# Emission Factor Documentation for AP-42
# Section 9.10.1.2

# SUGARBEET PROCESSING

## Final Report

**For U. S. Environmental Protection Agency**
**Office of Air Quality Planning and Standards**
**Emission Factor and Inventory Group**

**EPA Contract 68-D2-0159**
**Work Assignment No. 2-03 and 4-04**

**MRI Project No. 4602-03 and 4604-04**

**March 1997**

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For U. S. Environmental Protection Agency
Office of Air Quality Planning and Standards
Emission Factor and Inventory Group
Research Triangle Park, NC 27711

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NOTICE

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# PREFACE

This report was prepared by Midwest Research Institute (MRI) for the Office of Air Quality Planning and Standards (OAQPS), U. S. Environmental Protection Agency (EPA), under Contract No. 68-D2-0159, Work Assignment No. 2-03 and 4-04. Mr. Dallas Safriet was the EPA work assignment manager.

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# 1. 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 EPA to respond to new emission factor needs of EPA, State and local air pollution control programs, and industry.

An emission factor is a representative value that attempts to relate the quantity of a pollutant released to the atmosphere with an activity associated with the release of that pollutant. Emission factors usually are expressed as the weight of pollutant divided by the unit weight, volume, distance, or duration of the activity that emits the pollutant. The emission factors presented in AP-42 may be appropriate to use in a number of situations, such as making source-specific emission estimates for areawide inventories for dispersion modeling, developing control strategies, screening sources for compliance purposes, establishing operating permit fees, and making permit applicability determinations. The purpose of this report is to provide background information from test reports and other information to support preparation of AP-42 Section 9.10.1.2, Sugarbeet Processing.

This background report consists of five sections. Section 1 includes the introduction to the report. Section 2 gives a description of the sugarbeet processing industry. It includes a characterization of the industry, a description of the different process operations, a characterization of emission sources and pollutants emitted, and a description of the technology used to control emissions resulting from these sources. Section 3 is a review of emission data collection (and emission measurement) procedures. It describes the literature search, the screening of emission data reports, and the quality rating system for both emission data and emission factors. Section 4 details how the new AP-42 section was developed. It includes the review of specific data sets and a description of how candidate emission factors were developed. Section 5 presents the AP-42 Section 9.10.1.2, Sugarbeet Processing. Supporting documentation for emission factor development is presented in the Appendices.

# 2. INDUSTRY DESCRIPTION[1,2]

Sugarbeet processing is the production of sugar (sucrose) from sugarbeets. Byproducts of sugarbeet processing include pulp and molasses. Most of the molasses produced is processed further to remove the remaining sucrose. The pulp and most of the remaining molasses are mixed together, dried, and sold as livestock feed. The four-digit standard industrial classification (SIC) code for sugarbeet processing is 2063. The six-digit source classification code (SCC) for sugarbeet processing is 3-02-016; there are 16 eight-digit SCC's.

## 2.1 INDUSTRY CHARACTERIZATION[3]

In 1995, approximately 3,916,000 short tons of beet sugar were produced at 31 plants located in 12 States. Table 2-1 shows the number of sugarbeet processing plants by State. No new sugarbeet processing facilities have been built since the mid-1970's. In comparison to 1974, 25 fewer facilities are currently operating. However, the 31 facilities currently operating have been modified to produce more sugar more efficiently than the 56 facilities operating in 1974.

TABLE 2-1. SUGARBEET PROCESSING PLANTS BY STATE, 1996

| State | Number of plants |
|---|---|
| California | 4 |
| Colorado | 2 |
| Idaho | 3 |
| Michigan | 5 |
| Minnesota | 4 |
| Montana | 2 |
| Nebraska | 2 |
| New Mexico[a] | |
| North Dakota | 3 |
| Ohio | 1 |
| Oregon | 1 |
| Texas | 1 |
| Wyoming | 3 |
| Washington[a] | |

[a]State-produced small quantities of sugarbeets, but no sugarbeet processing plants are located in the State.

## 2.2 PROCESS DESCRIPTION[1,2,4,5]

Figures 2-1 and 2-2 are flow diagrams for a typical sugarbeet processing plant. Figure 2-1 shows the preprocessing operations and the livestock feed production operations, and Figure 2-2 shows the beet sugar production operations. Mechanically harvested sugarbeets are shipped to processing plants, where they are typically received by high-speed conveying and screening systems. The screening systems remove loose dirt from the beets and pinch the beet tops and leaves to facilitate separation from the beet roots. The conveyors transport the beets to storage areas and then to the final cleaning and trash removal operations that precede the processing operations. The beets are usually conveyed to the final cleaning

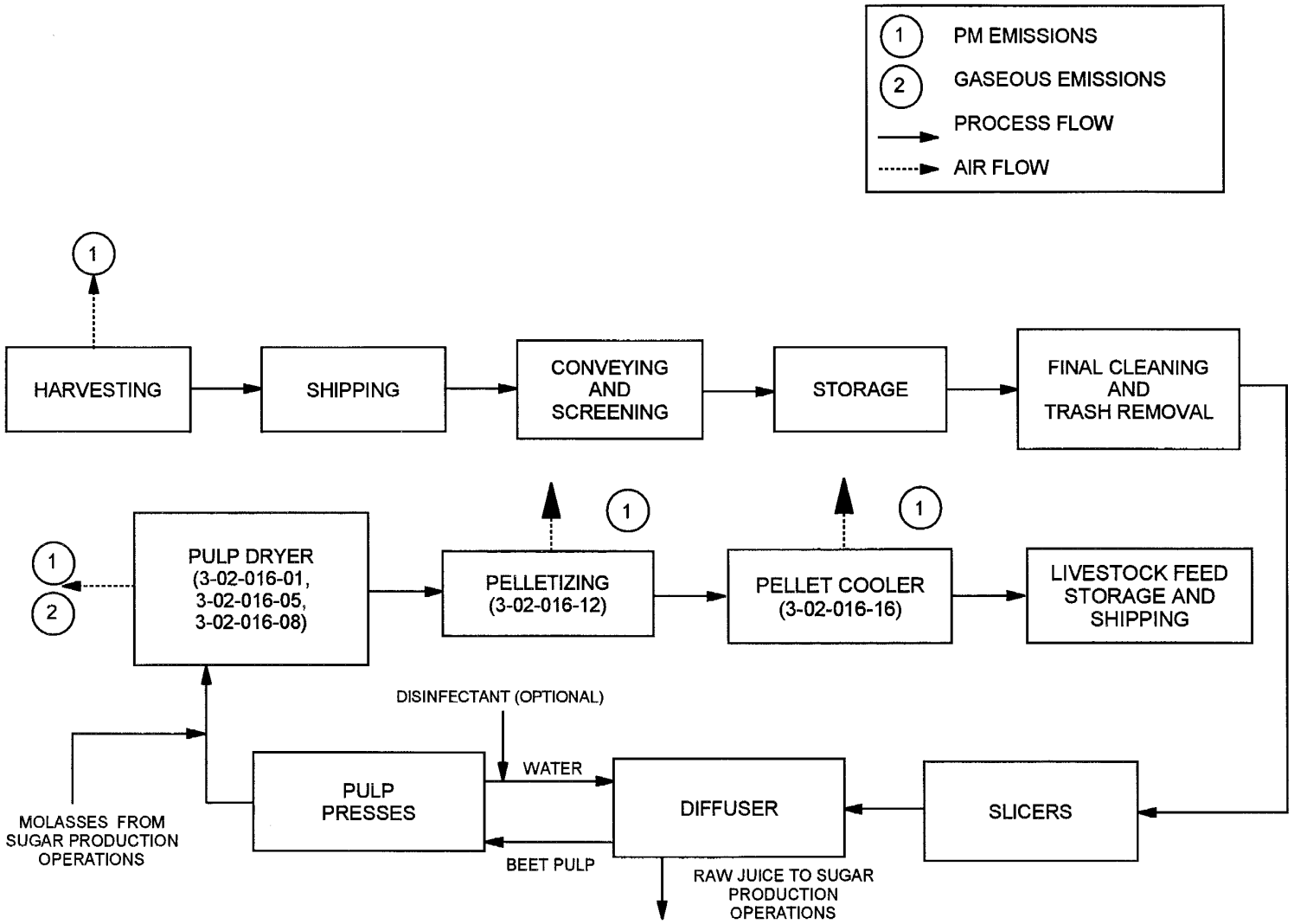


Figure 2-1. Preprocessing and livestock feed production operations at a sugarbeet processing plant. (Source Classification Code in parentheses.)

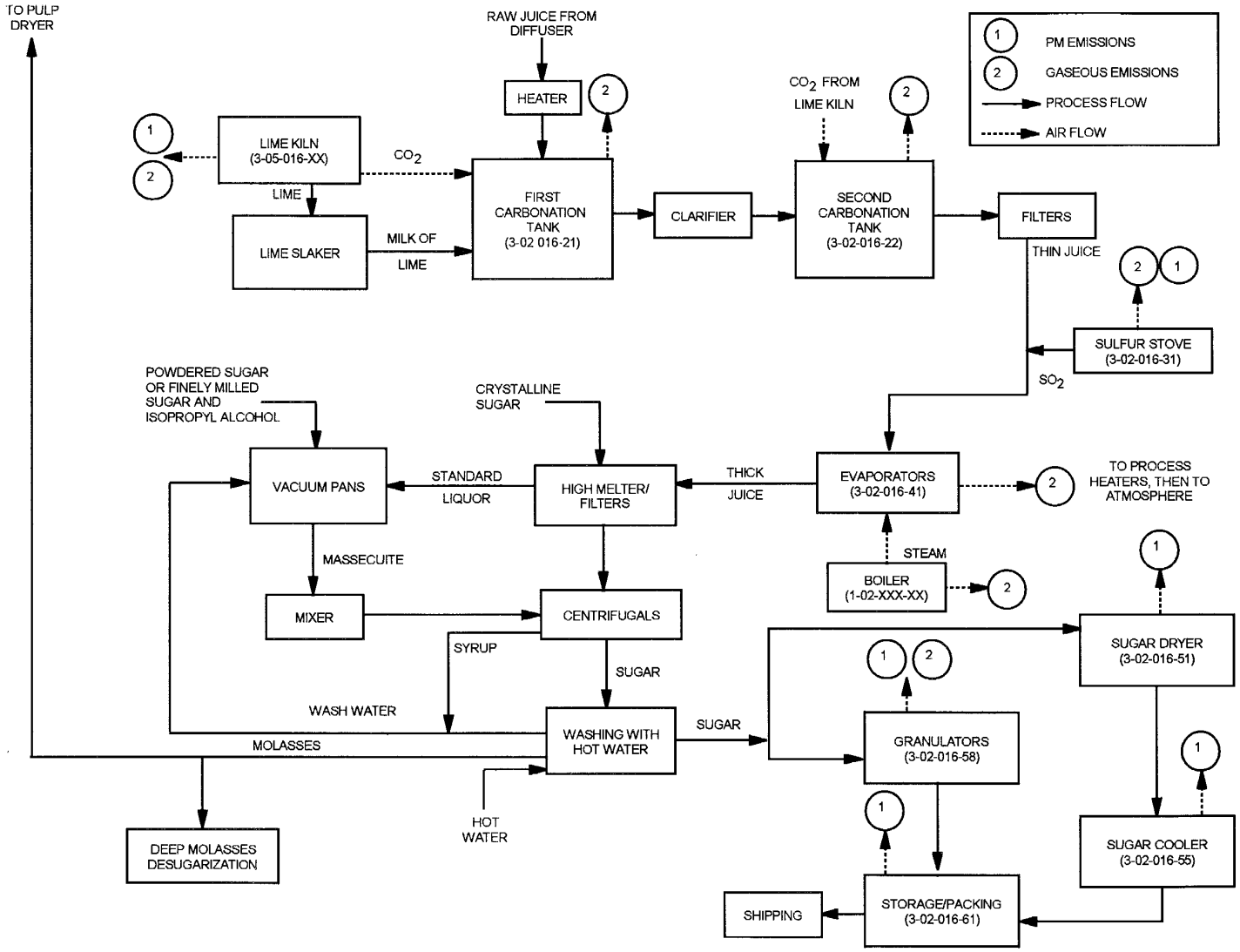


Figure 2-2. Sugar production operations at a sugarbeet processing plant.
(Source Classification Code in parentheses.)

phase using flumes, which use water to both move and clean the beets. Although most plants use flumes, some plants use dry conveyors in the final cleaning stage. The disadvantage of flume conveying is that some sugar leaches into the flume water from damaged surfaces of the beets. The flumes carry the beets to the beet feeder, which regulates the flow of beets through the system and prevents stoppages in the system. From the feeder, the flumes carry the beets through several cleaning devices, which may include rock catchers, sand separators, magnetic metal separators, water spray nozzles, and trash catchers. After cleaning, the beets are separated from the water, usually with a beet wheel, and are transported by drag chain, chain and bucket elevator, inclined belt conveyor, or beet pump to the processing operations.

Sugarbeet processing operations comprise several steps, including diffusion, juice purification, evaporation, crystallization, dried-pulp manufacture, and sugar recovery from molasses. Descriptions of these operations are presented in the following paragraphs.

Prior to removal of the sucrose from the beet by diffusion, the cleaned and washed beets are sliced into long, thin strips, called cossettes. The cossettes are conveyed to continuous diffusers, in which hot water is used to extract sucrose from the cossettes. In one diffuser design, the diffuser is slanted upwards and conveys the cossettes up the slope as water is introduced at the top of the diffuser and flows countercurrent to the cossettes. The water temperature in the diffuser is typically maintained between 50E and 80EC (122E and 176EF). This temperature is dependant on several factors, including the denaturization temperature of the cossettes, the thermal behavior of the beet cell wall, potential enzymatic reactions, bacterial activity, and pressability of the beet pulp. Formalin, a 40 percent solution of formaldehyde, was sometimes added to the diffuser water as a disinfectant but is not used at the present time. Sulfur dioxide, chlorine, ammonium bisulfite, or commercial FDA-approved biocides are also used as disinfectants. The sugar-enriched water that flows from the outlet of the diffuser is called raw juice and contains between 10 and 15 percent sugar. This raw juice proceeds to the juice purification operations. The processed cossettes, or pulp, leaving the diffuser are conveyed to the dried-pulp manufacture operations.

In the juice purification stage, non-sucrose impurities in the raw juice are removed so that the pure sucrose can be crystallized. First, the juice passes through screens to remove any small cossette particles. Then the mixture is heated to 80E to 85EC (176E to 185EF) and proceeds to the first carbonation tank. In some processes, the juice from the screen passes through a pre-limer, a heater, and a main limer before going to the first carbonation tank. In the first carbonation tank, milk of lime [$Ca(OH)_2$] is added to the mixture to adsorb or adhere to the impurities in the mixture, and carbon dioxide ($CO_2$) gas is bubbled through the mixture to precipitate the lime as insoluble calcium carbonate crystals. Lime kilns are used to produce the $CO_2$ and lime used in carbonation; the lime is converted to milk of lime in a lime slaker. The small, insoluble crystals (produced during carbonation) settle out in a clarifier, after which the juice is again treated with $CO_2$ (in the second carbonation tank) to remove the remaining lime and impurities. The pH of the juice is lower during this second carbonation, causing large, easily filterable, calcium carbonate crystals to form. After filtration, a small amount of sulfur dioxide ($SO_2$) is added to the juice to inhibit reactions that lead to darkening of the juice. Most facilities purchase $SO_2$ in liquid form, but a few facilities produce $SO_2$ by burning elemental sulfur in a sulfur stove. Following the addition of $SO_2$, the juice (known as thin juice) proceeds to the evaporators.

The evaporation process, which increases the sucrose concentration in the juice by removing water, is typically performed in a series of five evaporators. Steam from large boilers is used to heat the first evaporator, and the steam from the water evaporated in the first evaporator is used to heat the second evaporator. This transfer of heat continues through the five evaporators, and as the temperature decreases (due to heat loss) from evaporator to evaporator, the pressure inside each evaporator is also decreased,

allowing the juice to boil at the lower temperatures provided in each subsequent evaporator. Some steam is released from the first three evaporators, and this steam is used as a heat source for various process heaters throughout the plant. After evaporation, the percentage of sucrose in the "thick juice" is 50-65 percent. Crystalline sugars, produced later in the process, are added to the juice and dissolved in the high melter. This mixture is then filtered, yielding a clear liquid known as standard liquor, which proceeds to the crystallization operation.

Sugar is crystallized by low-temperature pan boiling. The standard liquor is boiled in vacuum pans until it becomes supersaturated. To begin crystal formation, the liquor is either "shocked" using a small quantity of powdered sugar or is "seeded" by adding a mixture of finely milled sugar and isopropyl alcohol. The seed crystals are carefully grown through control of the vacuum, temperature, feed-liquor additions, and steam. When the crystals reach the desired size, the mixture of liquor and crystals, known as massecuite or fillmass, is discharged to the mixer. From the mixer, the massecuite is poured into high-speed centrifugals, in which the liquid is centrifuged into the outer shell, and the crystals are left in the inner centrifugal basket. The sugar crystals are then washed with pure hot water and are sent to the granulator, which is a combination rotary drum dryer and cooler. Some facilities have separate sugar dryers and coolers, which are collectively called granulators. The wash water, which contains a small quantity of sucrose, is pumped to the vacuum pans for processing. After cooling, the sugar is screened and then either packaged or stored in large bins for future packaging.

The liquid that was separated from the sugar crystals in the centrifugals is called syrup. This syrup serves as feed liquor for the "second boiling" and is introduced back into the vacuum pans along with standard liquor and recycled wash water. The process is repeated once again, resulting in the production of molasses, which can be further desugarized using the an ion exchange process called deep molasses desugarization. Molasses that is not desugarized can be used in the production of livestock feed or for other purposes.

Wet pulp from the diffusion process is another product of sugarbeet processing. The pulp is first pressed, typically in horizontal double screw presses, to reduce the moisture content from about 95 percent to about 75 percent. The water removed by the presses is collected and used as diffusion water. After pressing, molasses is added to the pulp, which is then dried in a direct-fired horizontal rotating drum known as a pulp dryer. The pulp dryer, which can be fired by oil, natural gas, or coal, typically provides entrance temperatures between 482E and 927EC (900E and 1700EF). As the pulp is dried, the gas temperature decreases and the pulp temperature increases. The exit temperature of the flue gas is typically between 88E and 138EC (190E and 280EF). The resulting product is usually pelletized, cooled, and sold as livestock feed.

## 2.3 EMISSIONS[1,4,5]

Particulate matter (PM), combustion products, and volatile organic compounds (VOC) are the primary pollutants emitted from the sugarbeet processing industry. The pulp dryers, sugar granulators and coolers, sugar conveying and sacking equipment, lime kilns and handling equipment, carbonation tanks, sulfur stoves, evaporators, and boilers, as well as several fugitive sources are potential emission sources. Potential emissions from boilers are addressed in AP-42 Sections 1.1 through 1.4 (Combustion) and those from lime kilns are addressed in AP-42 Section 11.17, Lime Manufacturing. Potential sources of PM emissions include the pulp dryer and cooler, sugar granulators, dryers, and coolers, sugar conveying and sacking equipment, sulfur stove, and fugitive sources. Fugitive sources include unpaved roads, coal handling, and pulp loading operations. Although most facilities purchase $SO_2$, a few facilities still use sulfur stoves. The sulfur stove is a potential source of $SO_2$ emissions, and the pulp dryers may be

a potential source of nitrogen oxides ($NO_x$), $SO_2$, $CO_2$, carbon monoxide (CO), and VOC. Evaporators may be a potential source of $CO_2$, ammonia, $SO_2$, and VOC emissions from the juice. However, only the first three of five evaporators (in a typical five-stage system) release exhaust gases, and the gases may be used as a heat source for various process heaters before release to the atmosphere. Emissions from carbonation tanks are primarily water vapor but contain small quantities of ammonia ($NH_3$), VOC, and may also include $CO_2$ and other combustion gases from the lime kilns. There are no emission test data available for ammonia emissions from carbonation tanks.

## 2.4 EMISSION CONTROL TECHNOLOGY

Particulate matter emissions from pulp dryers are typically controlled by a cyclone or multiclone system, sometimes followed by a secondary device such as a wet scrubber or fabric filter. Wet scrubbers also provide some degree of control of some gaseous pollutants. Particulate matter emissions from granulators are typically controlled with wet scrubbers, and PM emissions from sugar conveying and sacking as well as lime dust handling operations are controlled by hood systems that duct the emissions to fabric filtration systems. Emissions from carbonation tanks and evaporators are not typically controlled.

## REFERENCES FOR SECTION 2


1. R.A. McGinnis, *Beet-Sugar Technology, Third Edition*, Beet Sugar Development Foundation, Fort Collins, CO, 1982.

2. *The Beet Sugar Story*, United States Beet Sugar Association, Washington, D.C., 1959.

3. *Directory of American Beet Sugar Companies*, United States Beet Sugar Association, Washington, D.C., 1997.

4. *Particulate, Aldehyde, and Semi-volatile Organic Compound (SVOC) Testing Report for the Pulp Dryer Stacks, 1st and 2nd Carbonation Tank Vents, and the Evaporator Heater Vents*, The Amalgamated Sugar Company, Nampa, ID, May 14, 1993.

5. *Emission Performance Testing of Four Boilers, Three Dryers, and One Cooler--Holly Sugar Corporation, Santa Maria, California*, Western Environmental Services, Redondo Beach, CA, June 1991.

# 3. GENERAL DATA REVIEW AND ANALYSIS PROCEDURES

## 3.1 LITERATURE SEARCH AND SCREENING

Data for this investigation were obtained from a number of sources within the Office of Air Quality Planning and Standards (OAQPS) and from outside organizations. The AP-42 background files located in the Emission Factor and Inventory Group (EFIG) were reviewed for information on the industry, processes, and emissions. The Factor Information and Retrieval (FIRE), Crosswalk/Air Toxic Emission Factor Data Base Management System (XATEF), and VOC/PM Speciation Data Base Management System (SPECIATE) data bases were searched by SCC code for identification of the potential pollutants emitted and emission factors for those pollutants. A general search of the Air CHIEF CD-ROM also was conducted to supplement the information from these data bases.

Information on the industry, including number of plants, plant location, and annual production capacities, was obtained from the *Directory of American Beet Sugar Companies* and other sources. The Aerometric Information Retrieval System (AIRS) data base also was searched for data on the number of plants, plant location, and estimated annual emissions of criteria pollutants. A number of sources of information were investigated specifically for emission test reports and data. A search of the Test Method Storage and Retrieval (TSAR) data base was conducted to identify test reports for sources within the sugarbeet processing industry. However, no test reports were located using the TSAR data base. The EPA library was searched for additional test reports. Using information obtained on plant locations, individual facilities and State and Regional offices were contacted about the availability of test reports. Publications lists from the Office of Research and Development (ORD) and Control Technology Center (CTC) were also searched for reports on emissions from the sugarbeet processing industry. In addition, representative trade associations, including the United States Beet Sugar Association and the American Society of Beet Sugar Technologists, were contacted for assistance in obtaining information about the industry and emissions. The trade associations suggested contacting individual sugarbeet processing companies to request test data. All of the test reports that were located were provided by individual companies.

To screen out unusable test reports, documents, and information from which emission factors could not be developed, the following general criteria were used:

1. Emission data must be from a primary reference:

a. Source testing must be from a referenced study that does not reiterate information from previous studies.

b. The document must constitute the original source of test data. For example, a technical paper was not included if the original study was contained in the previous document. If the exact source of the data could not be determined, the document was eliminated.

2. The referenced study should contain test results based on more than one test run. If results from only one run are presented, the emission factors must be down rated.

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.

## 3.2 DATA QUALITY RATING SYSTEM[1]

As part of the 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 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 (i.e., comparison of EPA Method 5 front half with 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.

Test data sets that were not excluded were assigned a quality rating. The rating system used was that specified by EFIG for preparing AP-42 sections. The data were rated as follows:

A—Multiple test runs that were performed using sound methodology and reported in enough detail for adequate validation. These tests do not necessarily conform to the methodology specified in EPA reference test methods, although these methods were 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 unproven or new methodology or that lacked a significant amount of background information.

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, and any variations in the sampling and process operation are noted. If a large spread between test results cannot be explained by information contained in the test report, the data are suspect and are 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 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[1]

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

A—Excellent: Developed from A- and B-rated source 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- or 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 industries. The source category is specific enough so that variability within the source category population may be minimized.

C—Average: Developed only from A-, B- and/or C-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. In addition, 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-, B-, and/or C-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 footnoted.

The use of these criteria is somewhat subjective and depends to an extent upon the individual reviewer. Details of the rating of each candidate emission factor are provided in Section 4.

## REFERENCE FOR SECTION 3

1. *Technical Procedures for Developing AP-42 Emission Factors and Preparing AP-42 Sections*, EPA-454/B-93-050, Office of Air Quality Planning and Standards, U. S. Environmental Protection Agency, Research Triangle Park, NC, October 1993.

# 4. AP-42 SECTION DEVELOPMENT

## 4.1 INTRODUCTION

This section describes how the AP-42 section on sugarbeet processing was developed. First, descriptions of data sets used for developing emission factors are presented, followed by a discussion of how emission factors were developed from the data. Finally, the development of the AP-42 section on sugarbeet processing is summarized.

## 4.2 REVIEW OF SPECIFIC DATA SETS

Twenty-five emission test reports were reviewed in the process of gathering data for developing emission factors. Data from one of the reports, Reference 18, were not used for emission factor development because the process data are presented without units. The other references are described in the following paragraphs.

### 4.2.1 Reference 1

This report documents a compliance test conducted at the Minnesota Beet Sugar Cooperative in Renville, Minnesota, on January 21, 1988. One of four stacks venting emissions from a fuel oil-fired pulp dryer (dryer A) followed by four cyclones (one for each stack) was tested for filterable PM, condensible PM, and carbon dioxide ($CO_2$) emissions. Particulate matter and $CO_2$ emissions were quantified using EPA Method 5 (including front- and back-half analysis) and EPA Method 3 (with an Orsat gas analyzer), respectively. Process data, including hourly wet beet pulp feed rates to the dryer, are included in the report. Because only one of four stacks venting dryer emissions was tested, the measured emissions were multiplied by four to estimate total dryer emissions. This calculation assumes that emissions from each of the four identical stacks are similar.

The data from this report are assigned a B rating. The test methodology appears to be sound, sufficient process data are provided, and adequate detail is included in the report. However, the assumption that emissions from each of the four identical stacks are similar may or may not be accurate. Pertinent test data, process data, and emission factor calculations are provided in Appendix A.

### 4.2.2 Reference 2

This report documents a compliance test conducted at the Minnesota Beet Sugar Cooperative in Renville, Minnesota, on December 14, 1988. One of four stacks venting emissions from a fuel oil-fired pulp dryer (dryer B) followed by four cyclones (one for each stack) was tested for filterable PM, condensible PM, and $CO_2$ emissions. Particulate matter and $CO_2$ emissions were quantified using EPA Method 5 (including front- and back-half analysis) and EPA Method 3 (with an Orsat gas analyzer), respectively. Process data, including hourly wet beet pulp feed rates to the dryer, are included in the report. Because only one of four stacks venting dryer emissions was tested, the measured emissions were multiplied by four to estimate total dryer emissions. This calculation assumes that emissions from each of the four identical stacks are similar.

The data from this report are assigned a B rating. The test methodology appears to be sound, sufficient process data are provided, and adequate detail is included in the report. However, the assumption that emissions from each of the four identical stacks are similar may or may not be accurate. Pertinent test data, process data, and emission factor calculations are provided in Appendix B.

### 4.2.3 Reference 3

This report documents a compliance test conducted at the Minnesota Beet Sugar Cooperative in Renville, Minnesota, on November 18, 1986. A stack venting emissions from both the sugar dryer (granulator) and cooler followed by two wet scrubbers (in parallel) was tested for filterable PM and $CO_2$ emissions. The scrubber water flow rate is about six gallons per minute, and the pressure drop across the scrubber was not specified in the report. Particulate matter and $CO_2$ emissions were quantified using EPA Methods 5 and 3 (with an Orsat gas analyzer), respectively. Because very small amounts (0.03 percent volume) of $CO_2$ were detected during all test runs, $CO_2$ emissions are assumed to be negligible. Process data, including an average sugar production rate, are included in the report.

The data from this report are assigned a B rating. The test methodology appears to be sound, sufficient process data are provided, and adequate detail is included in the report (except for the omission of the scrubber pressure drop). Pertinent test data, process data, and emission factor calculations are provided in Appendix C.

### 4.2.4 Reference 4

This report documents a compliance test conducted at the Minn-Dak Farmers Cooperative in Wahpeton, North Dakota, on October 18, 1983. Two stacks venting emissions from a lignite coal-fired pulp dryer followed by a bank of 28 cyclones were tested for filterable PM, sulfur dioxide ($SO_2$), and $CO_2$ emissions. The exhaust stream following the cyclones is split. Most of the exhaust is released through a stack, and a portion of the exhaust is used as a heat source for the flume water heater prior to release to the atmosphere. The two stacks tested were the main exhaust stack and the flume water heater stack, which vent all of the emissions from the dryer. Particulate matter, $SO_2$, and $CO_2$ emissions were quantified using EPA Methods 5 (including front- and back-half analysis), 6, and 3 (with an Orsat gas analyzer), respectively. Process data, including wet beet pulp feed rates to the dryer (during each test run), are included in the report.

The data from this report are assigned an A rating. The test methodology appears to be sound, sufficient process data are provided, and adequate detail is included in the report. Pertinent test data, process data, and emission factor calculations are provided in Appendix D.

### 4.2.5 Reference 5

This report documents a test conducted at the Amalgamated Sugar Company in Nampa, Idaho, on October 14 through December 3, 1992. The purpose of the test was to satisfy the requirements of a consent order from the Idaho Department of Health and Welfare. Three coal-fired pulp dryers (north, central, and south dryers) were tested for filterable and condensible PM emissions, the north and central dryers were tested for aldehyde emissions, and the north dryer was tested for semi-volatile organic compound (SVOC) emissions. In addition, the B-side first carbonation tank and second carbonation heater vents (venting emissions from the B-side first evaporator) were tested for SVOC emissions, and the B-side second carbonation tank, A-side No. 2 thin juice heater vent (venting emissions from the A-side first evaporator), and B-side second carbonation heater vent (venting emissions from the B-side first evaporator) were tested for aldehyde emissions. Filterable PM, condensible PM, aldehyde, and SVOC emissions were quantified using EPA Method 5, EPA Method 202, Modified EPA Method 5 (midget and standard impingers), and SW846 Method 0010, respectively. Table 4-1 shows a summary of the testing conducted, data ratings, and important details about the testing. Pertinent test data, process data, and emission factor calculations are provided in Appendix E.

TABLE 4-1. REFERENCE 5; TESTS CONDUCTED AND DATA RATINGS

| Source tested | Pollutant | No. of test runs | Data rating | Comments |
|---|---|---|---|---|
| North pulp dryer | Filterable PM | 7 | NR | Scrubber not typical |
| | Condensible PM | 7 | NR | |
| | Aldehydes | 6 | C | Incomplete data sets included in report |
| | SVOC[a] | 6 | C | Incomplete data sets included in report; production rates assumed similar to rates during aldehyde tests; some equipment problems occurred |
| Central pulp dryer | Filterable PM | 3 | A | Sum of emissions from east and west stacks; scrubber parameters--4-inch pressure drop, no water sprays, low impingement velocity |
| | Condensible PM | 3 | A | |
| | Aldehydes | 3 | C | Incomplete data sets included in report |
| South pulp dryer | Filterable PM | 4 | B | Emission from one of two stacks were sampled and doubled to represent both stacks; run 5 not used because scrubber was not operating typically; scrubber parameters--4-inch pressure drop, water sprays, high impingement velocity |
| | Condensible PM | 4 | B | |
| B-side first carbonation tank | SVOC | 3 | B | Average process rate in 1,000 gal/hr; samples were diluted during analysis |
| B-side second carbonation tank | Aldehydes | 1 | D | Only one test run conducted; process rate in 1,000 gal/hr |
| A-side No. 2 thin juice heater (first evaporator) | Aldehydes | 3 | C | Process rates in 1,000 gal/hr; high stack gas moisture content and temperature caused several problems that may have affected results |
| B-side second carbonation heater (first evaporator) | Aldehydes | 3 | C | Only one set of flow data for three test runs; process rates in 1,000 gal/hr; high stack gas moisture content and temperature caused several problems that may have affected results |
| | SVOC | 4 | C | Process rates in 1,000 gal/hr; high stack gas moisture content and temperature caused several problems that may have affected results |

[a]Data for a specific pollutant are rated C if three or more of the six test runs detected the pollutant. If a specific pollutant was detected in less than three test runs, the data for that pollutant are not rated.

### 4.2.6 Reference 6

This report documents a compliance test conducted at the Monitor Bay Sugar Company in Bay City, Michigan, on October 12, 1992. Two stacks, the north and south stacks, venting emissions from natural gas-fired pulp dryer No. 3 were tested for filterable PM and $CO_2$ emissions. Each stack was equipped with multiclones followed by a wet scrubber operating with a pressure drop of about 4 inches

water column (in. w.c.). Particulate matter and $CO_2$ emissions were quantified using EPA Methods 5 and 3 (with an Orsat gas analyzer), respectively. Process data, including hourly wet beet pulp feed rates to the dryer, are included in the report.

The data from this report are assigned an A rating. The test methodology appears to be sound, sufficient process data are provided, and adequate detail is included in the report. Pertinent test data, process data, and emission factor calculations are provided in Appendix F.

4.2.7 Reference 7

This report documents a compliance test conducted at the Monitor Bay Sugar Company in Bay City, Michigan, on October 13, 1992. Natural gas-fired pulp dryer No. 2, followed by multiclones and a wet scrubber operating with a pressure drop of about 4 in. w.c., was tested for filterable PM and $CO_2$ emissions. Particulate matter and $CO_2$ emissions were quantified using EPA Methods 5 and 3 (with an Orsat gas analyzer), respectively. Process data, including hourly wet beet pulp feed rates to the dryer, are included in the report.

The data from this report are assigned an A rating. The test methodology appears to be sound, sufficient process data are provided, and adequate detail is included in the report. Pertinent test data, process data, and emission factor calculations are provided in Appendix G.

4.2.8 Reference 8

This report documents a compliance test conducted at the Monitor Bay Sugar Company in Bay City, Michigan, on October 14, 1992. Natural gas-fired pulp dryer No. 1, followed by multiclones and a wet scrubber operating with a pressure drop of about 4 in. w.c., was tested for filterable PM and $CO_2$ emissions. Particulate matter and $CO_2$ emissions were quantified using EPA Methods 5 and 3 (with an Orsat gas analyzer), respectively. Process data, including hourly wet beet pulp feed rates to the dryer, are included in the report.

The data from this report are assigned an A rating. The test methodology appears to be sound, sufficient process data are provided, and adequate detail is included in the report. Pertinent test data, process data, and emission factor calculations are provided in Appendix H.

4.2.9 Reference 9

This report documents a compliance test conducted at the Western Sugar Company in Billings, Montana, on December 8-9, 1988. The east natural gas-fired pulp dryer, followed by a wet scrubber, was tested for filterable PM, condensible inorganic PM, and $CO_2$ emissions. Particulate matter emissions were quantified using EPA Method 5 (including front- and back-half analyses) and $CO_2$ emissions were measured using EPA Method 3 (with an Orsat gas analyzer). Process data, including an average wet beet pulp feed rate to the dryer, are included in the report.

The data from this report are assigned a B rating. The test methodology appears to be sound and sufficient process data are provided. However, the scrubber pressure drop is not provided in the report, and only an average process rate is provided. Pertinent test data, process data, and emission factor calculations are provided in Appendix I.

4.2.10 Reference 10

This report documents a compliance test conducted at the Western Sugar Company in Billings, Montana, on January 23-25, 1990. The west natural gas-fired pulp dryer, followed by a wet scrubber, was tested for filterable PM, condensible inorganic PM, and $CO_2$ emissions. Particulate matter emissions were quantified using EPA Method 5 (including front- and back-half analyses) and $CO_2$ emissions were

measured using EPA Method 3 (with an Orsat gas analyzer). Process data, including run-by-run wet beet pulp feed rates to the dryer, are included in the report.

The data from this report are assigned a B rating. The test methodology appears to be sound and sufficient process data are provided. However, the scrubber pressure drop is not provided in the report. Pertinent test data, process data, and emission factor calculations are provided in Appendix J.

4.2.11 Reference 11

This report documents a compliance test conducted at the Western Sugar Company in Billings, Montana, on January 23-25, 1991. A natural gas-fired pulp dryer, followed by a wet scrubber, was tested for filterable PM and condensible inorganic PM emissions. Particulate matter emissions were quantified using EPA Method 5 (including front- and back-half analyses). An average wet beet pulp feed rate to the dryer is included in the report. The pellet cooler was also tested, but process data for the pellet cooler are not provided in the report.

The data for emissions from the pulp dryer are assigned a C rating. The test methodology appears to be sound and process data are provided. However, only an average process rate based on historical data is provided, and the scrubber pressure drop in not provided in the report. Pertinent test data, process data, and emission factor calculations are provided in Appendix K.

4.2.12 Reference 12

This report documents a compliance test conducted at the Western Sugar Company in Scottsbluff, Nebraska, on December 12-13, 1989. A pulverized coal-fired pulp dryer, followed by a cyclone and wet scrubber (operating with a pressure drop of about 2 in. w.c.) on each of two stacks, was tested for filterable PM, condensible inorganic PM, and $CO_2$ emissions. Particulate matter and $CO_2$ emissions were quantified using EPA Methods 5 (including front- and back-half analyses) and 3, respectively. Process data, including run-by-run wet beet pulp feed rates to the dryer, are included in the report.

The data from this report are assigned an A rating. The test methodology appears to be sound, sufficient process data are provided, and adequate detail is included in the report. Pertinent test data, process data, and emission factor calculations are provided in Appendix L.

4.2.13 Reference 13

This report documents a compliance test conducted at Holly Sugar Corporation in Sidney, Montana, on October 19-23, 1993. Two No. 6 fuel oil-fired pulp dryers (north and south dryers) were tested for filterable PM, condensible inorganic PM, PM-10, $SO_2$, and $CO_2$ emissions. Emissions from the dryers were ducted to four stacks (two for each dryer), each equipped with a dry scrubber with skimmer fans and cyclones. Filterable PM, condensible PM, PM-10, $SO_2$, and $CO_2$ emissions were quantified using EPA Methods 5, 202, 201A, 6, and 3 (with an Orsat gas analyzer), respectively. Process data, including wet beet pulp feed rates to the dryer (during each test run), are included in the report. Plant personnel indicated that half of the beet pulp processed is fed to each dryer, and the process data are based on this estimate.

Several problems and deficiencies were encountered in this report. First, only one valid PM-10 test run (Run 1) was conducted on the north dryer (east stack), and two valid PM-10 test runs were conducted on the north dryer (west stack). To estimate PM-10 emissions from the north dryer, the PM-10 emission rate from each of the three single stack test runs was doubled. Second, Run 1 on both south dryer stacks was superisokinetic, and the data from this run are not used. Third, Run 3 on the south dryer (east stack) was subisokinetic. Therefore, to estimate emissions from the south dryer for Run 3, the south dryer (west stack) emission rates (for each pollutant) were doubled. Fourth, only one valid PM-10 test

run (Run 2) was conducted on the south dryer (east stack), and two valid PM-10 test runs were conducted on the south dryer (west stack). To estimate PM-10 emissions from the south dryer, the PM-10 emission rate from each of the three single stack test runs was doubled.

The filterable PM, condensible PM, $SO_2$, and $CO_2$ data for the north dryer test are assigned an A rating. The test methodology appears to be sound, sufficient process data are provided, and adequate detail is included in the report. The PM-10 data for the north and south dryers are assigned a B rating because each test run on each dryer included PM-10 measurements from only one of two stacks, and the emission rates were doubled to represent both stacks. The filterable PM, condensible PM, $SO_2$, and $CO_2$ data for the south dryer test are assigned a B rating because only two valid test runs (Runs 2 and 4) were conducted on the east stack, and the emission rates measured during Run 3 on the west stack were doubled to represent both stacks. Pertinent test data, process data, and emission factor calculations are provided in Appendix M.

4.2.14 Reference 14

This report documents a compliance test conducted at Holly Sugar Corporation in Santa Maria, California, on June 4-14, 1991. Three fuel oil-fired pulp dryers, each followed by two cyclones (and an air recirculation system), were tested for filterable PM, condensible inorganic PM, condensible organic PM, $CO_2$, $SO_2$, carbon monoxide (CO), nitrogen oxide ($NO_x$), volatile organic compounds (VOC), and methane emissions. One of two stacks on each dryer was tested, and emissions from each stack were multiplied by two to estimate the total emissions from each dryer. Also, a beet pulp cooler was tested for PM emissions, but all three test runs are invalid because the isokinetic ratios were all far below 90 percent. Particulate matter emissions were quantified using EPA Method 5 (including front- and back-half analyses). Continuous monitoring of $CO_2$, $SO_2$, CO, and $NO_x$ emissions was conducted according to CARB Method 100, which appears to be similar to EPA-approved continuous monitoring methods for the same pollutants. Sulfur dioxide emissions were not detected during any test run. Volatile organic compound and methane emissions were quantified by drawing gas samples into tedlar bags and analyzing the samples with a flame ionization detector gas chromatograph (similar to EPA Methods 18 and 25A). The report presents concentrations of C1 through C6 hydrocarbons, and VOC concentrations were calculated on an "as carbon" basis by multiplying the individual C1 through C6 concentrations by the corresponding number of carbons (C1 concentration multiplied by 1, C2 concentration multiplied by 2, etc.) and summing the adjusted concentrations. The reported C1 concentrations were assumed to be entirely methane, and were used to determine methane emissions. Production rates are provided for each dryer, but data needed to convert the production rates to dryer feed rates are only provided for dryer No. 1. Because the reported production rates are the same for the three dryers, the average feed rate calculated for dryer No. 1 is assumed to equal the feed rate for dryers 2 and 3.

The data for dryer No. 1 are assigned a B rating because only one of two stacks from the dryer was tested. Otherwise, the test methodology appears to be sound, sufficient process data are provided, and adequate detail is included in the report. The data for dryers 2 and 3 are assigned a C rating because the dryer feed rates are estimated using the average feed rate for dryer No. 1 and only one of two stacks from each dryer was tested. Pertinent test data, process data, and emission factor calculations are provided in Appendix N.

4.2.15 Reference 15

This report documents a compliance test conducted at the Great Lakes Sugar Company in Fremont, Ohio, on December 2, 1992. A fuel oil-fired pulp dryer, followed by a cyclone and a gas aspiration system, was tested for filterable PM, $CO_2$, and $SO_2$ emissions. Particulate matter and $CO_2$ emissions were quantified using EPA Methods 5 and 3 (with a Fyrite gas analyzer), respectively. Sulfur dioxide emissions were measured using a modified EPA Method 8 test, which was a Method 8 analysis of the impingers from the Method 5 sampling train. Three test runs were conducted, but the first run was

not valid because the isokinetic variation was not within the prescribed limits. Process data, including run-by-run wet beet pulp feed rates to the dryer, are included in the report.

The filterable PM and $SO_2$ data from this report are assigned a B rating because only two valid test runs were conducted. The test methodology appears to be sound, extensive process data are provided, and adequate detail is included in the report. The $CO_2$ data from this report are assigned a C rating because of the relative inaccuracy of Fyrite analyzers. Pertinent test data, process data, and emission factor calculations are provided in Appendix O.

4.2.16 Reference 16

This report documents a compliance test conducted at the American Crystal Sugar Company in East Grand Forks, Minnesota, on February 24, 1994. Three coal-fired pulp dryers (dryers A, B, and C), each controlled by multiclones, were tested for filterable PM, condensible organic PM, $CO_2$, and $NO_x$ emissions. In addition, a cascade impactor was used to determine the particle size distribution during a single test run for pulp dryer B. Particulate matter, $CO_2$, and $NO_x$ emissions were quantified using EPA Methods 5 (including front- and back-half analyses), 3 (with an Orsat gas analyzer), and 7, respectively. Three test runs were conducted for each pollutant and dryer, but only one valid $NO_x$ test run was conducted on dryers B and C. The $NO_x$ data for dryers B and C are not used for emission factor development. Process data, including hourly wet beet pulp feed rates to the dryer, are included in the report.

The data from this report are assigned an A rating. The test methodology appears to be sound, extensive process data are provided, and adequate detail is included in the report. Pertinent test data, process data, and emission factor calculations are provided in Appendix P.

4.2.17 Reference 17

This report documents a compliance test conducted at the American Crystal Sugar Company in Moorhead, Minnesota, on January 21, 1992. The south coal-fired pulp dryer was tested for filterable PM and $CO_2$ emissions both before and after the control system, which consisted of multiclones and a stack filter system. In addition, condensible organic PM emissions were measured following the control system. Particulate matter and $CO_2$ emissions were quantified using EPA Methods 5 (including front- and back-half analyses) and 3 (with an Orsat gas analyzer), respectively. Three simultaneous inlet and outlet test runs were conducted under each of four different exhaust gas recycle rates. Because the exhaust gas recycle rates had little effect on the magnitude of PM and $CO_2$ emissions, the twelve test runs are averaged together and considered a single test. Process data, including hourly wet beet pulp feed rates to the dryer, are included in the report.

The data from this report are assigned an A rating. The test methodology appears to be sound, extensive process data are provided, and adequate detail is included in the report. Pertinent test data, process data, and emission factor calculations are provided in Appendix Q.

4.2.18 Reference 19

This report documents a compliance test conducted at the American Crystal Sugar Company in Crookston, Minnesota, on March 11, 1993. A venturi scrubber-controlled sugar cooler was tested for filterable PM, condensible inorganic PM, condensible organic PM, and $CO_2$ emissions at the scrubber outlet. The scrubber operated with a pressure drop between 5 and 7 in. w.c. during testing. Particulate matter and $CO_2$ emissions were quantified using EPA Methods 5 (including front- and back-half analyses) and 3 (with an Orsat gas analyzer), respectively. However, $CO_2$ was not detected during any test run. Three test runs were conducted, and process data, including run-by-run sugar cooler throughput rates, are included in the report.

The data from this report are assigned an A rating. The test methodology appears to be sound, sufficient process data are provided, and adequate detail is included in the report. Pertinent test data, process data, and emission factor calculations are provided in Appendix R.

4.2.19 Reference 20

This report documents a compliance test conducted at the American Crystal Sugar Company in East Grand Forks, Minnesota, on November 11, 1993. Three coal-fired pulp dryers (dryers A, B, and C), each controlled by multiclones, were tested for filterable PM, condensible organic PM, $CO_2$, $SO_2$, CO, $NO_x$, and VOC emissions. Also, two stacks venting pellet cooler emissions and one stack venting emissions from a pellet loadout operation were tested for PM emissions, but process data are not provided for these tests. Particulate matter, $CO_2$, $NO_x$, and CO emissions were quantified using EPA Methods 5 (including front- and back-half analyses), 3 (with an Orsat gas analyzer), 7, and 10, respectively. Sulfur dioxide samples were collected in the back half of the Method 5 sampling train and were analyzed in accordance with the large impinger version of EPA Method 6. Volatile organic compound emissions were quantified by drawing gas samples into tedlar bags and analyzing the samples with a flame ionization detector calibrated against propane (similar to EPA Method 25A). The VOC data are reported on an "as carbon" basis and were converted to an "as methane" basis using the ratio of the molecular weights of methane and carbon. Process data, including hourly wet beet pulp feed rates to the dryer, are only provided for dryer A.

The data for dryer A are assigned an A rating. The test methodology appears to be sound, sufficient process data are provided, and adequate detail is included in the report. The data for the other sources tested are not rated because the necessary process data are not provided. Pertinent test data, process data, and emission factor calculations are provided in Appendix S.

4.2.20 Reference 21

This report documents a compliance test conducted at the American Crystal Sugar Company in Moorehead, Minnesota, on November 14, 1990. A sugar cooler and a sugar granulator, each controlled by a mechanical centrifugal separator with water sprays (rotoclone), were tested for filterable PM, condensible organic PM, and $CO_2$ emissions at the rotoclone outlets. Particulate matter and $CO_2$ emissions were quantified using EPA Methods 5 (including front- and back-half analyses) and 3 (with an Orsat gas analyzer), respectively. Because very small amounts (0.03 percent volume) of $CO_2$ were detected during all test runs, $CO_2$ emissions are assumed to be negligible. Three test runs were conducted, and process data, including run-by-run sugar cooler throughput rates (equivalent to sugar granulator output rates), are included in the report.

The data from this report are assigned an A rating. The test methodology appears to be sound, sufficient process data are provided, and adequate detail is included in the report. Pertinent test data, process data, and emission factor calculations are provided in Appendix T.

4.2.21 Reference 22

This report documents a compliance test conducted at the American Crystal Sugar Company in Crookston, Minnesota, on February 22, 1993. The No.1 and No.2 pulp dryers, each controlled by multiclones and a stack filter system, were tested for filterable PM, condensible organic PM, and $CO_2$ emissions. Particulate matter and $CO_2$ emissions were quantified using EPA Methods 5 (including front- and back-half analyses) and 3 (with an Orsat gas analyzer), respectively. Five valid test runs were conducted on dryer No. 1, and nine valid runs were conducted on dryer No. 2. Process data, including run-by-run wet pulp feed rates to the dryers, are included in the report.

The data from this report are assigned an A rating. The test methodology appears to be sound, sufficient process data are provided, and adequate detail is included in the report. Pertinent test data, process data, and emission factor calculations are provided in Appendix U.

4.2.22 Reference 23

This report documents a compliance test conducted at the Michigan Sugar Company in Caro, Michigan, on December 14, 1989. A natural gas-fired pulp dryer, followed by multiclones, was tested for filterable PM and $CO_2$ emissions. Hopper of multiclone is aspirated and airflow recirculated to combustion chamber of the dryer. Particulate matter and $CO_2$ emissions were quantified using EPA Methods 17 and 3 (with an Orsat gas analyzer), respectively. Five test runs were conducted, but Runs 1 and 3 were not valid and were not used to determine the emissions from the dryer. Process data are included in the report, and run-by-run dryer feed rates were calculated using the process data.

The data from this report are assigned an A rating. The test methodology appears to be sound, sufficient process data are provided, and adequate detail is included in the report. Pertinent test data, process data, and emission factor calculations are provided in Appendix V.

4.2.23 Reference 24

This report documents a compliance test conducted at the Michigan Sugar Company in Carrollton, Michigan, on November 14 and 16, 1989. A natural gas-fired pulp dryer, followed by multiclones, was tested for filterable PM and $CO_2$ emissions. A side stream from the multiclone is sent through a baghouse; the baghouse can be aspirated at two different aspiration rates. Aspiration rate is related to PM concentration. Particulate matter and $CO_2$ emissions were quantified using EPA Methods 17 and 3 (with an Orsat gas analyzer), respectively. Three test runs were conducted while the dryer operated at the two aspiration rates, but one run from each test was not valid because the isokinetic variation was not within the prescribed limits. The two aspiration rates did not appear to affect PM or $CO_2$ emissions; therefore, data from the four valid test runs are averaged. Process data are included in the report, and run-by-run dryer feed rates were calculated using the process data.

The data from this report are assigned an A rating. The test methodology appears to be sound, sufficient process data are provided, and adequate detail is included in the report. Pertinent test data, process data, and emission factor calculations are provided in Appendix W.

4.2.24 Reference 25

This report documents a compliance test conducted at the Michigan Sugar Company in Croswell, Michigan, on November 19, 1990. A fuel oil-fired pulp dryer, followed by multiclones and a gas aspiration system, was tested for filterable PM and $CO_2$ emissions. Particulate matter and $CO_2$ emissions were quantified using EPA Methods 5 and 3 (with an Orsat gas analyzer), respectively. Three test runs were conducted, process data are included in the report, and run-by-run dryer feed rates were calculated using the process data.

The data from this report are assigned an A rating. The test methodology appears to be sound, sufficient process data are provided, and adequate detail is included in the report. Pertinent test data, process data, and emission factor calculations are provided in Appendix X.

4.2.25 Reference 26

This report documents a compliance test conducted at the Western Sugar Company in Scottsbluff, Nebraska, on December 14-17, 1994. A natural gas-fired pulp dryer, followed by a wet scrubber on each of two stacks, was tested for filterable PM, condensible inorganic PM, and $CO_2$ emissions. Particulate matter and $CO_2$ emissions were quantified using EPA Method 5 (including front-

and back-half analyses) and 3, respectively. Process data on run-by-run wet beet pulp feed rate bases were not available; total wet pulp feed on the test days was used.

The data from this report are assigned a B rating. The test methodology appears to be sound, sufficient process data are provided, and adequate details is included in the report. The hourly wet pulp feed rate was a prorated figure based on the total feed rate on the day of the test. Pertinent test data, process data, and emission factor calculations are provided in Appendix Y.

### 4.2.26 Review of FIRE, XATEF, and SPECIATE Data Base Emission Factors

Emission factors for $NO_x$, sulfur oxides ($SO_x$) and VOC from dryers were found in the FIRE data base. However, the type of dryer is not specified, and the basis for the emission factors, raw beets, is incorrect because raw beets are not fed to a dryer at any point during processing operations. Therefore, these data are not included in the AP-42 section. Emission factors for sugarbeet processing from the SPECIATE data base are based solely on engineering judgment and are not included in the AP-42 section. Relevant data were not found in XATEF.

## 4.3 DEVELOPMENT OF CANDIDATE EMISSION FACTORS

Emission factors for rotary drum pulp dryers, first and second carbonation tanks, first evaporators, sugar coolers, and sugar granulators were developed using data from the references described in Section 4.2 of this document. Table 4-2 developed using these data. The emission factor ratings assigned to the factors for the revised AP-42 section are based on the guidelines presented in Section 3.3 of this report.

Emission factors were developed by grouping the data from similar combinations of source, pollutant, and control device, discarding the inferior data sets, and averaging the emission factors derived from each data set. In some cases, data were available from multiple tests on the same source. In such cases, the emission factors from the tests on that source were averaged first, and the resulting factor was then averaged with the factors from other similar sources. The following paragraphs describe how the data presented in Table 4-2 were used to develop the emission factors presented in Table 4-3. The emission factor units for the pulp dryers are mass of pollutant per mass of wet pulp feed, and the units for the tanks and evaporators are mass of pollutant per volume of juice produced.

### 4.3.1 Filterable PM

An emission factor for uncontrolled filterable PM emissions from a coal-fired pulp dryer was developed using A-rated data from Reference 17. The emission factor is 2.2 kg/Mg (4.4 lb/ton). This emission factor is assigned a D rating because it was developed using data from a single test.

An emission factor for filterable PM emissions from a coal-fired pulp dryer controlled with multiple cyclones was developed using A-rated data from eight tests conducted on seven different dryers. The dryers are located at four facilities. The data range from 0.21 kg/Mg (0.42 lb/ton) to 0.59 kg/Mg (1.2 lb/ton) and average 0.33 kg/Mg (0.66 lb/ton). This candidate emission factor is assigned a B rating because it was developed using A-rated data from 4 of the 31 sugarbeet processing plants currently operating in the United States.

An emission factor for filterable PM emissions from a coal-fired pulp dryer controlled with a wet scrubber was developed using A- and B-rated data from three tests conducted on two different dryers. The data range from 0.17 kg/Mg (0.34 lb/ton) to 0.36 kg/Mg (0.72 lb/ton) and average 0.25 kg/Mg (0.49 lb/ton). This candidate emission factor is assigned a D rating because it was developed using data from only 2 of the 31 sugarbeet processing plants currently operating in the United States.

TABLE 4-2. SUMMARY OF EMISSION DATA FOR SUGARBEET PROCESSING[a]

| Source | Control device | Pollutant | No. of test runs | Data rating | Emission factor range, kg/Mg (lb/ton) | Average emission factor, kg/Mg (lb/ton) | Ref. No. |
|---|---|---|---|---|---|---|---|
| Oil-fired pulp dryer | Cyclone | Filterable PM | 3 | B | 0.61-0.69 (1.2-1.4) | 0.64 (1.3) | 1 |
| Oil-fired pulp dryer | Cyclone | Condensible inorganic PM | 3 | B | 0.0092-0.017 (0.018-0.035) | 0.014 (0.027) | 1 |
| Oil-fired pulp dryer | Cyclone | Condensible organic PM | 3 | B | 0.015-0.018 (0.029-0.036) | 0.016 (0.032) | 1 |
| Oil-fired pulp dryer | Cyclone | $CO_2$ | 3 | B | 150-190 (300-370) | 170 (330) | 1 |
| Oil-fired pulp dryer | Cyclone | Filterable PM | 3 | B | 0.33-1.4 (0.66-2.8) | 0.72 (1.4) | 2 |
| Oil-fired pulp dryer | Cyclone | Condensible inorganic PM | 3 | B | 0.027-0.050 (0.055-0.10) | 0.040 (0.079) | 2 |
| Oil-fired pulp dryer | Cyclone | Condensible organic PM | 3 | B | 0.020-0.063 (0.040-0.093) | 0.043 (0.086) | 2 |
| Oil-fired pulp dryer | Cyclone | $CO_2$ | 3 | B | 190-360 (370-730) | 270 (550) | 2 |
| Sugar dryer and cooler | Wet scrubber | Filterable PM | 3 | B | 0.015-0.019 (0.029-0.039) | 0.018 (0.035) | 3 |
| Sugar dryer and cooler | Wet scrubber | $CO_2$ | 3 | B | ND | Negligible | 3 |
| Coal-fired pulp dryer | Multiple cyclones | Filterable PM | 3 | A | 0.48-0.66 (0.97-1.3) | 0.59 (1.2) | 4 |
| Coal-fired pulp dryer | Multiple cyclones | $SO_2$ | 3 | A | 0.66-0.69 (1.3-1.4) | 0.68 (1.4) | 4 |
| Coal-fired pulp dryer | Multiple cyclones | $CO_2$ | 3 | A | 220-250 (430-500) | 230 (460) | 4 |
| Coal-fired pulp dryer | Wet scrubber | Filterable PM | 3 | A | 0.18-0.23 (0.36-0.46) | 0.21 (0.42) | 5 |
| Coal-fired pulp dryer | Wet scrubber | Condensible PM | 3 | A | 0.18-0.33 (0.37-0.66) | 0.23 (0.47) | 5 |
| Coal-fired pulp dryer | Wet scrubber | Filterable PM | 4 | B | 0.12-0.23 (0.23-0.47) | 0.17 (0.34) | 5 |
| Coal-fired pulp dryer | Wet scrubber | Condensible PM | 4 | B | 0.11-0.25 (0.22-0.50) | 0.17 (0.33) | 5 |
| Coal-fired pulp dryer | Wet scrubber | Formaldehyde | 6 | C | ND | 0.0042 (0.0083) | 5 |
| Coal-fired pulp dryer | Wet scrubber | Acetaldehyde | 6 | C | ND | 0.0065 (0.013) | 5 |
| Coal-fired pulp dryer | Wet scrubber | Acrolein | 6 | C | ND | 0.0030 (0.0060) | 5 |
| Coal-fired pulp dryer | Wet scrubber | Crotonaldehyde | 6 | C | ND | 0.0012 (0.0024) | 5 |
| Coal-fired pulp dryer | Wet scrubber | Benzoic acid | 6 | C | ND | 0.0014 (0.0028) | 5 |
| Coal-fired pulp dryer | Wet scrubber | Benzaldehyde | 6 | C | ND | 0.00070 (0.0014) | 5 |
| Coal-fired pulp dryer | Wet scrubber | Bis(2-ethylhexyl)phthalate | 6 | C | ND | 0.00075 (0.0015) | 5 |
| Coal-fired pulp dryer | Wet scrubber | Phenol | 3 | C | ND | 0.00016 (0.00032) | 5 |
| Coal-fired pulp dryer | Wet scrubber | 2-nitrophenol | 5 | C | ND | $9.0 \times 10^{-5}$ (0.00018) | 5 |

TABLE 4-2. (continued)

| Source | Control device | Pollutant | No. of test runs | Data rating | Emission factor range, kg/Mg (lb/ton) | Average emission factor, kg/Mg (lb/ton) | Ref. No. |
|---|---|---|---|---|---|---|---|
| Coal-fired pulp dryer | Wet scrubber | 4-nitrophenol | 4 | C | ND | $7.0x10^{-5}$ (0.00014) | 5 |
| Coal-fired pulp dryer | Wet scrubber | 4-methylphenol | 5 | C | ND | $6.5x10^{-5}$ (0.00013) | 5 |
| Coal-fired pulp dryer | Wet scrubber | Naphthalene | 6 | C | ND | $5.5x10^{-5}$ (0.00011) | 5 |
| Coal-fired pulp dryer | Wet scrubber | Di-n-butylphthalate | 4 | C | ND | $2.6x10^{-5}$ ($5.2x10^{-5}$) | 5 |
| Coal-fired pulp dryer | Wet scrubber | Benzyl alcohol | 5 | C | ND | $3.6x10^{-5}$ ($7.1x10^{-5}$) | 5 |
| Coal-fired pulp dryer | Wet scrubber | 2,4-dinitrophenol | 2 | NR | ND | $2.6x10^{-5}$ ($5.1x10^{-5}$) | 5 |
| Coal-fired pulp dryer | Wet scrubber | 2-methylphenol | 5 | C | ND | $1.7x10^{-5}$ ($3.4x10^{-5}$) | 5 |
| Coal-fired pulp dryer | Wet scrubber | Nitrobenzene | 4 | C | ND | $9.5x10^{-6}$ ($1.9x10^{-5}$) | 5 |
| Coal-fired pulp dryer | Wet scrubber | 2,4-dimethylphenol | 4 | C | ND | $1.3x10^{-5}$ ($2.5x10^{-5}$) | 5 |
| Coal-fired pulp dryer | Wet scrubber | 2-methylnaphthalene | 5 | C | ND | $8.5x10^{-6}$ ($1.7x10^{-5}$) | 5 |
| Coal-fired pulp dryer | Wet scrubber | 4,6-Dinitro-2-methylphenol | 1 | NR | ND | $7.5x10^{-6}$ ($1.5x10^{-5}$) | 5 |
| Coal-fired pulp dryer | Wet scrubber | Dibenzofuran | 5 | C | ND | $5.5x10^{-6}$ ($1.1x10^{-5}$) | 5 |
| Coal-fired pulp dryer | Wet scrubber | Phenanthrene | 5 | C | ND | $6.0x10^{-6}$ ($1.2x10^{-5}$) | 5 |
| Coal-fired pulp dryer | Wet scrubber | Diethylphthalate | 3 | C | ND | $4.9x10^{-6}$ ($9.8x10^{-6}$) | 5 |
| Coal-fired pulp dryer | Wet scrubber | Acenaphthylene | 4 | C | ND | $8.5x10^{-7}$ ($1.7x10^{-6}$) | 5 |
| Coal-fired pulp dryer | Wet scrubber | Butylbenzylphthalate | 1 | NR | ND | $5.5x10^{-6}$ ($1.1x10^{-5}$) | 5 |
| Coal-fired pulp dryer | Wet scrubber | Fluoranthene | 1 | NR | ND | $3.0x10^{-6}$ ($6.0x10^{-6}$) | 5 |
| Coal-fired pulp dryer | Wet scrubber | Anthracene | 1 | NR | ND | $2.5x10^{-6}$ ($5.0x10^{-6}$) | 5 |
| Coal-fired pulp dryer | Wet scrubber | Formaldehyde | 3 | C | ND | 0.0030 (0.0059) | 5 |
| Coal-fired pulp dryer | Wet scrubber | Acetaldehyde | 3 | C | ND | 0.0080 (0.016) | 5 |
| Coal-fired pulp dryer | Wet scrubber | Acrolein | 3 | C | ND | 0.0046 (0.0092) | 5 |
| Coal-fired pulp dryer | Wet scrubber | Crotonaldehyde | 3 | C | ND | 0.00080 (0.0016) | 5 |
| First carbonation tank[b] | None | Benzaldehyde | 3 | B | $9.5x10^{-5}$-$1.2x10^{-4}$ | $1.1x10^{-4}$ | 5 |
| First carbonation tank[b] | None | Bis(2-ethylhexyl)phthalate | 3 | B | $9.6x10^{-6}$-$1.8x10^{-5}$ | $1.2x10^{-5}$ | 5 |
| First carbonation tank[b] | None | Benzoic acid | 3 | B | $6.2x10^{-6}$-$1.2x10^{-5}$ | $8.4x10^{-6}$ | 5 |

TABLE 4-2. (continued)

| Source | Control device | Pollutant | No. of test runs | Data rating | Emission factor range, kg/Mg (lb/ton) | Average emission factor, kg/Mg (lb/ton) | Ref. No. |
|---|---|---|---|---|---|---|---|
| First carbonation tank[b] | None | 2,4-dinitrophenol | 3 | B | NP-$1.1x10^{-5}$ | NP | 5 |
| First carbonation tank[b] | None | Naphthalene | 3 | B | $1.5x10^{-6}$-$2.4x10^{-6}$ | $2.0x10^{-6}$ | 5 |
| First carbonation tank[b] | None | Phenanthrene | 3 | B | $1.3x10^{-6}$-$1.4x10^{-6}$ | $1.4x10^{-6}$ | 5 |
| First carbonation tank[b] | None | Phenol | 3 | B | $1.1x10^{-6}$-$1.4x10^{-6}$ | $1.3x10^{-6}$ | 5 |
| First carbonation tank[b] | None | 4-methylphenol | 3 | B | $5.2x10^{-7}$-$8.7x10^{-7}$ | $6.6x10^{-7}$ | 5 |
| First carbonation tank[b] | None | 2-methylnaphthalene | 3 | B | $2.8x10^{-7}$-$6.4x10^{-7}$ | $5.1x10^{-7}$ | 5 |
| First carbonation tank[b] | None | Acenaphthene | 3 | B | NP-$1.5x10^{-6}$ | NP | 5 |
| Second carbonation tank[b] | None | Formaldehyde | 1 | D | ND | $1.6x10^{-5}$ | 5 |
| Second carbonation tank[b] | None | Acetaldehyde | 1 | D | ND | 0.0043 | 5 |
| Second carbonation tank[b] | None | Acrolein | 1 | D | ND | $2.4x10^{-4}$ | 5 |
| Second carbonation tank[b] | None | Crotonaldehyde | 1 | D | ND | $3.0x10^{-5}$ | 5 |
| First evaporator[c] | None | Formaldehyde | 3 | C | $2.5x10^{-7}$-$2.8x10^{-6}$ | $1.3x10^{-6}$ | 5 |
| First evaporator[c] | None | Acetaldehyde | 3 | C | $6.2x10^{-5}$-$1.4x10^{-4}$ | $1.1x10^{-4}$ | 5 |
| First evaporator[c] | None | Acrolein | 3 | C | $6.5x10^{-8}$-$2.6x10^{-7}$ | $1.5x10^{-7}$ | 5 |
| First evaporator[c] | None | Crotonaldehyde | 3 | C | $9.8x10^{-8}$-$3.0x10^{-7}$ | $1.9x10^{-7}$ | 5 |
| First evaporator[c] | None | Formaldehyde | 3 | C | $6.9x10^{-8}$-$1.5x10^{-7}$ | $1.0x10^{-7}$ | 5 |
| First evaporator[c] | None | Acetaldehyde | 3 | C | $1.5x10^{-5}$-$3.3x10^{-5}$ | $2.4x10^{-5}$ | 5 |
| First evaporator[c] | None | Acrolein | 3 | C | $5.6x10^{-7}$-$7.9x10^{-7}$ | $6.8x10^{-7}$ | 5 |
| First evaporator[c] | None | Crotonaldehyde | 3 | C | $6.9x10^{-8}$-$1.2x10^{-7}$ | $9.5x10^{-8}$ | 5 |
| First evaporator[c] | None | Benzaldehyde | 4 | C | $9.3x10^{-7}$-$3.5x10^{-6}$ | $2.2x10^{-6}$ | 5 |
| First evaporator[c] | None | Bis(2-ethylhexyl)phthalate | 4 | C | $8.0x10^{-8}$-$8.2x10^{-7}$ | $3.7x10^{-7}$ | 5 |
| First evaporator[c] | None | Benzyl alcohol | 4 | C | $6.4x10^{-8}$-$2.5x10^{-7}$ | $1.8x10^{-7}$ | 5 |
| First evaporator[c] | None | Naphthalene | 4 | C | NP-$5.2x10^{-8}$ | $2.5x10^{-8}$ | 5 |

TABLE 4-2. (continued)

| Source | Control device | Pollutant | No. of test runs | Data rating | Emission factor range, kg/Mg (lb/ton) | Average emission factor, kg/Mg (lb/ton) | Ref. No. |
|---|---|---|---|---|---|---|---|
| First evaporator[c] | None | Benzoic acid | 4 | C | NP-$5.0 \times 10^{-8}$ | NP | 5 |
| First evaporator[c] | None | Phenol | 4 | C | NP-$3.3 \times 10^{-8}$ | $1.2 \times 10^{-8}$ | 5 |
| First evaporator[c] | None | Diethylphthalate | 4 | C | NP-$4.6 \times 10^{-8}$ | NP | 5 |
| First evaporator[c] | None | Pyridine | 4 | C | $1.4 \times 10^{-8}$-$4.6 \times 10^{-8}$ | $3.4 \times 10^{-8}$ | 5 |
| First evaporator[c] | None | Dibenzofuran | 4 | C | NP-$1.7 \times 10^{-9}$ | NP | 5 |
| First evaporator[c] | None | Di-n-butylphthalate | 4 | C | NP-$3.1 \times 10^{-9}$ | $1.1 \times 10^{-9}$ | 5 |
| Natural gas-fired pulp dryer | Multiple cyclones and wet scrubber | Filterable PM | 3 | A | 0.13-0.16 (0.27-0.32) | 0.15 (0.30) | 6 |
| Natural gas-fired pulp dryer | Multiple cyclones and wet scrubber | $CO_2$ | 3 | A | 61-73 (120-150) | 68 (140) | 6 |
| Natural gas-fired pulp dryer | Multiple cyclones and wet scrubber | Filterable PM | 3 | A | 0.078-0.091 (0.16-0.18) | 0.082 (0.16) | 7 |
| Natural gas-fired pulp dryer | Multiple cyclones and wet scrubber | $CO_2$ | 3 | A | 33-41 (67-82) | 37 (73) | 7 |
| Natural gas-fired pulp dryer | Multiple cyclones and wet scrubber | Filterable PM | 3 | A | 0.070-0.090 (0.14-0.18) | 0.078 (0.16) | 8 |
| Natural gas-fired pulp dryer | Multiple cyclones and wet scrubber | $CO_2$ | 3 | A | 39-56 (78-110) | 45 (90) | 8 |
| Natural gas-fired pulp dryer | Wet scrubber | Filterable PM | 3 | B | 0.030-0.047 (0.060-0.093) | 0.038 (0.075) | 9 |
| Natural gas-fired pulp dryer | Wet scrubber | Condensible inorganic PM | 3 | B | 0.0074-0.0081 (0.015-0.016) | 0.0077 (0.015) | 9 |
| Natural gas-fired pulp dryer | Wet scrubber | $CO_2$ | 3 | B | 28-30 (57-61) | 29 (58) | 9 |
| Natural gas-fired pulp dryer | Wet scrubber | Filterable PM | 3 | B | 0.039-0.067 (0.078-0.13) | 0.055 (0.11) | 10 |
| Natural gas-fired pulp dryer | Wet scrubber | Condensible inorganic PM | 3 | B | 0.0054-0.019 (0.011-0.038) | 0.014 (0.027) | 10 |
| Natural gas-fired pulp dryer | Wet scrubber | $CO_2$ | 3 | B | 68-95 (140-190) | 78 (160) | 10 |

TABLE 4-2. (continued)

| Source | Control device | Pollutant | No. of test runs | Data rating | Emission factor range, kg/Mg (lb/ton) | Average emission factor, kg/Mg (lb/ton) | Ref. No. |
|---|---|---|---|---|---|---|---|
| Natural gas-fired pulp dryer | Wet scrubber | Filterable PM | 3 | C | 0.19-0.25 (0.37-0.49) | 0.22 (0.43) | 11 |
| Natural gas-fired pulp dryer | Wet scrubber | Condensible inorganic PM | 3 | C | 0.10-0.13 (0.20-0.27) | 0.12 (0.23) | 11 |
| Coal-fired pulp dryer | Cyclone and wet scrubber | Filterable PM | 3 | A | 0.30-0.40 (0.61-0.81) | 0.36 (0.72) | 12 |
| Coal-fired pulp dryer | Cyclone and wet scrubber | Condensible inorganic PM | 3 | A | 0.022-0.029 (0.043-0.057) | 0.025 (0.050) | 12 |
| Coal-fired pulp dryer | Cyclone and wet scrubber | $CO_2$ | 3 | A | 120-140 (250-270) | 130 (260) | 12 |
| Oil-fired pulp dryer | Dry scrubber and cyclone | Filterable PM | 3 | A | 0.32-0.45 (0.63-0.91) | 0.38 (0.77) | 13 |
| Oil-fired pulp dryer | Dry scrubber and cyclone | Condensible inorganic PM | 3 | A | 0.093-0.21 (0.19-0.42) | 0.15 (0.29) | 13 |
| Oil-fired pulp dryer | Dry scrubber and cyclone | Filterable PM-10 | 3 | B | 0.20-0.27 (0.40-0.54) | 0.23 (0.47) | 13 |
| Oil-fired pulp dryer | Dry scrubber and cyclone | $CO_2$ | 3 | A | 180-220 (360-440) | 190 (390) | 13 |
| Oil-fired pulp dryer | Dry scrubber and cyclone | $SO_2$ | 3 | A | 0.23-0.47 (0.47-0.95) | 0.31 (0.63) | 13 |
| Oil-fired pulp dryer | Dry scrubber and cyclone | Filterable PM | 3 | B | 0.69-0.89 (1.4-1.8) | 0.76 (1.5) | 13 |
| Oil-fired pulp dryer | Dry scrubber and cyclone | Condensible inorganic PM | 3 | B | 0.19-0.40 (0.38-0.80) | 0.27 (0.55) | 13 |
| Oil-fired pulp dryer | Dry scrubber and cyclone | Filterable PM-10 | 3 | B | 0.48-0.74 (0.97-1.5) | 0.59 (1.2) | 13 |
| Oil-fired pulp dryer | Dry scrubber and cyclone | $CO_2$ | 3 | B | 260-310 (530-620) | 290 (570) | 13 |
| Oil-fired pulp dryer | Dry scrubber and cyclone | $SO_2$ | 3 | B | 0.57-0.62 (1.1-1.2) | 0.60 (1.2) | 13 |
| Oil-fired pulp dryer | Dual cyclones | Filterable PM | 3 | B | 0.58-1.1 (1.2-2.2) | 0.79 (1.6) | 14 |
| Oil-fired pulp dryer | Dual cyclones | Condensible inorganic PM | 3 | B | 0.059-0.24 (0.12-0.47) | 0.13 (0.26) | 14 |

TABLE 4-2. (continued)

| Source | Control device | Pollutant | No. of test runs | Data rating | Emission factor range, kg/Mg (lb/ton) | Average emission factor, kg/Mg (lb/ton) | Ref. No. |
|---|---|---|---|---|---|---|---|
| Oil-fired pulp dryer | Dual cyclones | Condensible organic PM | 3 | B | 0-0.16 (0-0.32) | 0.054 (0.11) | 14 |
| Oil-fired pulp dryer | Dual cyclones | $CO_2$ | 3 | B | 170-180 (340-360) | 180 (350) | 14 |
| Oil-fired pulp dryer | Dual cyclones | $SO_2$ | 3 | B | NP | NP | 14 |
| Oil-fired pulp dryer | Dual cyclones | CO | 3 | B | 0.30-0.83 (0.61-1.7) | 0.51 (1.01) | 14 |
| Oil-fired pulp dryer | Dual cyclones | $NO_x$ | 3 | B | 0.28-0.33 (0.56-0.67) | 0.30 (0.60) | 14 |
| Oil-fired pulp dryer | Dual cyclones | VOC as methane | 3 | B | 0.049-0.065 (0.098-0.13) | 0.055 (0.11) | 14 |
| Oil-fired pulp dryer | Dual cyclones | Methane | 3 | B | 0.0070-0.024 (0.014-0.048) | 0.014 (0.028) | 14 |
| Oil-fired pulp dryer | Dual cyclones | Filterable PM | 3 | C | 0.31-0.46 (0.63-0.91) | 0.39 (0.78) | 14 |
| Oil-fired pulp dryer | Dual cyclones | Condensible inorganic PM | 3 | C | 0.052-0.16 (0.10-0.33) | 0.11 (0.23) | 14 |
| Oil-fired pulp dryer | Dual cyclones | Condensible organic PM | 3 | C | 0.0019-0.0036 (0.0038-0.0072) | 0.0029 (0.0057) | 14 |
| Oil-fired pulp dryer | Dual cyclones | $CO_2$ | 3 | C | 83-170 (170-340) | 130 (260) | 14 |
| Oil-fired pulp dryer | Dual cyclones | $SO_2$ | 3 | C | NP | NP | 14 |
| Oil-fired pulp dryer | Dual cyclones | CO | 3 | C | 0.44-0.47 (0.88-0.94) | 0.46 (0.92) | 14 |
| Oil-fired pulp dryer | Dual cyclones | $NO_x$ | 3 | C | 0.17-0.19 (0.35-0.39) | 0.18 (0.37) | 14 |
| Oil-fired pulp dryer | Dual cyclones | VOC as methane | 3 | C | 0.086-0.092 (0.17-0.18) | 0.089 (0.18) | 14 |
| Oil-fired pulp dryer | Dual cyclones | Methane | 3 | C | 0.0085-0.038 (0.017-0.077) | 0.020 (0.040) | 14 |
| Oil-fired pulp dryer | Dual cyclones | Filterable PM | 3 | C | 0.56-0.76 (1.1-1.5) | 0.64 (1.3) | 14 |
| Oil-fired pulp dryer | Dual cyclones | Condensible inorganic PM | 3 | C | 0.021-0.030 (0.042-0.059) | 0.026 (0.052) | 14 |
| Oil-fired pulp dryer | Dual cyclones | Condensible organic PM | 3 | C | 0.0022-0.0046 (0.0043-0.0093) | 0.0034 (0.0068) | 14 |
| Oil-fired pulp dryer | Dual cyclones | $CO_2$ | 3 | C | 120-170 (240-340) | 140 (280) | 14 |
| Oil-fired pulp dryer | Dual cyclones | $SO_2$ | 3 | C | NP | NP | 14 |
| Oil-fired pulp dryer | Dual cyclones | CO | 3 | C | 0.43-0.46 (0.86-0.92) | 0.45 (0.89) | 14 |
| Oil-fired pulp dryer | Dual cyclones | $NO_x$ | 3 | C | 0.19-0.20 (0.38-0.41) | 0.20 (0.39) | 14 |
| Oil-fired pulp dryer | Dual cyclones | VOC as methane | 3 | C | 0.084-0.10 (0.17-0.21) | 0.091 (0.18) | 14 |

TABLE 4-2. (continued)

| Source | Control device | Pollutant | No. of test runs | Data rating | Emission factor range, kg/Mg (lb/ton) | Average emission factor, kg/Mg (lb/ton) | Ref. No. |
|---|---|---|---|---|---|---|---|
| Oil-fired pulp dryer | Dual cyclones | Methane | 3 | C | 0.013-0.020 (0.026-0.041) | 0.017 (0.034) | 14 |
| Oil-fired pulp dryer | Multiple cyclones; aspiration | Filterable PM | 2 | B | 0.24-0.30 (0.49-0.61) | 0.27 (0.55) | 15 |
| Oil-fired pulp dryer | Multiple cyclones; aspiration | $CO_2$ | 2 | C | 200-230 (400-460) | 220 (430) | 15 |
| Oil-fired pulp dryer | Multiple cyclones; aspiration | $SO_2$ | 2 | B | 0.64-0.65 (1.3-1.3) | 0.65 (1.3) | 15 |
| Coal-fired pulp dryer[d] | Multiple cyclones | Filterable PM | 3 | A | 0.21-0.25 (0.41-0.49) | 0.22 (0.44) | 16 |
| Coal-fired pulp dryer[d] | Multiple cyclones | Condensible organic PM | 3 | A | 0.027-0.030 (0.054-0.060) | 0.028 (0.056) | 16 |
| Coal-fired pulp dryer[d] | Multiple cyclones | $CO_2$ | 3 | A | 160-180 (320-360) | 170 (340) | 16 |
| Coal-fired pulp dryer[d] | Multiple cyclones | $NO_x$ | 3 | A | 0.25-0.33 (0.50-0.66) | 0.28 (0.57) | 16 |
| Coal-fired pulp dryer | Multiple cyclones | Filterable PM | 3 | A | 0.33-0.48 (0.65-0.96) | 0.38 (0.76) | 16 |
| Coal-fired pulp dryer | Multiple cyclones | Condensible organic PM | 3 | A | 0.016-0.027 (0.032-0.053) | 0.021 (0.041) | 16 |
| Coal-fired pulp dryer | Multiple cyclones | $CO_2$ | 3 | A | 210-280 (410-560) | 230 (460) | 16 |
| Coal-fired pulp dryer | Multiple cyclones | Filterable PM | 3 | A | 0.26-0.33 (0.53-0.67) | 0.28 (0.57) | 16 |
| Coal-fired pulp dryer | Multiple cyclones | Condensible organic PM | 3 | A | 0.019-0.021 (0.037-0.041) | 0.019 (0.039) | 16 |
| Coal-fired pulp dryer | Multiple cyclones | $CO_2$ | 3 | A | 180-210 (350-420) | 200 (390) | 16 |
| Coal-fired pulp dryer | None | Filterable PM | 12 | A | 1.9-2.6 (3.9-5.1) | 2.2 (4.4) | 17 |
| Coal-fired pulp dryer | None | $CO_2$ | 12 | A | 170-240 (350-490) | 150 (310) | 17 |
| Coal-fired pulp dryer | Multiple cyclones and stack filter system | Filterable PM | 12 | A | 0.25-0.35 (0.50-0.70) | 0.31 (0.61) | 17 |
| Coal-fired pulp dryer | Multiple cyclones and stack filter system | Condensible organic PM | 12 | A | 0.037-0.086 (0.073-0.17) | 0.052 (0.10) | 17 |
| Coal-fired pulp dryer | Multiple cyclones and stack filter system | $CO_2$ | 12 | A | 130-180 (250-350) | 150 (300) | 17 |
| Sugar cooler | Venturi scrubber | Filterable PM | 3 | A | 0.028-0.040 (0.056-0.080) | 0.032 (0.065) | 19 |
| Sugar cooler | Venturi scrubber | Condensible organic PM | 3 | A | 0.0013-0.0026 (0.0026-0.0051) | 0.0021 (0.0042) | 19 |

TABLE 4-2. (continued)

| Source | Control device | Pollutant | No. of test runs | Data rating | Emission factor range, kg/Mg (lb/ton) | Average emission factor, kg/Mg (lb/ton) | Ref. No. |
|---|---|---|---|---|---|---|---|
| Sugar cooler | Venturi scrubber | Condensible inorganic PM | 3 | A | 0.0012-0.0035 (0.0024-0.0070) | 0.0024 (0.0047) | 19 |
| Coal-fired pulp dryer[e] | Multiple cyclones | Filterable PM | 3 | A | 0.23-0.33 (0.45-0.66) | 0.28 (0.57) | 20 |
| Coal-fired pulp dryer[e] | Multiple cyclones | Condensible organic PM | 3 | A | 0.027-0.031 (0.053-0.062) | 0.029 (0.058) | 20 |
| Coal-fired pulp dryer[e] | Multiple cyclones | $CO_2$ | 3 | A | 180-210 (350-420) | 200 (390) | 20 |
| Coal-fired pulp dryer[e] | Multiple cyclones | $SO_2$ | 3 | A | 0.085-0.10 (0.17-0.21) | 0.092 (0.18) | 20 |
| Coal-fired pulp dryer[e] | Multiple cyclones | $NO_x$ | 3 | A | 0.34-0.39 (0.67-0.78) | 0.37 (0.74) | 20 |
| Coal-fired pulp dryer[e] | Multiple cyclones | VOC as methane | 3 | A | 0.54-0.65 (1.1-1.3) | 0.59 (1.2) | 20 |
| Coal-fired pulp dryer[e] | Multiple cyclones | CO | 3 | A | 1.0-1.2 (2.1-2.4) | 1.1 (2.3) | 20 |
| Sugar cooler | Rotoclone | Filterable PM | 3 | A | 0.061-0.074 (0.12-0.15) | 0.066 (0.13) | 21 |
| Sugar cooler | Rotoclone | Condensible organic PM | 3 | A | 0.0019-0.0025 (0.0037-0.0051) | 0.0022 (0.0043) | 21 |
| Sugar granulator | Rotoclone | Filterable PM | 3 | A | 0.017-0.046 (0.034-0.092) | 0.032 (0.064) | 21 |
| Sugar granulator | Rotoclone | Condensible organic PM | 3 | A | 0.0015-0.0021 (0.0030-0.0041) | 0.0018 (0.0037) | 21 |
| Coal-fired pulp dryer | Multiple cyclones and stack filter system | Filterable PM | 5 | A | 0.21-0.29 (0.42-0.58) | 0.26 (0.52) | 22 |
| Coal-fired pulp dryer | Multiple cyclones and stack filter system | Condensible organic PM | 5 | A | 0.066-0.096 (0.13-0.19) | 0.086 (0.17) | 22 |
| Coal-fired pulp dryer | Multiple cyclones and stack filter system | $CO_2$ | 5 | A | 230-260 (470-520) | 240 (490) | 22 |
| Coal-fired pulp dryer | Multiple cyclones and stack filter system | Filterable PM | 9 | A | 0.17-0.24 (0.34-0.48) | 0.21 (0.42) | 22 |
| Coal-fired pulp dryer | Multiple cyclones and stack filter system | Condensible organic PM | 9 | A | 0.040-0.059 (0.081-0.12) | 0.047 (0.095) | 22 |
| Coal-fired pulp dryer | Multiple cyclones and stack filter system | $CO_2$ | 9 | A | 120-160 (240-320) | 140 (280) | 22 |
| Natural gas-fired pulp dryer | Multiple cyclones and gas recirculation | Filterable PM | 3 | A | 0.29-0.44 (0.58-0.87) | 0.38 (0.77) | 23 |

TABLE 4-2. (continued)

| Source | Control device | Pollutant | No. of test runs | Data rating | Emission factor range, kg/Mg (lb/ton) | Average emission factor, kg/Mg (lb/ton) | Ref. No. |
|---|---|---|---|---|---|---|---|
| Natural gas-fired pulp dryer | Multiple cyclones and gas recirculation | $CO_2$ | 3 | A | 65-100 (130-210) | 80 (160) | 23 |
| Natural gas-fired pulp dryer | Multiple cyclones and gas recirculation | Filterable PM | 4 | A | 0.18-0.43 (0.36-0.85) | 0.30 (0.60) | 24 |
| Natural gas-fired pulp dryer | Multiple cyclones and gas recirculation | $CO_2$ | 4 | A | 87-180 (170-360) | 120 (230) | 24 |
| Oil-fired pulp dryer | Multiple cyclones and fuel gas aspiration | Filterable PM | 3 | A | 0.30-0.34 (0.61-0.67) | 0.32 (0.65) | 25 |
| Oil-fired pulp dryer | Multiple cyclones and fuel gas aspiration | $CO_2$ | 3 | A | 180-210 (350-410) | 190 (380) | 25 |
| Natural gas-fired pulp dryer | Wet scrubber | Filterable PM | 3 | B | 0.16-0.21 (0.32-0.42) | 0.18 (0.36) | 26 |
| Natural gas-fired pulp dryer | Wet scrubber | Condensible inorganic PM | 3 | B | 0.0029-0.0087 (0.0058-0.017) | 0.0052 (0.011) | 26 |
| Natural gas-fired pulp dryer | Wet scrubber | $CO_2$ | 3 | B | 135-237 (270-474) | 170 (340) | 26 |

[a]Emission factor units are kg (lb) of pollutant per Mg (ton) of pressed wet pulp to the dryer, unless noted. ND = no data available. NP = pollutant not detected.
NR = not rated.
[b]Emission factor units are lb per 1,000 gallons of raw juice produced.
[c]Emission factor units are lb per 1,000 gallons of thin juice produced.
[d]Dryer is the same unit for which data are reported in Reference 20.
[e]Dryer is the same as one of the units for which data are reported in Reference 16.

TABLE 4-3. SUMMARY OF EMISSION FACTORS FOR SUGARBEET PROCESSING[a]

| Source | Control device | Pollutant | No. of tests | Emission factor rating | Emission factor range, kg/Mg (lb/ton) | Average emission factor, kg/Mg (lb/ton) | Ref. Nos. |
|---|---|---|---|---|---|---|---|
| Coal-fired pulp dryer | None | Filterable PM | 1 | D | NA | 2.2 (4.4) | 17 |
| Coal-fired pulp dryer | Multiple cyclones | Filterable PM | 8 | B | 0.21-0.59 (0.42-1.2) | 0.33 (0.66) | 4,16,17,20,22 |
| Coal-fired pulp dryer | Wet scrubber[b] | Filterable PM | 3 | D | 0.17-0.36 (0.34-0.72) | 0.25 (0.49) | 5,12 |
| Natural gas-fired pulp dryer | Multiple cyclones | Filterable PM | 2 | D | 0.30-0.38 (0.60-0.77) | 0.34 (0.69) | 23,24 |
| Natural gas-fired pulp dryer | Wet scrubber[b] | Filterable PM | 6 | D | 0.038-0.18 (0.075-0.36) | 0.097 (0.19) | 6-10,26 |
| Oil-fired pulp dryer | Cyclone | Filterable PM | 3 | C | 0.64-0.79 (1.3-1.6) | 0.72 (1.4) | 1,2,14 |
| Oil-fired pulp dryer | Dry scrubber and cyclone | Filterable PM | 2 | D | 0.38-0.76 (0.77-1.5) | 0.57 (1.1) | 13 |
| Oil-fired pulp dryer | Multiple cyclones | Filterable PM | 2 | D | 0.27-0.32 (0.55-0.65) | 0.30 (0.60) | 15,25 |
| Sugar cooler | Rotoclone | Filterable PM | 1 | D | NA | 0.066 (0.13) | 21 |
| Sugar cooler | Venturi scrubber | Filterable PM | 1 | D | NA | 0.032 (0.065) | 19 |
| Sugar granulator | Rotoclone | Filterable PM | 1 | D | NA | 0.032 (0.064) | 21 |
| Sugar dryer and cooler | Wet scrubber | Filterable PM | 1 | NR | NA | 0.018 (0.035) | 3 |
| Oil-fired pulp dryer | Dry scrubber and cyclone | Filterable PM-10 | 2 | D | 0.23-0.59 (0.47-1.2) | 0.41 (0.83) | 13 |
| Coal-fired pulp dryer | Wet scrubber[b] | Condensible inorganic PM | 1 | D | NA | 0.025 (0.050) | 12 |
| Natural gas-fired pulp dryer | Wet scrubber | Condensible inorganic PM | 3 | D | 0.0052-0.014 (0.011-0.027) | 0.009 (0.018) | 9,10,26 |
| Oil-fired pulp dryer | Cyclone | Condensible inorganic PM | 3 | C | 0.014-0.27 (0.027-0.55) | 0.12 (0.24) | 1,2,13, 14 |
| Sugar cooler | Venturi scrubber | Condensible inorganic PM | 1 | D | NA | 0.0024 (0.0047) | 19 |
| Coal-fired pulp dryer | Multiple cyclones | Condensible organic PM | 7 | C | 0.019-0.086 (0.039-0.17) | 0.042 (0.084) | 16,17, 20,22 |
| Oil-fired pulp dryer | Cyclone | Condensible organic PM | 3 | C | 0.016-0.054 (0.032-0.11) | 0.038 (0.076) | 1,2,14 |

TABLE 4-3. (continued)

| Source | Control device | Pollutant | No. of tests | Emission factor rating | Emission factor range, kg/Mg (lb/ton) | Average emission factor, kg/Mg (lb/ton) | Ref. Nos. |
|---|---|---|---|---|---|---|---|
| Coal-fired pulp dryer | Wet scrubber | Condensible PM | 2 | D | 0.17-0.23 (0.33-0.47) | 0.20 (0.40) | 5 |
| Coal-fired pulp dryer | [c] | VOC as methane | 1 | D | NA | 0.59 (1.2) | 20 |
| Oil-fired pulp dryer | [c] | VOC as methane | 1 | D | NA | 0.055 (0.11) | 14 |
| Oil-fired pulp dryer | [c] | Methane | 1 | D | NA | 0.014 (0.028) | 14 |
| Coal-fired pulp dryer | [c] | CO | 1 | D | NA | 1.1 (2.3) | 20 |
| Oil-fired pulp dryer | [c] | CO | 1 | D | NA | 0.51 (1.0) | 14 |
| Coal-fired pulp dryer | [c] | $CO_2$ | 10 | B | 130-240 (260-490) | 180 (370) | 4,12,16,17, 20,22 |
| Natural gas-fired pulp dryer | [c] | $CO_2$ | 8 | C | 29-170 (58-340) | 78 (156) | 6-10,23,24,26 |
| Oil-fired pulp dryer | [c] | $CO_2$ | 6 | C | 170-290 (330-570) | 210 (430) | 1,2,13,14,25 |
| Sugar dryer and cooler | [c] | $CO_2$ | 1 | NR | NA | Negligible | 3 |
| Coal-fired pulp dryer | [c] | $NO_x$ | 2 | D | 0.28-0.37 (0.57-0.74) | 0.33 (0.66) | 16,20 |
| Oil-fired pulp dryer | [c] | $NO_x$ | 1 | D | NA | 0.30 (0.60) | 14 |
| Coal-fired pulp dryer | [c] | $SO_2$ | 2 | D | 0.092-0.68 (0.18-1.4) | 0.40 (0.79) | 4,20 |
| Oil-fired pulp dryer | [c] | $SO_2$ | 3 | D | 0.31-0.65 (0.63-1.3) | 0.52 (1.0) | 13,15 |
| Coal-fired pulp dryer | Wet scrubber | Acetaldehyde | 2 | E | 0.0065-0.0080 (0.013-0.016) | 0.0073 (0.015) | 5 |
| Coal-fired pulp dryer | Wet scrubber | Acrolein | 2 | E | 0.0030-0.0046 (0.0060-0.0092) | 0.0038 (0.0076) | 5 |
| Coal-fired pulp dryer | Wet scrubber | Crotonaldehyde | 2 | E | 0.00080-0.0012 (0.0016-0.0024) | 0.0010 (0.0020) | 5 |
| Coal-fired pulp dryer | Wet scrubber | Formaldehyde | 2 | E | 0.0030-0.0042 (0.0059-0.0083) | 0.0036 (0.0071) | 5 |
| Second carbonation tank[d] | None | Acetaldehyde | 1 | E | NA | 0.0043 | 5 |
| Second carbonation tank[d] | None | Acrolein | 1 | E | NA | $2.4 \times 10^{-4}$ | 5 |
| Second carbonation tank[d] | None | Crotonaldehyde | 1 | E | NA | $3.0 \times 10^{-5}$ | 5 |

TABLE 4-3. (continued)

| Source | Control device | Pollutant | No. of tests | Emission factor rating | Emission factor range, kg/Mg (lb/ton) | Average emission factor, kg/Mg (lb/ton) | Ref. Nos. |
|---|---|---|---|---|---|---|---|
| Second carbonation tank[d] | None | Formaldehyde | 1 | E | NA | $1.6x10^{-5}$ | 5 |
| First evaporator[e] | None | Acetaldehyde | 2 | E | $2.4x10^{-5}$-$1.1x10^{-4}$ | $6.7x10^{-5}$ | 5 |
| First evaporator[e] | None | Acrolein | 2 | E | $1.5x10^{-7}$-$6.8x10^{-7}$ | $4.2x10^{-7}$ | 5 |
| First evaporator[e] | None | Crotonaldehyde | 2 | E | $9.5x10^{-8}$-$1.9x10^{-7}$ | $1.4x10^{-7}$ | 5 |
| First evaporator[e] | None | Formaldehyde | 2 | E | $1.0x10^{-7}$-$1.3x10^{-6}$ | $7.0x10^{-7}$ | 5 |
| Coal-fired pulp dryer | Wet scrubber | 2-methylnaphthalene | 1 | E | NA | $8.5x10^{-6}$ ($1.7x10^{-5}$) | 5 |
| Coal-fired pulp dryer | Wet scrubber | 2-nitrophenol | 1 | E | NA | $9.0x10^{-5}$ (0.00018) | 5 |
| Coal-fired pulp dryer | Wet scrubber | 2-methylphenol | 1 | E | NA | $1.7x10^{-5}$ ($3.4x10^{-5}$) | 5 |
| Coal-fired pulp dryer | Wet scrubber | 2,4-dimethylphenol | 1 | E | NA | $1.3x10^{-5}$ ($2.5x10^{-5}$) | 5 |
| Coal-fired pulp dryer | Wet scrubber | 4-methylphenol | 1 | E | NA | $6.5x10^{-5}$ (0.00013) | 5 |
| Coal-fired pulp dryer | Wet scrubber | 4-nitrophenol | 1 | E | NA | $7.0x10^{-5}$ (0.00014) | 5 |
| Coal-fired pulp dryer | Wet scrubber | Acenaphthylene | 1 | E | NA | $8.5x10^{-7}$ ($1.7x10^{-6}$) | 5 |
| Coal-fired pulp dryer | Wet scrubber | Benzaldehyde | 1 | E | NA | 0.00070 (0.0014) | 5 |
| Coal-fired pulp dryer | Wet scrubber | Benzoic acid | 1 | E | NA | 0.0014 (0.0028) | 5 |
| Coal-fired pulp dryer | Wet scrubber | Benzyl alcohol | 1 | E | NA | $3.6x10^{-5}$ ($7.1x10^{-5}$) | 5 |
| Coal-fired pulp dryer | Wet scrubber | Bis(2-ethylhexyl)phthalate | 1 | E | NA | 0.00075 (0.0015) | 5 |
| Coal-fired pulp dryer | Wet scrubber | Di-n-butylphthalate | 1 | E | NA | $2.6x10^{-5}$ ($5.2x10^{-5}$) | 5 |
| Coal-fired pulp dryer | Wet scrubber | Dibenzofuran | 1 | E | NA | $5.5x10^{-6}$ ($1.1x10^{-5}$) | 5 |
| Coal-fired pulp dryer | Wet scrubber | Diethylphthalate | 1 | E | NA | $4.9x10^{-6}$ ($9.8x10^{-6}$) | 5 |
| Coal-fired pulp dryer | Wet scrubber | Naphthalene | 1 | E | NA | $5.5x10^{-5}$ (0.00011) | 5 |
| Coal-fired pulp dryer | Wet scrubber | Nitrobenzene | 1 | E | NA | $9.5x10^{-6}$ ($1.9x10^{-5}$) | 5 |
| Coal-fired pulp dryer | Wet scrubber | Phenanthrene | 1 | E | NA | $6.0x10^{-6}$ ($1.2x10^{-5}$) | 5 |
| Coal-fired pulp dryer | Wet scrubber | Phenol | 1 | E | NA | 0.00016 (0.00032) | 5 |

TABLE 4-3. (continued0

| Source | Control device | Pollutant | No. of tests | Emission factor rating | Emission factor range, kg/Mg (lb/ton) | Average emission factor, kg/Mg (lb/ton) | Ref. Nos. |
|---|---|---|---|---|---|---|---|
| First carbonation tank[d] | None | 2-methylnaphthalene | 1 | D | NA | $5.1x10^{-7}$ | 5 |
| First carbonation tank[d] | None | 2,4-dinitrophenol | 1 | D | NA | NP | 5 |
| First carbonation tank[d] | None | 4-methylphenol | 1 | D | NA | $6.6x10^{-7}$ | 5 |
| First carbonation tank[d] | None | Acenaphthene | 1 | D | NA | NP | 5 |
| First carbonation tank[d] | None | Benzaldehyde | 1 | D | NA | $1.1x10^{-4}$ | 5 |
| First carbonation tank[d] | None | Benzoic acid | 1 | D | NA | $8.4x10^{-6}$ | 5 |
| First carbonation tank[d] | None | Benzyl alcohol | 1 | D | NA | $5.0x10^{-6}$ | 5 |
| First carbonation tank[d] | None | Bis(2-ethylhexyl)phthalate | 1 | D | NA | $1.2x10^{-5}$ | 5 |
| First carbonation tank[d] | None | Naphthalene | 1 | D | NA | $2.0x10^{-6}$ | 5 |
| First carbonation tank[d] | None | Phenanthrene | 1 | D | NA | $1.4x10^{-6}$ | 5 |
| First carbonation tank[d] | None | Phenol | 1 | D | NA | $1.3x10^{-6}$ | 5 |
| First evaporator[e] | None | 4-methylphenol | 1 | E | NA | NP | 5 |
| First evaporator[e] | None | Benzaldehyde | 1 | E | NA | $2.2x10^{-6}$ | 5 |
| First evaporator[e] | None | Benzoic acid | 1 | E | NA | NP | 5 |
| First evaporator[e] | None | Benzyl alcohol | 1 | E | NA | $1.8x10^{-7}$ | 5 |
| First evaporator[e] | None | Bis(2-ethylhexyl)phthalate | 1 | E | NA | $3.7x10^{-7}$ | 5 |
| First evaporator[e] | None | Di-n-butylphthalate | 1 | E | NA | $1.1x10^{-9}$ | 5 |
| First evaporator[e] | None | Dibenzofuran | 1 | E | NA | NP | 5 |
| First evaporator[e] | None | Diethylphthalate | 1 | E | NA | NP | 5 |
| First evaporator[e] | None | Isophorone | 1 | E | NA | NP | 5 |
| First evaporator[e] | None | Naphthalene | 1 | E | NA | $2.5x10^{-8}$ | 5 |
| First evaporator[e] | None | Phenanthrene | 1 | E | NA | $1.6x10^{-8}$ | 5 |
| First evaporator[e] | None | Phenol | 1 | E | NA | $1.2x10^{-8}$ | 5 |

TABLE 4-3. (continued)

| Source | Control device | Pollutant | No. of tests | Emission factor rating | Emission factor range, kg/Mg (lb/ton) | Average emission factor, kg/Mg (lb/ton) | Ref. Nos. |
|---|---|---|---|---|---|---|---|
| First evaporator[e] | None | Pyridine | 1 | E | NA | $3.4x10^{-8}$ | 5 |

[a]Emission factor units are kg (lb) of pollutant per Mg (ton) of pressed wet pulp to the dryer, unless noted. NA = not applicable. NP = pollutant not detected. NR = not rated.
[b]Emission factor includes data for dryers controlled by a cyclone or multiple cyclones, followed by a wet scrubber.
[c]Because the control devices typically used to control beet pulp dryer emissions are not specifically designed to control gaseous emissions, this emission factor is assumed to be applicable to dryers controlled by a cyclone, multiple cyclones, a wet scrubber, a venturi scrubber, or any combination of these control devices.
[d]Emission factor units are lb per 1,000 gallons of raw juice produced.
[e]Emission factor units are lb per 1,000 gallons of thin juice produced.

An emission factor for filterable PM emissions from a natural gas-fired pulp dryer controlled with multiple cyclones and gas recirculation systems was developed using A-rated data from two tests conducted at two facilities. Different aspiration rates were used at each facility. The data range from 0.30 kg/Mg (0.60 lb/ton) to 0.38 kg/Mg (0.77 lb/ton) and average 0.34 kg/Mg (0.69 lb/ton). This candidate emission factor is assigned a D rating because it was developed using data from only 2 of the 31 sugarbeet processing plants currently operating in the United States.

An emission factor for filterable PM emissions from a natural gas-fired pulp dryer controlled with a wet scrubber was developed using A- and B-rated data from six tests conducted on six different dryers. The dryers are located at three facilities. The data range from 0.038 kg/Mg (0.075 lb/ton) to 0.18 kg/Mg (0.36 lb/ton) and average 0.097 kg/Mg (0.19 lb/ton). This candidate emission factor is assigned a D rating because it was developed using data from only 3 of the 31 sugarbeet processing plants currently operating in the United States.

An emission factor for filterable PM emissions from a fuel oil-fired pulp dryer controlled with a cyclone was developed using B-rated data from three tests conducted at three facilities. The data range from 0.64 kg/Mg (1.3 lb/ton) to 0.79 kg/Mg (1.6 lb/ton) and average 0.72 kg/Mg (1.4 lb/ton). This candidate emission factor is assigned a C rating because it was developed using data from 3 of the 31 sugarbeet processing plants currently operating in the United States.

An emission factor for filterable PM emissions from a fuel oil-fired pulp dryer controlled with a dry scrubber followed by a cyclone was developed using A- and B-rated data from tests conducted on two dryers located at the same facility. The data range from 0.38 kg/Mg (0.77 lb/ton) to 0.76 kg/Mg (1.5 lb/ton) and average 0.57 kg/Mg (1.1 lb/ton). This candidate emission factor is assigned a D rating because it was developed using data from only 1 of the 31 sugarbeet processing plants currently operating in the United States.

An emission factor for filterable PM emissions from a fuel oil-fired pulp dryer controlled with multiple cyclones was developed using A- and B-rated data from two tests conducted at different facilities. The data range from 0.27 kg/Mg (0.55 lb/ton) to 0.32 kg/Mg (0.65 lb/ton) and average 0.30 kg/Mg (0.60 lb/ton). This candidate emission factor is assigned a D rating because it was developed using data from only 2 of the 31 sugarbeet processing plants currently operating in the United States.

An emission factor for filterable PM emissions from a sugar cooler controlled with a mechanical centrigual separator with water sprays was developed using A-rated data from a single test. The emission factor is 0.066 kg/Mg (0.13 lb/ton). This emission factor is assigned a D rating because it was developed using data from only a single test.

An emission factor for filterable PM emissions from a sugar cooler controlled with a venturi scrubber was developed using A-rated data from a single test. The emission factor is 0.032 kg/Mg (0.065 lb/ton). This emission factor is assigned a D rating because it was developed using data from only a single test.

An emission factor for filterable PM emissions from a sugar granulator controlled with a mechanical centrigual separator with water sprays was developed using A-rated data from a single test. The emission factor is 0.032 kg/Mg (0.064 lb/ton). This emission factor is assigned a D rating because it was developed using data from only a single test.

An emission factor for filterable PM emissions from a sugar granulator and cooler controlled with a wet scrubber was developed using B-rated data from a single test. The data are not used for emission factor development because the emission source is a combined source and data are available for the individual sources.

4.3.2 Filterable PM-10

An emission factor for filterable PM-10 emissions from a fuel oil-fired pulp dryer controlled with a dry scrubber followed by a cyclone was developed using B-rated data from tests conducted on two dryers located at the same facility. The data range from 0.23 kg/Mg (0.47 lb/ton) to 0.59 kg/Mg (1.2 lb/ton) and average 0.41 kg/Mg (0.83 lb/ton). This candidate emission factor is assigned a D rating because it was developed using data from only 1 of the 31 sugarbeet processing plants currently operating in the United States.

4.3.3 Condensible PM

An emission factor for condensible inorganic PM emissions from a coal-fired pulp dryer controlled with a wet scrubber was developed using A-rated data from a single test. The emission factor is 0.025 kg/Mg (0.050 lb/ton). This emission factor is assigned a D rating because it was developed using data from only a single test.

An emission factor for condensible inorganic PM emissions from a natural gas-fired pulp dryer controlled with a wet scrubber was developed using B-rated data from tests conducted on three dryers located at two facilities. The data range from 0.0052 kg/Mg (0.011 lb/ton) to 0.014 kg/Mg (0.027 lb/ton) and average 0.009 kg/Mg (0.018 lb/ton). This candidate emission factor is assigned a D rating because it was developed using data from only 2 of the 31 sugarbeet processing plants currently operating in the United States.

An emission factor for condensible inorganic PM emissions from a fuel oil-fired pulp dryer controlled with a cyclone was developed using B-rated data from five tests conducted at four facilities. Two of the dryers were equipped with a dry scrubber and a cyclone, but the condensible inorganic PM emissions from these two dryers were greater than the emissions from the cyclone-controlled dryers. Therefore, the dry scrubber was assumed to have no effect on condensible inorganic PM emissions, and the data were combined. The data range from 0.014 kg/Mg (0.027 lb/ton) to 0.27 kg/Mg (0.55 lb/ton) and average 0.12 kg/Mg (0.24 lb/ton). This candidate emission factor is assigned a C rating because it was developed using data from 4 of the 31 sugarbeet processing plants currently operating in the United States.

An emission factor for condensible inorganic PM emissions from a sugar cooler controlled with a venturi scrubber was developed using A-rated data from a single test. The emission factor is 0.0024 kg/Mg (0.0047 lb/ton). This emission factor is assigned a D rating because it was developed using data from only a single test.

An emission factor for condensible organic PM emissions from a coal-fired pulp dryer controlled with multiple cyclones was developed using A-rated data from seven tests conducted on seven different dryers. The dryers are located at three facilities. The data range from 0.019 kg/Mg (0.039 lb/ton) to 0.086 kg/Mg (0.17 lb/ton) and average 0.042 kg/Mg (0.084 lb/ton). This candidate emission factor is assigned a C rating because it was developed using data from 3 of the 31 sugarbeet processing plants currently operating in the United States.

An emission factor for condensible organic PM emissions from a fuel oil-fired pulp dryer controlled with a cyclone was developed using B-rated data from three tests conducted at three facilities. The data range from 0.016 kg/Mg (0.032 lb/ton) to 0.054 kg/Mg (0.11 lb/ton) and average 0.038 kg/Mg (0.076 lb/ton). This candidate emission factor is assigned a C rating because it was developed using data from 3 of the 31 sugarbeet processing plants currently operating in the United States.

An emission factor for condensible organic PM emissions from a sugar cooler controlled with a mechanical centrigual separator with water sprays was developed using A-rated data from a single test.

The emission factor is 0.0022 kg/Mg (0.0043 lb/ton). This emission factor is assigned a D rating because it was developed using data from only a single test.

An emission factor for condensible organic PM emissions from a sugar cooler controlled with a venturi scrubber was developed using A-rated data from a single test. The emission factor is 0.0021 kg/Mg (0.0042 lb/ton). This emission factor is assigned a D rating because it was developed using data from only a single test.

An emission factor for condensible organic PM emissions from a sugar granulator controlled with a mechanical centrigual separator with water sprays was developed using A-rated data from a single test. The emission factor is 0.0018 kg/Mg (0.0037 lb/ton). This emission factor is assigned a D rating because it was developed using data from only a single test.

An emission factor for total condensible PM emissions from a coal-fired pulp dryer controlled with a wet scrubber was developed using A- and B-rated data from two tests conducted on different dryers located at the same facility. The data range from 0.17 kg/Mg (0.33 lb/ton) to 0.23 kg/Mg (0.47 lb/ton) and average 0.20 kg/Mg (0.40 lb/ton). This candidate emission factor is assigned a D rating because it was developed using data from only 2 of the 31 sugarbeet processing plants currently operating in the United States.

### 4.3.4 Volatile Organic Compounds

An emission factor for VOC emissions from a coal-fired pulp dryer was developed using A-rated data from a single test. The emission factor is 0.59 kg/Mg (1.2 lb/ton). Because the control devices typically used to control beet pulp dryer emissions are not designed to control VOC emissions, this emission factor is assumed to be applicable to coal-fired dryers controlled by a cyclone, multiple cyclones, a wet scrubber, a venturi scrubber, or any combination of these control devices. This emission factor is assigned a D rating because it was developed using data from only a single test.

An emission factor for VOC emissions from a fuel oil-fired pulp dryer was developed using B-rated data from a single test. The emission factor is 0.055 kg/Mg (0.11 lb/ton). Because the control devices typically used to control beet pulp dryer emissions are not designed to control VOC emissions, this emission factor is assumed to be applicable to fuel oil-fired dryers controlled by a cyclone, multiple cyclones, a wet scrubber, a venturi scrubber, or any combination of these control devices. This emission factor is assigned a D rating because it was developed using data from only a single test.

### 4.3.5 Methane

An emission factor for methane emissions from a fuel oil-fired pulp dryer was developed using B-rated data from a single test. The emission factor is 0.014 kg/Mg (0.028 lb/ton). Because the control devices typically used to control beet pulp dryer emissions are not designed to control methane emissions, this emission factor is assumed to be applicable to fuel oil-fired dryers controlled by a cyclone, multiple cyclones, a wet scrubber, a venturi scrubber, or any combination of these control devices. This emission factor is assigned a D rating because it was developed using data from only a single test.

### 4.3.6 Carbon Monoxide

An emission factor for CO emissions from a coal-fired pulp dryer was developed using A-rated data from a single test. The emission factor is 1.1 kg/Mg (2.3 lb/ton). Because the control devices typically used to control beet pulp dryer emissions are not designed to control CO emissions, this emission factor is assumed to be applicable to coal-fired dryers controlled by a cyclone, multiple cyclones, a wet scrubber, a venturi scrubber, or any combination of these control devices. This emission factor is assigned a D rating because it was developed using data from only a single test.

An emission factor for CO emissions from a fuel oil-fired pulp dryer was developed using B-rated data from a single test. The emission factor is 0.51 kg/Mg (1.0 lb/ton). Because the control devices typically used to control beet pulp dryer emissions are not designed to control CO emissions, this emission factor is assumed to be applicable to fuel oil-fired dryers controlled by a cyclone, multiple cyclones, a wet scrubber, a venturi scrubber, or any combination of these control devices. This emission factor is assigned a D rating because it was developed using data from a single test.

4.3.7 Carbon Dioxide

An emission factor for $CO_2$ emissions from a coal-fired pulp dryer was developed using A-rated data from ten tests conducted on nine different dryers. The dryers are located at five facilities. The data range from 130 kg/Mg (260 lb/ton) to 240 kg/Mg (490 lb/ton) and average 180 kg/Mg (370 lb/ton). Because the control devices typically used to control beet pulp dryer emissions are not designed to control $CO_2$ emissions, this emission factor is assumed to be applicable to coal-fired dryers controlled by a cyclone, multiple cyclones, a wet scrubber, a venturi scrubber, or any combination of these control devices. This candidate emission factor is assigned a B rating because it was developed using A-rated data from 5 of the 31 sugarbeet processing plants currently operating in the United States.

An emission factor for $CO_2$ emissions from a natural gas-fired pulp dryer was developed using A- and B-rated data from eight tests conducted on eight different dryers. The dryers are located at five facilities. The data range from 29 kg/Mg (58 lb/ton) to 170 kg/Mg (340 lb/ton) and average 78 kg/Mg (156 lb/ton). Because the control devices typically used to control beet pulp dryer emissions are not designed to control $CO_2$ emissions, this emission factor is assumed to be applicable to natural gas-fired dryers controlled by a cyclone, multiple cyclones, a wet scrubber, a venturi scrubber, or any combination of these control devices. This candidate emission factor is assigned a C rating because it was developed using A- and B-rated data from 5 of the 31 sugarbeet processing plants currently operating in the United States.

An emission factor for $CO_2$ emissions from a fuel oil-fired pulp dryer was developed using A- and B-rated data from six tests conducted on six different dryers. The dryers are located at four facilities. The data range from 170 kg/Mg (330 lb/ton) to 290 kg/Mg (570 lb/ton) and average 210 kg/Mg (430 lb/ton). Because the control devices typically used to control beet pulp dryer emissions are not designed to control $CO_2$ emissions, this emission factor is assumed to be applicable to fuel oil-fired dryers controlled by a cyclone, multiple cyclones, a wet scrubber, a venturi scrubber, or any combination of these control devices. This candidate emission factor is assigned a C rating because it was developed using A- and B-rated data from 4 of the 31 sugarbeet processing plants currently operating in the United States.

Carbon dioxide emissions from a sugar granulator and cooler were measured during one test and were negligible during all of the test runs.

4.3.8 Nitrogen Oxides

An emission factor for $NO_x$ emissions from a coal-fired pulp dryer was developed using A-rated data from two tests conducted on the same dryer. The data range from 0.28 kg/Mg (0.57 lb/ton) to 0.37 kg/Mg (0.74 lb/ton) and average 0.33 kg/Mg (0.66 lb/ton). Because the control devices typically used to control beet pulp dryer emissions are not designed to control $NO_x$ emissions, this emission factor is assumed to be applicable to coal-fired dryers controlled by a cyclone, multiple cyclones, a wet scrubber, a venturi scrubber, or any combination of these control devices. This emission factor is assigned a D rating because it was developed using data from only a single facility.

An emission factor for $NO_x$ emissions from a fuel oil-fired pulp dryer was developed using B-rated data from a single test. The emission factor is 0.30 kg/Mg (0.60 lb/ton). Because the control devices typically used to control beet pulp dryer emissions are not designed to control $NO_x$ emissions,

this emission factor is assumed to be applicable to fuel oil-fired dryers controlled by a cyclone, multiple cyclones, a wet scrubber, a venturi scrubber, or any combination of these control devices. This emission factor is assigned a D rating because it was developed using data from only a single test.

4.3.9 Sulfur Dioxide

An emission factor for $SO_2$ emissions from a coal-fired pulp dryer was developed using A-rated data from two tests conducted at different facilities. The data range from 0.092 kg/Mg (0.18 lb/ton) to 0.68 kg/Mg (1.4 lb/ton) and average 0.40 kg/Mg (0.79 lb/ton). Because the control devices typically used to control beet pulp dryer emissions are not specifically designed to control $SO_2$ emissions, this emission factor is assumed to be applicable to coal-fired dryers controlled by a cyclone, multiple cyclones, a wet scrubber, a venturi scrubber, or any combination of these control devices. Wet scrubbers on coal-fired boilers at beet sugar facilities may show up to 50 to 70 percent efficiency for $SO_2$ control; wet scrubbers on coal-fired dryers may also achieve some level of $SO_2$ control. This emission factor is assigned a D rating because it was developed using data from only 2 of the 31 sugarbeet processing plants currently operating in the United States..

An emission factor for $SO_2$ emissions from a fuel oil-fired pulp dryer was developed using A-and B-rated data from three tests conducted on three different dryers. The dryers are located at two facilities. One other test included $SO_2$ measurements, but $SO_2$ emissions were not detected; the data from this additional test are not used for emission factor development because the other three tests document levels of $SO_2$ that are well above the detection limit of the test method. The data range from 0.31 kg/Mg (0.63 lb/ton) to 0.65 kg/Mg (1.3 lb/ton) and average 0.52 kg/Mg (1.0 lb/ton). Because the control devices typically used to control beet pulp dryer emissions are not designed to control $SO_2$ emissions, this emission factor is assumed to be applicable to fuel oil-fired dryers controlled by a cyclone, multiple cyclones, a wet scrubber, a venturi scrubber, or any combination of these control devices. This emission factor is assigned a D rating because it was developed using data from only 2 of the 31 sugarbeet processing plants currently operating in the United States.

4.3.10 Acetaldehyde, Acrolein, Crotonaldehyde, Formaldehyde

Emission factors for acetaldehyde, acrolein, crotonaldehyde, and formaldehyde emissions from a coal-fired pulp dryer controlled with a wet scrubber were developed using C-rated data from two tests conducted on two dryers located at the same facility. These emission factors are assigned an E rating because they are based on C-rated data.

Emission factors for acetaldehyde, acrolein, crotonaldehyde, and formaldehyde emissions from a second carbonation tank were developed using C-rated data from a single test. These emission factors are assigned an E rating because they are based on C-rated data. The units for these emission factors are pounds of pollutant per 1,000 gallons of raw juice produced.

Emission factors for acetaldehyde, acrolein, crotonaldehyde, and formaldehyde emissions from a first evaporator were developed using C-rated data from two tests. These emission factors are assigned an E rating because they are based on C-rated data. The units for these emission factors are pounds of pollutant per 1,000 gallons of thin juice produced.

4.3.11 Semivolatile Organic Compounds

Emission factors for speciated SVOC emissions from a coal-fired pulp dryer controlled with a wet scrubber were developed using C-rated data from a single test. These emission factors are assigned an E rating because they are based on C-rated data.

Emission factors for speciated SVOC emissions from a first carbonation tank were developed using B-rated data from a single test. These emission factors are assigned a D rating because they are based on data from only a single test.

Emission factors for speciated SVOC emissions from a first evaporator were developed using C-rated data from a single test. These emission factors are assigned an E rating because they are based on C-rated data.

## 4.4 SUMMARY OF DEVELOPMENT OF AP-42 SECTION

### 4.4.1 Section Narrative

A process description was written using the most recent available references, and a process flow diagram was developed from the process description. In addition, emissions from sugarbeet processing operations and types of emission control systems currently in use are discussed.

### 4.4.2 Emission Factors

The emission factors discussed in section 4.3 of this report are presented in the proposed AP-42 Section 9.10.1.2, Sugarbeet Processing.

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14. *Emission Performance Testing of Four Boilers, Three Dryers, and One Cooler--Holly Sugar Corporation, Santa Maria, California*, Western Environmental Services, Redondo Beach, CA, June 1991.

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17. *Results of the January 28-31, 1992, Particulate Emission Tests, South Pulp Dryer--American Crystal Sugar Company, Moorehead, Minnesota*, Bay West, Inc., St. Paul, MN, March 26, 1992.

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19. *Results of a Source Emission Compliance Test on the Sugar Cooler Stack at American Crystal Sugar Company, Crookston, Minnesota, March 11, 1993*, Twin City Testing Corporation, St. Paul, MN, April 16, 1993.

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