plied to an oil like cottonseed oil which contains a substantial proportion of solid fatty acids but hardly any trisaturated glyceride, the process will raise the melting point because it increases the proportion of fully saturated glycerides. The compositions that can be produced by this type of process from a given starting-material lie within the range between the starting material and its "randomized" composition. Within this range it is quite possible that practical advantages will be found for products not now being made.

The directed interesterification process increases the number of possibilities for, depending upon how it is applied, it may be used to increase the proportion of high-melting glycerides and to improve plastic range, as in the case just described, or it may be operated in such a way as to increase the proportion of intermediate-melting glycerides and thus change some of the physical properties in an opposite direction. Together the various interesterification processes may be expected to continue to increase the interchangeability of use of the various fats and oils and to make possible the production of improved products.

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Outline of Processes Used in the Drying of Soaps and Detergents

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BECAUSE OF THE MAGNITUDE of the subject this discussion will be confined to those processes in which there is a significant reduction in the moisture content of the product. This will eliminate from consideration the subjects of "skin drying" of bar soaps and the so-called chemical drying in which moisture is merely "fixed" as water of crystallization.

J. C. Ingram

A classification of all drying systems used by industry would include about 20 separate and fairly distinct methods and apparatus for the reduction of moisture in a wide variety of products. Only four of these systems have attained significant application in soap and detergent processing. With the approximate dates of their commercial application to soaps and detergents, they are conveyor drying, about 1894; spray drying, about 1920; drum drying, about 1930; flash drying, about 1937.

In the soap and detergent industry the drying processes perform an important function other than the simple reduction of moisture, *i.e.*, in many cases they are the final or finishing process and as such are responsible for the physical form in which the products appear on the market. They have also a considerable influence on such other important characteristics as solubility and density. Over the long term the industry has been working toward the development of forms that make for improved solubility, and these processes have made significant contributions toward that end.

According to the latest available statistics, the total production of soaps and detergents in this country for the year 1955 approximated four billion lbs., of which, two-and-three-quarter billion lbs. were finished in the drying process. The above figures indicate an industry drying capacity approaching ten million lbs. a day.

The story of the drying processes in our industry is largely that of invention and development of specialized types of equipment as well as adaptation and modification of existing machinery. In the drying field some of the most important developments have come from within the industry. In a description of the four processes used for drying there will be a brief description of the most modern equipment, an outline of the unit's operation, a short discussion of the products of the operation, and a mention of the basic problems involved in producing specific products.

The Conveyor or Flake Dryer

The original of this type was exhibited at the World's Columbian Exposition in Chicago by a French manufacturer. It was bought by a small but progressive Chicago soap maker and operated for many years to make "chips" for toilet milling. This type with its five-roll chilling unit and its 500-lb.-per-hour capacity was the forerunner of the two-roll, 4,000-lbs.-per-hour units that displaced it and carried the burden of production all through the "Soap Flake Era," roughly 1900 to 1935.

Description. Figure 1 supplements the description of the equipment and operation of one of the most modern units: the chilling unit, consisting of a feed hopper and small spreader roll mounted atop the large water cooled roll, each being independently driven through a vari-speed connection; an independently driven, variable speed carry-in conveyor; and a sectional drying chamber containing a three-pass screen conveyor, individually driven air-circulating exhaust, cooling fans, heating coils, and temperature control instruments.

Operation. Molten soap, either neat or containing the usual builders, is transferred from batch or continuous mixers to the feed hopper, where the spreader roll, which forms one side of the hopper, transfers a thin film of the soap to the chilling roll. During each revolution of the chill roll this film is picked up, marked longitudinally into $\frac{5}{16}$-in. ribbons and scraped off by a self-cleaning scraper knife. The speed of the carry-in conveyor is set so that the ribbons are pulled away from the roll without breaking and deposited on the top screen in the drying unit without matting. The ribbons are carried through the drying zones on the three-pass conveyor and cooled just before reaching the discharge end. The complete drying cycle requires about seven minutes. The speed of the several components is made controllable in order to handle a wide range of formulations, being processed to flakes of different thicknesses and moisture content. These controllable features are the setting and speed of the rolls in relation to the speed of the dryer conveyor and the temperature of the drying unit. The optimum cooling-water temperature seems to be about 50–55°F., and a refrigerated cooling and recirculating system can be justified economically where and when available water temperatures are above 65°F.

Products. Until a few years ago all of the important American toilet soap base was dried on conveyor dryers of the basic type described, usually starting with a 30% moisture neat soap and finishing with a rough flake at 12–14% moisture at 6 to 8 mils. in thickness. For subsequent toilet soap milling, physical appearance is not too important but the uniformity of drying is and can be held at 1% plus or minus the standard by proper initial setting of the roll speed and flake thickness with relation to the drying conditions.

Initially and for many years, all of the two-roll units were operated with the feed hopper located toward the front of the unit, the chill roll running counter-clockwise and the feed roll running clockwise (Figure 2). This arrangement was perfectly satisfactory for flakes for toilet soap and milling and also for packaged household flakes until the question of improving the solubility of the latter became important. It was then pointed out that with this arrangement of hopper and roll direction the flakes had one smooth side and one rough side which consisted of criss-crossed ridges made when the feed roll pulled away from the chill roll. This caused not only varying thickness and poor solubility but also tended to produce curled flakes because of the difference in the rate of drying of the two sides.

In the mid-1920's the problem of making a flat flake of uniform thickness was solved by a very clever arrangement of hopper and roll direction. The hopper was relocated back of top center, the roll was made the front end of the hopper, reversed in direction, and its relative speed was set so as to give an ironing effect. The bottom of the hopper was provided with a movable slot, which regulated the amount of soap picked up by the chill roll. This arrangement produced a semi-transparent flake of 4 to 6 mils. in thickness, more uniformly dried, with a longitudinal instead of a horizontal fracture. With this type of

FIG. 1. Continuous soap-chilling and conveyor-drying unit.
Courtesy, Proctor and Schwartz Inc., Philadelphia

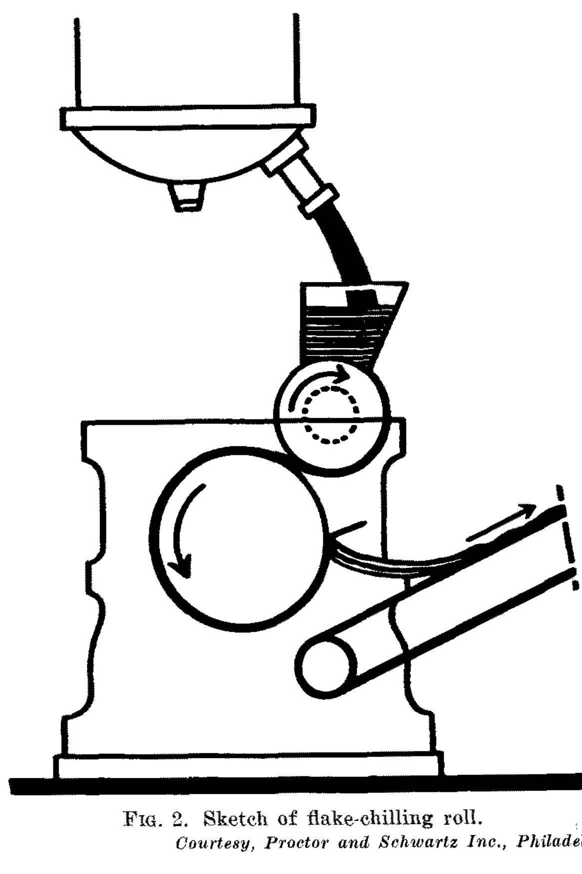

FIG. 2. Sketch of flake-chilling roll.
Courtesy, Proctor and Schwartz Inc., Philadelphia

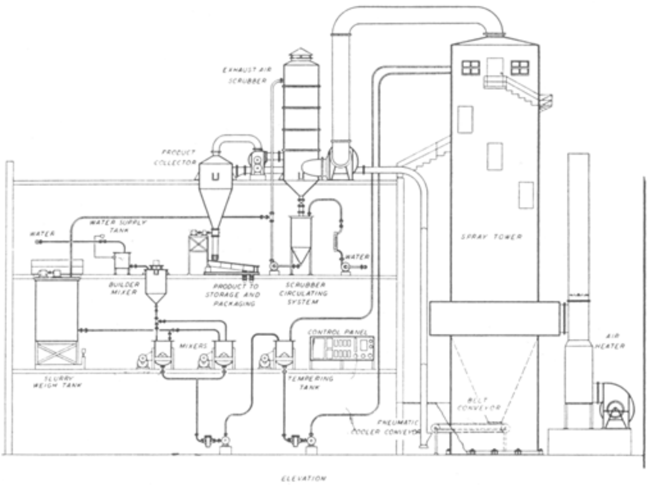

FIG. 3. Continuous spray-process synthetic detergent plant. Countercurrent type.
Courtesy, Wurster and Sanger Inc., Chicago

flake the industry took another step toward more rapid and complete solubility.

The desired finished moisture content of the product is the principal factor that determines the capacity of these units. Under the most favorable conditions the largest units will produce about 5,000 lbs. per hour at a finished moisture content of 13–14% and about 3,000 lbs. per hour of a product dried to 4% moisture.

Spray-Drying Systems

These are the drying systems that today produce somewhat in excess of 60% of the total American tonnage of soaps and detergents. Practically all of the popular brands of packaged detergents, both light and heavy duty, are produced in spray towers. One of the first commercial applications of spraying in the industry was in the production of a well known "washing powder" by a spray-crystallizing or cooling system in 1920. This was soon followed by a spray-drying system for pure soap and the development of several patented but conflicting systems that were not completely adjudicated until 1937. Most of the important production units are the result of gradual development within the several companies; only certain component parts are supplied by outside manufacturers.

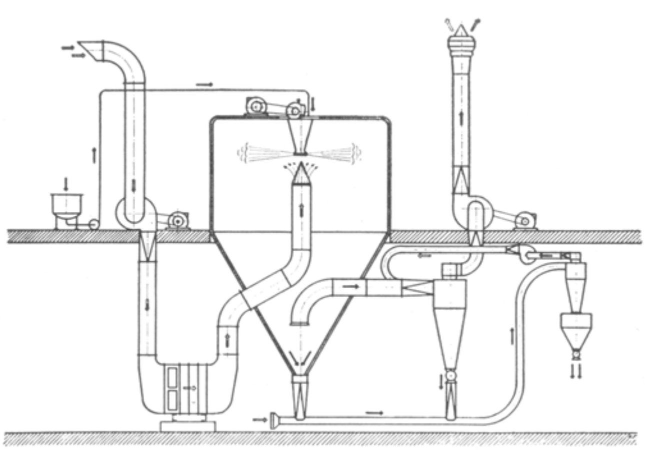

FIG. 4. Continuous spray drying process. Concurrent type.
Courtesy, Nichols Engineering and Research Corporation, New York

Since the patent protection (1, 2) on the basic principles of spray-drying equipment has long since expired, the details of the latest improvements are naturally well-guarded secrets. Therefore it might be well to state that the material for the following discussion has come entirely from the author's personal experience plus what he has been able to gather from sources outside of the industry. Fortunately the same basic equipment used for soap, with suitable modifications and additions, can be used in the spray-drying of synthetic detergents.

The objective of all systems for the spray-drying of soaps and detergents is to produce a free flowing granule of low apparent specific gravity (0.20–0.35) for packaged products. The granular form plus the thin wall of the puffed particle are largely responsible for the more rapid solution of this type and mark another step toward the goal of ready solubility. An important reason for the success of the spray-dried synthetic detergents is that they are more readily soluble than soap granules of comparable size and appearance.

Description of Equipment. Because of the similarity of the spray-drying processes (Figures 3 and 4) used for soap and for synthetic detergents and because the emphasis today is on the latter, the following discussion will concern itself largely with the synthetics. Since no photographs or drawings of the industry's larger installations are available, illustrations are those supplied by engineering firms who have built and operated comparable systems. All of the various systems have the same basic component parts: towers, air circulating and heating system, nozzles, slurry mixers and strainers, slurry pumps, and product collection and cooling systems.

The Towers. These have been built completely of mild steel, of mild steel straight sides with a stainless steel cone, of No. 304 stainless clad steel or lined with No. 304 stainless. Even linings of plastics or ceramic tile have been used. Diameters have ranged from 12 ft. to 24 ft. and over-all height from 40 ft. to 125 ft. In shape most of them are cylindrical with cone bottoms, some with slightly larger diameter at the top than at the bottom, some rectangular, and a few made with special shapes to secure certain air current patterns.

Two separate systems have been in use for many years: the concurrent, in which the air and the sprayed particles are introduced at the top of the tower and travel downward together, and the countercurrent, in which the spray is introduced at the top of the tower and the heavier particles travel downward against a rising current of air introduced near the base of the tower. Both systems have advantages and disadvantages, which will be touched on during the discussion on operation.

The Air Circulating and Heating System. Initially, indirect heating of the air was used, but soon furnaces were developed that would burn completely the oil or gas fuel, and now in practically all installations the air is heated directly and the products of combustion are sent along with it through the tower. The presence of CO_2 and the somewhat lowered oxygen content seem to have some effect in lessening the fire and explosion hazard.

In both concurrent and countercurrent systems blowing and suction fans are used, and the air circuit is so balanced as to create a slightly reduced pressure in the tower, usually 1–1½ in. of water by draft gauge. In countercurrent towers the air is usually introduced at a point just above the cone through a plenum equipped with ports or vanes to give the current of air a tangential motion. In concurrent towers the air enters at a point or points above or behind the nozzles and is directed straight downward. In both systems the air leaves through cyclone or centrifugal collectors to final dust collectors, from which it is dispersed to the atmosphere.

The Nozzles. In the early days many forms of nozzles or other spray-producing devices were invented and patented, each claiming some special advantage. At the present time only two general types are being used in the larger installations; the single fluid types (Figure 5) and the two-fluid nozzle (Figure 6). The former operates at high pressure (600–1,000 p.s.i.) and the latter at low pressure (50–100 p.s.i.). Both types are available in a large range of sizes and capacities so that the selection of their size, number, and arrangement is subject to wide variation in the different installations. Nozzles with capacities from 1,200 to 2,500 lbs. per hour are the most widely used for the larger productions. In countercurrent drying it is especially important that the spray pattern cover practically the entire area of the tower to minimize short circuiting of the air stream (3). In two-fluid nozzles steam or air pressure is the usual atomizing medium.

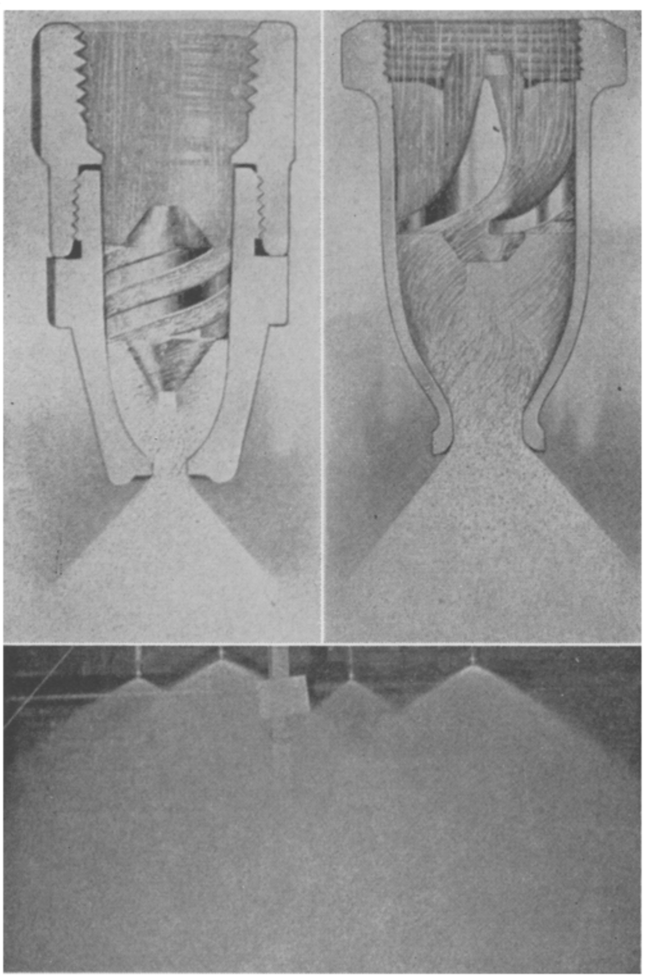

FIG. 5. Single-fluid nozzles with illustration of overlapping spray pattern.
Courtesy, Spray Engineering Company, Somerville, Mass.

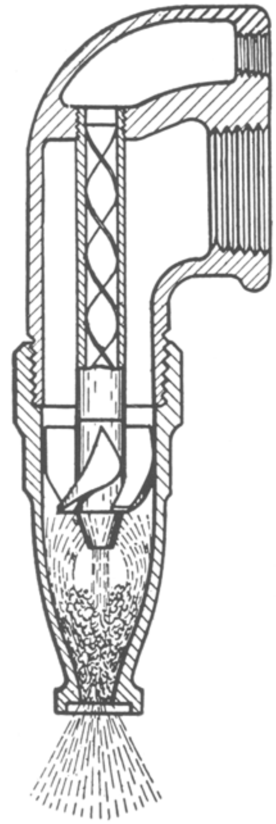

FIG. 6. Two-fluid nozzle.
Courtesy, Spray Engineering Company, Somerville, Mass.

Slurry Mixers and Strainers. Formulation of most of the current spray-dried soaps and detergents requires the intimate mixing of several liquids with a number of different granulated or powdered materials. Both batch-type and continuous mixers are being used, also a combination of batch mixing of most of the ingredients with the continuous addition of others to the batch mix just prior to the spraying operation. Fine screening of the slurry is essential to prevent or minimize nozzle blockage. The main screening is usually accomplished by a series of strainers placed in the line between the feed pump and the spray pump; the final screen is placed between the latter and the nozzles.

Slurry Pumps. The slurries handled for spraying soap-formulations are not nearly as viscous or abrasive as those required for the present synthetic detergent formulae and can be satisfactorily sprayed with a single pump set-up although in many cases the same type of tandem pump arrangement is used. For high-pressure spraying of both soap and synthetics and for the low-pressure spraying of the latter the tandem pump set-up gives the most consistent results. Tri-Plex pumps of several types are in operation in many of the larger installations, some the ball-valve construction and some the guided-wing type. There is less agreement as to the type of pump used to feed the Tri-Plex; many types have been and still are being employed for this service, gear pumps, screw pumps, centrifugals, simplex and duplex steam pumps. In the pumping of synthetic formulations at

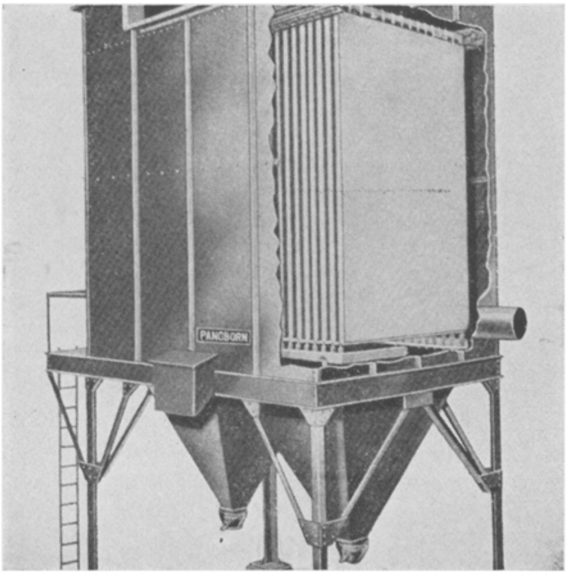

FIG. 7. Dust collector. Cloth-bag type.
Courtesy, Pangorn Corporation, Hagerstown, Md.

high pressure there is considerable wear on all parts that contact the slurry and, even though most of the abrasive resistant metals and materials have been tried, replacement of valves, valve seats, cylinders, and pistons is still a considerable source of trouble and expense.

Product Collection and Cooling Systems. Countercurrent System. Because of lower air velocity and the fact that the particles are descending against a rising current of air, most of the product falls into the cone of the tower and is removed through a star valve or regulated opening onto a conveyor belt or into the hopper of an air-lift system. The smaller particles, in good practice not over 7–10%, are carried out of the top of the tower to cyclone collectors and to a dust-collecting system.

Concurrent System. In this the air velocity is usually higher and the air temperature hotter than in countercurrent practice, and consequently a larger percentage of the heavier particles are swept out of the tower with the air and must be recovered in the cyclone collectors. A somewhat larger installation is therefore required than is needed for the countercurrent system. In the case of the low-gravity products the entire production leaves the tower with the air stream and is separated in the collectors. Cooling of the product, usually to a maximum of 100°F. is necessary to minimize caking and is accomplished in several ways: by conveying pneumatically, by cooling on slow-moving belts, by special cascading conveyors or cascading towers or by simply holding in buggies or bins. The cooling problem is aggravated in the case of certain synthetic detergent formulations, which have a tendency to reheat after cooling, possibly because of rearrangement of hydrates of their builders. Figures 7 and 8 illustrate the two types of final collectors used for handling both soap and synthetic detergent dusts.

Operation of Spray Dryers

To obtain any uniformity of product with a spray dryer requires round-the-clock operation with as few stops and starts as practicable. The start-up and leveling-out cycle may be as long as four hours even under favorable conditions, and during that period much product may be made that will have to be reworked. Usually the larger units give less start-up trouble and better product uniformity.

The usual soap slurries formulated for spray drying contain 45–50% of total solids with a high percentage of soap while in the case of the popular heavy duty synthetic detergents the average solids content is 60–65%. It is understood that some installations are atomizing a detergent slurry containing somewhat over 70% total solids and operating at remarkably high capacities. The moisture content of the product from the tower is usually in the range of 10–14% for heavy duty synthetics and somewhat lower for the light duty. Some towers that were built with sufficient heating capacity to handle the higher moisture-containing soap slurries are capable of doubling their output when operated on synthetic detergent slurries.

Air temperatures vary somewhat depending on method of operation, type, and formulation of product. In concurrent towers the highest temperatures are in the nozzle zone and range from 600–750°F., producing a more highly puffed or hollow spherical particle (4). Under these conditions the particles

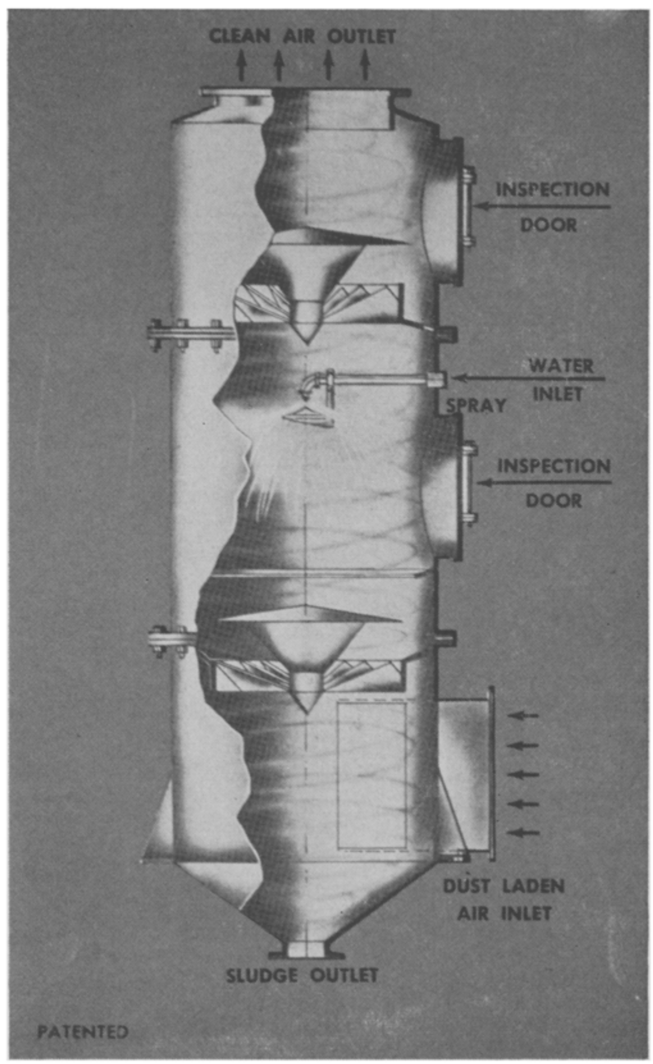

FIG. 8. Dust collector. Wet type.
Courtesy, Ducon Corporation, Mincola, N. Y.

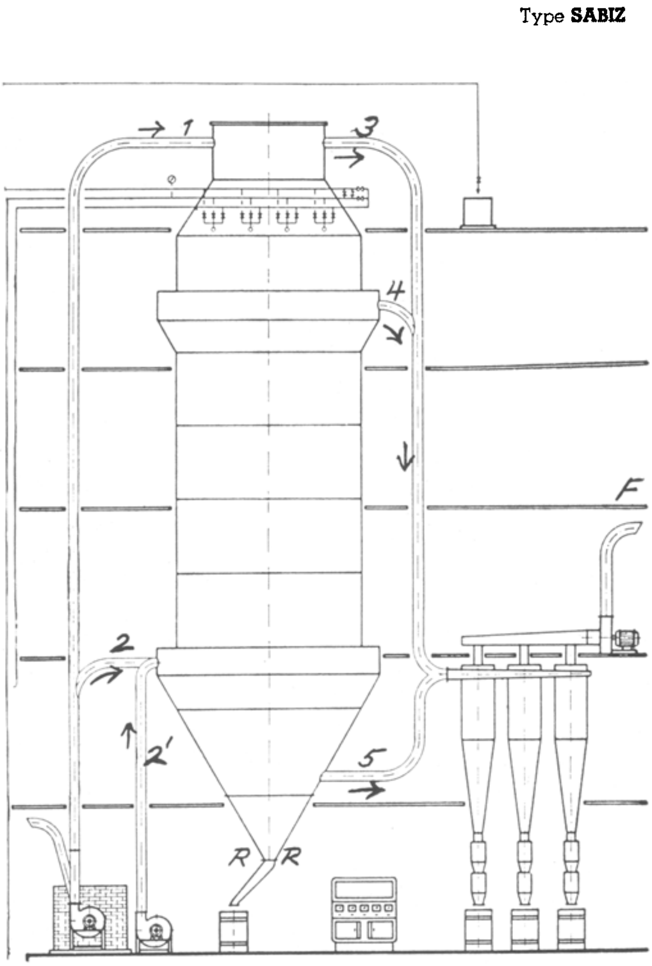

FIG. 9. Sketch illustrating air circuit of combination countercurrent and concurrent spray drying system.
Courtesy, Meccaniche Moderne, Busto Arsizio, Italy

are usually smaller and lighter in apparent gravity than those produced by countercurrent spraying. In the latter method the highest temperature is found at the bottom of the tower and varies from 350 to 450°F., and there is produced a larger and heavier particle, which is irregularly puffed or multi-cellular. In general, many consider the countercurrent system most suitable for the production of the present form of heavy duty synthetic detergent and soap formulations and prefer the concurrent operation for light duty products, both soap and synthetic.

Formulation is a complete subject in itself and will be touched on only as it affects tower operation. Soap slurries present no problems other than those incident to making a homogeneous mix. Synthetic detergent slurries in which a variety of builders are used require a certain standard procedure both as to formulation, temperature control, and timing. While soap slurries can be held for long periods, certain synthetic formulations containing the newer types of phosphates must be handled quickly and at temperatures not to exceed 160°F.

Just prior to packaging, the products are given a double screening; the over- and under-size portion together with dust from the dry collectors and slurry from the wet collectors are returned for reprocessing.

Figure 9 shows a flow diagram of a process that can be operated as a concurrent, countercurrent or combination (mixed current) system. A number of these units have been operating in several European countries where spray-dried soaps and synthetic detergents are made comparable to those turned out in the United States. The nozzles are located at the top of the tower, and three possible air circuits are provided as follows:

Concurrent—hot air in at 1, cold air in at R, air out at 5.
Product—hollow beads, apparent sp. gr. 0.05–0.20.
Countercurrent—hot air in at 2, cold air in at R, air out at 3.
Product—multi-cellular, apparent sp. gr. 0.25–0.45.
Mixed Circuit—hot air in at 1 and 2, cold air in at 2', air out at 4.
Product—mixture of types made in 1 and 2 but containing higher moisture content when using proper alkaline salts. These units are furnished in capacities from 500 to 7,000 lbs. per hour with fully automatic controls.

The Products. As mentioned previously, the spray drying process accounts for well over half of the total American tonnage of combined soap and synthetic detergents. Both classes are widely distributed as packaged products in the light and heavy duty fields and for industrial use in the textile and allied industries.

The light duty types are formulated specially for dish-washing and for fine textile washing. Usually they are of the hollow bead type, light in apparent gravity, and of smaller particle size than the heavy duty. While there are some important variations in composition between brands, the single characteristic in common seems to be the absence of any significant percentage of alkaline builders.

Heavy duty products are characterized by a somewhat larger particle size, a higher apparent gravity, and an alkaline builder content specifically designed for the more exacting and more difficult cleaning problems met with in the general family wash.

The Drum Dryer

The Double Drum Dryer (Figure 10) continues to apply to some of the specialized drying problems in the soap and detergent industry. Products of high, active synthetic detergent content are best adapted to this type of unit although all types described above are being made with it. This type of unit consists of two large, smooth steel or plated drums mounted on trunnions, one revolving clockwise and the other counter-clockwise so as to form a V-shaped trough between them. Each drum is heated with steam, usually at 50 to 100 p.s.i. Adjustments are provided for varying the space between the rolls to accommodate feeds of varying viscosities, and varispeed drives give an additional control over the drying rate. The dried material is scraped off each roll after ¾ to ⅞ of a revolution and taken away in the conveyor trough or stripped off with a blast of air and handled pneumatically. The product comes off in sheets that break up into flat irregular plates when passed through a special type of flaker.

The capacities of the larger units are reported to be 1,000 to 1,200 lbs. per hour on light duty and up to 2,000 lbs. on heavy duty formulations. Since drying is effected by the direct application of steam and not through the medium of air, the thermal efficiencies of these units are somewhat better than for other methods described.

Flash Drying

While spray drying could be classified as a type of flash drying, use of the former term is confined to

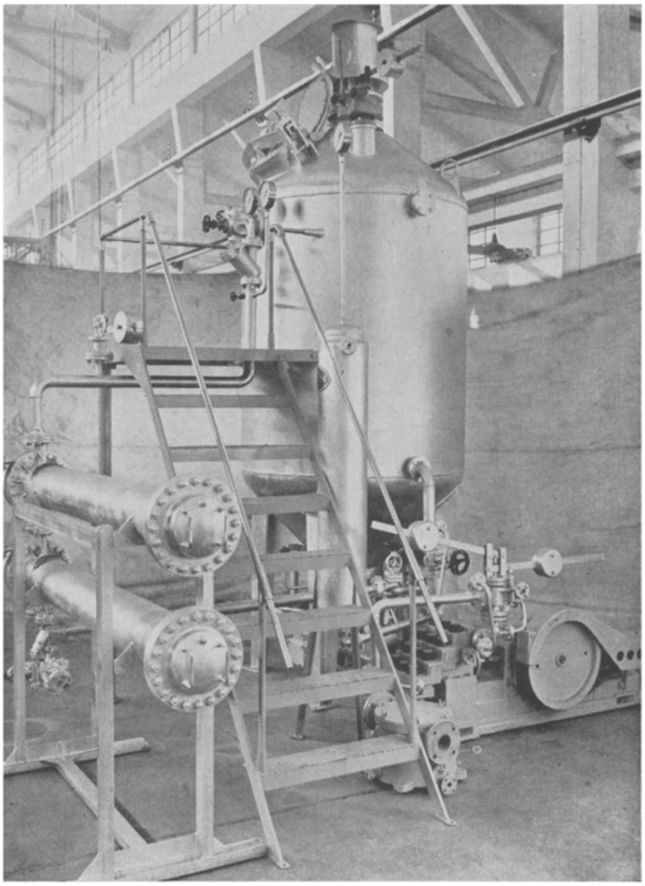

FIG. 10. Continuous atmospheric flash-drying unit.
Courtesy, Meccaniche Moderne, Busto Arsizio, Italy

those processes in which the evaporation of water takes place in a current of heated air. The term flash drying is applied to those processes where most or all of the heat is contained in the material to be dried (5). The process has been in operation in this country in the soap industry for about 15 years and is applied mainly to the partial drying of neat or direct-made soap in the manufacture of the bar toilet variety. The processes and equipment were again developed entirely within the industry, and details are not available at this time. Fortunately two processes have been perfected by European companies and are beginning to enjoy increasing acceptance in this field.

The Meccaniche Moderne Flash Dryer. A completely engineered and self-contained commercial unit (Figure 10) consisting of high pressure pump, heat exchangers, and flash chamber with the necessary piping, expansion and safety valves, thermometers, gauges, soap strainer, nozzle and motor. The process is guaranteed to concentrate pure soap or filled soap from 62% to 72–74% T.F.A. Pure soap concentrated to 72–74% T.F.A. will have a moisture content of 15–16.5%. It is being built in capacities from 1,000 to 4,000 lbs. per hour and, in connection with their cooling and extrusion equipment, forms a continuous unit for the production of improved toilet and laundry soaps.

The Mazzoni Process. Figure 11 shows the vacuum flash drying unit 1 with pump and vertical heat exchanger; the extrusion units 2 and 3, with intervening vacuum chamber, and 4 a conveyor to transfer the dried and extruded product to the finishing equipment. By flashing under sub-atmospheric conditions a lower initial temperature can be employed to obtain concentrations comparable with those of other systems, *i.e.,* 72–74% T.F.A. Through the use of one or more vacuum plodders concentrations beyond 74% T.F.A. are easily obtainable with pure soaps.

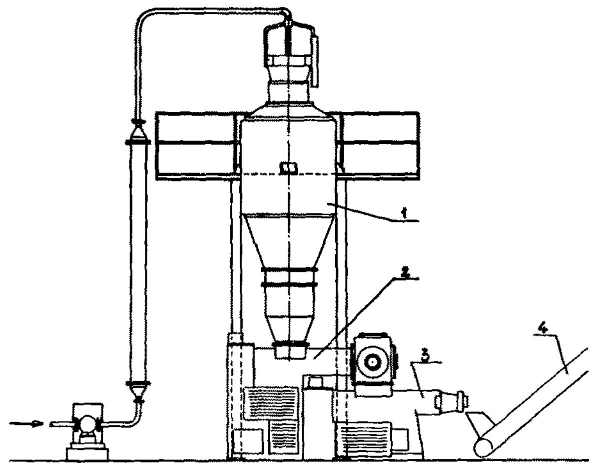

FIG. 11. Continuous vacuum flash-drying unit.
Courtesy, G. Mazzoni, Busto Arsizio, Italy

It is claimed by the advocates of flash drying that a more homogenous and uniformly dried product is produced since it is not a surface-drying operation. It is however almost universally agreed that flash drying helps to produce a product with improved physical properties such as hardiness, resistance to warping, better solubility, and lathering qualities (7). By a combination of flash drying with rapid cooling and extrusion or with rapid cooling and milling some very interesting translucent and transparent toilet soaps are being produced without the use of special formulations.

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