# Emission Factor Documentation for Section 6.18 Ammonium Sulfate Manufacture

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## 1.0 Introduction

This documentation shows how the emission factors for ammonium sulfate manufacture, shown in Table 6.18-1 of AP-42, were derived.

The emission factor data were obtained from four emission test reports listed below:

1. Source Emission Test Report Occidental Chemical Company, EPA/EMB Report 78-NHF-6, Contract No. 68-02-2816, Work Assignment No. 2, Roy F. Weston Environmental Consultants, West Chester, PA, March 1979.
2. Emission Testing at an Ammonium Sulfate Manufacturing Plant, EPA/EMB Report 78-NHF-1, Contract No. 68-02-2817, Work Assignment No. 5 and 6, Clayton Environmental Consultants, Inc., Southfield, Michigan, November 1978.
3. Emission Test Report Valley Nitrogen Helm, California, EPA/EMB Report 78-NHF-6, U.S. Environmental Protection Agency, Research Triangle Park, NC, March 1979.
4. Emission Test Report Chevron Chemical Richmond, California, EPA/EMB Report 79-NHF-12, U.S. Environmental Protection Agency, Research Triangle Park, NC, March 1979.

Each report contains the test data for one facility. These reports were commissioned by EPA under contract to provide a data base for the development of new source performance standards for ammonium sulfate manufacture. The test results are reported and discussed in Reference 1.

## 2.0 Test Results

Ammonium sulfate particulate emissions were measured at all four facilities. Three used rotary drum dryers and one used a fluidized-bed dryer as shown below.

| Facility Report No. | Facility Designation | Dryer type |
|---|---|---|
| 1 | A | Rotary |
| 2 | B | Fluidized-bed |
| 3 | C | Rotary |
| 4 | D | Rotary |

A brief description of each facility is given in Appendix A, and a summary of test results and test conditions is given in Appendix B. The derivation of the emission factors for particulates and volatile organic compounds (VOCs) is presented below.

### 2.1 Derivation of Particulate Emission Factors

The uncontrolled emissions were measured at each facility at the inlet of the control device which was a wet-scrubber. At three of the facilities, the controlled emissions were also measured. This involved measuring the emissions at the outlet of the control device. EPA Reference Method 5 (front half catch) was followed for each test.

The emission factor for each dryer type, both uncontrolled and controlled, were obtained by averaging the results of each test run as shown in Table 2.1-1. The results are expressed in terms of emissions by weight per unit of ammonium sulfate production by weight.

The emission factors were converted from units of kg/Mg to lb/ton by multiplying by a factor of 2.

Table 2-1. Particulate Emission Factors[a]

| Facility | Source Category | | | |
|---|---|---|---|---|
| | Rotary Dryers | | Fluidized-Bed Dryers | |
| | Uncontrolled kg/Mg | Wet-Scrubbers kg/Mg | Uncontrolled kg/Mg | Wet-Scrubbers kg/Mg |
| A | 0.24<br>0.24<br>0.75 | | | |
| B | | | 110.5<br>102.<br>114.5 | 0.13<br>0.06<br>0.24 |
| C | 4.55<br>2.56 | 0.06<br>0.095<br>0.085 | | |
| D | 75.5<br>77.5 | 0.145<br>0.09<br>0.24 | | |
| Average | 23.0 | 0.12 | 109. | 0.14 |

[a]Emission factors are expressed as emissions by weight per weight of ammonium sulfate production by weight.

## 2.2 Derivation of VOC Emission Factors

VOC emissions were measured only at facility B, a caprolatam by-product plant. Only one facility was tested because VOC emissions were not considered to be significant compared to the particulate emissions. Furthermore, the new source performance standard was for particulate emissions. A caprolactam by-product plant was tested to verify the low VOC emissions. This facility used a fluidized-bed dryer. The results of each test run and the average emission factor is shown in Table 2.2-1 for both uncontrolled and controlled emissions.

Table 2.2-1. VOC Emission Factors[a]

| | Fluidized-Bed Dryers | |
|---|---|---|
| Facility | Uncontrolled kg/Mg[a] | Wet-Scrubber kg/Mg |
| B | 0.65 | 0.087 |
| | 0.77 | 0.104 |
| | 0.81 | 0.126 |
| Average | 0.74 | 0.105 |

[a]Emission factors are expressed as emissions by weight per unit of ammonium sulfate production by weight.

It was assumed that the VOC emission factors for fluidized-bed dryers were also applicable to rotary dryers. This assumption was based on the fact that the VOC emissions were small. The test results showed that the controlled particulate emissions were nearly the same for both dryer types, and the amount of caprolactam in the process would be about the same in either case.

A summary of all the test results and test conditions is presented in Appendix B, page B-9 and B-10. The emission factors were converted from units of kg/Mg to lb/ton by multiplying by a factor of 2.

## 3.0 Emission Factor Rating

Emission factor rating of B was assigned according to the criteria specified in the document entitled, "Technical Procedures for Developing AP-42 Emission Factors and Preparing AP-42 Sections."

Rationale: The emission factors are above average, but not excellent. They were developed from A-rated test data, shown in Appendix B for four different facilities. At least three separate test runs were made at each test site. No specific bias in the data is evident and the facilities tested were representative of the industry. Since all emission factors were based on at least three test runs, a B-rating was assigned.

## 4.0 Reference

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

# APPENDIX A

## Description of Facilities

Description of Facilities

The following descriptions were taken from Reference 1, Appendix C, pp. 2-4.

Plant A

Gas-fired rotary dryer rated at 16.3 Mg/hr (18 TPH). AS particulate emissions are collected by a reverse jet type baghouse. Two sets of baghouse outlet emission tests were conducted at Plant A using EPA Method 5. The first set of outlet tests (Table C-2) was rejected due to discovery of some punctured bags which resulted in an abnormally high grain loading result. The second set of baghouse outlet tests (Table C-3) was conducted during a period of normal operation. Uncontrolled AS emissions and particle size distribution data were determined at the baghouse inlet (Tables C-1 and C-13, respectively). Visible emission observations were made at the baghouse exhaust using EPA Method 9 (Table C-17).

Plant B

Fluidized-bed dryer rated at 26.5 Mg/hr (29.2 TPH). The AS bed in this unit is fluidized by two streams of air: steam-heated air for drying the moisture-laden AS, introduced at the front end of the dryer, and ambient air for cooling of the AS product introduced at the back end of the dryer. AS particulate emissions from the dryer are controlled by a venturi scrubber. Emission tests were conducted only during periods when the process was operating normally. Scrubber inlet and outlet AS particulate levels were measured using EPA Method 5 (Tables C-4 and C-5). Particle size distribution data were determined at the scrubber inlet (Table C-14). Visible emission

observations were made of the stack gas leaving the scrubber using EPA Method 9 (Table C-18). Since Plant B is a caprolactam AS production facility, measurements were made of caprolactam emissions at both the scrubber inlet and outlet. Actual determinations of caprolactam concentrations were made using gas chromatograph methods and results are shown in Tables C-11 and C-12.

Plant C

Gas-fired rotary dryer rated at 15.2 Mg/hr (16.7 TPH). AS particulate emissions are collected by a wet scrubber of the centrifugal type. Emission tests were conducted during periods of normal operation. Scrubber inlet and outlet AS particulate levels were measured using EPA Method 5 (Tables C-6 and C-7). Particle-size distribution data were determined at the scrubber inlet (Table C-15). Visible emission observations were made of the stack gas leaving the scrubber using EPA Method 9 (Table C-19).

Observed opacities at Plant C range between 10 and 15 percent during the test. Controlled grain loading averaged 0.20 gr/dscm. The control equipment in this case is a centrifugal scrubber designed for a $\Delta P$ of approximately 6" W.G. and an L/G ratio of about 5.0 gal/1000 acfm. Actual values of these parameters could not be calculated from the available test data so it is not known whether one or both of these key scrubber factors were operating at design values.

Plant D

Gas-fired rotary dryer rated at 8.4 Mg/hr (9.2 TPH). AS particulate emissions are collected by a venturi scrubber. Scrubber inlet and outlet AS particulate levels were measured using EPA Method 5 (Tables C-8 and C-9). Particle-size distribution data were determined at the scrubber inlet (Table C-16). Visible emission observations were made of the stack gas leaving the scrubber using EPA Method 9 (Table C-20).

Observed opacities at Plant D were 0 percent during the test. Controlled grain loading averaged 0.192 grams/dscm. The control equipment in this case, a venturi scrubber, is designed for a $\Delta P$ of approximately 13 inches W.G. and a L/G ratio of about 27 gal/1000 acf. Actual values of these parameters could not be calculated from the available test data; so it is not known whether one or both of these key scrubber factors were operating at design values. The company, however, is not able to provide the original design data for this unit which was installed in 1965.[1] With respect to variations in process operation, it was indicated that the crystallizer at Plant D periodically goes into a fines cycle, lasting anywhere from 10 to 15 hours, during which time a much heavier proportion of AS fines is produced in the dryer product than is usual (approximately 4 to 5 times the normal amount).[2]

APPENDIX B

Summary of Results

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Facility A — Uncontrolled Particulate Emissions

| Run Number | 1 | 2 | 3 |
|---|---|---|---|
| Date | 9/12/78 | 9/12/78 | 9/13/78 |
| Test Time-Minutes | 120 | 120 | 120 |
| AS Production Rate - Mg/hr (TPH) | 15.8 (17.4) | 14.9 (16.4) | 18.7 (20.6) |
| **Dryer Vent Gas Data** | | | |
| Flow rate - acm/min (acfm) | 36.7 (1300) | 37.2 (1320) | 37.2 (1320) |
| Flow rate - dscm/min (dscfm) | 27.1 (960) | 26.8 (950) | 26.8 (950) |
| Temperature - °C (°F) | 67 (153) | 80 (176) | 76 (170) |
| Water vapor - Vol. % | 12.9 | 12.4 | 13.0 |
| **Particulate Emissions** | | | |
| **Probe and Filter Catch** | | | |
| gm/dscm (gr/dscf) | 2.29 (1.01) | 2.17 (0.96) | 8.69 (3.83) |
| gm/acm (gr/acf) | 1.70 (0.75) | 1.56 (0.69) | 6.26 (2.76) |
| kg/hr (lb/hr) | 3.8 (8.36) | 3.56 (7.84) | 14.1 (31.2) |
| kg/Mg (lb/ton) | 0.24 (0.48) | 0.24 (0.48) | 0.75 (1.51) |

Facility B — Uncontrolled Particulate Emissions

| Run Number | 1 | 2 | 3 |
|---|---|---|---|
| Date | 10/3/78 | 10/4/78 | 10/4/78 |
| Test Time-Minutes | 120 | 120 | 120 |
| AS Capacity* - Mg/hr (TPH) | 26.5 (29.2) | 26.5 (29.2) | 26.5 (29.2) |
| **Dryer Vent Gas Data** | | | |
| Flow rate - acm/min (acfm) | 1500 (53,100) | 1491 (52,800) | 1494 (52,900) |
| Flow rate - dscm/min (dscfm) | 1214 (43,000) | 1194 (42,300) | 1192 (42,200) |
| Temperature - °C (°F) | 83 (182) | 86 (188) | 86 (188) |
| Water vapor - Vol. % | 3.5 | 3.7 | 4.0 |
| **Particulate Emissions** | | | |
| **Probe and Filter Catch** | | | |
| gm/dscm (gr/dscf) | 39.7 (17.5) | 37.4 (16.5) | 40.1 (17.7) |
| gm/acm (gr/acf) | | | |
| kg/hr (lb/hr) | 2927 (6,440) | 2713 (5,970) | 2913 (6,410) |
| kg/Mg (lb/ton) | 110.5 (221) | 102 (204) | 114.5 (229) |

*Plant B was operating close to capacity at the time of testing. Actual production rate is held company-confidential.

Facility B — Controlled Particulate Emissions

| Run Number | 1 | 2 | 3 |
|---|---|---|---|
| Date | 10/3/78 | 10/4/78 | 10/4/78 |
| Test Time-Minutes | 120 | 120 | 120 |
| AS Capacity* - Mg/hr (TPH) | 26.5 (29.2) | 26.5 (29.2) | 26.5 (29.2) |
| **Stack Gas Data** | | | |
| Flow rate - acm/min (acfm) | 1646 (58,300) | 1629 (57,700) | 1644 (58,200) |
| Flow rate - dscm/min (dscfm) | 1443 (51,100) | 1418 (50,200) | 1440 (51,000) |
| Temperature - °C (°F) | 40 (105) | 43 (110) | 40 (104) |
| Water vapor - Vol. % | 6.1 | 6.1 | 6.4 |
| **Particulate Emissions** | | | |
| **Probe and Filter Catch** | | | |
| gm/dscm (gr/dscf) | 0.038 (0.017) | 0.018 (0.008) | 0.072 (0.032) |
| gm/acm (gr/acf) | 0.034 (0.015) | 0.015 (0.007) | 0.063 (0.028) |
| kg/hr (lb/hr) | 3.40 (7.50) | 1.62 (3.58) | 6.45 (14.2) |
| kg/Mg (lb/ton) | 0.13 (0.26) | 0.06 (0.12) | 0.24 (0.49) |

*Plant B was operating close to capacity at the time of testing. Actual production rate is held company-confidential.

| Facility C | UnControlled Particulate Emissions | | |
|---|---|---|---|
| Run Number | 1 | 2 | 3* |
| Date | | | |
| Test Time-Minutes | 1000 | 30 | |
| AS Production Rate - Mg/hr (TPH) | 6.09 (16.7) | 6.09 (16.7) | |
| Dryer Vent Gas Data | | | |
| Flow rate - acm/min (acfm) | 131.4 (4654) | 131.8 (4666) | - - |
| Flow rate - dscm/min (dscfm) | 99.9 (3537) | 92.9 (3290) | - - |
| Temperature - °C (°F) | 84 (184) | 82 (181) | - - |
| Water vapor - Vol. % | 7.2 | 14.2 | - |
| Particulate Emissions | | | |
| Probe and Filter Catch | | | |
| gm/dscm (gr/dscf) | 11.39 (5.02) | 6.35 (2.80) | - - |
| gm/acm (gm/acm) | 8.64 (3.81) | 4.47 (1.97) | - - |
| kg/hr (lb/hr) | 69.1 (152.2) | 3.58 (7.89) | - - |
| kg/Mg (lb/ton) | 4.55 (9.11) | 2.56 (4.72) | - - |

*Results of this run not included due to non-isokinetic sampling.

Facility C — Controlled Particulate Emissions

| | | | |
|---|---|---|---|
| **Run Number** | 1 | 2 | 3 |
| **Date** | 12/6/78 | 12/6/78 | 12/6/78 |
| **Test Time-Minutes** | 60 | 60 | 60 |
| **AS Production Rate - Mg/hr (TPH)** | 15.1 (16.7) | 15.1 (16.7) | 15.1 (16.7) |
| **Stack Gas Data** | | | |
| **Flow rate - acm/min (acfm)** | 121 (4313) | 120 (4255) | 119 (4245) |
| **Flow rate - dscm/min (dscfm)** | 97 (3436) | 93 (3304) | 100 (3542) |
| **Temperature - °C (°F)** | 60 (140) | 60 (140) | 57 (136) |
| **Water vapor - Vol. %** | 9.6 | 11.9 | 6.2 |
| **Particulate Emissions** | | | |
| **Probe and Filter Catch** | | | |
| **gm/dscm (gr/dscf)** | 0.155 (0.0686) | 0.256 (0.1132) | 0.208 (0.0918) |
| **gm/acm (gr/acf)** | 0.124 (0.0547) | 0.199 (0.0879) | 0.173 (0.0766) |
| **kg/hr (lb/hr)** | 0.90 (2.0) | 1.45 (3.2) | 1.27 (2.8) |
| **kg/Mg (lb/ton)** | 0.06 (0.12) | 0.095 (0.19) | 0.085 (0.17) |

Facility D — Uncontrolled Particulate Emissions

| Run Number | 1* | 2 | 3** | 4 |
|---|---|---|---|---|
| Date | 12/12/78 | 12/12/78 | 12/13/78 | 12/13/78 |
| Test Time-Minutes | -- | 110 | -- | 50 |
| AS Production Rate - Mg/hr | -- | 8.4 | 8.4 | 8.4 |
| (TPH) | -- | (9.3) | (9.3) | (9.3) |
| Dryer Vent Gas Data | | | | |
| Flow rate - acm/min | -- | 131 | -- | 143 |
| (acfm) | -- | (4652) | -- | (5092) |
| Flow rate - dscm/min | -- | 102 | -- | 113 |
| (dscfm) | -- | (3612) | -- | (3994) |
| Temperature - °C | -- | 81 | -- | 82 |
| (°F) | -- | (178) | -- | (181) |
| Water vapor - Vol. % | -- | 7.4 | -- | 6.1 |
| Particulate Emissions | | | | |
| Probe and Filter Catch | | | | |
| gm/dscm | -- | 103.23 | -- | 95.45 |
| (gr/dscf) | -- | (45.48) | -- | (42.05) |
| gm/acm | -- | 80.15 | -- | 74.93 |
| (gr/acf) | -- | (35.31) | -- | (33.01) |
| kg/hr | -- | 640 | -- | 654 |
| (lb/hr) | -- | (1408) | -- | (1439) |
| kg/Mg | -- | 75.5 | -- | 77.5 |
| (lb/ton) | -- | (151) | -- | (155) |

*Run No. 1 aborted due to test difficulties
**Run No. 3 data found to be invalid due to leak in sampling equipment

Facility D — Controlled Particulate Emissions

| Run Number | 1 | 2 | 3 |
|---|---|---|---|
| Date | 12/12/78 | 12/12/78 | 12/13/78 |
| Test Time-Minutes | 120 | 120 | 120 |
| AS Production Rate - Mg/hr (TPH) | 8.45 (9.3) | 8.45 (9.3) | 8.45 (9.3) |
| **Stack Gas Data** | | | |
| Flow rate - acm/min (acfm) | 131 (4663) | 124 (4399) | 139 (4929) |
| Flow rate - dscm/min (dscm) | 113 (4027) | 108 (3830) | 120 (4256) |
| Temperature - °C (°F) | 45 (114) | 43 (111) | 45 (114) |
| Water vapor - Vol. % | 7.4 | 7.1 | 7.1 |
| **Particulate Emissions** | | | |
| **Probe and Filter Catch** | | | |
| gm/dscm (gr/dscf) | 0.179 (0.079) | 0.118 (0.052) | 0.254 (0.122) |
| gm/acm (gr/acf) | 0.154 (0.068) | 0.102 (0.045) | 0.238 (0.105) |
| kg/hr (lb/hr) | 1.22 (2.7) | 0.77 (1.7) | 2.04 (4.5) |
| kg/Mg (lb/ton) | 0.145 (0.29) | 0.09 (0.18) | 0.24 (0.48) |

Facility B — Uncontrolled VOC Emissions

| Run Number | 1 | 2 | 3 |
|---|---|---|---|
| Date | 10/3/78 | 10/4/78 | 10/4/78 |
| Test Time-Minutes | 120 | 120 | 120 |
| AS Capacity* - Mg/hr (TPH) | 26.5 (29.2) | 26.5 (29.2) | 26.5 (29.2) |
| Stack Effluent | | | |
| Flow rate - acm/min (acfm) | 1497 (53,000) | 1491 (52,800) | 1494 (52,900) |
| Flow rate - dscm/min (dscfm) | 1214 (43,000) | 1194 (42,300) | 1192 (42,200) |
| Temperature - °C (°F) | 83 (182) | 86 (188) | 86 (188) |
| Water vapor - Vol. % | 3.5 | 3.7 | 4.0 |
| **Caprolactam Emissions** | | | |
| **Probe and Filter Catch** | | | |
| ppm | 1.90 | 4.67 | <0.35 |
| kg/hr (lb/hr) | 0.65 (1.44) | 1.58 (3.48) | <0.118 (0.26) |
| kg/Mg (lb/ton) | 0.024 (0.049) | 0.059 (0.119) | <0.004 (0.009) |
| **Total In Vapor Phase** | | | |
| ppm | 49.9 | 60.3 | 63.3 |
| kg/hr (lb/hr) | 17.18 (37.8) | 20.45 (45.0) | 21.45 (47.2) |
| kg/Mg (lb/ton) | 0.65 (1.30) | 0.77 (1.54) | 0.81 (1.62) |

*Plant B was operating close to capacity at the time of testing. Actual production rate is held company-confidential.

| Facility B | Controlled VOC Emissions | | |
|---|---|---|---|
| Run Number | 1 | 2 | 3 |
| Date | 10/3/78 | 10/4/78 | 10/4/78 |
| Test Time-minutes | 120 | 120 | 120 |
| AS Capacity* - Mg/hr (TPH) | 26.5 (29.2) | 26.5 (29.2) | 26.5 (29.2) |
| Stack Effluent | | | |
| Flow rate - acm/min (acfm) | 1646 (58,300) | 1629 (57,700) | 1644 (58,200) |
| Flow rate - dscm/min (dscfm) | 1443 (51,100) | 1418 (50,200) | 1440 (51,000) |
| Temperature - °C (°F) | 40 (105) | 43 (110) | 40 (104) |
| Water vapor - Vol. % | 6.1 | 6.1 | 6.4 |
| **Caprolactam Emissions** | | | |
| **Probe and Filter Catch** | | | |
| ppm | 0.201 | 0.26 | 0.28 |
| kg/hr (lb/hr) | 0.082 (0.181) | < 0.104 (0.28) | <0.113 (0.25) |
| kg/Mg (lb/ton) | 0.003 (0.006) | < 0.004 (0.008) | < 0.0045 (0.009) |
| **Total In Vapor Phase** | | | |
| ppm | 5.64 | 6.89 | 8.23 |
| kg/hr (lb/hr) | 2.31 (5.09) | 2.77 (6.10) | 3.36 (7.40) |
| kg/Mg (lb/ton) | 0.087 (0.174) | 0.104 (0.209) | 0.126 (0.253) |

*Plant B was operating close to capacity at the time of testing. Actual production rate is held company-confidential.