[With the publication of the Fifth Edition of AP-42, the Chapter and Section number for Urea changed to 8.2.]

BACKGROUND REPORT

AP-42 SECTION 6.14

UREA

Prepared for

U.S. Environmental Protection Agency
OAQPS/TSD/EIB
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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, 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 two source test reports to support revision of the process description and to verify the emission factors for urea.

Including the introduction (Chapter 1), this report contains four chapters. Chapter 2 gives a description of the urea 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 urea 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 includes the review of specific data sets, details criteria and noncriteria pollutant emission factor development, and presents the results of a data gap analysis. Appendix A presents AP-42 Section 6.14.

2.0 INDUSTRY DESCRIPTION

2.1 GENERAL

Urea [$CO(NH_2)_2$], also known as carbamide or carbonyl diamide, is marketed as a solution or in solid form. Most urea solution produced is used in fertilizer mixtures, with a small amount going to animal feed supplements. Most solids are produced as prills or granules for use as fertilizer, as a protein supplement in animal feed, and in plastics manufacturing. There are 29 urea plants in the U.S and about 7.3 million megagrams (8 million tons) of urea were produced in 1991. About 85 percent was used in fertilizers (both solid and liquid forms), 3 percent in animal feed supplements, and the remaining 12 percent in plastics and other uses.

2.2 PROCESS DESCRIPTION

The process for manufacturing urea involves a combination of up to seven major unit operations. These operations, illustrated by the flow diagram in Figure 2.2-1, are solution synthesis, solution concentration, solids formation, solids cooling, solids screening, solids coating, and bagging and/or bulk shipping.

The combination of processing steps is determined by the desired end products. For example, plants producing urea solution use only the solution formulation and bulk shipping operations. Facilities producing solid urea employ these two operations and various combinations of the remaining five operations, depending upon the specific end product being produced.

In the solution synthesis operation, ammonia (NH_3) and carbon dioxide (CO_2) are reacted to form ammonium carbamate ($NH_2CO_2NH_4$). Typical operating conditions include temperatures from 180 to 200°C (347 to 392°F), pressures from 140 to 250 atm (2050 to 3700 kpa), NH_3:CO_2 molar ratios from 3:1 to 4:1, and a retention time of 20 to 30 minutes. The

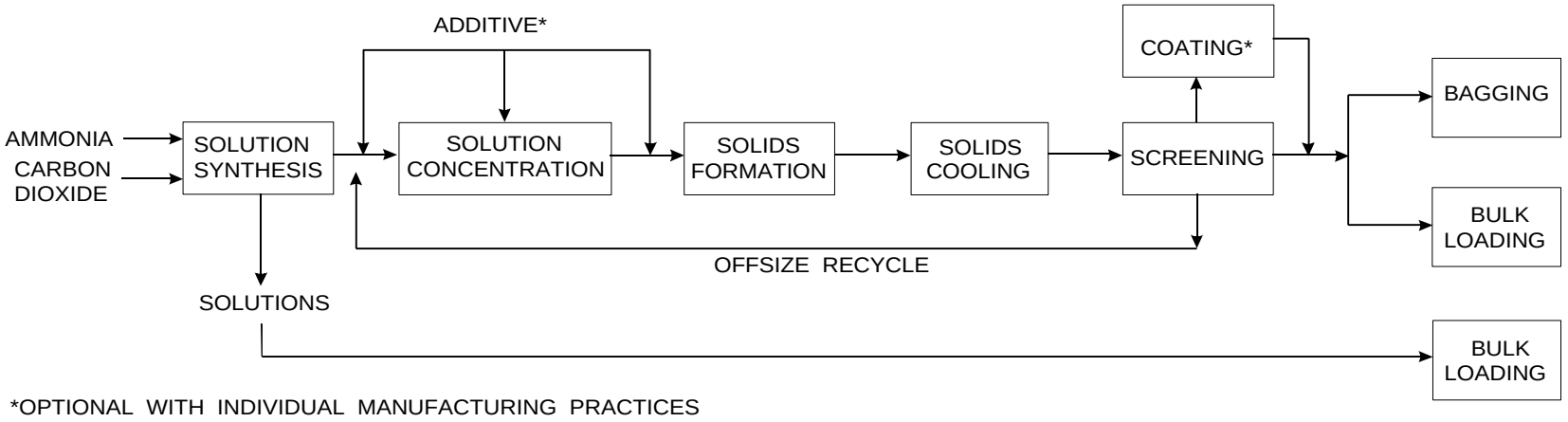

Figure 2.2-1 Major urea manufacturing operations

carbamate is then dehydrated to yield 70 to 77 percent aqueous urea solution. These reactions are as follows:

$$2\,NH_3 + CO_2 \rightarrow NH_2CO_2NH_4 \quad (1)$$

$$NH_2CO_2NH_4 \rightarrow NH_2CONH_2 + H_2O \quad (2)$$

The urea solution can be used as an ingredient of nitrogen solution fertilizers, or it can be concentrated further to produce solid urea.

The three methods of concentrating the urea solution are vacuum concentration, crystallization, and atmospheric evaporation. The method chosen depends upon the level of biuret ($NH_2CONHCONH_2$) impurity allowable in the end product. Aqueous urea solution begins to decompose at 60°C (140°F) to biuret and ammonia. The most common method of solution concentration is evaporation.

The concentration process furnishes urea "melt" for solids formation. Urea solids are produced from the urea melt by two basic methods: prilling and granulation. Prilling is a process by which solid particles are produced from molten urea. Molten urea is sprayed from the top of a prill tower. As the droplets fall through a countercurrent air flow, they cool and solidify into nearly spherical particles. There are two types of prill towers, fluidized bed and nonfluidized bed. The major difference is that a separate solids cooling operation may be required to produce agricultural grade prills in a nonfluidized bed prill tower.

Granulation is used more frequently than prilling in producing solid urea for fertilizer. Granular urea is generally stronger than prilled urea, both in crushing strength and abrasion resistance. There are two granulation methods, drum granulation and pan granulation. In drum granulation, solids are built up in layers on seed granules placed in a rotating drum granulator/cooler approximately 4.3 meters (14 feet) in diameter. Pan granulators also form the product in a layering process, but different equipment is used and pan granulators are not commonly used in the U.S.

The solids cooling operation is generally accomplished during solids formation, but for pan granulation processes and for some agricultural grade prills, some supplementary cooling is provided by auxiliary rotary drums.

The solids screening operation removes offsize product from solid urea. The offsize material may be returned to the process in the solid phase or be redissolved in water and returned to the solution concentration process.

Clay coatings are used in the urea industry to reduce product caking and urea dust formation. The coating also reduces the nitrogen content of the product. The use of clay coating has diminished considerably, being replaced by injection of formaldehyde additives into the liquid or molten urea before solids formation. Formaldehyde reacts with urea to methylenediurea, which is the conditioning agent. Additives reduce solids caking during storage and urea dust formation during transport and handling.

The majority of solid urea product is bulk shipped in trucks, enclosed railroad cars, or barges, but approximately 10 percent is bagged.

2.3 EMISSIONS AND CONTROLS

Emissions from urea manufacture are mainly ammonia, a hazardous air pollutant (HAP), and particulate matter. Formaldehyde and methanol (HAPs) may be emitted if additives are used. Formalin™, used as a formaldehyde additive, may contain up to 15 percent methanol. Ammonia is emitted during the solution synthesis and solids production processes. Particulate matter is the primary emission in urea processes. There have been no reliable measurements of free gaseous formaldehyde emissions. The chromotropic acid procedure that has been used to measure formaldehyde is not capable of distinguishing between gaseous formaldehyde and methylenediurea, the principle compound formed when the formaldehyde additive reacts with hot urea.

In the solution synthesis process, some emission control is inherent in the recycle process where carbamate gases and/or liquids are recovered and recycled. Typical emission sources from the solution synthesis process are noncondensable vent streams from ammonium carbamate decomposers and separators. Emissions from synthesis processes are generally combined with emissions from the solution concentration process and are vented through a common stack. Combined particulate emissions from urea synthesis and concentration operations are small compared to particulate emissions from a typical solids-producing urea plant. The synthesis and concentration operations are usually uncontrolled except for recycle provisions to recover ammonia. For this reason, no factor for controlled emissions from synthesis and concentration processes is given.

Uncontrolled emission rates from prill towers may be affected by the following factors: 1) product grade being produced, 2) air flow rate through the tower, 3) type of tower bed, 4) melt spray conditions, and 5) ambient temperature and humidity.

The total emissions for feed grade prill production is usually lower than for agricultural grade prills, due to lower airflows. Uncontrolled particulate emission rates for fluidized bed prill towers are higher than

those for nonfluidized bed prill towers making agricultural grade prills, and are approximately equal to those for nonfluidized bed feed grade prills. Ambient air conditions can affect prill tower emissions. Available data indicate that colder temperatures promote the formation of smaller particles in the prill tower exhaust. Since smaller particles are more difficult to remove, the efficiency of prill tower control devices tends to decrease with ambient temperature. This can lead to higher emission levels for prill towers operated during cold weather. Ambient humidity can also affect prill tower emissions. Air flow rates must be increased with high humidity, and higher air flow rates usually cause higher emissions.

The design parameters of drum granulators and rotary drum coolers may affect emissions. Drum granulators have an advantage over prill towers in that they are capable of producing very large particles without difficulty. Granulators also require less air for operation than do prill towers. A disadvantage of granulators is their inability to produce the smaller feed grade granules economically. To produce smaller granules, the drum must be operated at a higher seed particle recycle rate. It has been reported that, although the increase in seed material results in a lower bed temperature, the corresponding increase in fines in the granulator causes a higher emission rate. Cooling air passing through the drum granulator entrains approximately 10 to 20 percent of the product. This air stream is controlled with a wet scrubber, which is standard process equipment on drum granulators.

In the solids screening process, dust is generated by abrasion of urea particles and the vibration of the screening mechanisms. Therefore, almost all screening operations used in the urea manufacturing industry are enclosed or are covered over the uppermost screen. This operation is a small emission source; therefore, particulate emission factors from solids screening are not presented.

Emissions attributable to coating include entrained clay dust from loading and inplant transfer, and leaks from the seals of the coater. No emissions data are available to quantify this fugitive dust source.

Solid bagging operations are sources of particulate emissions. Dust is emitted during bagging when dust-laden air is displaced from the bag by urea. Bagging operations are conducted inside warehouses and are usually vented to keep dust out of the workroom area, as mandated by OSHA regulations. Most vents are controlled with baghouses. Nationwide, approximately 90 percent of solid urea produced is bulk loaded. Few plants control their bulk loading operations. Generation of visible fugitive particles is negligible.

Urea manufacturers presently control particulate matter emissions from prill towers, coolers, granulators, and bagging operations. With the exception of bagging operations, urea emission sources are usually controlled with wet scrubbers. Scrubber systems are preferred over dry collection systems primarily

for the easy recycling of dissolved urea collected in the device. Scrubber liquors are recycled to the solution concentration process to eliminate waste disposal problems and to recover the urea collected.

Fabric filters (baghouses) are used to control fugitive dust from bagging operations, where humidities are low and binding of the bags is not a problem. However, many bagging operations are uncontrolled.

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) Arcadian Corporation, Memphis, TN.
2) Arkansas Department of Pollution Control and Ecology, Little Rock, AK.
3) Chemical Manufacturers Association, Washington, DC.
4) Florida Department of Environmental Regulation, Tallahassee, FL.
5) Georgia Department of Natural Resources, Atlanta, GA.
6) J.R. Simplot Co., Pocatello, ID.
7) Kansas Department of Health and Environment, Topeka, KS.
8) Michigan Department of Natural Resources, Lansing, MI.
9) Missouri Department of Natural Resources, Jefferson City, MO.
10) Ohio Environmental Protection Agency, Bowling Green, OH.
11) Pennsylvania Department of Environmental Resources, Harrisburg, PA.
12) The Fertilizer Institute, Washington, DC.
13) Tennessee Valley Authority, Muscle Shoals, TN.

A source test report was received from Arcadian Corporation (Source #1) and from the Ohio EPA (Source #10). The source test report received from Arcadian provided controlled particulate and ammonia emissions from the urea prill tower. However, it did not provide any description of the type of prill tower used (fluidized bed or nonfluidized bed) or the type of urea produced (feed grade or agricultural grade) during the test. Therefore, the test report could not be used to update the emission factors for this revision. The report from the Ohio EPA summarized source tests for BP Chemicals from 1984 through 1988. Since this report did not provide any raw field data, production data, or test procedure documentation, it could not be used to revise the emission factors for this revision.

The only change made to the general and process description in this revision was the addition of 1991 urea production data provided by The Tennessee Valley Authority (TVA), Source #13. TVA provided a list of U.S. fertilizer producers and their fertilizer production capacities (Reference #13). The 1991 statistical data in Section 2.1 were obtained from this reference.

2.5 REFERENCES FOR CHAPTER 2

1. Urea Manufacturing Industry: Technical Document, EPA-450/3-81-001, U.S. Environmental Protection Agency, Research Triangle Park, NC, January 1981.

2. D.F. Bress, M.W. Packbier, "The Startup of Two Major Urea Plants," Chemical Engineering Progress, May 1977, p. 80.

3. Written communication from Gary McAlister, U.S. Environmental Protection Agency, Emission Measurement Branch, to Eric Noble, U.S. Environmental Protection Agency, Emission, Industrial Studies Branch, Research Triangle Park, NC, July 28, 1983.

4. Formaldehyde Use in Urea-Based Fertilizers, Report of the Fertilizer Institute's Formaldehyde Task Group, The Fertilizer Institute, Washington, DC, February 4, 1983.

5. J.H. Cramer, "Urea Prill Tower Control Meeting 20% Opacity." Presented at the Fertilizer Institute Environment Symposium, New Orleans, LA, April 1980.

6. Written communication from M.I. Bornstein, GCA Corporation, Bedford, MA, to E.A. Noble, U.S. Environmental Protection Agency, Research Triangle Park, NC, August 2, 1978.

7. Written communication from M.I. Bornstein and S.V. Capone, GCA Corporation, Bedford, MA, to E.A. Noble, U.S. Environmental Protection Agency, Research Triangle Park, NC, June 23, 1978.

8. Urea Manufacture: Agrico Chemical Company Emission Test Report, EMB Report 78-NHF-4, U.S. Environmental Protection Agency, Research Triangle Park, NC, April 1979.

9. Urea Manufacture: CF Industries Emission Test Report, EMB Report 78-NHF-8, U.S. Environmental Protection Agency, Research Triangle Park, NC, May 1979.

10. Urea Manufacture: Union Oil of California Emission Test Report, EMB Report 80-NHF-15, U.S. Environmental Protection Agency, Research Triangle Park, NC, September 1980.

11. Urea Manufacture: W.R. Grace and Company Emission Test Report, EMB Report 80-NHF-3, U.S. Environmental Protection Agency, Research Triangle Park, NC, December 1979.

12. Urea Manufacture: Reichhold Chemicals Emission Test Report, EMB Report 80-NHF-14, U.S. Environmental Protection Agency, Research Triangle Park, NC, August 1980.

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

3.0 GENERAL EMISSION DATA REVIEW AND ANALYSIS PROCEDURES

3.1 LITERATURE SEARCH AND SCREENING SOURCE TESTS

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

AP-42 background files maintained by the Emission Factor and Methodologies Section. PES obtained some of the references cited in the previous version of AP-42 Section 6.14 (January 1984) from the EPA background file. However, four of the references were missing. Therefore, PES obtained the missing references from other sources as discussed below.

EPA Library. PES obtained all of the missing references (References 8, 9, 11 and 12 as listed in Chapter 4) that were cited in the AP-42 Section 6.14 Urea emission factor table, but were not contained in the EPA background file.

Locating and Estimating reports (as applicable) published by the Emission Factor and Methodologies Section. PES did not find any new emission information related to urea production.

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 information was found from these databases.

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).

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 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

Uncontrolled and controlled emission factors for particulate and ammonia in the previous version of Section 6.14 (January 1984) were derived from five source test reports (References 8 through 12). Reference 14 (Emission Report for Agrico Chemical, September 1980) in the previous version of AP-42 was cited in the emission factor Table 6.14-1. However, PES has verified the emission factors and determined that Reference 14 was not used in developing the emission factors. Therefore, Reference 14 was removed from the list of references for this revision. Reference 17 (Emission Test Report for Union Oil, October 1979) in the previous version of AP-42 was not cited in Table 6.14-1 nor was it used in the text or in emission factor calculations. Therefore, Reference 17 was also removed from the list of references for Section 6.14.

Only one source test report (Reference 10) was available in the EPA background file for Section 6.14. The remaining test reports were obtained from the EPA Library. Reference 1 provided summaries of these test reports, but it was not sufficient to evaluate the accuracy of the original tests. The background file does not provide a clear explanation or written calculations on how the emission factors were developed. However, PES was able to verify both the uncontrolled and controlled particulate and ammonia emission factors shown in Table 6.14-1. The emission test reports used to developed the emission factors are discussed below.

Reference #8: Urea Manufacture: Agrico Chemical Company Emission Test Report, April 1979.

The test was conducted by The Research Corporation (TRC) at the inlet and outlet of the granulator. Each granulator has its own impingement type water scrubber. The granulator exhaust goes through a scrubber and fan prior to being discharged from a stack. The test was performed in accordance with prescribed EPA test methods to determine particulate and ammonia emissions. Ammonia analysis was done by direct Nesslerization with preliminary distillation/titrimetric method. The reports contains two tests which were conducted on two different dates. Emission tests at both the inlet and outlet of the scrubber were not performed simultaneously. The report was given an "A" rating. The production rates for the first test conducted at the scrubber inlet were 397, 387, and 350 tons per day, and particulate emission rates were 4726, 5594, and 4753 pounds per hour, respectively. Assuming the plant operated 24 hours per day, the average particulate emission factor at the inlet (uncontrolled) is then:

[4726/16.54 + 5594/16.12 + 4753/14.58]/3 = 319.6 pounds per ton.

Ammonia emission rates at the scrubber inlet were 39.19, 38.77, and 35.28 pounds per hour. Assuming the plant operated 24 hours per day, the average uncontrolled ammonia emission factor is then:

[39.19/16.54 + 38.77/16.12 + 35.28/14.58]/3 = 2.398 pounds per ton.

Production rates at the scrubber outlet were 392, 391, and 350 tons per day and particulate emission rates at the outlet were 2.523, 4.723, and 3.953 pounds per hour, respectively. Assuming the plant operated 24 hours per day, the average controlled particulate emission factor is then:

[2.523/16.33 + 4.723/16.29 + 3.953/14.58]/3 = 0.238 pounds per ton.

The production rates at the scrubber inlet for the second test were 397, 400, and 419 tons per day and particulate emission rates were 4946, 4629, and 4376 pounds per hour, respectively. Assuming the plant operated 24 hours per day, the average uncontrolled particulate emission factor is

[4946/16.54 + 4629/16.67 + 4376/17.46]/3 = 275.8 pounds per ton.

Ammonia emission rates at the scrubber inlet were 42.04, 26.45, and 27.94 pounds per hour. The average uncontrolled ammonia emission factor is thus

[42.04/16.54 + 26.45/16.67 + 27.94/17.46]/3 = 1.910 pounds per ton.

There were only two runs conducted at the granulator scrubber outlet for the second test. The production rates were 400 and 417 tons per day and particulate emission rates at the outlet were 5.86 and 1.57 pounds per hour, respectively. Assuming that the plant operated 24 hours per day, the average controlled particulate emission factor is thus

[5.86/16.67 + 1.57/17.38]/2 = 0.221 pounds per ton.

Reference 9: Urea Manufacture: CF Industries Emission Test Report, May 1979.

This emission test was conducted by TRC Environmental at the inlet and outlet of the granulator. The urea is made by seven granulators. Each granulator has its own impingement type water scrubber. The granulator exhaust goes through the scrubber fan and is discharged from a stack. The urea concentration in the samples was determined by the Kjeldahl method of analysis and is corrected for possible urea loss during analysis. Ammonia concentrations were determined by direct Nesslerization and corrected for possible conversion of urea to ammonia. The company kept the production and emission test rates confidential and only emission factors for each test run were available. The average corrected uncontrolled and controlled particulate emission factors are 127.2 and 0.244 pounds per ton, respectively. The average uncontrolled ammonia emission factor is 2.13 pounds per ton.

Another three test runs were performed by TRC at the urea synthesis tower vent. A filter was not used in the sampling point and only one sampling point was used because of physical restrictions imposed by the in-stack orifice nozzle. The average corrected particulate and ammonia emission factors are 0.0317 and 8.02 pounds per ton, respectively.

Reference #10: Urea Manufacture: Union Oil of California Emission Test Report, September 1980

The test was performed at the outlet of one of the prill tower scrubbers and at the inlet of the rotary drum cooler scrubber. However, this report was only used to determine uncontrolled particulate and ammonia emission factors for rotary drum cooler in the previous version (January 1984) of AP-42 Section 6.14. Urea analyses were performed with the p-dimethylaminobenzaldehyde (PDAB) method (with preliminary distillation). Ammonia analyses were performed with the specific ion electrode (SIE) method. The test was conducted during the production of fertilizer (agricultural) grade urea and the report was given an "A" rating. The production rate for three test runs at the rotary drum cooler scrubber inlet was 11.7 tons per hour. Particulate emissions rates were 107.60, 75.67, and 89.65 pounds per hour, and ammonia emission rates were 0.44, 0.64, and 0.72 pounds per hour, respectively. The uncontrolled particulate emission factor from the rotary drum cooler is thus

$$[(107.60 + 75.67 + 89.65)/11.7]/3 = 7.78 \text{ pounds per ton;}$$

and the uncontrolled ammonia emission factor is

$$[(0.44 + 0.64 + 0.72)/11.7]/3 = 0.051 \text{ pounds per ton.}$$

Reference #11: Urea Manufacture: W.R. Grace and Company Emission Test Report, December 1979.

Emission tests were conducted by TRC on the inlet and outlet of two of the eight fluidized bed prill tower scrubbers (A and C) during the production of both fertilizer and feed grade urea. In addition, emission tests were performed in the main solution formation vent on the synthesis tower vent during the production of feed grade urea. Urea concentrations were determined with the p-dimethylaminobenzaldehyde (PDAB) colorimetric analysis method. Direct Nessler method and specific ion electrode method were used in ammonia analysis. However, only direct Nessler method results from synthesis tower vent were used to determine ammonia emission factors for solution formation.

Production rates at the inlet and outlet of Scrubber A during fertilizer grade urea production were 43.5, 45.8, and 45.5 tons per hour. Particulate emission rates at the inlet were 39.35, 54.43, and 48.51 and

ammonia emission rates at the inlet were 15.93, 22.14, and 22.84 pounds per ton, respectively. The uncontrolled particulate emission factor for fluidized bed prilling is

[39.35/43.5 + 54.43/45.8 + 48.51/45.5]/3 = 1.053 pounds per ton,

and the uncontrolled ammonia emission factor is

[15.93/43.5 + 22.14/45.8 + 22.84/45.5]/3 = 0.450 pounds per ton.

Particulate emission rates at the outlet of Scrubber A were 2.478, 6.410, and 4.503 pounds per hour. The controlled particulate emission factor is thus

[2.478/43.5 + 6.410/45.8 + 4.503/45.5]/3 = 0.099 pounds per ton.

Production rates at the inlet and outlet of Scrubber C during agricultural grade production were 43.5, 45.8, and 45.5 tons per hour. Particulate emission rates at the inlet of Scrubber C were 24.80, 18.67, and 24.60 pounds per hour and ammonia emission rates were 11.01, 10.90, and 15.49 pounds per hour, respectively. The average uncontrolled particulate emission factor is

[24.80/43.5 + 18.67/45.8 + 24.60/45.5]/3 = 0.506 pounds per ton,

and the average uncontrolled ammonia emission factor is

[11.01/43.5 + 10.90/45.8 + 15.49/45.5]/3 = 0.277 pounds per ton.

Particulate emission rates at the outlet of Scrubber C were 2.750, 5.089, and 5.270 pounds per hour. The average controlled particulate emission factor is then

[2.750/43.5 + 5.089/45.8 + 5.270/45.5]/3 = 0.097 pounds per ton.

Production rates at the inlet and outlet of Scrubber A during feed grade urea production were 47.2, 47.4, and 45.9 tons per hour. Particulate emission rates at the inlet were 34.31, 51.96, and 48.07 pounds per hour and ammonia emission rates at the inlet were 46.24, 50.18, and 57.25 pounds per hour, respectively. The average uncontrolled particulate emission factor is

[34.31/47.2 + 51.96/47.4 + 48.07/45.9]/3 = 0.957 pounds per ton,

and the average uncontrolled ammonia emission factor is

[46.24/47.2 + 50.18/47.4 + 57.25/45.9]/3 = 1.095 pounds per ton.

Particulate emission rates at the outlet of Scrubber A were 2.213, 6.892, and 8.305 pounds per hour and ammonia emission rates were 21.33, 21.41, and 29.18 pounds per hour, respectively. The average controlled particulate emission factor is

[2.213/47.2 + 6.892/47.4 + 8.305/45.9]/3 = 0.124 pounds per ton,

and the average controlled ammonia emission factor is

[21.33/47.2 + 21.41/47.4 + 29.18/45.9]/3 = 0.513 pounds per ton.

Production rates at the inlet and outlet of Scrubber C during feed grade urea production were 47.2, 47.4, and 45.9 tons per hour. Particulate emission rates at the inlet were 37.20, 39.47, and 41.75 pounds per hour and ammonia emission rates were 48.86, 44.58, and 43.56 pounds per hour, respectively. The uncontrolled average particulate emission factor is

[37.20/47.2 + 39.47/47.4 + 41.75/45.9]/3 = 0.843 pounds per ton,

and the average uncontrolled ammonia emission factor is

[48.86/47.2 + 44.58/47.4 + 43.56/45.9]/3 = 0.975 pounds per ton.

Particulate emission rates at the outlet of Scrubber C were 2.703, 6.232, and 7.274 pounds per hour and ammonia emission rates were 23.52, 20.63, and 29.68 pounds per hour, respectively. The average controlled particulate emission factor is

[2.703/47.2 + 6.232/47.4 + 7.274/45.9]/3 = 0.116 pounds per ton,

and the average controlled ammonia emission factor is

[23.52/47.2 + 20.63/47.4 + 29.68/45.9]/3 = 0.527 pounds per ton.

The production rates at main vent test synthesis tower were 47.9, 47.9, and 49.9 tons per hour. Particulate emission rates were 0.578, 0.470, and 0.454 pounds per hour and ammonia emission rates were 1424.0, 1391.8, and 1391.7 pounds per ton, respectively. The average particulate emission factor is thus

[0.578/47.9 + 0.470/47.9 + 0.454/49.9]/3 = 0.0103 pounds per ton,

the ammonia emission factor is

[1,424.0/47.9 + 1,391.8/47.9 + 1,391.7/49.9]/3 = 28.89 pounds per ton.

Reference #12: Urea Manufacture: Reichhold Chemicals Emission Test Report

Emission testing was performed on the inlet and outlet of the Cleanable High Efficiency Air Filter (CHEAF) scrubber during production of fertilizer (agricultural) grade urea. The test consisted of two series: simultaneous inlet and outlet emissions tests with the scrubber preconditioning sprays off for test series A and on for test series B. Uncontrolled particulate and ammonia emission factors for nonfluidized bed prilling agricultural grade were calculated only from test series A. Particulate emissions at the inlet were 42.03, 30.42, and 64.75 pounds per hour and production rates were 12.0, 12.7, and 11.9 tons per hour, respectively. The average uncontrolled particulate emission factor for nonfluidized bed prilling for agricultural grade is thus

[(42.03/12.0) + (30.42/12.7) + (64.75/11.9)]/3 = 3.78 pounds per ton.

Ammonia emissions at the inlet were 10.39, 10.88, and 10.24 pounds per hour. The average uncontrolled ammonia emission factor for nonfluidized bed prilling for agricultural grade is thus

$$[(10.39/12.0) + (10.88/12.7) + (10.24/11.9)]/3 = 0.87 \text{ pounds per ton.}$$

Only runs two and three from test Series A were used to develop controlled particulate emission factor. The production rate for runs two and three was 12.1 tons per hour. The controlled particulate emissions rates for runs two and three were 0.6239 and 0.8899 pounds per hour, respectively. The controlled particulate emission factors for nonfluidized bed prilling for agricultural grade is thus

$$[(0.6239 + 0.8899)/12.1]/2 = 0.063 \text{ pounds per ton.}$$

4.2 CRITERIA POLLUTANT EMISSIONS DATA

No data on emissions of volatile organic compounds, lead, sulfur dioxide, nitrogen oxides, or carbon monoxide were found nor expected for urea manufacturing process. The remaining criteria pollutant, particulate matter, is discussed below.

Total Particulate Matter .

Five source test reports were cited in the previous version of Section 6.14 as being used in the development of the particulate emission factors (References 8, 9, 10, 11, and 12 of this chapter). A summary of both uncontrolled and controlled particulate emission factors for urea production is presented in Table 4.2-1.

Uncontrolled particulate emission factor for solution formation and concentration was derived by averaging the average emission factors from the main synthesis vent tower in References 9 and 11, but not in Reference 8 as reported in the previous version (January 1984) of Section 6.14. The average uncontrolled particulate emission factor from solution formation and concentration is

$$[0.0317 + 0.0103]/2 = 0.021 \text{ pounds per ton.}$$

Uncontrolled and controlled particulate emission factors for nonfluidized bed prilling for fertilizer (agricultural) grade urea production in the previous version of AP-42 were derived from Reference 12. The production rates at the inlet were 12.0, 12.7, and 11.9 tons per hour and particulate emission rates at the inlet were 42.03, 30.42, and 64.75 pounds per hour, respectively. The average uncontrolled particulate emission factor is

$$[(42.03/12.0 + 30.42/12.7 + 64.75/11.9)/3] = 3.8 \text{ pounds per ton.}$$

Only Runs 2 and 3 were used to determine controlled particulate emission factor. Production rate at the outlet for Runs 2 and 3 was 12.1 tons per hour and particulate emission rates at the outlet were 0.6239 and 0.8899 pounds per hour, respectively. The average controlled particulate emission factor is then

$$[(0.6239 + 0.8899)/12.1]/2 = 0.063 \text{ pounds per ton.}$$

The controlled particulate emission factor for nonfluidized bed prilling for agricultural grade is 0.063 pounds per ton, and not 0.064 pounds per ton as reported in the previous version of Ap-42.

Since nonfluidized and fluidized bed towers operate with approximately the same air flow during production of feed grade urea, uncontrolled particulate emissions are approximately the same for these two types of prill towers. Therefore, the uncontrolled particulate emission factor for nonfluidized bed prilling for feed grade urea production is the same as for fluidized bed prilling.

Uncontrolled and controlled particulate emission factors for fluidized bed prilling during both fertilizer (agricultural) and feed grade urea production were derived solely from Reference 11. During fertilizer grade urea production, eight scrubbers were used at the prill tower, but emissions from only two scrubbers (A and C) were tested. Therefore, the emission results from these two scrubbers were combined and multiplied by 4 to estimate emissions from eight scrubbers. During feed grade urea production, however, only four scrubbers were used at the prill tower, and emissions from only two scrubbers were tested. Therefore, the emission results from these two scrubbers were combined and multiplied by 2 to estimate emissions from four scrubbers. Total uncontrolled particulate emission factor for fluidized bed prilling tower during fertilizer grade urea production is

$$4 \times (1.053 + 0.506) = 6.2 \text{ pounds per ton.}$$

Total controlled particulate emission factor was 0.78 pounds per ton and calculated in a similar fashion.

Total uncontrolled particulate emission factor for fluidized bed prilling during feed grade urea production is

$$2 \times (0.957 + 0.843) = 3.6 \text{ pounds per ton.}$$

Total controlled particulate emission factor for fluidized bed prilling feed grade urea was calculated in a similar fashion. The controlled particulate emission factor is 0.48 pounds per ton.

Uncontrolled and controlled particulate emission factors for drum granulation in the previous version were derived from two tests reported in Reference 8 and one test reported in Reference 9. The average uncontrolled particulate emission factor from the drum granulator is

$$[319.6 + 275.8 + 127.2]/3 = 241 \text{ pounds per ton,}$$

and the average controlled particulate emission factor is

[0.238 + 0.221 + 0.244]/3 = 0.234 pounds per ton.

Uncontrolled particulate emission factor for rotary drum cooler was derived solely from Reference 10. Uncontrolled particulate emission factor from the rotary drum is 7.78 lb/ton, not 7.45 lb/ton as stated in the previous (January 1984) version of AP-42. Currently, no EPA test data are available to determine emission rates from any control devices used to control drum cooler emissions. The controlled particulate emission factor for rotary drum cooler in the previous version (0.2 lb/ton) was reported by one of the industry which used a tray type control device (Reference 1). Since PES was unable to obtain an emission test report for this industry, the controlled particulate emission factor for rotary drum cooler was then downgraded from "C" to "E."

Uncontrolled particulate emission factor for the bagging operation in the previous version of AP-42 (0.19 lb/ton) was provided by industry and not from an EPA source test. Therefore, the rating was downgraded from "C" to "E."

TABLE 4.2-1 (METRIC UNITS)
TOTAL PARTICULATE MATTER

Control Equipment	Test Rating	Test Method	Run #	Production Rate[a]	Emission Rate[b]	Emission Factor[c]
Reference 8. Granulator						
None	A	Colorimetric analysis	1	15.00	2144	142.93
			2	14.62	2537	173.53
			3	13.23	2156	162.96
			Average	14.28	2279	159.59
Reference 8. Granulator						
None	A	Colorimetric analysis	1	15.00	2243	149.53
			2	15.12	2104	139.15
			3	15.84	1989	125.57
			Average	15.32	2112	138.08
Reference 8. Granulator						
Scrubber	A	Colorimetric analysis	1	14.81	1.147	0.077
			2	14.78	2.147	0.145
			3	13.23	1.797	0.136
			Average	14.27	1.697	0.119
Reference 8. Granulator						
Scrubber	A	Colorimetric analysis	2	15.12	2.66	0.176
			3	15.77	0.79	0.050
			Average	15.45	1.73	0.113

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

TABLE 4.2-1 (METRIC UNITS)
TOTAL PARTICULATE MATTER (Continued)

Control Equipment	Test Rating	Test Method	Run #	Production Rate[a]	Emission Rate[b]	Emission Factor[c]
Reference 9. Granulator						
None	A	Kjeldahl analysis	1	d	d	59.65
			2	d	d	64.25
			3	d	d	67.00
			Average	d	d	63.63
Reference 9. Granulator						
Scrubber	A	Kjeldahl analysis	1	d	d	0.124
			2	d	d	0.128
			3	d	d	0.113
			Average	d	d	0.122
Reference 9. Main Synthesis Vent Tower						
None	A	Kjeldahl analysis	1	d	d	0.0135
			2	d	d	0.0189
			3	d	d	0.0153
			Average	d	d	0.0159
Reference 10. Rotary drum cooler						
None	A	PDAB Colorimetric Analysis	1	10.61	48.91	4.483
			2	10.61	34.40	3.242
			3	10.61	40.75	3.841
			Average	10.61	41.35	3.855

[a]Units in Mg/hr.
[b]Units in kg/hr.
[c]Units in kg/Mg of urea.
[d]Confidential.

TABLE 4.2-1 (METRIC UNITS)
TOTAL PARTICULATE MATTER (Continued)

Control Equipment	Test Rating	Test Method	Run #	Production Rate[a]	Emission Rate[b]	Emission Factor[c]
Reference 11. Fluidized bed prill tower (Agricultural grade)						
None (Stack A)	A	PDAB Colorimetric analysis	1	39.46	17.89	0.453
			2	41.55	24.74	0.595
			3	41.28	22.05	0.534
			Average	40.76	21.56	0.527
Reference 11. Fluidized bed prill tower (Agricultural grade)						
None (Stack A)	A	PDAB Colorimetric analysis	1	39.46	1.124	0.028
			2	41.55	2.908	0.070
			3	41.28	2.043	0.049
			Average	40.76	2.075	0.049
Reference 11. Fluidized bed prill tower (Feed grade)						
None (Stack A)	A	PDAB Colorimetric analysis	1	42.82	15.56	0.363
			2	43.00	23.57	0.548
			3	41.64	21.80	0.0524
			Average	42.49	20.31	0.478
Reference 11. Fluidized bed prill tower (Feed grade)						
Scrubber A	A	PDAB Colorimetric analysis	1	42.82	1.004	0.023
			2	43.00	3.126	0.073
			3	41.64	3.767	0.090
			Average	42.49	2.644	0.062

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

TABLE 4.2-1 (METRIC UNITS)
TOTAL PARTICULATE MATTER (Continued)

Control Equipment	Test Rating	Test Method	Run #	Production Rate[a]	Emission Rate[b]	Emission Factor[c]
Reference 11. Fluidized bed prill tower (Agricultural grade)						
None (stack C)	A	PDAB Colorimetric analysis	1	39.46	11.25	0.285
			2	41.55	8.47	0.204
			3	41.28	11.16	0.270
			Average	40.76	10.29	0.253
Reference 11. Fluidized bed prill tower (Agriculture grade)						
Scrubber C	A	PDAB Colorimetric analysis	1	39.46	1.247	0.032
			2	41.55	2.308	0.056
			3	41.28	2.390	0.058
			Average	40.76	1.982	0.049
Reference 11. Fluidized bed prill tower (Feed grade)						
None (Stack C)	A	PDAB Colorimetric analysis	1	42.82	16.87	0.394
			2	43.00	17.69	0.418
			3	41.64	18.94	0.455
			Average	42.49	17.92	0.422
Reference 11. Fluidized bed prill tower (Feed grade)						
Scrubber C	A	PDAB Colorimetric analysis	1	42.82	1.226	0.029
			2	43.00	2.827	0.066
			3	41.64	3.299	0.079
			Average	42.49	2.451	0.058

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

TABLE 4.2-1 (METRIC UNITS)
TOTAL PARTICULATE MATTER (Continued)

Control Equipment	Test Rating	Test Method	Run #	Production Rate[a]	Emission Rate[b]	Emission Factor[c]
Reference 11.	Main synthesis vent tower					
None	A	PDAB Colorimetric analysis	1	43.45	0.262	0.0060
			2	43.45	0.213	0.0049
			3	45.27	0.206	0.0046
			Average	44.06	0.227	0.0052
Reference 12.	Nonfluidized bed prill tower (Agricultural grade)					
Scrubber A	A	PDAB Colorimetric analysis	2	10.98	0.283	0.026
			3	10.98	0.404	0.037
			Average	10.98	0.344	0.031
Reference 12.	Nonfluidized bed prill tower (Agricultural grade)					
None	A	PDAB Colorimetric analysis	1	10.89	19.06	1.75
			2	11.52	13.80	1.20
			3	10.80	29.37	2.72
			Average	11.07	20.74	1.89

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

TABLE 4.2-1 (ENGLISH UNITS)
TOTAL PARTICULATE MATTER

Control Equipment	Test Rating	Test Method	Run #	Production Rate[a]	Emission Rate[b]	Emission Factor[c]
Reference 8. Granulator						
None	A	Colorimetric analysis	1	16.54	4726	285.73
			2	16.12	5594	347.02
			3	14.58	4753	325.99
			Average	15.75	5024	319.60
Reference 8. Granulator						
None	A	Colorimetric analysis	1	16.54	4946	299.03
			2	16.67	4629	277.68
			3	17.46	4376	250.63
			Average	16.89	4650	275.78
Reference 8. Granulator						
Scrubber	A	Colorimetric analysis	1	16.33	2.523	0.154
			2	16.29	4.723	0.290
			3	14.58	3.953	0.271
			Average	15.73	3.733	0.238
Reference 8. Granulator						
Scrubber	A	Colorimetric analysis	2	16.67	5.86	0.352
			3	17.38	1.57	0.090
			Average	3.46	3.72	0.221

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

TABLE 4.2-1 (ENGLISH UNITS)
TOTAL PARTICULATE MATTER (Continued)

Control Equipment	Test Rating	Test Method	Run #	Production Rate[a]	Emission Rate[b]	Emission Factor[c]
Reference 9. Granulator						
None	A	Kjeldahl analysis	1	d	d	119.3
			2	d	d	128.5
			3	d	d	134.0
			Average	d	d	127.2
Reference 9. Granulator						
Scrubber	A	Kjeldahl analysis	1	d	d	0.248
			2	d	d	0.255
			3	d	d	0.226
			Average	d	d	0.244
Reference 9. Main Synthesis Tower Vent						
None	A	Kjeldahl analysis	1	d	d	0.0271
			2	d	d	0.0377
			3	d	d	0.0306
			Average	d	d	0.0317
Reference 10. Rotary drum cooler						
None	A	PDAB Colorimetric analysis	1	11.70	107.60	9.197
			2	11.70	75.67	6.468
			3	11.70	89.65	7.686
			Average	11.70	90.97	7.784

[a]Units in ton/hr.
[b]Units in lb/hr.
[c]Units in lb/ton of urea.
[d]Confidential.

TABLE 4.2-1 (ENGLISH UNITS)
TOTAL PARTICULATE MATTER (Continued)

Control Equipment	Test Rating	Test Method	Run #	Production Rate[a]	Emission Rate[b]	Emission Factor[c]
Reference 11. Fluidized bed prill tower (Agricultural grade)						
None (Stack A)	A	PDAB Colorimetric analysis	1	43.5	39.35	0.905
			2	45.8	54.43	1.188
			3	45.5	48.51	1.066
			Average	44.9	47.15	1.053
Reference 11. Fluidized bed prill tower (Agricultural grade)						
Scrubber A	A	PDAB Colorimetric analysis	1	43.5	2.478	0.057
			2	45.8	6.410	0.140
			3	45.5	4.503	0.099
			Average	44.9	4.466	0.099
Reference 11. Fluidized bed prill tower (Feed grade)						
None (Stack A)	A	PDAB Colorimetric analysis	1	47.2	34.31	0.727
			2	47.4	51.96	1.096
			3	45.9	48.07	1.047
			Average	46.8	44.79	0.957
Reference 11. Fluidized bed prill tower (Feed grade)						
Scrubber A	A	PDAB Colorimetric analysis	1	47.2	2.213	0.047
			2	47.4	6.892	0.145
			3	45.9	8.305	0.181
			Average	46.8	5.782	0.124

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

TABLE 4.2-1 (ENGLISH UNITS)
TOTAL PARTICULATE MATTER (Continued)

Control Equipment	Test Rating	Test Method	Run #	Production Rate[a]	Emission Rate[b]	Emission Factor[c]
Reference 11. Fluidized bed prill tower (Agricultural grade)						
None (stack C)	A	PDAB Colorimetric analysis	1	43.5	24.80	0.570
			2	45.8	18.67	0.408
			3	45.5	24.60	0.541
			Average	44.9	22.66	0.506
Reference 11. Fluidized bed prill tower (Agricultural grade)						
Scrubber C	A	PDAB Colorimetric analysis	1	43.5	2.750	0.063
			2	45.8	5.089	0.111
			3	45.5	5.270	0.116
			Average	44.9	4.363	0.097
Reference 11. Fluidized bed prill tower (Feed grade)						
None (Stack C)	A	PDAB Colorimetric analysis	1	47.2	37.20	0.788
			2	47.4	39.47	0.833
			3	45.9	41.75	0.910
			Average	46.8	39.47	0.843
Reference 11. Fluidized bed prill tower (Feed grade)						
Scrubber C	A	PDAB Colorimetric analysis	1	47.2	2.703	0.057
			2	47.4	6.232	0.132
			3	45.9	7.274	0.158
			Average	46.8	5.433	0.116

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

TABLE 4.2-1 (ENGLISH UNITS)
TOTAL PARTICULATE MATTER (Continued)

Control Equipment	Test Rating	Test Method	Run #	Production Rate[a]	Emission Rate[b]	Emission Factor[c]
Reference 11. Main synthesis vent tower						
None	A	PDAB Colorimetric analysis	1	47.9	0.578	0.0121
			2	47.9	0.470	0.0098
			3	49.9	0.454	0.0091
			Average	48.6	0.500	0.0103
Reference 12. Nonfluidized bed prill tower (Agricultural grade)						
Scrubber A	A	PDAB Colorimetric analysis	2	12.1	0.624	0.052
			3	12.1	0.890	0.074
			Average	12.1	0.757	0.063
Reference 12. Nonfluidized bed prill tower (Agricultural grade)						
None	A	PDAB Colorimetric analysis	1	12.0	42.03	3.50
			2	12.7	30.42	2.40
			3	11.9	64.75	5.44
			Average	12.2	45.71	3.78

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

4.3 NONCRITERIA POLLUTANT EMISSIONS DATA

Hazardous Air Pollutants.

As discussed in Section 2.3, ammonia, a Title III hazardous air pollutant (HAP) is emitted in the urea manufacturing processes. Both uncontrolled and controlled ammonia emission factors in Table 6.14-1 in the previous version (January 1984) of AP-42 were verified and the data were presented in Table 4.3-1.

The source test report received from Arcadian Corporation (Reference 14) provided ammonia emissions data from the prill tower controlled by scrubbers. However, the data in this report could not be used to revise the existing emission factor since the report did not indicate the type of prill tower used (fluidized or nonfluidized bed) or the type of urea produced (feed grade or agricultural grade) during the test. Therefore, the existing controlled ammonia emission factors were left unchanged.

Uncontrolled ammonia emission factor for solution formation and concentration was derived by averaging the corrected average emission factors from References 9 and 11, not from References 8, 9, and 11 as reported in the previous version (January 1984) of Section 6.14. The average uncontrolled ammonia emission factor from solution formation is

$$[8.02 + 28.89]/2 = 18.46 \text{ pounds per ton.}$$

The average uncontrolled ammonia emission factor from solution formation is 18.46 pounds per ton, not 18.24 pounds per ton as reported in the previous version of AP-42. The discrepancy has been corrected in the current revision.

Uncontrolled ammonia emission factor for nonfluidized bed prilling for agricultural grade urea production in the previous version of AP-42 were derived from Reference 12. The production rates at the inlet were 12.0, 12.7, and 11.9 tons per hour and ammonia emission rates at the inlet were 10.39, 10.88, and 10.24 pounds per hour, respectively. The average uncontrolled ammonia emission factor is

$$[(10.39/12.0 + 10.88/12.7 + 10.24/11.9)/3] = 0.87 \text{ pounds per ton.}$$

Uncontrolled and controlled ammonia emission factors for fluidized bed prilling during both fertilizer (agricultural) and feed grade urea production were derived from Reference 11. During fertilizer grade urea production, eight scrubbers were used at the prill tower, but emissions from only two scrubbers (A and C) were tested. Therefore, the emission results from two scrubbers were combined and multiplied by 4 to reflect emissions from eight scrubbers. During feed grade urea production, however, only four scrubbers were used at the prill tower, and emissions from only two scrubbers were tested. Therefore, the emission results from two scrubbers were combined and multiplied by 2 to reflect emissions from four scrubbers.

Total uncontrolled ammonia emission factor for fluidized bed prilling during agricultural grade urea production is

$$4 \times (0.45 + 0.277) = 2.91 \text{ pounds per ton.}$$

Total uncontrolled ammonia emission factor for fluidized bed prilling during feed grade urea production is

$$2 \times (1.097 + 0.976) = 4.14 \text{ pounds per ton.}$$

Total controlled ammonia emission factor for fluidized bed prilling during feed grade urea production was calculated in similar fashion. The total controlled ammonia emission factor is 2.08 pounds per ton.

Uncontrolled ammonia emission factors for drum granulation in the previous version were derived from two tests reported in Reference 8 and one test reported in Reference 9. The average uncontrolled ammonia emission factor is

$$[2.398 + 1.910 + 2.130]/3 = 2.15 \text{ pounds per ton.}$$

Uncontrolled ammonia emission factors for rotary drum cooler were derived solely from Reference 10.

Test data have indicated that formaldehyde, also a HAP, is emitted during urea granular production (Reference 1). Formaldehyde has been added to the urea melt in recent years for the purpose of reducing urea dust emissions and to prevent solid urea product from caking during storage. Formaldehyde is added as an additive to the urea melt in concentrations of 0.5 percent or less prior to solids formation. The test data indicate that formaldehyde emissions range from 0.0020 kg/Mg (0.0040 lb/ton) of urea produced for a fluidized bed prill tower producing feed grade urea to 0.0095 kg/Mg (0.0190 lb/ton) of urea produced for a fluidized bed prill tower producing agricultural grade urea. However, the data were collected by the chromotropic analysis method which is not selective for free formaldehyde. Thus, the test results showed the total formaldehyde present both in free form or tied up in chemical compounds such as methylenediurea (MDU). MDU, a true conditioning agent, is formed by reacting formaldehyde with urea. Therefore, the emission factors for formaldehyde would not be included in this revision.

TABLE 4.3-1 (METRIC UNITS)
HAZARDOUS AIR POLLUTANTS: AMMONIA

Control Equipment	Test Rating	Test Method	Run #	Production Rate[a]	Emission Rate[b]	Emission Factor[c]
Reference 8. Granulator						
None	A	Nesslerization analysis	1	15.00	17.78	1.185
			2	14.62	17.59	1.203
			3	13.23	16.00	1.209
			Average	14.28	17.12	1.199
Reference 8. Granulator						
None	A	Nesslerization analysis	1	15.00	19.07	1.27
			2	15.12	12.00	0.79
			3	15.84	12.67	0.80
			Average	15.32	14.58	0.95
Reference 9. Granulator						
None	A	Nesslerization analysis	1	d	d	0.95
			2	d	d	1.02
			3	d	d	1.22
			Average	d	d	1.06
Reference 9. Main Synthesis Tower Vent						
None	A	Nesslerization analysis	1	d	d	d
			2	d	d	d
			3	d	d	d
			Average	d	d	4.01

[a]Units in Mg/hr.
[b]Units in kg/hr.
[c]Units in Mg/kg of urea.
[d]Confidential.

TABLE 4.3-1 (METRIC UNITS)
HAZARDOUS AIR POLLUTANTS: AMMONIA (Continued)

Control Equipment	Test Rating	Test Method	Run #	Production Rate[a]	Emission Rate[b]	Emission Factor[c]
Reference 10. Rotary drum cooler						
None	A	SIE	1	10.61	0.20	0.019
			2	10.61	0.29	0.027
			3	10.61	0.33	0.031
			Average	10.61	0.27	0.025
Reference 11. Fluidized bed prill tower (Agricultural grade)						
None (Stack A)	A	Nessler and SIE	1	39.46	7.23	0.183
			2	41.55	10.04	0.242
			3	41.28	10.36	0.251
			Average	40.76	9.21	0.225
Reference 11. Fluidized bed prill tower (Agricultural grade)						
None (Stack C)	A	Nessler and SIE	1	39.46	4.99	0.126
			2	41.55	4.94	0.119
			3	41.28	7.03	0.170
			Average	40.76	5.65	0.138
Reference 11. Fluidized bed prill tower (Feed grade)						
None (Stack A)	A	Nessler and SIE	1	42.82	20.97	0.490
			2	43.00	22.76	0.529
			3	41.64	25.97	0.624
			Average	42.49	23.23	0.548

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

TABLE 4.3-1 (METRIC UNITS)
HAZARDOUS AIR POLLUTANTS: AMMONIA (Continued)

Control Equipment	Test Rating	Test Method	Run #	Production Rate[a]	Emission Rate[b]	Emission Factor[c]
Reference 11. Fluidized bed prill tower (Feed grade)						
Scrubber A	A	Nessler and SIE	1	42.82	9.68	0.226
			2	43.00	9.71	0.226
			3	41.64	13.24	0.318
			Average	42.49	10.88	0.256
Reference 11. Main Synthesis vent tower						
None	A	Nessler and SIE	1	43.45	645.92	14.87
			2	43.45	631.32	14.53
			3	45.27	631.36	13.95
			Average	44.06	636.20	14.45
Reference 12. Nonfluidized bed prill tower (agricultural grade)						
None	A	Nessler and SIE	1	10.9	4.71	0.43
			2	11.5	4.94	0.43
			3	10.8	4.64	0.43
			Average	11.1	4.76	0.43

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

TABLE 4.3-1 (ENGLISH UNITS)
HAZARDOUS AIR POLLUTANTS: AMMONIA

Control Equipment	Test Rating	Test Method	Run #	Production Rate[a]	Emission Rate[b]	Emission Factor[c]
Reference 8. Granulator						
None	A	Nessler and SIE	1	16.54	39.19	2.369
			2	16.12	38.77	2.405
			3	14.58	35.28	2.420
			Average	15.75	37.75	2.398
Reference 8. Granulator						
None	A	Nessler and SIE	1	16.54	42.04	2.54
			2	16.67	26.45	1.59
			3	17.46	27.94	1.60
			Average	16.89	32.14	1.91
Reference 9. Granulator						
None	A	Nesslerization analysis	1	d	d	1.90
			2	d	d	2.03
			3	d	d	2.45
			Average	d	d	2.13
Reference 9. Main Synthesis Vent Tower						
None	A	Nesslerization analysis	1	d	d	d
			2	d	d	d
			3	d	d	d
			Average	d	d	8.02

[a]Units in ton/hr.
[b]Units in lb/hr.
[c]Units in lb/ton of urea.
[d]Confidential.

TABLE 4.3-1 (ENGLISH UNITS)
HAZARDOUS AIR POLLUTANTS: AMMONIA (Continued)

Control Equipment	Test Rating	Test Method	Run #	Production Rate[a]	Emission Rate[b]	Emission Factor[c]
Reference 10. Rotary drum cooler						
None	A	SIE	1	11.70	0.44	0.038
			2	11.70	0.64	0.055
			3	11.70	0.72	0.061
			Average	11.70	0.60	0.051
Reference 11. Fluidized bed prill tower (Agricultural grade)						
None (Stack A)	A	Nessler and SIE	1	43.5	15.93	0.366
			2	45.8	22.14	0.483
			3	45.5	22.84	0.502
			Average	44.9	20.30	0.450
Reference 11. Fluidized bed prill tower (Agricultural grade)						
None (Stack C)	A	Nessler and SIE	1	43.5	11.01	0.253
			2	45.8	10.90	0.238
			3	45.5	15.49	0.340
			Average	44.9	12.47	0.277
Reference 11. Fluidized bed prill tower (Feed grade)						
None (Stack A)	A	Nessler and SIE	1	47.2	46.24	0.980
			2	47.4	50.18	1.059
			3	45.9	57.25	1.247
			Average	46.8	51.22	1.095

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

TABLE 4.3-1 (ENGLISH UNITS)
HAZARDOUS AIR POLLUTANTS: AMMONIA (Continued)

Control Equipment	Test Rating	Test Method	Run #	Production Rate[a]	Emission Rate[b]	Emission Factor[c]
Reference 11. Fluidized bed prill tower (Feed grade)						
Scrubber A	A	Nessler and SIE	1	47.2	21.33	0.452
			2	47.4	21.41	0.452
			3	45.9	29.18	0.636
			Average	46.8	23.97	0.513
Reference 11. Synthesis Main Vent Tower						
None	A	Nessler and SIE	1	47.9	1424.0	29.73
			2	47.9	1391.8	29.06
			3	49.9	1391.9	27.89
			Average	48.57	1402.5	28.89
Reference 12. Nonfluidized bed prill tower (agricultural grade)						
None	A	Nessler and SIE	1	12.0	10.39	0.87
			2	12.7	10.88	0.86
			3	11.9	10.24	0.86
			Average	12.2	10.50	0.87

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

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 urea processes.

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 nor expected for urea processes.

4.4 DATA GAP ANALYSIS

Both particulate and ammonia emission factors in the previous version (January 1984) were derived from five source test reports (References 8 through 12) and not from seven source test reports as previously reported. PES has verified both particulate and ammonia emission factors shown in Table 6.14-1. Due to lack of response and information, the emission factors and some of the ratings were not changed. The controlled particulate emission factor for rotary drum cooler and the uncontrolled particulate emission factor for bagging were downgraded from "C" to "E" since they were not calculated from source tests.

4.5 REFERENCES FOR CHAPTER 4

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5. J.H. Cramer, "Urea Prill Tower Control Meeting 20% Opacity." Presented at the Fertilizer Institute Environment Symposium, New Orleans, LA, April 1980.

6. Written communication from M.I. Bornstein, GCA Corporation, Bedford, MA, to E.A. Noble, U.S. Environmental Protection Agency, Research Triangle Park, NC, August 2, 1978.

7. Written communication from M.I. Bornstein and S.V. Capone, GCA Corporation, Bedford, MA, to E.A. Noble, U.S. Environmental Protection Agency, Research Triangle Park, NC, June 23, 1978.

8. Urea Manufacture: Agrico Chemical Company Emission Test Report, EMB Report 78-NHF-4, U.S. Environmental Protection Agency, Research Triangle Park, NC, April 1979.

9. Urea Manufacture: CF Industries Emission Test Report, EMB Report 78-NHF-8, U.S. Environmental Protection Agency, Research Triangle Park, NC, May 1979.

10. Urea Manufacture: Union Oil of California Emission Test Report, EMB Report 80-NHF-15, U.S. Environmental Protection Agency, Research Triangle Park, NC, September 1980.

11. Urea Manufacture: W.R. Grace and Company Emission Test Report, EMB Report 78-NHF-3, U.S. Environmental Protection Agency, Research Triangle Park, NC, December 1979.

12. Urea Manufacture: Reichhold Chemicals Emission Test Report, EMB Report 80-NHF-14, U.S. Environmental Protection Agency, Research Triangle Park, NC, August 1980.

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

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/hr	2.205	lb/hr
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:

$$°F = 1.8(°C) + 32$$