

[NOTE: The Section number for Soap and Detergents was changed to 6.8 with the publication of the Fifth Edition of AP-42.]

BACKGROUND REPORT

AP-42 SECTION 5.15

SOAP AND DETERGENTS

Prepared for

**U.S. Environmental Protection Agency
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1.0 INTRODUCTION

The document "Compilation of Air Pollutant Emission Factors" (AP-42) has been published by the U.S. Environmental Protection Agency (EPA) since 1972. Supplements to AP-42 have been routinely published to add new emission source categories and to update existing emission factors. AP-42 is routinely updated by the EPA to respond to new emission factor needs of the EPA, state and local air pollution control programs, and industry.

An emission factor relates the quantity (weight) of pollutants emitted to a unit of activity of the source. The uses for the emission factors reported in AP-42 include:

1. Estimates of area-wide emissions;
2. Emission estimates for a specific facility; and
3. Evaluation of emissions relative to ambient air quality.

The purpose of this report is to provide background information obtained from industry comment and 2 test reports to support revision of emission factors for Section 5.15.

Including the introduction (Chapter 1) this report contains four chapters. Chapter 2 gives descriptions of the soap and detergent industry. It includes a characterization of the industry, an overview of the different process types, a description of emissions, and a description of the technology used to control emissions resulting from soap and detergent production.

Chapter 3 is a review of emissions data collection and analysis procedures. It describes the literature search, the screening of emission data reports, and the quality rating system for both emission data and emission factors. Chapter 4 details criteria and noncriteria pollutant emission factor development. It includes the review of specific data sets and the results of data analysis. Particle size determination and particle size data analysis methodology are described where applicable. The appendix presents AP-42 Section 5-15.

2.0 INDUSTRY DESCRIPTION

2.1 GENERAL

Soap Manufacturing

The term "soap" refers to a particular type of detergent in which the water-solubilized group is carboxylate and the positive ion is usually sodium or potassium. The largest soap market is bar soap used for personal bathing. Synthetic detergents replaced soap powders for home laundering in the late 1940s, because the carboxylate ions of the soap react with the calcium and magnesium ions in the natural hard water to form insoluble materials called lime soap. Some commercial laundries that have soft water continue to use soap powders. Metallic soaps are alkali-earth or heavy-metal long-chain carboxylates which are insoluble in water but soluble in nonaqueous solvents. They are used as additives in lubricating oils, greases, rust inhibitors, and jellied fuels.

Detergent Manufacturing

The term "synthetic detergent products" applies broadly to cleaning and laundering compounds containing surface-active (surfactant) compounds along with other ingredients. Heavy-duty powders and liquids for home and commercial laundry detergent comprise 60 to 65 percent of the U.S. soap and detergent market and were estimated at 2.6 megagrams (2.86 million tons) in 1990.

Until the early 1970s, almost all laundry detergents sold in the U.S. were heavy-duty powders. Liquid detergents were introduced that utilized sodium citrate and sodium silicate. The liquids offered superior performance and solubility at a slightly increased cost. Heavy-duty liquids now account for 40 percent of the laundry detergents sold in the U.S., up from 15 percent in 1978. As a result, 50 percent of the spray drying facilities for laundry granule production have closed since 1970. The introduction of superconcentrated powder detergents will probably lead to an increase in spray drying operations at some facilities.

2.2 PROCESS DESCRIPTION

Soap Process Description

From American colonial days to the early 1940s, soap was manufactured by an alkaline hydrolysis reaction called saponification. Soap was made in huge kettles into which fats, oils, and caustic soda were piped and heated to a brisk boil. After cooling for several days, salt was added, causing the mixture to separate into two layers with the "neat" soap on top and spent lye and water on the bottom. The soap was pumped to a closed mixing tank called a crutcher where builders, perfumes, and other ingredients were added. Builders are alkaline compounds which improve the cleaning performance of the soap. Finally, the soap was rolled into flakes, cast or milled into bars, or spray-dried into soap powder.

An important modern process (post 1940s) for making soap is the direct hydrolysis of fats by water at high temperatures. This permits fractionation of the fatty acids, which are neutralized to soap in a continuous process as shown in Figure 2.2-1.

Advantages for this process include better control of the soap concentration, the ability to prepare soaps of certain chain lengths for specific purposes, and easy recovery of glycerin, a byproduct. After the soap is recovered, it is pumped to the crutcher and treated the same as the product from the kettle process.

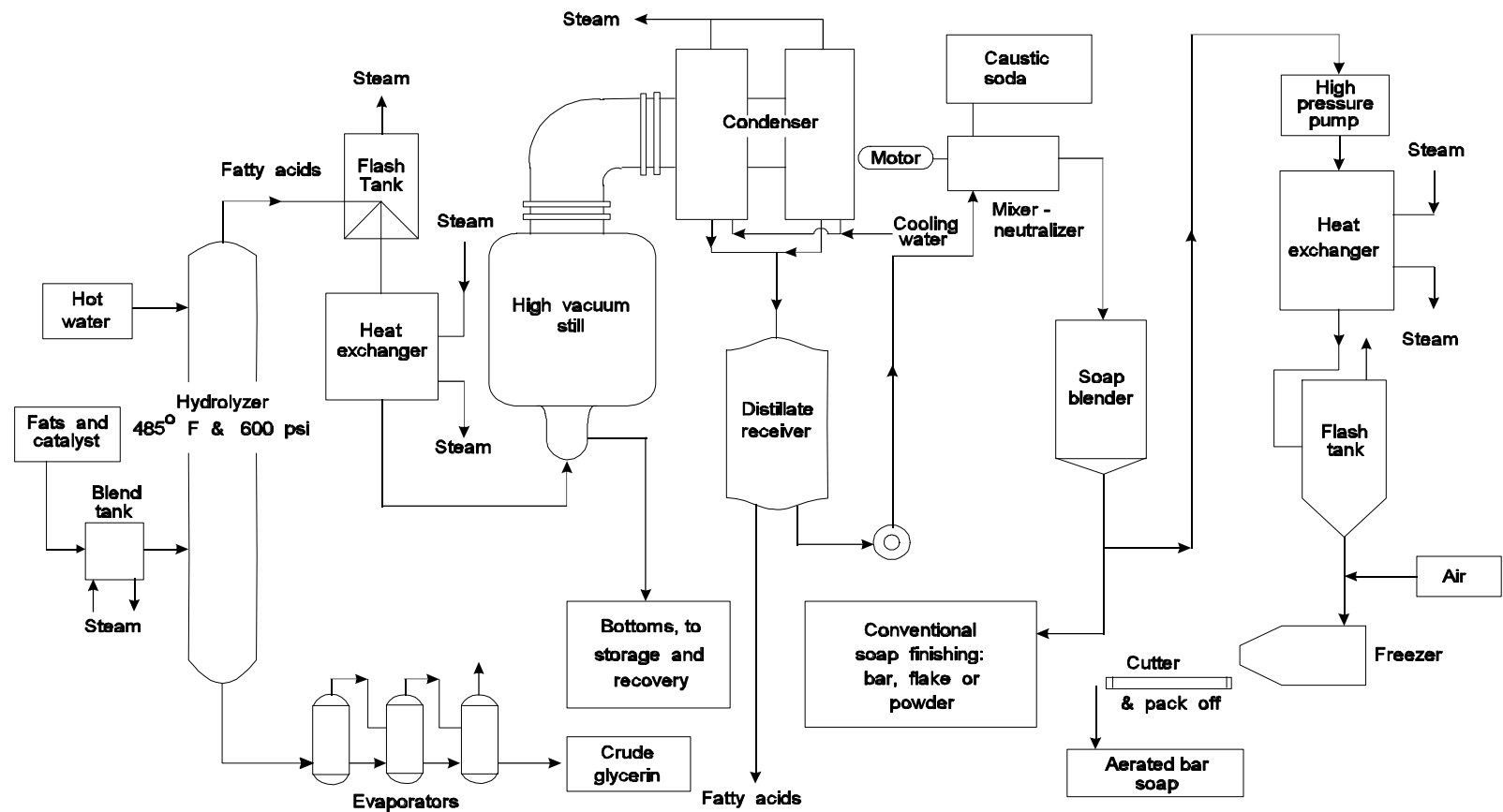


Figure 2.2.-1 Continuous process for fatty acids and soaps

Detergent Process Description

The manufacture of spray-dried detergent has three main processing steps: 1) slurry preparation, 2) spray drying and 3) granule handling. The three major components of detergent are surfactants (to remove dirt and other unwanted materials), builders (to treat the water to improve surfactant performance) and additives to improve cleaning performance. Additives may include bleaches, bleach activators, antistatic agents, fabric softeners, optical brighteners, antiredeposition agents, and fillers.

The formulation of slurry for detergent granules requires the intimate mixing of various liquid, powdered, and granulated materials. Detergent slurry is produced by blending liquid surfactant with powdered and liquid materials (builders and other additives) in a closed mixing tank called a soap crutcher. Premixing of various minor ingredients is performed in a variety of equipment prior to charging to the crutcher or final mixer. Figure 2.2-2 illustrates the various operations. Liquid surfactant used in making the detergent slurry is produced by the sulfonation of either a linear alkylate or a fatty acid, which is then neutralized with a caustic solution containing sodium hydroxide (NaOH). The blended slurry is held in a surge vessel for continuous pumping to a spray dryer. The slurry is atomized by spraying through nozzles rather than by centrifugal action. The slurry is sprayed at pressures of 4.1 to 6.9 kPa (600 to 1000 pounds per square inch) in single-fluid nozzles and at pressures of 340 to 690 kPa (50 to 100 psi) in two-fluid nozzles. Steam or air is used as the atomizing fluid in the two-fluid nozzles. The slurry is sprayed at high pressure into a vertical drying tower having a stream of hot air of from 315 to 400°C (600 to 750°F). All spray drying equipment designed for detergent granule production incorporates the following components: spray drying tower, air heating and supply system, slurry atomizing and pumping equipment, product cooling equipment, and conveying equipment. Most towers designed for detergent production are countercurrent, with slurry introduced at the top and heated air introduced at the bottom. The towers are cylindrical with cone bottoms and range in size from 4 to 7 meters (12 to 24 feet) in diameter and 12 to 38 meters (40 to 125 feet) in height. The detergent granules are conveyed mechanically or by air from the tower to a mixer to incorporate additional dry or liquid ingredients, and finally to packaging and storage.

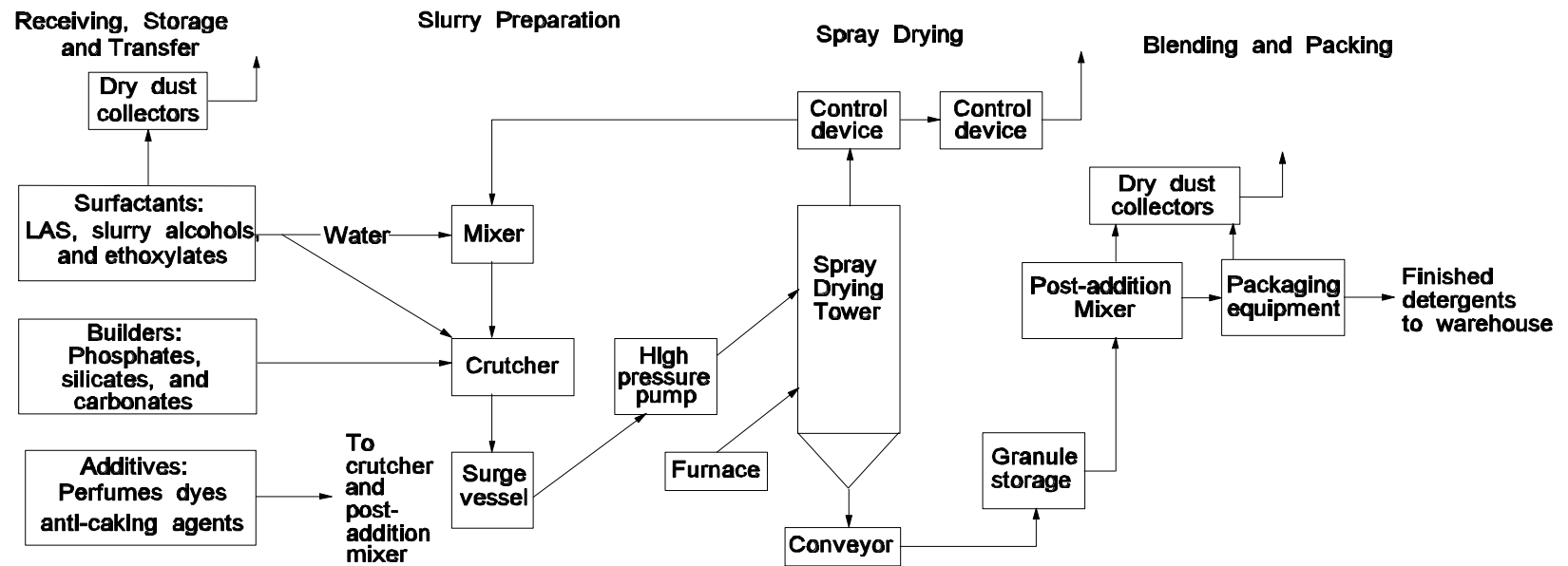


Figure 2.2-2 Manufacture of spray-dried detergents

2.3 EMISSIONS AND CONTROLS

Soap Manufacturing Emissions and Controls

The main atmospheric pollution problem in soap manufacturing is odor. The storage and handling of liquid ingredients (including sulfonic acids and salts) and sulfates are some of the sources of this odor. Vent lines, vacuum exhausts, raw material and product storage, and waste streams are all potential odor sources. Control of these odors may be achieved by scrubbing exhaust fumes and, if necessary, incinerating the remaining volatile organic compounds (VOCs). Odors emanating from the spray dryer may be controlled by scrubbing with an acid solution.

Blending, mixing, drying, packaging and other physical operations may all involve particulate emissions. The production of soap powder by spray drying is the single largest source of dust in the manufacture of synthetic detergents. Dust emissions from other finishing operations can be controlled by dry filters such as baghouses. The large sizes of the particulate from soap powder operations means that high efficiency cyclones installed in series can achieve satisfactory control.

Detergent Manufacturing Emissions and Controls

The exhaust air from detergent spray drying towers contains two types of air contaminants: 1) fine detergent particles and 2) organics vaporized in the higher temperature zones of the tower.

Dust emissions are generated at scale hoppers, mixers, and crutchers during the batching and mixing of fine dry ingredients to form slurry. Conveying, mixing, and packaging of detergent granules can also cause dust emissions. Pneumatic conveying of fine materials causes dust emissions when conveying air is separated from bulk solids. For this process, fabric filters are generally used, not only to reduce or to eliminate dust emissions, but also to recover raw materials. The dust emissions principally consist of detergent compounds, although some of the particles are uncombined phosphates, sulfates, and other mineral compounds.

Dry cyclones and cyclonic impingement scrubbers are the primary collection equipment employed to capture the detergent dust in the spray dryer exhaust for return to processing. Dry cyclones are used in parallel or in series to collect this particulate and recycle it back to the crutcher. The dry cyclone separators can remove 90 percent or more by weight of the detergent product fines from the exhaust air. Cyclonic impingement scrubbers are used in parallel to collect the particulate from a scrubbing slurry and to recycle it to the crutcher.

Secondary collection equipment is used to collect fine particulates that escape from primary devices. For example, cyclonic impingement scrubbers are often followed by mist eliminators, and dry cyclones are followed by fabric filters or scrubber/electrostatic precipitator units. Several types of scrubbers can be used following the cyclone collectors. Venturi scrubbers have been used but are being replaced with packed bed scrubbers. Packed bed scrubbers are usually followed by wet-pipe-type electrostatic precipitators built immediately above the packed bed in the same vessel. Fabric filters have been used after cyclones but have limited applicability especially on efficient spray dryers due to condensing water vapor and organic aerosols binding the fabric filter.

In addition to particulate emissions, volatile organics may be emitted when the slurry contains organic materials with low vapor pressures. The VOCs originate primarily from the surfactants included in the slurry. The amount vaporized depends on many variables, such as tower temperature and the volatility of organics used in the slurry. These vaporized organic materials condense in the tower exhaust airstream into droplets or particles. Paraffin alcohols and amides in the exhaust stream can result in a highly visible plume that persists after the condensed water vapor plume has dissipated.

Opacity and organics emissions are influenced by granule temperature and moisture at the end of drying, temperature profiles in the dryer, and formulation of the slurry. A method for controlling visible emissions would be to remove offending organic compounds (i.e., by substitution) from the slurry. Otherwise, tower production rate may be reduced thereby reducing air inlet temperatures and exhaust temperatures. Lowering production rate will also reduce organic emissions

2.4 REVIEW OF SPECIFIC DATA SETS

Pacific Environmental Services (PES) contacted the following sources on process descriptions and emissions for this industry:

- 1) R. Gore
Alabama Air Division, ADEM
1751 Dickinson Drive
Montgomery, AL 36130
- 2) G. Suter
Church and Dwight Co
Syracuse, NY
- 3) K. Ries
Dial Corp.
Phoenix, AZ
- 4) J. Pennington
Florida Dept. of Environmental Regulation
Bureau of Air Quality Management
2600 Blair Stone Road
Tallahassee, FL 32399-2400
- 5) M. Fogle
Georgia Dept. of Natural Resources
Environmental Protection Division
270 Washington Street
Atlanta, GA 32301
- 6) B. Ascher
Illinois EPA, Division of Air Pollution Control
2200 Churchill Road
Springfield, IL 62794
- 7) D. Morris
Kansas Dept. of Health and Environmental, Bureau of Air Quality
Topeka, KS 66620
- 8) D. Zapcic
Lever Brothers Corp.
390 Park Avenue
New York, NY 10022

- 9) K. Armbruster
Michigan Dept. of Natural Resources, Air Pollution Control Division
4th Floor, Mason Building
Lansing, MI
- 10) M. Tharpe
Missouri Dept. of Natural Resources, Division of Environmental Quality
P.O. Box 176
Jefferson City, MO 65102
- 11) T. Brooks
Pennsylvania Dept. of Environmental Resources
P.O. Box 2063
Harrisburg, PA 17120
- 12) R. Ostendorf
Procter and Gamble Co.
6110 Center Hill Ave.
Cincinnati, OH 45224
- 13) R. Sedlak
Soap and Detergent Association
NY

Several sources, including state environmental agencies, soap and detergent manufacturers, and the Soap and Detergent Association were sent letters requesting information, but no responses were received.

Reference #1: *Source Category Survey: Detergent Industry*

Descriptions of processes and emissions from the soap and detergent industry were partially taken from this reference. The references provided information on manufacturers and plant locations.

Reference #2: *"Air Pollution Aspects of Soap and Detergent Manufacture."*

This report from the background files was reviewed for background informational purposes. It was not used to modify this section.

Reference #3: *Chemical Process Industries (Third Edition)*

This reference was used directly to revise the soap manufacturing and process descriptions. The process description for soap manufacturing was derived principally from this source.

Reference #4: *Chemical Engineers Handbook (Fourth Edition)*

The Chemical Engineer's Handbook provided information on detergent manufacturing which was included in the Emissions and Controls section. This information included spray drying technology and different control techniques for the detergent manufacturing industry.

Reference #5: *Soap and Detergent Manufacturing: Point Source Category*

This report from the background files was reviewed for background informational purposes. It was not used to modify this section.

Reference #6: *Air Pollution Engineering Manual (2nd Edition)*

The Air Pollution Engineering Manual (May 1973) provided much information on both soap and detergent manufacturing processes, emissions, and controls. It provided data which were used to modify the previous sections on soap manufacturing processes. The Air Pollution Engineering Manual was used to support revisions in the sections on detergent manufacturing processes and emissions.

Reference #7: *"Sulfonation and Sulfation Technology."*

This report from the background files was reviewed for background informational purposes. It was not used to modify this section.

Reference #8: *Draft Copy AP-40 Air Pollution Engineering Manual: Soaps and Detergents*

In response to a request from PES, Mr. Richard Scherr of ENSR sent an updated AP-40 revision of soap and detergent manufacturing which he had prepared for the Air and Waste Management Association. The AP-40 revision was used to rewrite the sections relating to detergent manufacturing processes, emissions, and controls.

2.5 REFERENCES FOR CHAPTER 2

1. Source Category Survey: Detergent Industry. Prepared for the U. S. Environmental Protection Agency, Research Triangle Park, NC. Contract Number 68-02-3059. June 1980.
2. Phelps, A.H., "Air Pollution Aspects of Soap and Detergent Manufacture." Reprinted from APCA Journal, Vol. 17, No. 8, pages 505-507. August 1967.
3. Shreve, R.N., Third Edition: Chemical Process Industries, Chapter 29, pages 544-564. McGraw-Hill Book Company.
4. Perry, J.H., Fourth Edition: Chemical Engineers Handbook, Section 20, page 20-59. McGraw-Hill Book Company.
5. Soap and Detergent Manufacturing: Point Source Category. Prepared for the U. S. Environmental Protection Agency, Research Triangle Park, NC. EPA-440/1-74-018-a. April 1974.
6. Danielson, J.A., Air Pollution Engineering Manual (2nd Edition). Pages 737-765. Prepared for the U. S. Environmental Protection Agency, Research Triangle Park, NC. May 1973.
7. Lanteri, A., "Sulfonation and Sulfation Technology." Journal of the American Oil Chemists Society, Vol. 55, pages 128-132. January 1978.
8. Scherr, D.C., Draft Copy AP-40 Air Pollution Engineering Manual: Soaps and Detergents. ENSR Consulting and Engineering, Houston, TX. Prepared for the Air & Waste Management Association. January 1992.

3.0 GENERAL EMISSION DATA REVIEW AND ANALYSIS PROCEDURES

3.1 LITERATURE SEARCH AND SCREENING OF SOURCE TESTS

The first step in the investigative process involved a search of available literature relating to criteria and noncriteria pollutant emissions associated with the soap and detergent industry. This search included the following references:

- 1) AP-42 background files maintained by the Emission Factor and Methodologies Section.
- 2) Files maintained by the Emission Standards Division.
- 3) Information in the *Air Facility Subsystems* (AFS) of the EPA *Aerometric Information Retrieval System* (AIRS).
- 4) The *VOC/Particulate Matter* (PM) *Speciation Database Management System* (SPECIATE).

To reduce the amount of literature collected to a final group of references pertinent to this report, the following general criteria were used:

1. Emissions data must be from a primary reference; i.e., the document must constitute the original source of test data. For example, a technical paper was not included if the original study was contained in a previous document.
2. The referenced study must contain test results based on more than one test run.
3. The report must contain sufficient data to evaluate the testing procedures and source operating conditions (e.g., one-page reports were generally rejected).

If no primary data were found and the previous update utilized secondary data, these secondary data were still used and the Emission Factor Rating lowered, if needed. A final set of reference materials was compiled after a thorough review of the pertinent reports, documents, and information according to these criteria. The final set of reference materials is given in Chapter 4.

3.2 EMISSION DATA QUALITY RATING SYSTEM

As part of Pacific Environmental Services' analysis of the emission data, the quantity and quality of the information contained in the final set of reference documents were evaluated. The following data were always excluded from consideration:

1. Test series averages reported in units that cannot be converted to the selected reporting units;
2. Test series representing incompatible test methods (e.g., comparison of the EPA Method 5 front-half with the EPA Method 5 front- and back-half);
3. Test series of controlled emissions for which the control device is not specified;
4. Test series in which the source process is not clearly identified and described; and
5. Test series in which it is not clear whether the emissions were measured before or after the control device.

Data sets that were not excluded were assigned a quality rating. The rating system used was that specified by the OAQPS for the preparation of AP-42 sections. The data were rated as follows:

A Rating

Multiple tests performed on the same source using sound methodology and reported in enough detail for adequate validation. These tests do not necessarily conform to the methodology specified in either the inhalable particulate (IP) protocol documents or the EPA reference test methods, although these documents and methods were certainly used as a guide for the methodology actually used.

B Rating

Tests that were performed by a generally sound methodology but lack enough detail for adequate validation.

C Rating

Tests that were based on an untested or new methodology or that lacked a significant amount of background data.

D Rating

Tests that were based on a generally unacceptable method but may provide an order-of-magnitude value for the source.

The following criteria were used to evaluate source test reports for sound methodology and adequate detail:

1. Source operation. The manner in which the source was operated is well documented in the report. The source was operating within typical parameters during the test.
2. Sampling procedures. The sampling procedures conformed to a generally acceptable methodology. If actual procedures deviated from accepted methods, the deviations are well documented. When this occurred, an evaluation was made of the extent to which such alternative procedures could influence the test results.
3. Sampling and process data. Adequate sampling and process data are documented in the report. Many variations can occur unnoticed and without warning during testing. Such variations can induce wide deviations in sampling results. If a large spread between test results cannot be explained by information contained in the test report, the data are suspect and were given a lower rating.
4. Analysis and calculations. The test reports contain original raw data sheets. The nomenclature and equations used were compared to those (if any) specified by the EPA to establish equivalency. The depth of review of the calculations was dictated by the reviewer's confidence in the ability and conscientiousness of the tester, which in turn was based on factors such as consistency of results and completeness of other areas of the test report.

3.3 EMISSION FACTOR QUALITY RATING SYSTEM

The quality of the emission factors developed from analysis of the test data was rated utilizing the following general criteria:

A (Excellent)

Developed only from A-rated test data taken from many randomly chosen facilities in the industry population. The source category is specific enough so that variability within the source category population may be minimized.

B (Above average)

Developed only from A-rated test data from a reasonable number of facilities. Although no specific bias is evident, it is not clear if the facilities tested represent a random sample of the industries. As in the A-rating, the source category is specific enough so that variability within the source category population may be minimized.

C (Average)

Developed only from A- and B-rated test data from a reasonable number of facilities. Although no specific bias is evident, it is not clear if the facilities tested represent a random sample of the industry. As in the A-rating, the source category is specific enough so that variability within the source category population may be minimized.

D (Below average)

The emission factor was developed only from A- and B-rated test data from a small number of facilities, and there is reason to suspect that these facilities do not represent a random sample of the industry. There also may be evidence of variability within the source category population. Limitations on the use of the emission factor are noted in the emission factor table.

E (Poor)

The emission factor was developed from C- and D-rated test data, and there is reason to suspect that the facilities tested do not represent a random sample of the industry. There also

may be evidence of variability within the source category population. Limitations on the use of these factors are always noted.

The use of these criteria is somewhat subjective and depends to an extent on the individual reviewer.

3.4 REFERENCES FOR CHAPTER 3

1. Technical Procedures for Developing AP-42 Emission Factors and Preparing AP-42 Sections. U.S. Environmental Protection Agency, Emission Inventory Branch, Office of Air Quality Planning and Standards, Research Triangle Park, NC, 27711, April, 1992. [Note: this document is currently being revised at the time of this printing.]
2. Compilation of Air Pollutant Emission Factors, Volume I: Stationary Sources, Supplement A, Appendix C.2, "Generalized Particle Size Distributions." U.S. Environmental Protection Agency, Office of Air Quality Planning and Standards. October, 1986.

4.0 POLLUTANT EMISSION FACTOR DEVELOPMENT

4.1 REVIEW OF SPECIFIC DATA SETS

The emission factors from the previous revision (September 1988) were derived from five references and six source test summaries. One of the references, "Communication from Maryland State Department of Health," could not be located. The other four references (References #3, #4, #5, #8) provided some data on the efficiencies of control equipment, but could not be used to validate the previous emission factors. The six source test summaries did not contain enough documentation to determine what test methods were used and what control equipment was involved. The six source test summaries could not be used to generate new emission factors or to validate the old emission factors.

The emission factors generated by the previous revision (September 1988) were apparently based on an estimated uncontrolled emission factor of 45 kg/Mg of product (90 lbs/ton of product) and estimated efficiencies of various control devices. No references were found to verify these efficiencies, though they appear to be reasonable. The emission factors appear to be based on the control system efficiencies, but the calculations are of various degrees of precision. The typical error in the calculations is within 5 percent, but the cyclone/wet scrubber/ESP emission factors error is 195 percent. No references were found to validate these calculations.

Due to the lack of documented source tests and supporting references, the particulate emission factors have not been changed and have been downgraded from a B rating to an E rating. The particulate size distribution and size specific emission factors presented in the previous revision (September 1988) were based on the six source test summaries. These source test summaries could not be used as previously mentioned to verify the old emission factors or to generate new ones. The particle size emission factors from the previous revision had been rated D, indicating poor quality, and it was decided not to present them in the section.

An additional particulate emission factor is presented based on the source test data in Reference #9. The facility utilizes a cyclone/packed bed/ESP control system.

Reference #9 Procter and Gamble, Augusta, GA, July 1988

The test was performed in accordance with EPA Reference Methods 1 through 5, but does not contain all the documentation for validation and is therefore rated "B." This test was used to generate a new emission factor for a cyclone/packed bed/ESP control system for a detergent spray drying operation. The emission factor was rated E since only this test was used to calculate it.

Reference #10 Time Products, Atlanta, GA, November 1988

The test was performed in accordance with EPA Reference Methods 1 through 3, but mentions an unknown Method 5T for measuring particulate, and is therefore rated "C."

4.2 CRITERIA POLLUTANT EMISSIONS DATA

Volatile organic compounds.

No data were found for volatile organic compound emissions from the soap and detergent industry.

Total Suspended Particulate (TSP) & PM₁₀.

The particulate emission factors have not been changed as mentioned in Section 4.1, but have been downgraded from a B rating to an E rating. The particulate size distribution and size specific emission factors presented in the previous revision (September 1988) were based on the six source test summaries. These source test summaries could not be used as previously mentioned to verify the old emission factors or to generate new ones. The particle size emission factors from the previous revision had been rated D, indicating poor quality, and it was decided not to present them in the section.

The TSP emissions are shown in Table 4.2-1 for two source tests which were provided by the Georgia Department of Environmental Resources. The source test numbers correspond to the references given in Section 4.5.

Each source test has been rated according to the criteria presented in Chapter 3. The ratings are subjective and are meant only to present the relative quality and reliability of the data. If the source test has been documented properly, then the type of control device, the test methods used to perform the source tests, the emission rates, and the production rates are given in Table 4.2-1 in both metric and English units.

The emission factors are calculated by taking the emission rate and dividing by the production rate. For example, the average metric emission factor for source test #1 would be:

$$\text{Emission factor} = \frac{\text{Emission Rate}}{\text{Production Rate}} = \frac{10.1 \text{ kg/hr}}{21.6 \text{ Mg/hr}} = 0.47 \text{ kg/Mg}$$

The emission factors listed for the various control measures were calculated by multiplying the assumed uncontrolled emission factor by the control efficiency of the particular device. For example, the emission factor for the cyclone/spray chamber control system is:

$$\begin{aligned}\text{Emission factor (kg/Mg)} &= (1 - .92) \times 45 \text{ kg/Mg} \\ &= 3.6 \text{ kg/Mg}\end{aligned}$$

4.3 NONCRITERIA POLLUTANT EMISSIONS DATA

No data on emissions of HAPs or ODCs were found for soap and detergent manufacturing operations. However, a speciation of the VOCs emitted from the spray drying operations may reveal that some HAPs are present.

Global Warming Gases.

Pollutants such as methane, carbon dioxide, and N₂O have been found to contribute to overall global warming. A source test from the Georgia Department of Natural Resources was utilized to calculate carbon dioxide emissions from one particular source. The CO₂ emission rate for the Time Products facility in Atlanta, Georgia was calculated as follows:

$$\begin{aligned}\text{Carbon Dioxide Emission Rate} &= \text{CO}_2 \text{ Concentration (\%/100)} / \\ &\quad [1 - \text{Average Gas Moisture (\%/100)}] \times \\ &\quad \text{Average Gas Flow Rate (DSCFH)} / 8.159 \text{ ft}^3/\text{lb} \\ &= 0.0445 \times 186.1 / 8.159 \\ &= 1.02 \text{ lbs CO}_2/\text{hr}.\end{aligned}$$

The resulting emission factor for carbon dioxide, using a production rate of 1.65 tons/hr is:

$$\text{Emission Factor (CO}_2\text{)} = 1.02/1.65 = 0.62 \text{ lbs CO}_2/\text{ton}.$$

A single source test was considered insufficient, by itself, to warrant the inclusion of carbon dioxide emission factors in the AP-42 section.

**TABLE 4.2-1 (METRIC UNITS)
TOTAL SUSPENDED PARTICULATE**

Control Equipment	Test Rating	Test Method	Run #	Production Rate ^a	Emission Rate ^b	Emission Factor ^c
Reference 9						
Cyclones/Packed Bed Scrubber/Electrostatic Precipitator	B	5	1	21.6	8.4	0.39
			2	21.6	11.8	0.55
			3	21.6	10.2	0.47
			Average	21.6	10.1	0.47
Reference 10						
Cyclone/ Spray Chamber/ Mist Eliminator	C	5T	1	1.53	0.34	0.22
			2	1.53	0.26	0.17
			3	1.53	0.31	0.20
			Average	1.53	0.30	0.20

^aUnits in Mg/hr.

^bUnits in kg/hr.

^cUnits in kg/Mg.

**TABLE 4.2-1 (ENGLISH UNITS)
TOTAL SUSPENDED PARTICULATE**

Control Equipment	Test Rating	Test Method	Run #	Production Rate ^a	Emission Rate ^b	Emission Factor ^c
Reference 9						
Cyclones/Packed Bed Scrubber/Electrostatic Precipitator	B	5	1	23.8	18.5	0.78
			2	23.8	26.0	1.09
			3	23.8	22.4	0.94
			Average	23.8	22.3	0.94
Reference 10						
Cyclone/ Spray Chamber/ Mist Eliminator	C	5T	1	1.69	0.74	0.44
			2	1.69	0.58	0.34
			3	1.69	0.68	0.40
			Average	1.69	0.67	0.39

^aUnits in tons/hr.

^bUnits in lbs/hr.

^cUnits in lb/ton.

4.4 DATA GAP ANALYSIS

Six source test summaries referenced by the previous revision (September 1988) were not used in calculating emission factors because of their lack of documentation. Emission factors for specific particulate sizes are not included in this revision since the data were derived from the undocumented source tests and were previously rated D.

For future revisions, it is suggested that new source test data be gathered and that emission factors should be calculated that are based on these data. Data on emissions of VOCs, HAPs, global warming gases, heavy metals, and other pollutants should also be collected via the new source tests, and emission factors calculated for these pollutants, if applicable.

To summarize the emission factors given in this current AP-42 section are generally unsupported by any current source test data and have therefore been given a quality rating of "E."

4.5 REFERENCES FOR CHAPTER 4

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5. Soap and Detergent Manufacturing: Point Source Category. Prepared for the U. S. Environmental Protection Agency, Research Triangle Park, NC. EPA-440/1-74-018-a. April 1974.
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7. Lanteri, A., "Sulfonation and Sulfation Technology." Journal of the American Oil Chemists Society, Vol. 55, pages 128-132. January 1978.
8. Scherr, D.C., Draft Copy AP-40 Air Pollution Engineering Manual: Soaps and Detergents. ENSR Consulting and Engineering, Houston, TX. Prepared for the Air & Waste Management Association. January 1992.
9. Emission Test Report, Procter and Gamble, Augusta, GA, Georgia Department of Natural Resources, Atlanta, GA, July 1988.
10. Emission Test Report, Time Products, Atlanta, GA, Georgia Department of Natural Resources, Atlanta, GA, November 1988.
11. AIRS Facility Subsystem Source Classification Codes and Emission Factor Listing for Criteria Air Pollutants. Prepared for the U. S. Environmental Protection Agency, Research Triangle Park, NC. EPA Number 450/4-90-003. March 1990.

**TABLE 4.5-1.
LIST OF CONVERSION FACTORS**

Multiply:	by:	To obtain:
mg/dscm	4.37 x 10 ⁻⁴	gr/dscf
m ²	10.764	ft ²
acm/min	35.31	acfm
m/s	3.281	ft/s
kg/hr	2.205	lb/hr
kPa	1.45 x 10 ⁻⁴	psia
kg/Mg	2.0	lb/ton
Mg	1.1023	ton

Temperature conversion equations:

Fahrenheit to Celsius:

$$\frac{^{\circ}\text{F} - 32}{1.8} = ^{\circ}\text{C}$$

Celsius to Fahrenheit:

$$(1.8^{\circ}\text{C}) + 32 = ^{\circ}\text{F}$$

APPENDIX.

AP-42 SECTION 5.15.

[See AP-42, Fifth Edition, Chapter 6, Section 8.]