[Note: with the publication of the Fifth Edition of AP-42, the Chapter and Section number for Ammonium Sulfate was changed to 8.4.]

BACKGROUND REPORT

AP-42 SECTION 6.18

AMMONIUM SULFATE

Prepared for

U.S. Environmental Protection Agency
OAQPS/TSD/EIB
Research Triangle Park, NC 27711

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Pacific Environmental Services, Inc.
PO Box 12077
Research Triangle Park, NC 27709
919/941-0333

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AP-42 Background Report

TECHNICAL SUPPORT DIVISION

U.S. ENVIRONMENTAL PROTECTION AGENCY
Office of Air Quality Planning and Standards
Research Triangle Park, North Carolina 27711

This report has been reviewed by the Technical Support Division of the Office of Air Quality Planning and Standards, EPA. Mention of trade names or commercial products is not intended to constitute endorsement or recommendation for use. Copies of this report are available through the Library Services Office (MD-35), U.S. Environmental Protection Agency, Research Triangle Park, NC 27711.

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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 from process information obtained from industry comment and a test report to support revision of the process description and/or emission factors for ammonium sulfate.

Including the introduction (Chapter 1), this report contains four chapters. Chapter 2 gives a description of the ammonium sulfate 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 the production of ammonium sulfate, and a review of references.

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 includes the review of specific data sets, details criteria and noncriteria pollutant emission factor development and presents the results of a data gap analysis. Particle size determination and particle size data analysis methodology are described where applicable. Appendix A presents AP-42 Section 6.18.

2.0 INDUSTRY DESCRIPTION

2.1 GENERAL

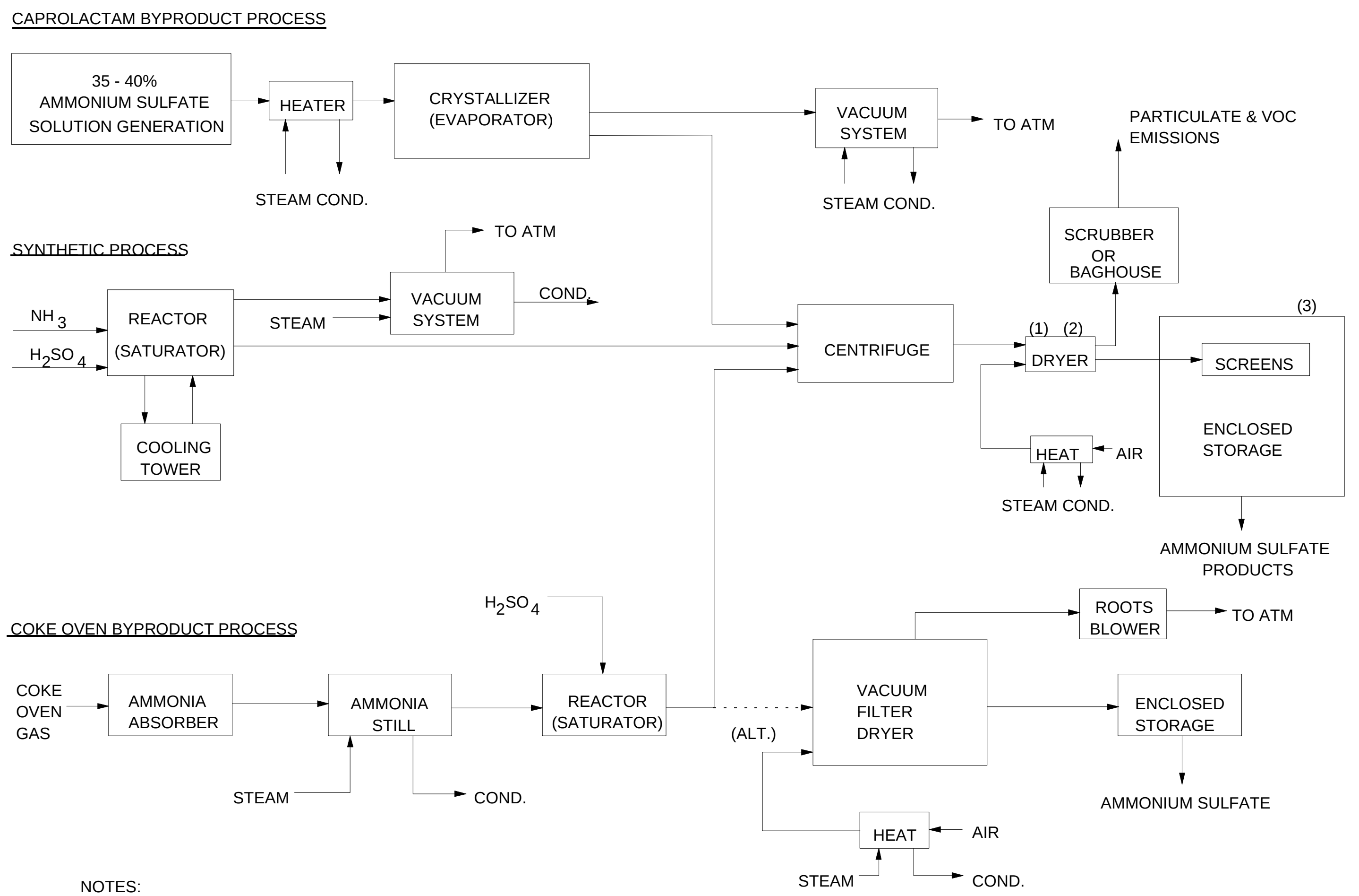
Ammonium sulfate [$(NH_4)_2SO_4$] is commonly used as fertilizer. In 1991, U.S. facilities produced about 2.7 million megagrams (three million tons) of ammonium sulfate in about 35 plants. Production rates at these plants range from 1.8 to 360 megagrams (2 to 400 tons) per year.

2.2 PROCESS DESCRIPTION

About 90 percent of ammonium sulfate is produced by three different processes: 1) as a byproduct of caprolactam [$(CH_2)_5COHN$] production, 2) synthetic manufacture from pure ammonia and concentrated sulfuric acid, and 3) as a coke oven byproduct. The remaining 10 percent is produced as a byproduct in nickel manufacture, or as a byproduct of methyl methacrylate manufacture or from ammonia scrubbing of tail gas at sulfuric acid (H_2SO_4) plants. These minor processes are not discussed here.

Ammonium sulfate is produced as a byproduct from the caprolactam oxidation process stream and the rearrangement reaction stream. Synthetic ammonium sulfate is produced by combining anhydrous ammonia and sulfuric acid in a reactor. Coke oven byproduct ammonium sulfate is produced by reacting the ammonia recovered from coke oven offgas with sulfuric acid. Figure 2.2-1 shows the typical process flow diagram for ammonium sulfate manufacturing for each of the three primary commercial processes.

Figure 2.2-1 Typical flow diagram for ammonium sulfate processes.



NOTES:

(1.) Dryer may be rotary or fluidized bed type.
(2.) Coke oven plant may integrate centrifuge and drying or centrifuging only.
(3.) Coke oven plant product not screened.

Figure 8.4-1. Typical diagram of ammonium sulfate processes.

After formation of the ammonium sulfate solution, manufacturing operations of each process are similar. Ammonium sulfate crystals are formed by circulating the ammonium sulfate liquor through an evaporator. Evaporation of the water thickens the solution. Ammonium sulfate crystals are separated from the liquor in a centrifuge. In the caprolactam byproduct process, the product is first transferred to a settling tank to reduce the liquid load on the centrifuge. The saturated liquor is returned to the dilute ammonium sulfate brine of the evaporator. The crystals, which contain about 1 to 2.5 percent moisture by weight after the centrifuge, are fed to either a fluidized-bed (SCC code 3-01-130-05) or rotary drum dryer (SCC code 3-01-130-04). Fluidized-bed dryers are continuously steam-heated while the rotary dryers are either fired directly with oil, natural gas, or steam-heated air.

At coke oven byproduct plants, rotary vacuum filters may be used in place of a centrifuge and dryer. The crystal layer deposits on the filter and is removed as product. These crystals are generally not screened, although they contain a wide range of particle sizes. They are then carried by conveyors to bulk storage.

At synthetic plants, a small quantity (about 0.05 percent) of an anti-caking agent (i.e., high molecular weight organic) is added to the product after drying to reduce caking.

Dryer exhaust gases pass through a particulate collection device, such as a wet scrubber. This collection controls emissions and reclaims residual product. After being dried, the ammonium sulfate crystals are screened into coarse and fine crystals. This screening is done in an enclosed area to minimize fugitive dust in the building.

2.3 EMISSIONS AND CONTROLS

Ammonium sulfate particulate is the principal emission from ammonium sulfate manufacturing plants. The exhaust of the dryers contains nearly all the emitted ammonium sulfate. Other plant processes, such as evaporation, screening, and materials handling, are not significant sources of emissions.

The particulate emission rate of a dryer is dependent on the gas velocity and the particle size distribution. Gas velocity, and thus the emission rate, varies according to the dryer type. Generally, the gas velocity of fluidized-bed dryers is higher than for most rotary drum dryers. Therefore, the particulate emission rates are higher for fluidized-bed dryers. At caprolactam byproduct plants, relatively small amounts of volatile organic compounds (such as caprolactam hydrocarbons) are emitted from the dryers.

Some plants use baghouses for emission control; however, wet scrubbers, such as venturi and centrifugal scrubbers, are more suitable for reducing particulate emissions from the dryers. Wet scrubbers use the process streams as the scrubbing liquid so that the collected particulate can be easily recycled to the production system.

2.4 REVIEW OF REFERENCES FOR CHAPTER 2

Pacific Environmental Services (PES) contacted the following sources to obtain the most up-to-date information on process descriptions and emissions for this industry:

1) Alabama Air Division, Montgomery, AL.
2) Allied-Signal, Hopewell, VA.

3) Florida Department of Environmental Regulation, Tallahassee, FL.
4) Georgia Department of Natural Resources, Atlanta, GA.
5) Idaho Department of Health and Welfare, Idaho
6) Indiana Department of Environmental Management, Indianapolis, IN.
7) J.R. Simplot Company, Pocatello, ID.
8) Kansas Department of Health and Environment, Topeka, KS.
9) Michigan Department of Natural Resources, Lansing, MI.
10) Missouri Department of Natural resources, Jefferson City, MO.
11) Ohio Environmental Protection Agency, Ohio.
12) Pennsylvania Department of Environmental Resources, Harrisburg, PA.

Only one response, from the Idaho Department of Health and Welfare (Source #5), was received. The response consisted of a source test report conducted at the J.R. Simplot plant located in Pocatello, Idaho. The data from J.R. Simplot was used to revise the controlled particulate emission factor for rotary dryers. References used to revise Section 6.18 are discussed below.

Reference #1: Ammonium Sulfate Manufacture: Background Information for Proposed Emission Standards

This document used as a reference in the previous revision (April 1981) provided general process description and emissions and controls sections for ammonium sulfate processing.

Reference #2: North American Fertilizer Capacity Data

This report, obtained from the Tennessee Valley Authority (TVA), contained information regarding ammonium sulfate producers, plant status, locations and estimating productions. The report was used in estimating ammonium sulfate production for 1992.

Reference #3: Emission Factor Documentation for Section 6.18 Ammonium Sulfate Manufacture

This report taken from the EPA background file for Section 6.18 contained information on how particulate and VOC emission factors in the previous revision (April 1981) of AP-42 were generated. It also provided summaries of source test data and the calculations used to develop these emission factors.

2.5 REFERENCES FOR CHAPTER 2

1. Ammonium Sulfate Manufacture: Background Information for Proposed Emission Standards, EPA-450/3-79-034a, U.S. Environmental Protection Agency, Research Triangle Park, North Carolina, December 1979.

2. North American Fertilizer Capacity Data, Tennessee Valley Authority, Muscle Shoals, AL 35660, December 1991.

3. Emission Factor Documentation for Section 6.18 Ammonium Sulfate Manufacture, Pacific Environmental Services, Inc., March 1981.

3.0 GENERAL EMISSION DATA REVIEW AND ANALYSIS PROCEDURES

3.1 LITERATURE SEARCH AND SCREENING OF SOURCE TESTS

The first step of this investigation involved a search of available literature relating to criteria and noncriteria pollutant emissions associated with ammonium sulfate production. This search included the following reference:

AP-42 background files maintained by the Emission Factor and Methodologies Section. PES was able to use the information in these files to ascertain that the emission factors were correctly taken from the cited references. No new information was found.

Information in the *Air Facility Subsystems* (AFS) of the EPA *Aerometric Information Retrieval System* (AIRS), *Clearinghouse for Inventories and Emission Factors* (CHIEF) and *National Air Toxics Information Clearinghouse* (NATICH), *VOC/Particulate Matter* (PM) *Speciation Database Management System* (SPECIATE), the *Crosswalk/Air Toxic Emission Factor Data Base Management System* (XATEF). No unique information was found from these sources.

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.
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).

The emission factors in the previous version (April 1981) were derived from the source data in the primary reference material. PES has reviewed the source test reports, which were given "B" ratings. Particulate and VOC emission factors in the existing document were not changed except for the controlled particulate emission factor for rotary dryers.
However, the ratings were downgraded from "B" to "C" (see Section 4.1).

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

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

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

C

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

D

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. Details of the rating of each candidate emission factor are provided in Chapter 4 of this report.

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, Emissions 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. AP-42, Supplement A, Appendix C.2, "Generalized Particle Size Distributions." U.S. Environmental Protection Agency, October 1986.

4.0 POLLUTANT EMISSION FACTOR DEVELOPMENT

4.1 REVIEW OF SPECIFIC DATA SETS

Particulate and VOC emission factors for both rotary and fluidized-bed dryers in the previous revision (April 1981) were taken from Reference 3, emission factor documentation, from the EPA background file for Section 6.18. These emission factors were derived from four emission source tests performed in 1978 and 1979 at four separate ammonium sulfate plants (References 4 through 7). Three of the four plants used rotary dryers and one (the only caprolactam by-product plant) used a fluidized-bed dryer.

The uncontrolled and controlled particulate emission factors for rotary dryers were derived by averaging emission factors from three source tests (References 4, 6, and 7). The average uncontrolled and controlled particulate emission factors for fluidized-bed dryers were derived solely from one source test (Reference 5).

VOC emissions were measured only at the caprolactam by-product plant (Reference 5) which utilize a fluidized-bed dryer. It was assumed in the previous section (April 1981) that the VOC emission factor for fluidized-bed dryers was also applicable to rotary dryers. This assumption was based on the fact that the VOC emissions were small.

PES has obtained all four of the source test reports and they are individually discussed in detail below.

Reference #4 : Source Emissions Test Report: Occidental Chemical Company, Houston, TX.

A series of three EPA Reference Method 5 tests were conducted at the inlet to the ammonium sulfate dryer baghouse stack to determine uncontrolled particulate emissions. The sampling was performed at one point of average velocity for a total test time of 120 minutes. This point was chosen before each test by running a rough velocity traverse across the open area of the duct. The test data were recorded every five minutes during all test periods. Visible emission observations were made at the baghouse exhaust using EPA Reference Method 9. The appendices for raw field data, calibration data, and sampling temperature were not available. Therefore, the test report was given a "B" rating.
The production rate of ammonium sulfate for three runs was 17 tons per hour (TPH) and the uncontrolled particulate emissions rates from the rotary dryer were 8.36, 7.84, and 31.2 pounds

per hour (PPH). The average uncontrolled particulate emission factor from the rotary dryer is thus

[(8.36/17) + (7.84/17) + (31.2/17)]/3 = 0.93 pounds per ton.

Reference #5: Emission source Test Report: Dow-Badische, Inc., Freeport, TX.

The test was conducted to determine controlled and uncontrolled ammonium sulfate particulate emissions from the fluidized-bed dryer. The ammonium sulfate bed in this unit is fluidized by two streams of air: steam-heated air for drying the moisture-laden ammonium sulfate introduced at the front end of the dryer, and ambient air for cooling the ammonium sulfate product introduced at the back end of the dryer. The control device used for this plant was a venturi scrubber. The particulate emission tests were measured using EPA Reference Method 5. Ammonium sulfate throughput was 29.2 tons per hour (TPH). It was assumed that the plant was operating close to capacity at the time of testing. The actual production rate was declared confidential. Since this report did not use the actual production rate for emission factors calculations and it did not contain complete calibration data, the report was given a "B" rating. Three measurements taken for the uncontrolled particulate emissions rates were 6440, 5970, and 6410 pounds per hour (PPH). The average uncontrolled particulate emission factor from fluidized-bed dryer is thus

[(6440/29.2) + (5970/29.2) + (6410/29.2)]/3 = 214.8 pounds per ton.

Three emission tests were also conducted to determine caprolactam emissions as VOC emissions at both the inlet and outlet of the fluidized-bed dryer. Actual determinations of caprolactam concentrations were made using gas chromatograph (GC) methods. The inlet emission rates for three runs were 37.8, 45.0, and 47.2 PPH and the outlet emission rates were 5.09, 6.10, and, 7.40 PPH. The average uncontrolled VOC emission factor from the fluidized-bed dryer is

[(37.8/29.2) + (45.0/29.2) + (47.2/29.2)]/3 = 1.48 pounds per ton,

and the average controlled VOC emission factor is

[(5.09/29.2) + (6.10/29.2) + (7.40/29.2)]/3 = 0.21 pounds per ton.

Reference #6: Emission Test Report: Valley Nitrogen, Helm, CA.

Three runs were performed at the inlet and outlet of a cyclonic scrubber to determine uncontrolled and controlled emissions from the rotary dryer. Both controlled and uncontrolled particulate emissions were measured using EPA Reference Method 5. Run 3 of the emission test at the inlet was not included in the emission factor calculation due to non-isokinetic sampling. Due to lack of calibration data and data for sampling Methods 2 and 3, the test report was given a "B" rating. The production rate for three runs was 400 tons per day or 16.7 tons per hour (assuming the plant operated 24 hours per day). Particulate emission rates at the inlet were 152.2, and 78.9 pounds per hour (PPH) and at the outlet were 2.0, 3.2, and 2.8 PPH. The average uncontrolled particulate emission factor for the rotary dryer is thus

$$[(152.2/16.7) + (78.9/16.7)]/2 = 6.9 \text{ pounds per ton,}$$

and the controlled particulate emission factor is

$$[(2.0/16.7) + (3.2/16.7) + (2.8/16.7)]/3 = 0.16 \text{ pounds per ton.}$$

Reference #7: Emission Test Report: Chevron Chemical, Richmond, CA.

Three runs were conducted at the inlet and outlet of a venturi scrubber to determine the uncontrolled and controlled particulate emissions from an ammonium sulfate dryer. Particulate emissions were measured using EPA Reference Method 5. The ammonium sulfate throughput for the three runs was 220 tons per day or 9.2 tons per hour (assuming the plant operated 24 hours per day). The particulate emission rates at the inlet were 1408 and 1439 pounds per hour (PPH). The emission rate for the second run is not included due to a leak in the sample train. Particulate emission rates for the outlet were 2.7, 1.7, and 4.5 pounds per hour. Therefore, the average uncontrolled particulate emission factor for the rotary dryer is

$$[(1408/9.2) + (1439/9.2)]/2 = 154.7 \text{ pounds per ton,}$$

and the average controlled particulate emission factor is

$$[(2.7/9.2) + (1.7/9.2) + (4.5/9.2)]/3 = 0.32 \text{ pounds per ton.}$$

Due to the leak in the sampling train and lack of calibration data, the test report was given a "B" rating.

Particulate and VOC emission factors calculated from the above four test reports (References 4 through 7) in the previous revision (April 1981) were not changed in the new revision except for the controlled particulate emission factor for rotary dryers. Since the particulate and VOC emission factors for both rotary and fluidized-bed dryers were developed from B-rated source test reports, they were downgraded from "A" to "C" ratings. The rating was assigned according to the criteria specified in Chapter 3 of this report.

The particulate emission factor for rotary dryers controlled by a wet scrubber in the April 1981 document (0.24 lb/ton) was revised by the new emission factor (0.04 lb/ton) calculated from the new source test data from J.R. Simplot Company. This report is discussed in further detail below.

<u>Reference #8: Compliance Test Report: J.R. Simplot Company, Pocatello, Idaho, February, 1990.</u>

Three test runs were performed to determine controlled particulate emissions and efficiency of the scrubber from the rotary dryer. Particulate removal efficiency of the venturi scrubber was determined based on the total particulate emission rate. Since the report contained all the necessary documentation, it was given an "A" rating. Particulate emissions rates were 0.28, 0.22, and 0.35 pounds per hour (PPH). This report did not indicate the production rate at the time of the test was conducted. The production rate was obtained and estimated based on the report published by the Tennessee Valley Authority (TVA). The production rate for ammonium sulfate in 1990 was 7.326 tons per hour (TPH). The average controlled particulate emission factor is thus

$$[(0.28/7.326) + (0.22/7.326) + (0.35/7.326)]/3 = 0.04 \text{ pounds per ton.}$$

4.2 CRITERIA POLLUTANT EMISSION DATA

No data on emissions of lead, sulfur dioxide, nitrogen oxides, or carbon monoxide were found nor expected for ammonium sulfate manufacture.

Volatile organic compounds.

As discussed in Section 2.3, a small amount of volatile organic compounds (caprolactam vapor) is emitted at caprolactam byproduct plants. The caprolactam vapor present in the exit gas resulted from the vapor pressure at the temperature of the dryer. Due to lack of response and test data, VOC emission factors for both rotary and fluidized-bed dryers in the previous version (April 1981) were not changed. PES verified the VOC emission factors for fluidized-bed dryers from Reference 5 and presented it in Table 4.2-1. It was assumed that the VOC emission factor from fluidized-bed dryers was also applicable to rotary dryers. Caprolactam is also identified as a hazardous air pollutant (HAP) and will be discussed in Section 4.3.

Total Particulate Matter

Emissions of particulate matter can be divided into three categories: filterable, organic condensible, and inorganic condensible. Filterable particulate matter is that which collects on the filter and in the sampling probe assembly of a particulate sampling train. All of the particulate emissions reported in the source tests (References 4 through 8) followed the procedure for measuring filterable particulate emissions.

The controlled particulate emission factor obtained from the J.R. Simplot source test (Reference 8) was used to revise the emission factor for rotary dryers controlled by wet scrubbers in the previous (April 1981) revision. The emission rates from the test data were given in pounds of pollutant per hour. The report did not provide any production data needed to calculate the emission factor in units of kilogram (pound) of pollutant per megagram (ton) of product. Therefore, the production rate of ammonium sulfate for that year was obtained and estimated from the report published by the TVA.

The uncontrolled particulate emission factor for rotary dryers in the April 1981 version was not changed. PES was able to verify the emission factor that was derived based on the test data in References 4, 6, and 7. Since the data used were derived from "B"-rated reports, a "C" rating was assigned according to the criteria explained in Chapter 3. The uncontrolled particulate emission factor for rotary dryers was calculated by averaging the uncontrolled particulate emission factors from each test run and yielded:

$$[0.49 + 0.46 + 1.83 + 9.11 + 4.72 + 153.04 + 156.41]/7 = 46 \text{ pounds per ton.}$$

Table 4.2-2 presents summaries of particulate emission factors used in the revised section.

TABLE 4.2-1 (METRIC UNITS)
VOLATILE ORGANIC COMPOUNDS

Control Equipment	Test Rating	Test Method	Run #	Production Rate[a]	Emission Rate[b]	Emission Factor[c]
Reference 5. Fluidized-bed dryer						
None	A	GC	1	26.49	17.15	0.65
			2	26.49	20.41	0.77
			3	26.49	21.41	0.81
			Average	26.49	19.57	0.74
Reference 5. Fluidized-bed dryer						
Scrubber	A	GC	1	26.49	2.31	0.09
			2	26.49	2.77	0.10
			3	26.49	3.36	0.13
			Average	26.49	2.81	0.11

[a] Units in Mg/hr.
[b] Units in kg/hr.
[c] Units in kg/Mg of product.

TABLE 4.2-1 (ENGLISH UNITS)
VOLATILE ORGANIC COMPOUNDS

Control Equipment	Test Rating	Test Method	Run #	Production Rate[a]	Emission Rate[b]	Emission Factor[c]
Reference 5. Fluidized-bed dryer						
None	A	GC	1	29.20	37.80	1.29
			2	29.20	45.00	1.54
			3	29.20	47.20	1.62
			Average	29.20	43.33	1.48
Reference 5. Fluidized-bed dryer						
Scrubber	A	GC	1	29.20	5.09	0.17
			2	29.20	6.10	0.21
			3	29.20	7.40	0.25
			Average	29.20	6.20	0.21

[a] Units in ton/hr.
[b] Units in lb/hr.
[c] Units in lb/ton of product.

TABLE 4.2-2 (METRIC UNITS)
FILTERABLE PARTICULATE MATTER

Control Equipment	Test Rating	Test Method	Run #	Production Rate[a]	Emission Rate[b]	Emission Factor[c]
Reference 4. Rotary dryer						
None	B	5	1	15.42	3.79	0.24
			2	15.42	3.56	0.23
			3	15.42	14.15	0.92
			Average	15.42	7.17	0.46
Reference 5. Fluidized-bed dryer						
None	B	5	1	26.49	2921.16	110.27
			2	26.49	2707.97	102.22
			3	26.49	2907.56	109.76
			Average	26.49	2845.41	107.41
Reference 6. Rotary dryer						
None	B	5	1	15.15	69.04	4.56
			2	15.15	35.79	2.36
			Average	15.15	52.41	3.46
Reference 7. Rotary dryer						
None	B	5	1	8.35	638.66	76.49
			2	8.35	652.73	78.17
			Average	8.35	645.70	77.33

[a] Units in Mg/hr.
[b] Units in kg/hr.
[c] Units in kg/Mg of product.

TABLE 4.2-2 (METRIC UNITS)
FILTERABLE PARTICULATE MATTER (*concluded*)

Control Equipment	Test Rating	Test Method	Run #	Production Rate[a]	Emission Rate[b]	Emission Factor[c]
Reference 8. Rotary dryer						
Wet scrubber	A	5	1	6.65	0.13	0.019
			2	6.65	0.10	0.015
			3	6.65	0.16	0.024
			Average	6.65	0.13	0.019

[a] Units in Mg/hr.
[b] Units in kg/hr.
[c] Units in kg/Mg of product.

TABLE 4.2-2 (ENGLISH UNITS)
FILTERABLE PARTICULATE MATTER

Control Equipment	Test Rating	Test Method	Run #	Production Rate[a]	Emission Rate[b]	Emission Factor[c]
Reference 4. Rotary dryer						
None	B	5	1	17.00	8.36	0.49
			2	17.00	7.84	0.46
			3	17.00	31.20	1.83
			Average	17.00	15.80	0.93
Reference 5. Fluidized-bed dryer						
None	B	5	1	29.20	6440	220.5
			2	29.20	5970	204.4
			3	29.20	6410	219.5
			Average	29.20	6273	214.8
Reference 6. Rotary dryer						
None	B	5	1	16.70	152.20	9.11
			2	16.70	78.90	4.72
			Average	16.70	115.55	6.92
Reference 7. Rotary dryer						
None	B	5	1	9.20	1408.00	153.0
			2	9.20	1439.00	156.4
			Average	9.20	1423.50	154.7

[a] Units in ton/hr.
[b] Units in lb/hr.
[c] Units in lb/ton of product.

TABLE 4.2-2 (ENGLISH UNITS)
FILTERABLE PARTICULATE MATTER (*concluded*)

Control Equipment	Test Rating	Test Method	Run #	Production Rate[a]	Emission Rate[b]	Emission Factor[c]
Reference 8. Rotary dryer						
Wet scrubber	A	5	1	7.33	0.28	0.038
			2	7.33	0.22	0.030
			3	7.33	0.35	0.048
			Average	7.33	0.28	0.039

[a] Units in ton/hr.
[b] Units in lb/hr.
[c] Units in lb/ton of product.

4.3 NONCRITERIA POLLUTANT EMISSIONS DATA

Hazardous Air Pollutants.

Hazardous Air Pollutants (HAPs) are defined in the 1990 Clean Air Act Amendments. No information or source test data were found regarding ammonia and methyl methacrylate (HAPs) emissions from ammonium sulfate production. Caprolactam (another HAP) vapor present in the exit gas of the dryer was also considered as a VOC. Due to lack of information and source test data, VOC emission factors for rotary dryers and fluidized-bed dryers were not changed. PES has verified the emission factors derived from Reference 5. It was assumed that the VOC emission factor for fluidized-bed dryers was also applicable to rotary dryers. A summary of the emission factors was presented in Table 4.2-1.

Global Warming Gases.

Pollutants such as methane, carbon dioxide, and nitrous oxide have been found to contribute to overall global warming. No data on emissions of these pollutants were found nor expected for the ammonium sulfate process.

Ozone Depletion Gases.

Chlorofluorocarbons and nitric oxide have been found to contribute to depletion of the ozone layer. No data on emissions of these pollutants were found for the ammonium sulfate process.

4.4 DATA GAP ANALYSIS

Some of the emission factors in this revision were derived from the source tests performed more than ten years ago. As discussed in Section 4.1, all four test reports have been reviewed and given "B" ratings. Due to lack of response and very little data available, only the controlled particulate emission factor for a rotary dryer has been revised. PES recommends further testing to determine uncontrolled emission factors for both rotary dryers and fluidized-bed dryers and a controlled emission factor for fluidized-bed dryers.

4.5 REFERENCES FOR CHAPTER 4

1. Ammonium Sulfate Manufacture: Background Information for Proposed Emission Standards, EPA-450/3-79-034a, U.S. Environmental Protection Agency, Research Triangle Park, North Carolina, December 1979.

2. North American Fertilizer Capacity Data, Tennessee Valley Authority, Muscle Shoals, AL, December 1991.

3. Emission Factor Documentation for Section 6.18 Ammonium Sulfate Manufacture, Pacific Environmental Services, Inc., March 1981.

4. Source Emission Test Report Occidental Chemical Company, EPA/EMB Report 78-NHF-6, U.S. Environmental Protection Agency, Research Triangle Park, North Carolina, March 1979.

5. Emission Testing at an Ammonium Sulfate Manufacturing Plant, EPA/EMB Report 78-NHF-1, U.S. Environmental Protection Agency, Research Triangle Park, North Carolina, October 1978.

6. Emission Test Report Valley Nitrogen Helm, California, EPA/EMB Report 78-NHF-6, U.S. Environmental Protection Agency, Research Triangle Park, North Carolina, March 1979.

7. Emission Test Report Chevron Chemical Richmond, California, EPA/EMB Report 79-NHF-12, U.S. Environmental Protection Agency, Research Triangle Park, North Carolina, March 1979.

8. "Compliance Test Report: J.R. Simplot Company," Pocatello, Idaho, February 1990.

TABLE 4.5-1

LIST OF CONVERSION FACTORS

Multiply:	**by:**	**To obtain:**
mg/dscm	4.37×10^{-4}	gr/dscf
m^2	10.764	ft^2
acm/min	35.31	acfm
m/s	3.281	ft/s
kg	2.205	lb
kPa	1.45×10^{-1}	psia
kg/Mg	2.0	lb/ton
Mg	1.1023	ton

Temperature conversion equations:

Fahrenheit to Celsius:

$$°C = \frac{(°F - 32)}{1.8}$$

Celsius to Fahrenheit:

$$°F = 1.8(°C) + 32$$

APPENDIX A

AP-42 SECTION 6.18.

[Not included here. See instead current AP-42 Section 8.4]