is usually around 485 ° to 500 °F. The oil droplets travel up the column, while the water-glycerine solution flows down the column. The fatty acids then pass overhead to a flash tank for the removal of entrained water, or they may be decanted from the water after cooling and then passed to a settling tank where further separation occurs.

As shown in Figure 570, the glycerine and water solution, called sweetwater, is drawn from the bottom of the hydrolyzer tower and is passed through a series of evaporators, or to a flash tank to remove some of the water, and then to storage as crude glycerine.

The fatty acids produced are characteristic of the particular type oils being processed. Distillation is employed frequently on-stream with continuous hydrolization to further refine fatty acids. When chemical and industrial products are manufactured from these fatty acids, fractional distillation is used. When soap stock is produced, simple distillation in a continuous vacuum-type still is used as shown in Figure 570.

In the vacuum still, the boiling fatty acids pass overhead through a series of condensers. They are then either drawn off and pumped to storage as fatty acids or passed through a line mixer where caustic soda or soda ash is added to produce the salt of the fatty acids, which is a soluble soap. The soap stock thus produced is then held in storage for use in the various soap manufacturing and finishing operations.

Table 201. COMPARISON OF THREE CURRENT FAT-SPLITTING PROCESSES (Shreve, 1967)

	Twitchell	Batch autoclave	Continuous countercurrent
Temperature, °F	212 to220	300 to350 (450 without catalyst)	485 approx.
Pressure, psig	0	75 to 150 (425 to 450 without catalyst)	600 to700
Catalyst	Alkyl-aryl sulfonic acids or cycloaliphatic sulfonic acids, both used with sulfuric acid, 0.75 to 1.25% of the charge	Zinc calcium, or magnesium oxides. 1 to 2%	Optional
Time, hr	12 to 48	5 to 10	2 to 3
Operation	Batch	Batch	Continuous
Equipment	Lead-lined, copper-lined, monel-lined, or wooden tanks	Copper or stainless-steel autoclave	Type 316 stainless tower
Hydrolyzed	85 to 98 % hydrolyzed; 5 to 15 % glycerol solution obtained, depending on number of stages and type of fat	85 to 98 % hydrolyzed; 10 to 15 % glycerol, depending on number of stages and type of fat	97 to 99 %. hydolyzid; 10 to 25 % glycerol, depending on type of fat
Advantages	Low temperature and pressure; adaptable to small scales; low first cost because of relatively simple and inexpensive equipment	Adaptable to small scale; lower first cost for small scale than continuous process; faster than Twitchell	Small floor space; uniform product quality; high glycerin concentration; low labor cost; more accurate and automatic control; constant utility load
Disadvantages	Catalyst handling; long reaction time; fat stocks of poor quality must often be acid-refined to avoid catalyst poisoning; high steam consumption; tendency to form dark-colored acids; need for more than one stage for good yield and high glycerin concentration; not adaptable to automatic control; high labor cost	High first cost; catalyst handling; longer reaction time than continuous process; not so adaptable to automatic control as continuous; high labor cost; need for more than one stage for good yield and high glycerin concentration	High first cost; high temperature and pressure; greater operating skill

The fatty acids, which may contain considerable unsaturated organic acids, can be further processed by hydrogenation. Hydrogenation, with the use of a catalyst, saturates the double bonds of the unsaturated fatty acids. The process helps to eliminate objectionable odors and hardens the soap stock. The hydrogenation operation is usually on-stream with the hydrolysis operation.

GLYCERINE PRODUCTION

The saponification of natural oils can be represented by the following reaction:

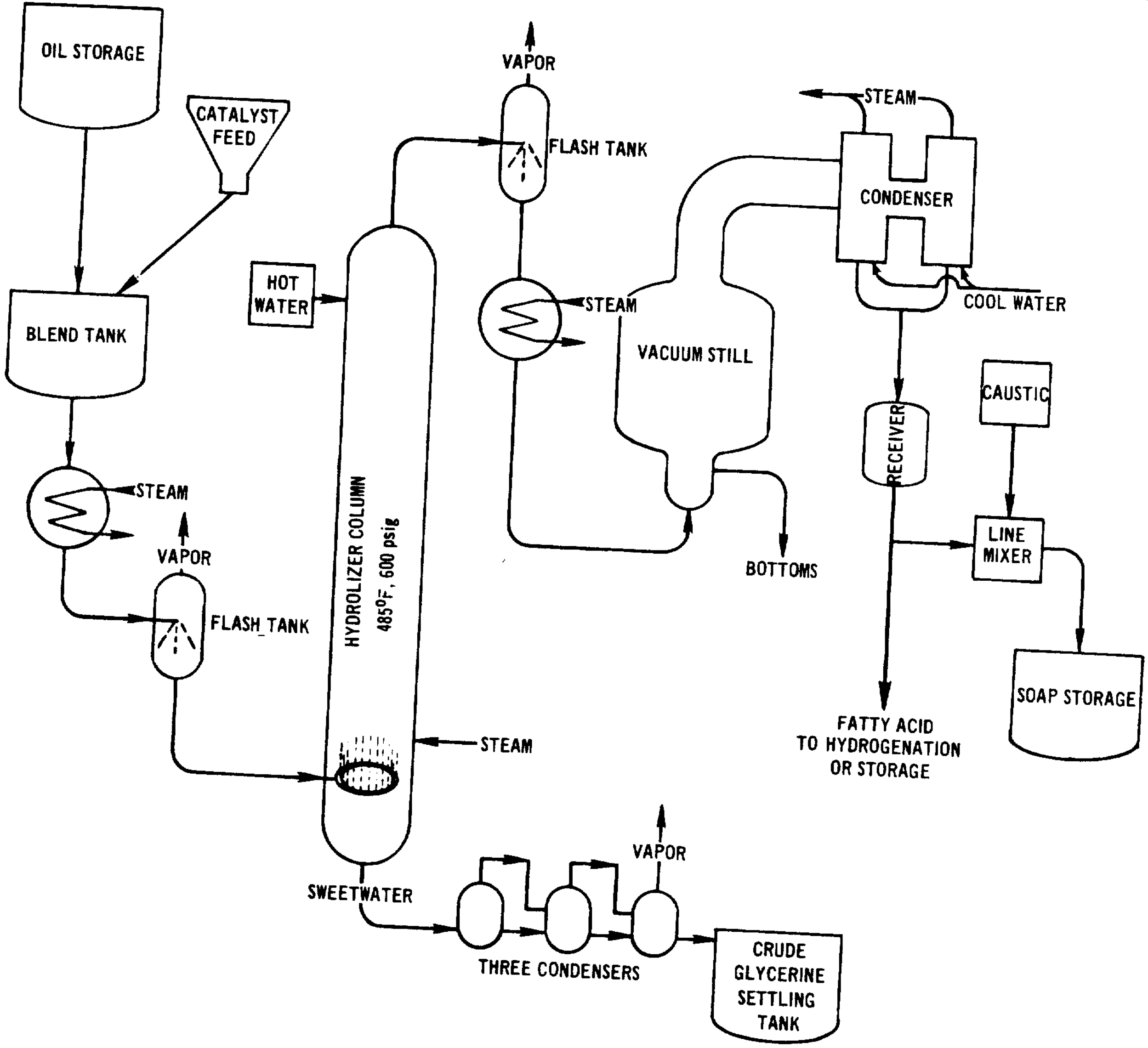
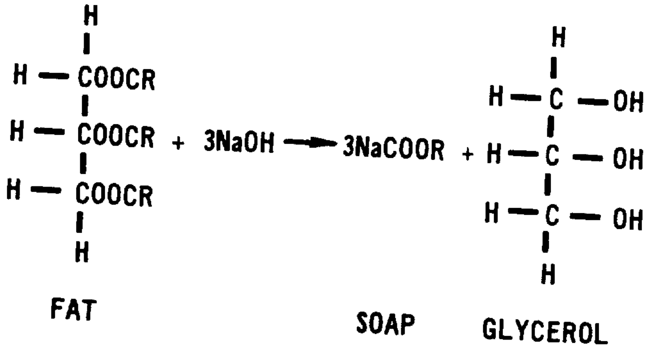


Figure 570. Flow diagram of a continuous process for hydrolysis of natural fats.



$$\begin{array}{l} \quad\mathrm{H} \\ \quad | \\ \mathrm{H-COOCR} \\ \quad | \\ \mathrm{H-COOCR} \\ \quad | \\ \mathrm{H-COOCR} \\ \quad | \\ \quad\mathrm{H} \end{array} + \mathrm{3NaOH} \longrightarrow \mathrm{3NaCOOR} + \begin{array}{l} \quad\;\mathrm{H} \\ \quad\;| \\ \mathrm{H-C-OH} \\ \quad\;| \\ \mathrm{H-C-OH} \\ \quad\;| \\ \mathrm{H-C-OH} \\ \quad\;| \\ \quad\;\mathrm{H} \end{array}$$

Whether soap is manufactured by the older method of saponification of natural oils illustrated by the preceding reaction or by the newer method of direct saponification of fatty acids, glycerine is always an accompanying product.

Figure 571 illustrates a typical soap plant glycerine purification operation. The crude weak glycerine solution derived from the hydrolysis process is refined to produce both commercial and pharmaceutical grades of glycerine. The processing of the glycerine obtained from the continuous hydrolysis process is a much easier operation than the processing of the spent soap lye glycerine from the kettle or batch processes of soap making. The sweetwater drawn from the bottom of the hydrolizer column has a concentration of about 12 percent glycerol. This sweetwater usually is so hot that, upon passing through three evaporators in sequence, the glycerol concentration increases to about 75 to 80 percent by weight. This crude glycerine then is held in a settling tank for at least 48 hours at elevated temperatures to reduce whatever fatty impurities are still present. It then is distilled under vacuum (60 mm Hg absolute) at temperatures of approximately 400 °F. Small amounts of caustic are added to the still feed to saponify the

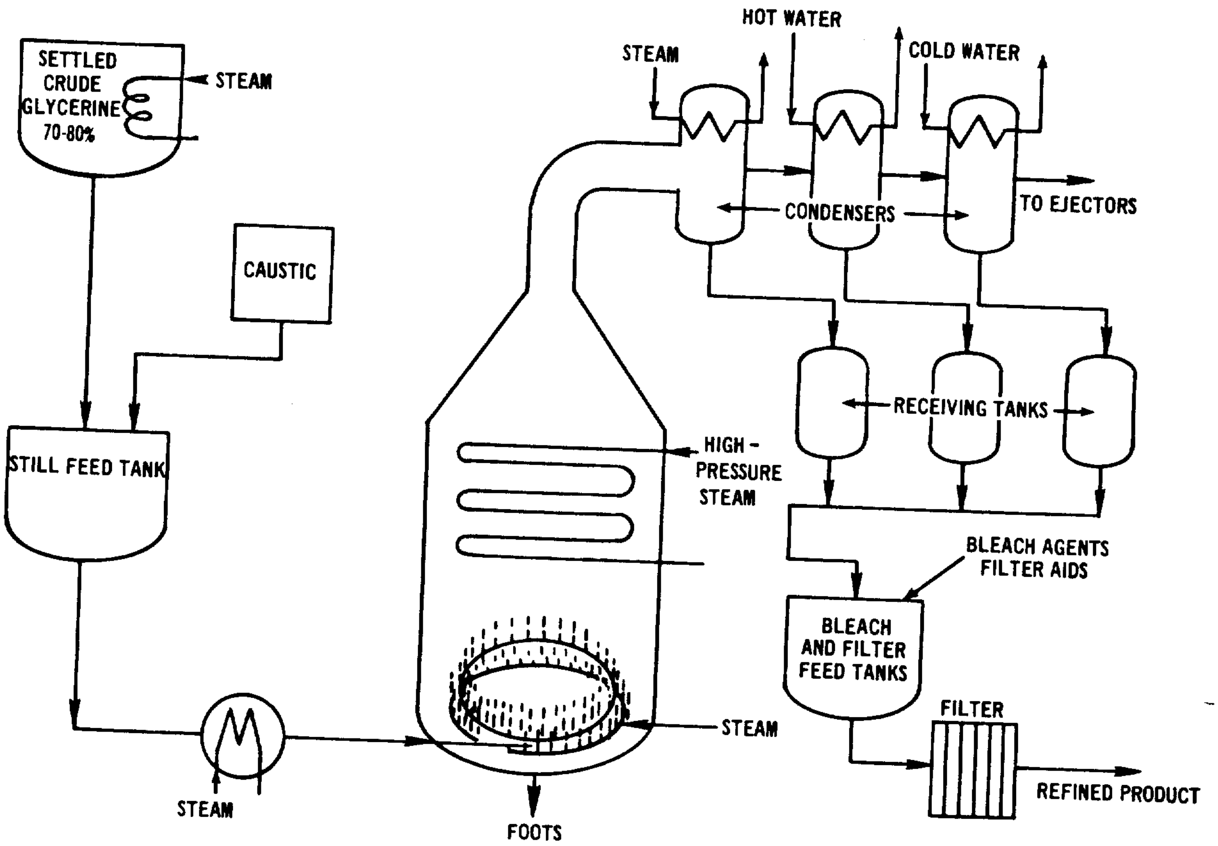


Figure 571. Flow diagram for glycerine manufacture from hydrolysis sweetwaters.

small amounts of fatty acid impurities which are present so that they will not boil off. The overhead product glycerine from the vacuum still then is condensed in a three-stage condensing system with progressively lower temperatures at each stage. The staged condensation yields different grades of glycerine. The highest temperature first-stage condensate usually contains 99 percent glycerol. Lower quality grades are collected from the lower temperature condensers. The glycerine is purified by bleeching and filtration or ion exchange.

In the making of soap by alkaline saponification of fats, glycerine always is formed and commonly is recovered in solution in the soap lye. The spent lye removed from the saponification process averages around 4 to 5 percent glycerine when removed directly, and may exceed 10 percent when other washing processes are used. The spent lye, in addition to the glycerine, contains roughly 10 percent by weight of salt and some small amount of soaps that are still soluble in the lye.

Figure 572 illustrates a typical spent soap lye processing plant. The first step is the purification of the lye solution removed from the saponification operation. The lye is neutralized by treating with mineral acids to form a salt. The neutralized solution is heated and agitated to precipitate any remaining soap. After filtration, the solution then is evaporated. Vacuum evaporation, either in a series of batch vessels or continuously in cone bottom vessels, causes the salt crystallization point to be reached.

As the salt concentration increases, salt crystallizes out and separates. In the continuous vessel, a portion of the separated salt is intermittently removed from the bottom. In the batch separation, the salt is removed from the slurry by pumping it through filters or centrifuges. Recovered salt is reused in the soap making process. The concentrated glycerine is boiled down to remove even more salt until a concentrated crude soap lye glycerine is obtained. At this stage the crude glycerine constitutes 80 to 82 percent by weight of the solution with approximately 2 percent by weight of nonvolatile organic matter, the remainder being a mild salt solution in water. Further treatment of this crude glycerine follows the same procedures used with the crude glycerine obtained from fat splitting operations.

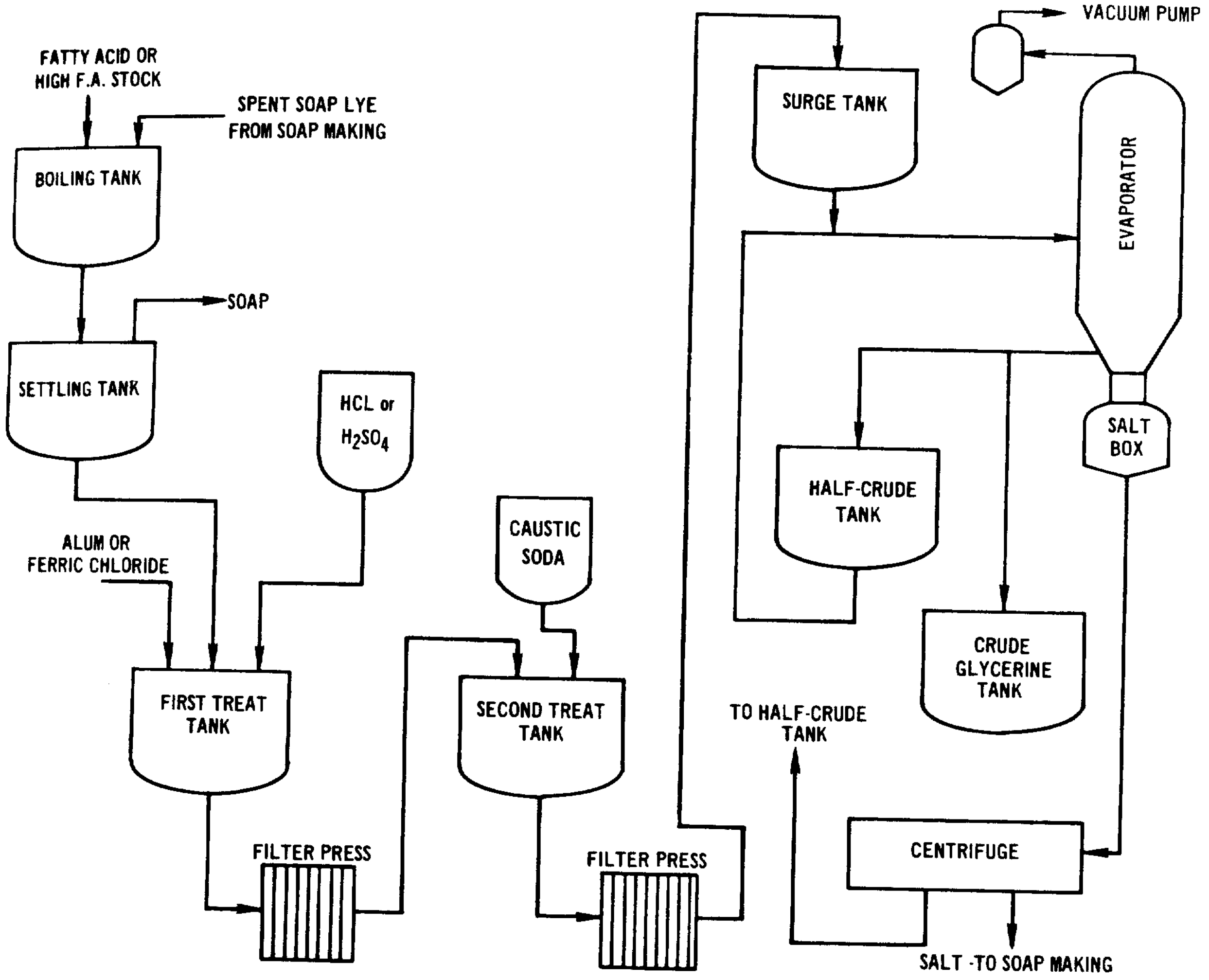


Figure 572. Spent soap lye plant for recovery of crude glycerine.

SOAP MANUFACTURING

The soap-making processes, either those utilizing the alkaline saponification of fats and oils or those employing the saponification of fatty acids, are variously batch or continuous. The kettle or full-boiled process is a batch process which follows the historical and traditional soap-making methods since the beginning of the industry. This process involves several steps or operations in a single kettle or, in large operations, a series of kettles. The kettles or pans used in these processes vary considerably in size depending upon production requirements. Small operations or producers of specialty soaps may employ a kettle which will only produce a few hundred pounds of soap. Large commercial producers of soaps may use kettles which will produce 150,000 pounds of soap per batch.

The steps or operations performed include saponification of the fats and oils by boiling in a caustic solution using live steam, followed by "graining" or precipitating the soft curds of soap out of the aqueous lye solution by adding sodium chloride salt. The soap solution then is washed to remove glycerine and color body impurities to leave the settled or "neat" soap to form on standing. Neat soap is the almost pure soap produced in the full-boiled process and remains as the upper layer of soap from which "nigre" soap and lye solutions have settled. The steps described above in the full-boiled process, including that of the final settling, can require a period of several days. The smaller kettles using this process may require up to 24 hours per batch, while the larger kettles may require up to a full week to complete a batch.

Other batch processes of saponification of fats and oils, still used for small production runs of specialty soaps, include the semiboiled process, the cold process, the autoclave process, the methyl ester process and the jet saponification process.

Two proprietary processes for continuous saponification of natural oils are used by some soap manufacturers. These are the Sharples Process and the Mon Savon Process. Both processes, while dissimilar, eliminate the large kettles and lengthy process time required by the old traditional batch operations. All processes, however, accomplish the same steps of soap manufacture.

The manufacture of soap by direct saponification of fatty acids is easily accomplished in continuous processes. However, many plants employ conventional soap kettle processes. Batch saponification also is performed in mixing kettles, commonly called crutchers. Fatty acids obtained by continuous hydrolysis are usually neutralized with 50 percent caustic soda continuously in a high-speed mixer-neutralizer to form soap. The neat soap produced is discharged at 200°F into an agitated blending tank to even out any inequalities of neutralization. The neat soap contains approximately 30 percent water at this stage. This soap stock then is held at an elevated temperature for use in the various soap finishing operations.

SOAP FINISHING

(Soap is finished for consumer use in various forms such as liquid, powder, granule, chip, flake, or bar.) Part of the finishing operation for soap is the addition of various ingredients to accomplish the purposes for which the final product is designed. Toilet bars of the purest type of soap will have the minimum of additional ingredients. Heavy-duty laundry soaps will have a maximum of other ingredients added. All soap, after finishing, contains some water, usually between 10 and 30 percent, because anhydrous soap would be too insoluble to use easily. The finished soap product contains perfume which, while frequently not apparent, has been mixed in with the soap to disguise somewhat unappealing odors.

Bar soap is produced in three general processes. The oldest process, the framing process, seldom is used today except for some special types of soap. In this process, liquid soap, after mixing or crutching with other necessary ingredients, is poured as a semiliquid paste into large vertical molds. The soap hardens upon cooling in these molds. The sides of the molds or frames are removed and the soap is cut by mechanical sawing processes into rough shapes and sizes of the bars. They are then stamped into the final shape, with whatever markings are desired, and wrapped for shipment.

Most bar soap today is manufactured by a second process, the "milling" process. Milled soaps, as they are called by the industry, usually are manufactured in one of two processes. In the older and still more commonly used process shown in Figure 573, the soap stock is batched in a mixer, called a "crutcher", with other ingredients. The batch is then flowed onto chill rolls, and then flaked off and passed through a steam-heated hot-air dryer. The flakes can be packaged as flake soap or ground and packaged as powder. When soap bars are made, the flakes from the dryer are "plodded" (mixed in a screw or sugar tubular mixer) or mixed with final ingredients such as perfume. The plodded material then is fed to a roll mill. The flaky soap produced by the roll mill then is plodded again to throughly mix ingredients and improve texture and is extruded in a continuous bar shape for cutting, stamping, and wrapping.

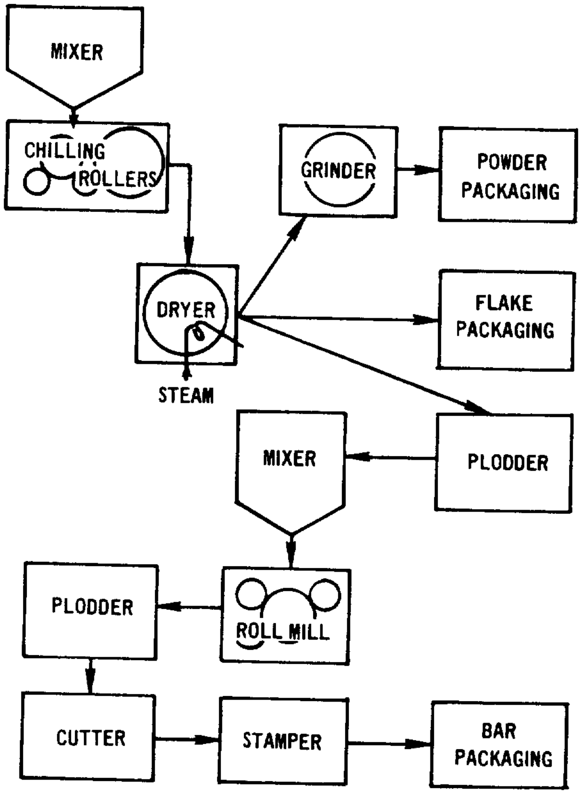


Figure 573. Flow diagram of milling soap finishing process.

In the second and more recent milled soap process, the basic blended soap stock is pumped through atomizing nozzles against the inside wall of a vacuum chamber and dropped from the chamber into a plodder. Figure 574 is a diagram of this process. The plodded soap is immediately

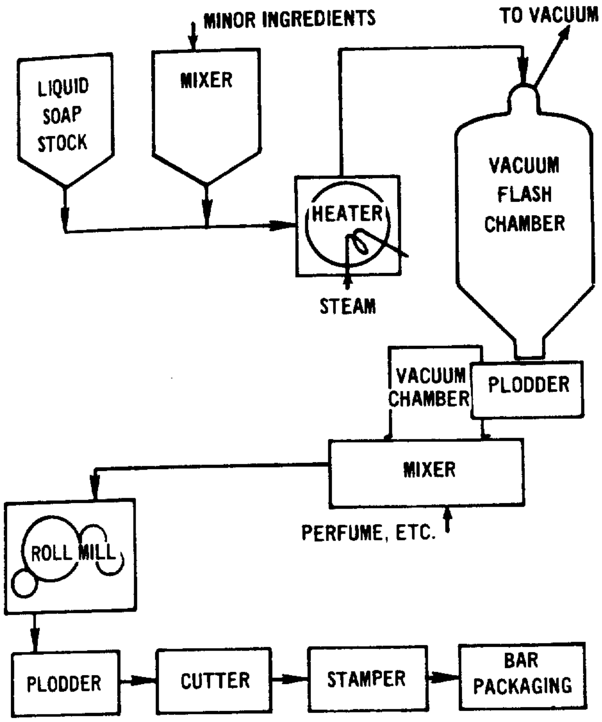


Figure 574. Flow diagram of vacuum flash drying process for bar soap production.

mixed with the necessary additional ingredients and then passed through a series of roll mills and plodders until it is extruded in a continuous bar for cutting, stamping, and wrapping.

A third process, illustrated in Figure 575, produces aerated soap bars. Neat soap is heated under pressure and then water is flashed off. Air is mixed with the soap, perfume is added, and the paste chilled and then extruded continuously. After cutting to rough shape, the bars are "aged" or cooled, and then stamped and wrapped.

Soap also is finished for marketing in flake or chip form. In manufacturing this type of product, the same procedures are followed as were described for the framing process. The only exception is that after hot air-drying, the soap is not milled or plodded.

Soap powder formerly was produced by grinding the chips coming from the hot air-dryer discussed above and shown in Figure 573. This method of soap powder manufacture has been highly unsatisfactory since it produced a product containing excessive fines. However, this process is still used occasionaly in some soap plants. Soap powders now are manufactured almost exclusively by first crutching the soap stock with the fillers and other additives to produce the final composition and then spray drying the slurry mix. The spray drying of soap and the spray drying of synthetic detergent compounds are very similar processes. Spray drying is discussed in much greater detail in the section of this manual dealing with detergents.

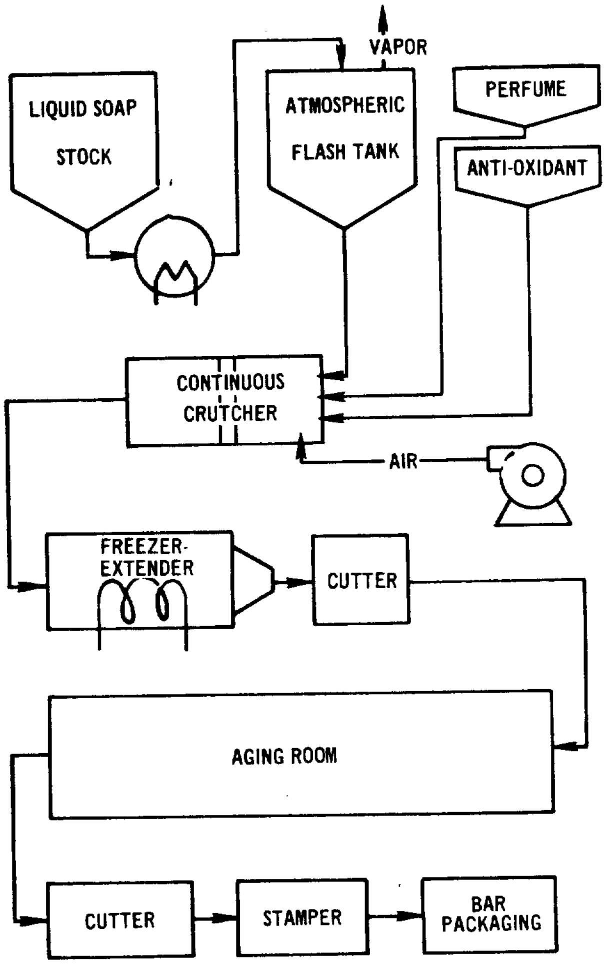


Figure 575. Flow diagram of aerated soap bar production.

Liquid soaps very rarely are manufactured today except for some very specialized products such as "pure soap hair shampoo." Top quality liquid soap is blended in tanks with the other ingredients desired and then packaged in standard bottle filling equipment.

THE AIR POLLUTION PROBLEM

All chemical processes and some of the other operations involved in the making of soap, production of fatty acids, and the purification of glycerine have ~~odors as a~~ common air ~~pollution~~ problem. Blending, mixing, drying, packaging, and other physical operations are subject to the air pollution problems of dust emissions.

Odors may be emitted from equipment used for the following operations:

1. Receiving and storage of animal and vegetable oils
2. saponification of fats and oils or of fatty acids
3. hydrolization of natural fats and oils to produce fatty acids
4. distillation of fatty acids
5. hydrogenation of fatty acids
6. concentration and distillation of glycerine.

During their receiving and storage, natural fats and oils are heated to temperatures not over 150°F to reduce viscosity for pumping. The fats and oils used by most soap manufacturers are of high quality, and odors usually do not cause a local nuisance unless the equipment is located adjacent to homes or businesses.

Fats and oils are heated during the direct saponification, resulting in the emission of odors. These odors may cause a local nuisance, depending upon the location of the equipment in the community, and may require control equipment.

Odors also are emitted during the deaeration and hydrolization of fats and oils to produce fatty acids. Distillation and hydrogenation of the fatty acids emit odors. Fortunately, the flash deaeration of fats and oils is performed under a vacuum, produced usually by water or steam jets. Steam jets are followed by contact barometric condensers which in effect serve as scrubbers. This arrangement of equipment provides satisfactory odor control so that the installation of additional control equipment usually is not necessary. All stages of these operations are vented similarly. Figure 576 illustrates several vacuum ejector and condenser systems.

The flash dehydration of glycerine has been found to emit only mild odors. Equipment for glycerine distillation under vacuum is vented through steam jets and barometric condensers. Emissions again are very light and odors do not cause any nuisance problems.

In soap-finishing operations, dust can be emitted from equipment performing the following operations: Addition of powdered and fine crystalline materials to crutchers, mechanical sawing and cutting of cold frame soap, milling and plodding soap, air drying of soap in steam-heated dryers, milling, forming, and packaging. Although dust emissions from these equipment sources rarely violate existing air pollution regulations, the dust emissions cause an internal plant hygiene problem. Various pieces of process equipment must therefore be vented to control equipment for worker comfort and safety.

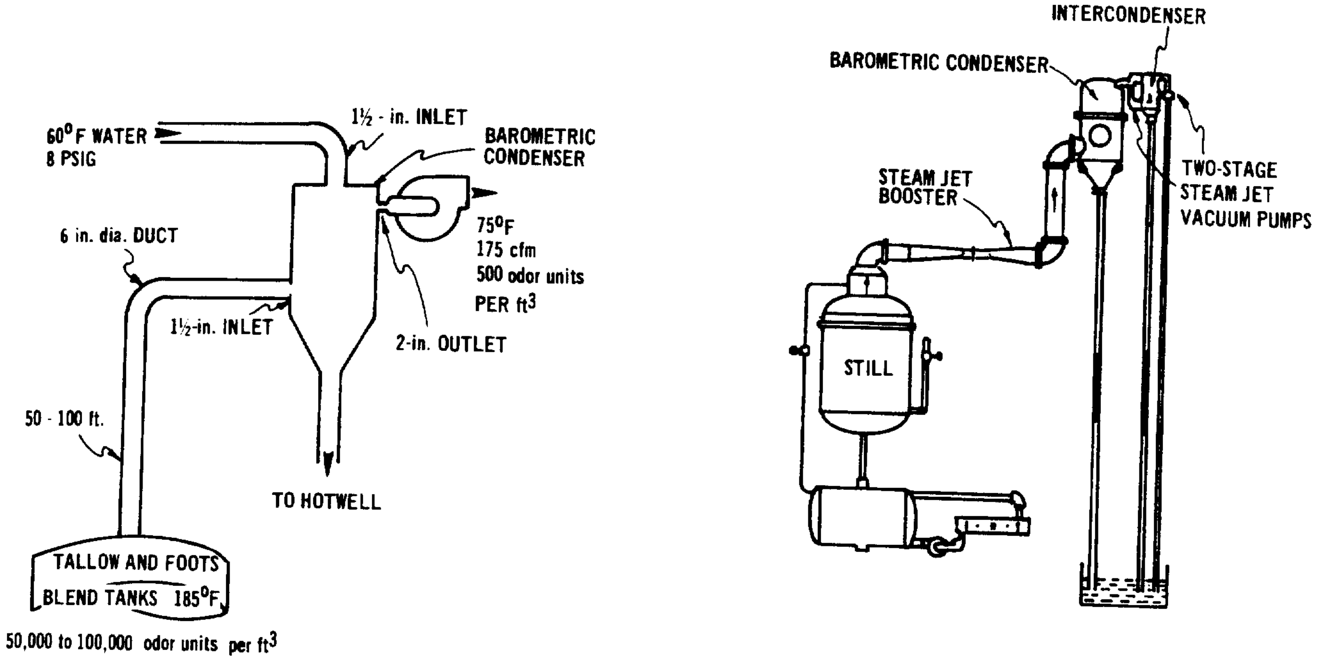
There are, however, other equipment sources of dust emissions which usually exceed air pollution regulations. The sources are: Grinding of soap chips, pneumatic conveying of powders, and spray drying of soap. Installation of control equipment is necessary for compliance with air pollution regulations as well as worker comfort and safety.

The production of soap powder by spray drying creates the largest single source of dust in the manufacture of soap. Spray drying is designed to produce relatively coarse granules followed by highly efficient separation of soap granules from the drying air before the air is vented to the atmosphere. Most towers for the spray drying of soap are the concurrent type where both the heated air and soap slurry spray are introduced at the top of the tower. Heated air and soap granules are separated at the bottom of the tower in a baffled area which causes the granule-laden air to make sharp 180° turns. Most of the soap is deposited in the baffled section and drops into the cone bottom of the spray dryer. However, a few soap particles still remain in the heated air after passage through the baffled area. The particles range in size from 2 to 200 microns, with a median particle size of over 20 microns. Air pollution control equipment is required before venting the contaminated air to the atmosphere.

The hot soap granules removed from the bottom of the spray dryer must be cooled to prevent caking and then screened and stored or sent to packaging equipment. The most common way to cool soap granules is by pneumatic conveying of the soap granules to elevated locations for gravity flow through screens into storage or packaging equipment. Cyclone separators or gravity settling chambers are used to remove the soap granules from the conveying air. Soap particles venting from the separator or settling chamber are finer in size than the soap particles in the exhaust air from the spray drying tower and are in such concentrations that they must be collected by control equipment in order to comply with air pollution regulations.

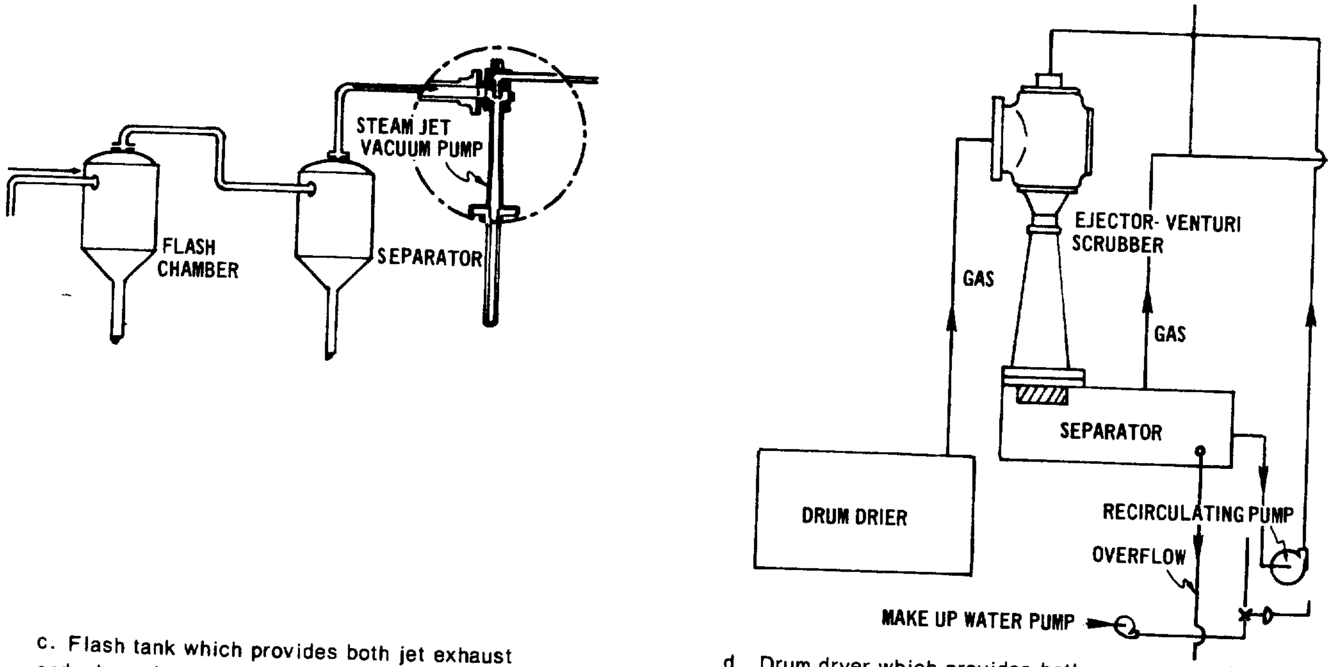
AIR POLLUTION CONTROL EQUIPMENT

The elimination of odors from the manufacture of raw soap, fatty acids, and glycerine can be accomplished by scrubbers such as water ejectors or barometric condensers. Figure 576a shows a contact type scrubber which successfully vents odorous emissions from a vessel used for dehydrating blends of tallow and foots oils by heating them above 200°F. This water jet contact scrubber



a. Barometric condenser and fan venting odorous oil blending operations.

b. Vacuum still which also provides odor reduction.



c. Flash tank which provides both jet exhaust and odor reduction.

d. Drum dryer which provides both vapor removal and odor reduction.

Figure 576. Steam and water ejector and barometric condenser combinations which also effect odor reduction.

(condenser) reduces odor levels by over 90 percent. The odor-containing gases vented from this scrubber are in very low volumes. The residual odors are diluted in the atmosphere well below their threshold levels in traveling through the atmosphere for only a short distance from the scrubber exhaust.

Dust emissions from equipment used in the soap-finishing operations other than spray drying can be controlled by dry filters and baghouses. Moisture content of the dust-laden air is well below saturation and close to ambient so that condensation in the baghouse is not a problem. Dust collected in filters or baghouses can be recycled to the process. Methods for hooding and ventilation of equipment emitting dust and the design of baghouses or filters are discussed in Chapter 4 of this manual.

Air pollution control equipment for soap spray drying towers is designed specifically for the operating parameters of the particular tower. These parameters include: Materials sprayed, tower operating temperature, tower dimensions, gas velocities, and others. Because of the relatively large size of the particulates in soap drying, high-efficiency cyclones installed in series may be satisfactory in controlling emissions. Cyclones permit the recovery of materials for reuse in the process. However, small particulates may escape collection by the second cyclone and may be in such concentrations and quantities as to cause emissions which violate regulations. Control equipment of higher collection efficiency than the cyclones must be used in place of the cyclones or be installed in series on the exhaust from the last cyclone when this occurs. A baghouse presents problems because the exhaust air is usually saturated at temperatures of 100° to 150 °F and, at this saturated condition, caking and blinding of the bag fabric can occur unless a special heated baghouse design is employed. Figure 577 is a flow diagram illustrating the control of a soap spray drying operation. Multistage centrifugal scrubbers or venturi scrubbers have proven to be satisfactory when additional control is required. Recirculation of scrubbing liquid has not been employed because soap slurry can cause severe foaming problems. Details on the design of scrubbers are given in Chapter 4 of this manual. Further discussion which is applicable to spray drying towers for soap also can be found in the following section on synthetic detergents.

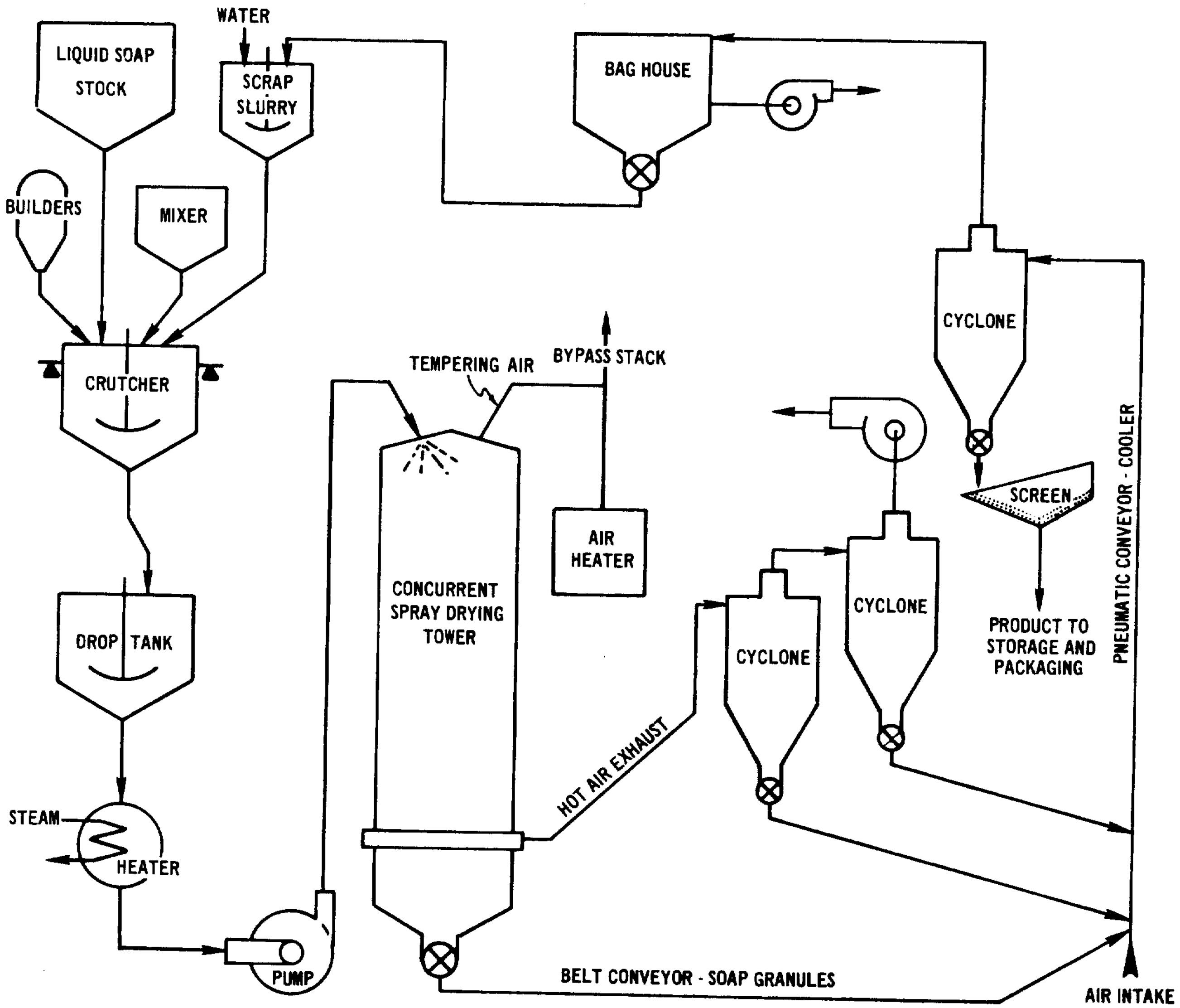


Figure 577. Flow diagram of soap spray drying process with cyclones and baghouse for air pollution control.

duct. Fatty acid vapor, water vapor, and inert gas are vented from the reactor through a condenser to a separator tank. Fatty acids separated are recycled to the reactor, the water is sent to the sewer, and the inert gas is returned to a gas holder. The reaction is completed after several hours, and the product is then pumped to a jacketed vacuum stripper tank. The temperature is maintained, tallow fatty acid and more catalyst are added, and inert gas is sparged into the tank. The vessel is held under slight vacuum for a short period while the contents are agitated. The vacuum is then increased to strip any remaining unreacted fatty acid. Water vapor, inert gas, and fatty acid vapors are vented through a condenser. The condensate from the condenser consists primarily of coconut fatty acid and is returned to storage. The fresh surfactant is discharged through a line mixer where a small amount of water is added for cooling purposes. It is then transferred to a holding vessel for use in formulation of toilet bars. The water content flashes off in the holding vessel.

The Air Pollution Problem

The first of the two reactions involved in the production of alkyltaurates, the fatty acyl chloride reaction, also creates HCl acid mist emissions similar to those from the chlorosulfonation reaction. The second reaction, with the N-methyltaurine, is accomplished in the vessel without venting until the reaction is complete.

The vacuum system employed in the second process to produce the sulfoester consists of compound steam ejectors with barometric condensers. The condensers discharge to a hot well. Visible and odiferous emissions, principally fatty acid vapors, occur from the hot well. Uncondensable gases in the reactor recirculation system also are vented and cause odors and visible emissions. The flashed off water vapor from the product hold tank can also contain contaminants of an odorous nature. No other air pollutant emissions occur from this process.

Air Pollution Control Equipment

The same control equipment shown in Figure 584 for HCl acid mist serves to control the emissions from the first sulfoalkylation process producing the alkyltaurate.

The hot well receiving condenser water and uncondensed gas and vapor from the vacuum jet systems in the second process for sulfoesters must be closed and vented to control equipment to eliminate odors and visible acid mist emissions. Scrubbers with gas pressure drops ranging from 7 to 12 inches water column usually control these emissions.

SYNTHETIC DETERGENT PRODUCT MANUFACTURING EQUIPMENT

INTRODUCTION

"Synthetic detergent products" applies broadly to cleaning and laundering compounds containing surfactants along with other ingredients formulated for use in aqueous solutions. These products are marketed as heavy- or light-duty granules or liquids, cleansers, and laundry or toilet bars. The heavy-duty granules represent the major portion of all products manufactured, with the light- and heavy-duty liquid or light-duty granules in far lesser production. The manufacture of all detergent products incorporates equipment and processes similar to those for manufacturing soap products. The manufacture of the granular products is of paramount interest, with more severe air pollution problems than those encountered with soap granule production. The manufacture of liquid detergent and bar products is of lesser importance, with little or no difference from similar soap products in either process equipment or air pollution potential, and will not be discussed.

Raw Materials

The surfactants used in formulating synthetic detergent products are either anionic or nonionic. The products also contain other chemical compounds which supplement the detergent of the surfactant. Each particular formulation depends upon the ultimate design for consumer use. Table 203 illustrates the formulations commonly used in large-volume granule and liquid detergent manufacture.

Sodium tripolyphosphate (STP) or tetrasodium pyrophosphate (TSPP) are incorporated in most granular formulations as "builders" or sequestering agents. They serve to eliminate interference with the detergent action by the calcium and magnesium ions (hardness) in the water used in the wash solution. STP and TSPP may be used in powder, prill, or granule form, and are received in carlots. These ingredients are most often blended into the slurry before spray drying.

Nitrilotriacetic acid (NTA) and its sodium salts have recently been incorporated in some heavy-duty granule products to replace part of the STP. It is more expensive than STP, but is a better sequestrant. The growing public concern with the role phosphates in detergents may play in deterioration of water quality has generated manufacturers' interest in this substitute. Indications are that it will be employed in the near future in more formulations and in larger quantities. The acid is a crystalline powder and the salts (disodium or trisodium) are powders. They are received in carlots. NTA is added to the slurry mix before drying.

Table 203. FORMULATIONS (IN PERCENT) FOR LARGE-VOLUME DETERGENT MANUFACTURE IN THE UNITED STATES

Constituent	Heavy duty					Light duty		Function
	High suds granules		Low suds granules		Liquid	Granules	Liquid	
	Brand A	Brand B	Brand C	Brand D				
Surfactants								
Alcohol sulfate	8	-	-	-	0-35	25-32	-	Cleaning agent for oily and organic soil
Alkyl sulfonate	8	18	6	17	0-35	25-32	20-25 or	
Ethoxulated fatty alcohol	-	-	6	-	0-35	-	20-25	
Alkyl amine oxide	-	-	-	-	0-15	-	-	
Soap	-	-	2	-	-	-	10-12	
Builders								
Fatty alcohol or amines	1.5-2	0-0.5	-	-	0-12	-	5-12	Foam booster or stabilizer
STP/NTA	60	50-60	50-60	50-60	-	-	2-15	Overcome water hardness and clean inorganic stains
TSP	-	-	-	-	0-20	-	0-20	
Additives								
CMC	0.5-0.9	0.5-0.9	0.5-0.9	0.5-0.9	0.5-0.9	0-5	-	Antiredeposition
Sodium silicate	5-7	5-7	7-9	7-9	5-7	0-4	0-4	Corrosion inhibitor
Sodium sulfate	10-20	10-20	10-30	10-30	-	60-70	-	Filler
Enzyme	0.2-0.75	0.2-0.75	0.2-0.75	0.2-0.75	0.2-0.75	-	-	Clean protein stain
Other	0-5	0-5	0-5	0-5	0-5	0-5	0-5	Perfume, dye, bleach, etc.

Fillers, usually sodium sulfate or sodium carbonate, are incorporated in granule products. They are either powders or crystalline powders and are added in bulk form to the slurry before drying.

Amides of various types are used as supplementary surfactants in many formulations. They improve detergency of the sulfonic and sulfate surfactants and act as foam boosters or stabilizers. Amides used include the higher fatty amides (e.g. cocomonethanolamide), ethanolamides, dialkyl and alkylol (hydroxyalkyl) amides, morpholides, and nitriles, as well as the lower acyl derivatives of higher fatty amines. These materials are handled as liquids and received in tank cars or barrels. In granule manufacture, they are either incorporated in the slurry before drying or blended with the detergent granules after drying.

Trisodium phosphate (TSP) is used in detergent granule formulations such as dishwasher compounds and wall cleaners which are designed to clean hard surfaces. TSP is considered functionally as an alkali rather than a sequestering agent. It is usually handled as a crystalline powder and is received in carlots, drums, or bags.

Carboxy methylcellulose (CMC; sodium cellulose glycolate) usually is added to heavy-duty granules and serves to prevent redeposition onto the fabric of the dirt removed by the detergent. This chemical is received in bags or drums as a powder or granule. It is added to the slurry mixture before drying.

Sodium silicate is added in most synthetic detergent formulations to inhibit the surfactant's tendency to corrode metal. It also is used to overcome production and packaging problems encountered with detergent granules. It is functionally used as a primary detergent alkali in compounds designed for hard surface washing, e.g., machine dishwashing compounds. It can serve to retain uniform viscosity in the mixing and pumping of the slurry before it is dried, and it reduces the "tackiness" of the dried granules, facilitating their handling and reducing caking of the product after packaging. The sodium silicates are received in tank cars as water solutions.

Optical brightners are added to many formulations. These are usually fluorescent dyes which absorb ultraviolet rays and reflect them as visible light. The dyes are received as powders in bags or as liquids in drums, and they are usually blended in the slurry before drying.

Perfumes are added to almost all detergent products to overcome unpleasant odors and impart a pleasing scent to laundered fabrics. The perfumes are added by spraying onto the dried granules or mixing with the liquid detergents. They are handled as liquids in small-size containers or drums.

Bleaches of various kinds are frequently incorporated in heavy-duty detergents. Sodium perborate, along with magnesium silicate as a stabilizer, is commonly employed. They are received as powders or crystals in boxes or bags and are added to the granules after drying.

Enzymes have recently been introduced as part of the formulation of heavy-duty detergent products to assist in the removal of protein-based stains from fabrics. The enzymes are received as powders in bags or drums. The enzymes are heat sensitive and are destroyed if heated to 212°F. Most manufacturers blend the enzymes into the detergent granules after drying.

Many other compounds may be incorporated in various products. Preservatives, antioxidants, foam-suppressors and other types of additives are used. The scouring cleansers are composed principally of finely pulverized silica, active detergent, small amounts of phosphates, and frequently a bleach.

Detergent surfactants include alkyl sulfonic, alkyl sulfate, and alcohol sulfates, discussed above, and almost the entire range of anionic and nonionic detergents, including soap. Plants manufacturing their own sulfonic and sulfate surfactants also use other surfactants in some or all of their products. The detergents are received and handled mostly as liquid solutions of varying strength, but some surfactants are received as flake or powder. Surfactants are principally mixed with the slurry before drying.

Processes

The only manufacturing process to be discussed here will be the production of detergent granule formulations incorporating spray-drying processes. All other products are produced in processes, such as drum drying, similar to soap production, discussed in the previous section.

Manufacture of detergent granules incorporates three separate steps: Slurry preparation, spray drying, and granule handling (including cooling, additive blending, and packaging). Figure 586 illustrates the various operations.

SLURRY PREPARATION

The formulation of slurry for detergent granules requires the intimate mixing of various liquid, powdered, and granulated materials. The soap crutcher is almost universally used for this mixing operation. Premixing of various minor ingredients is performed in a variety of equipment prior to charging to the crutcher or final mixer. The slurry, mixed in batch operations, is then held in surge vessels for continuous pumping to the spray drier.

The Air Pollution Problem

The receiving, storage, and batching of the various dry ingredients creates dust emissions. Pneumatic conveying of fine materials causes dust emissions when conveying air is separated from the bulk solids. Many detergent products require raw materials with high percentages of fines, viz., typical specifications for some raw materials include the following percentage of fine materials passing a 200 mesh screen: Sodium sulfate - 12 percent; sodium tetrapyrophosphate - 74 percent; sodium tripolyphosphate - 53 percent.

The storage and handling of the liquid ingredients, including the sulfonic acids, sulfonic salts, and sulfates, do not cause emission problems other than mild odors.

In the batching and mixing of fine dry ingredients to form slurry, dust emissions are generated at scale hoppers, mixers, and the crutcher. Liquid ingredient addition to the slurry creates no visible emissions but may cause odors.

Air Pollution Control Equipment

Control of dusts generated from pneumatic or mechanical conveying or from discharge of fine materials into bins or vessels is described in Chapters 3 and 4. There are no unique problems in hooding or exhaust systems for controlling dust emissions from conveying and slurry preparation.

Baghouses are employed not only to reduce and eliminate the dust emissions but for salvage of raw materials. None of the dusts causes any serious corrosion problems. Filter fabrics should be selected which have good resistance to alkalis. Filter ratios for baghouses with intermittent shaking cleaning mechanisms should be under 3 cfm per square foot.

SPRAY DRYING

All spray drying equipment designed for detergent granule production incorporates the following components: Spray-drying tower, air heating and supply system, slurry atomizing equipment, slurry pumping equipment, product cooling equipment, and conveying equipment. The towers are cylindrical with cone bottoms and range in size from 12 to 24 feet in diameter and 40 to 125 feet in height. Single towers may be of varying diameter, being larger at the top and smaller at the bottom. Air is supplied to the towers from direct-heated furnaces fired with either natural gas or fuel oil. The products of combustion are tempered with outside air to lower temperatures and then are blown to the dryer under forced draft. The towers are usually maintained under slightly negative pressure, between 0.05 and 1.5 inches of water column, with exhaust blowers adjusted to provide this balance. Most towers designed for detergent production are of the countercurrent type, with the slurry introduced at the top and the heated air introduced at the bottom. A few towers of the concurrent type are used for detergent spray drying, with both hot air and slurry introduced at the top. Some towers are equipped for either mode of operation as illustrated in Figure 586.

In most towers today, the slurry is atomized by spraying through a number of nozzles, rather than by centrifugal action. The slurry is sprayed at pressures of 600 to 1000 psi in single-fluid nozzles, and at pressures of 50 to 100 psi in two-fluid nozzles. Steam or air is used as the atomizing fluid in the two-fluid nozzles.

Tower operations vary widely between manufacturers and between products. Heated air supplied to the tower varies from 350° to 750°F. Temperatures of air supplied to countercurrent towers are generally lower, and most often range from 500° to 650°F. Concurrent tower temperatures are somewhat higher. Solids content of slurrys for detergent spray drying varies from 50 to 65 percent by weight, with some operations to as high as 70 percent. Moisture content of the dried product varies from 10 to 17 percent. Towers are designed for specific air-flow rates, and these rates are maintained throughout all phases of operation. Slurry temperatures may vary, but in most formulations they do not exceed 160°F. Frequently, they are as low as 80°F. Exit gas temperatures range from 150° to 250°F with wet-bulb temperatures of 120° to 150°F. Air velocities in concurrent towers are usually higher than velocities in countercurrent towers. The concurrent towers produce granules which are mostly hollow beads of light specific gravity (0.05 to 0.20). Countercurrent towers produce granules which are multicellular and irregularly shaped and which have higher specific gravities ranging from 0.25 to 0.45.

In countercurrent towers, with lower air velocities and droplets descending against a rising column of air, most of the dried granules fall into the cone at the bottom of the tower. They are discharged through a star valve, or regulated opening, while still hot. Cooling of the granules is discussed below with other granule processing procedures. Unlike other product spray drying operations, e.g., powdered milk, the desired detergent granule product is comparatively large in size. The specifications for some well known granular products require 50 percent by weight or more to be retained on a 28-mesh screen. A certain amount of the product is dried to comparatively small size. This amount is dependent on tower feed rates, the liquid droplet size in slurry atomization, the paste viscosity, the particular product, and other variables. Usually the exhaust air entrains 7 to 10 percent of that portion of the granular product which is too fine to settle out at the base of the tower.

Concurrent towers, operate with higher air velocities than countercurrent towers. The air is vented just above the bottom of these towers through a baffle which causes violent changes of direction to the exhaust air to dynamically separate the dried granules, which then fall to the cone bottom for discharge. Concurrent towers producing very low-gravity granules vent air still conveying the product to auxiliary equipment for separation. The loss of detergent fines entrained in the exhaust air stream will be somewhat higher from concurrent towers than from countercurrent towers.

The Air Pollution Problem

The exhaust air from detergent spray drying towers contains two types of air contaminants. One is the fine detergent particles entrained in the exhaust air discussed above; the second consists of organic materials vaporized in the higher temperature zones of the tower.

The detergent particles entrained in the exhaust air are relatively large in size. Over 50 percent by weight of these particles are over 40 microns. These particles constitute over 95 percent of the total weight of air contaminants in the exhaust air (Phelps, 1967). They consist principally of deter-

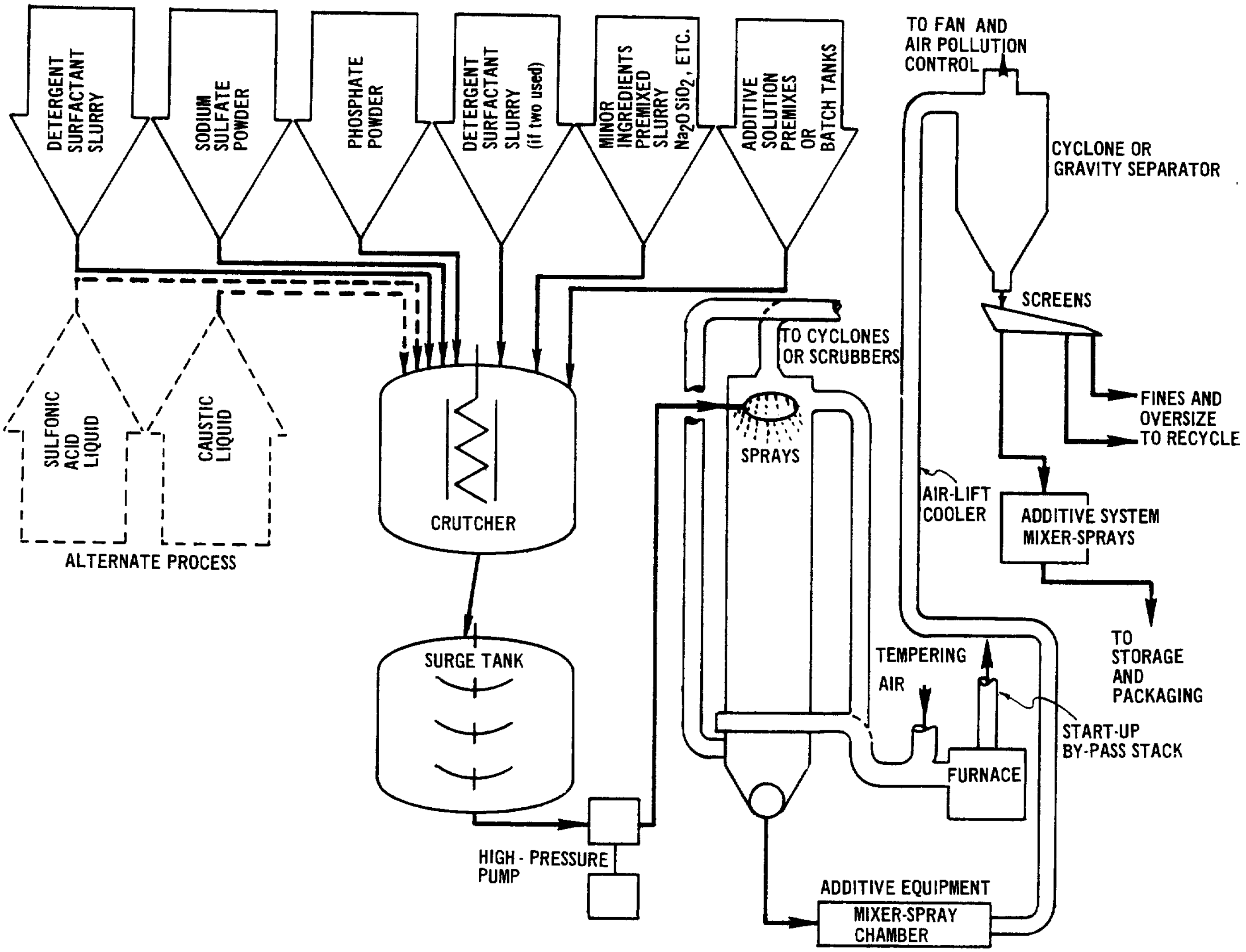


Figure 586. Detergent spray-drying with tower equipped for either concurrent or countercurrent operation (dampers in countercurrent mode of operation).

gent compounds, although some of the particles are uncombined phosphates, sulfates, and other mineral compounds.

The second type of the air contaminant in the exhaust air can create serious air pollution control problems. Various organic components in the slurry vaporize in the tower. The amount vaporized is dependent upon many variables, such as tower zone temperatures and volatility of the organics in the slurry mixture. The vaporized organic materials condense upon cooling in the tower exhaust air stream into micron- and submicron-size droplets or particles. Spray drying of one particular product resulted in the measured discharge of condensed organic particulates in the tower exhaust air ranging in size from 0.2 to 0.5 micron.

The variety of possible detergent compounds is almost infinite, and manufacturers are continually introducing new formulations or reformulating older ones. It is not always possible to predict how certain organic compounds in a slurry mixture will affect stack emission. If amides are present in the slurry in amounts greater than 0.5 percent by weight, emission problems will occur. Source tests of exhaust air from an air pollution control scrubber with amides present in the slurry being dried in the spray tower revealed 0.08 grain of organic particulates per scf of exhaust gas. The presence of this relatively low concentration of submicron-size aerosols causes water vapor plumes to persist for long distances. Following the break or end of the water vapor plume, a highly visible contaminant plume persists for even greater distances. The amide emission rate increases exponentially with increases in tower operating temperatures. Many tower operating variables affect air contaminant emissions, but the temperature of the exhaust air probably is the most important. At one spray drier installation, opacities of organic aerosol emissions were reduced by approximately 30 percent when tower operation was altered to effect a reduction of exhaust gas temperature from 200° to 180°F.

Slurry formulations containing ethoxylated alcohol surfactants cause similar aerosol emissions. When this nonionic detergent is used in the slurry, source tests of the aerosol leaving the scrubber indicate a particle size range of 0.2 to 1 micron. Plumes persist for long distances following the disappearance of the water vapor plume.

Air Pollution Control Equipment

The collection of air contaminants not only provides for the economic return of detergent fines to the process, but also provides for control of submicron particles to ensure compliance with air pollution prohibitory rules.

Manufacturers producing detergent granules have developed two separate approaches for capturing the detergent fines in the spray drier effluent for return to process. One method utilizes centrifugal separators to capture most of the product dust. The exhaust gases then are vented from the separators to scrubbers for removal of micron-size particles. The cyclone separators remove approximately 90 percent by weight of the detergent product fines in the tower exhaust air. The detergent dust remaining in the effluent vented from the cyclones consists of particles almost all of which are over 2 microns in size. Size distribution of these particles by weight will peak in the range of 7 to 10 microns. Particulate concentrations vary from 0.1 to 1.0 grain per scf. The cyclones are designed for relatively high efficiencies and operate at pressure drops from 8 to 10 inches of water column (Phelps, 1967). A venturi type scrubber is used downstream of the cyclone, using water at 8 to 10 psig distributed through nozzles in the throat. Throat velocities of the exhaust gases average 8,500 fpm. With water supplied to the throat at a ratio of 4.5 to 5.0 gallons per 1,000 cubic feet of effluent, scrubber exhaust gases have loadings of about 0.085 grain per scf when slurries with amides are spray dried. A highly visible plume persists after the condensed water vapor plume has dissipated.

In the second method of recovery of detergent fines, the centrifugal collector is eliminated, and only a scrubber is used. However, the scrubber uses detergent slurry as a scrubbing medium rather than water. The scrubbing slurry is maintained at a high enough concentration to prevent foam, but at a low enough concentration to permit pumping and spraying. No further control device is used to cleanse the exhaust gases from the scrubber. When slurries with volatile organic materials are spray dried, highly visible plumes persist after the condensed water vapor plume has dissipated. A plume was even observed from a pilot venturi scrubber operating at a high pressure drop of 50 inches of water column. A 40 percent solids slurry was used as the scrubbing fluid delivered at gas scrubbing ratios of 60 to 100 gallons per 1000 cubic feet of gas.

An alternative method for controlling emissions from the drier caused by volatile organics in the slurry is to reformulate the slurry to eliminate these offending organic compounds. When amide compounds were identified as causing the emission problems, some manufacturers developed other formulations or methods for adding the amides to the spray dried granules to achieve a comparable product.

When reformulation is not possible, the tower production rate may be reduced, permitting operation at lower air inlet temperatures and lower exhaust gas temperatures. When tower temperatures are reduced, lesser amounts of organic compounds are vaporized in the spray drier, and the scrubber is able to collect these emissions.

GRANULE HANDLING

Many manufacturers discharge hot granules from the spray tower into mixers where dry or liquid ingredients are added. The granules are usually mechanically conveyed away from the tower or mixer discharge and then are air-conveyed to storage and packaging. Air conveying serves to cool the granules and to elevate them for gravity flow through further processing equipment to storage and packaging. Air conveying of low-density granules usually is designed for 50 to 75 scfm air per pound of granules conveyed. At the end of the conveyor, centrifugal separators remove granule product from the conveying air. Some manufacturers mechanically lift the granules from the spray tower to aeration bins where the granules are cooled or aged by injecting air at the bottom of the bin. This air percolates upward through the scrubber.

The cooled granules are screened to deagglomerate the large granules and to remove undersize or oversize particles. Further mixing or blending may be performed to add heat-sensitive compounds to the detergent products. Many manufacturers do not store the finished granules, but convey them directly to packaging equipment. Some detergent products are held in storage, either in large fixed bins or small-wheeled buggy bins, and then are charged to packaging equipment. Packaging is done with either scale or volumetric filling machines.

The Air Pollution Problem

Conveying, mixing, packaging, and other equipment used for granules can cause dust emissions. The granule particles, which are hollow beads, are crushed during mixing and conveying, and generate fine dusts. Dusts emitted from screens, mixers, bins, mechanical-conveying equipment, and air-conveying equipment are quite irritating to eyes and nostrils with continuous exposure. Some of the additive materials, such as enzymes also cause serious health problems. Equipment involving enzymes requires very efficient ventilation in addition to proper dust collection. Dust emissions in most cases represent a significant product loss, and their collection and return to process (usually as an ingredient of the slurry to be spray dried) is necessary for economic plant operation as well as for air pollution control.

Air Pollution Control Equipment

Dust generated by granule processing, conveying, and storage equipment does not create unique air pollution control problems. Usually, baghouses provide the best control. Collection efficiencies for baghouses are high; in many cases, efficiencies exceed 99 percent. No extreme conditions of temperature or humidity have to be met, but filter fabrics selected must show good resistance to alkaline materials. Baghouses utilizing intermittent shaking mechanisms should not have filtering velocities exceeding 3 fpm. Baghouses with continuous cleaning mechanisms may have filtering velocities as high as 6 fpm.

GLASS MANUFACTURE

Glass has been made for over 3,500 years, but only in the last 75 years have engineering and science been able to exploit its basic properties of hardness, smoothness, and transparency so that it can now be made into thousands of diverse products.

The economics and techniques connected with mass production of glass articles have led to the construction of glass-manufacturing plants near or within highly populated areas. Unfortunately, airborne contaminants generated by these glass plants can contribute substantially to the air pollution problem of the surrounding community. Control of dust and fumes has, therefore, been, and must continue to be, inherent to the progress of this expanding industry.

Air pollution control is necessary, not only to eliminate nuisances, but also to bring substantial savings by extending the service life of the equipment and by reducing operating expenses and down time for repair. Reduction in plant source emissions can be accomplished by several methods, including control of raw materials, batch formulation, efficient combustion of fuel, proper design of glass-melting furnaces, and the installation of control equipment.

TYPES OF GLASS

Nearly all glass produced commercially is one of five basic and broad types: Soda-lime, lead, fused silica, borosilicate, and 96 percent silica. Of these, modern soda-lime glass is well suited for melting and shaping into window glass, plate glass, containers, inexpensive tableware, electric light bulbs, and many other inexpensive, mass-produced articles. It presently constitutes 90 percent of the total production of commercial glass (Kirk and Othmer, 1947).

Typical compositions of soda-lime glass and the four other major types of commercial glass are shown on Table 204. Major ingredients of soda-lime glass are sand, limestone, soda ash, and cullet. Minor ingredients include salt cake, aluminum oxide, barium oxide, and boron oxide. Minor ingredients may be included as impurities in one or more of the major raw ingredients. Soda-lime glasses are colored by adding a small percentage of oxides of nickel, iron, manganese, copper, and cobalt, and elemental carbon as solutions or colloidal particles (Tooley, 1953).

Although glass production results in tens of thousands of different articles, it can be divided into the following general types (Kirk and Othmer, 1947):

	%
Flat glass	25
Containers	50
Tableware	8
Miscellaneous instruments, scientific equipment, and others	17

GLASS-MANUFACTURING PROCESS

Soda-lime glass is produced on a massive scale in large, direct-fired, continuous melting furnaces. Other types of glass are melted in small batch furnaces having capacities ranging from only a few pounds to several tons per day. Air pollution from the batch furnaces is minor, but the production of soda-lime glass creates major problems of air pollution control.

A complete process flow diagram for the continuous production of soda-lime glass is shown in Figure 587. Silica sand, dry powders, granular oxides, carbonates, cullet (broken glass), and other raw materials are transferred from railroad hopper cars and trucks to storage bins. These materials are withdrawn from the storage bins, batch weighed, and blended in a mixer. The mixed batch is then conveyed to the feeders attached to the side of the furnace. Although dust emissions are created during