Emission Factor Documentation for AP-42
Section 9.10.1.1

Sugarcane Processing

Final Report

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

EPA Contract 68-D2-0159
Work Assignment No. 3-01 and 4-04

MRI Project No. 4603-01-03 and 4604-04

June 1997

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Research Triangle Park, NC 27711

Attn: Mr. Dallas Safriet (MD-14)

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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. 3-01-03 and 4-04. Mr. Dallas Safriet was the requester of the work.

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June 1997

TABLE OF CONTENTS

LIST OF FIGURES

EMISSION FACTOR DOCUMENTATION FOR AP-42 SECTION 9.10.1.1
Sugarcane Processing

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 revisions to AP-42 Section 9.10.1.1, Sugarcane Processing.

This background report consists of five sections. Section 1 includes the introduction to the report. Section 2 gives a description of the sugarcane 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 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 revised AP-42 section was developed. It includes the review of specific data sets, a description of how candidate emission factors were developed, and a summary of changes to the AP-42 section. Section 5 presents the AP-42 Section 9.10.1.1, Sugarcane Processing. Supporting documentation for emission factor development is presented in the Appendices.

2. INDUSTRY DESCRIPTION[1-5]

Sugarcane processing is focussed on the production of cane sugar from sugarcane. Other products of the processing include bagasse, molasses, and filtercake. Bagasse, the residual woody fiber of the cane, is used for several purposes: fuel for the boilers and lime kilns, production of numerous paper and paperboard products and reconstituted panelboard, agricultural mulch, and as a raw material for production of chemicals. Bagasse and bagasse residue from chemical production are categorized by the sugar industry and government regulators as a co-product of cane sugar production. Bagasse and bagasse residue are primarily used as a fuel source for the boilers in the generation of process steam. Thus, bagasse is a renewable resource. Dried filtercake is used as an animal feed supplement, fertilizer, and source of sugarcane wax. Molasses is produced in two forms: inedible for humans (blackstrap) or as an edible syrup. Blackstrap molasses is used primarily as an animal feed additive but also used to produce ethanol, compressed yeast, citric acid, and rum. Edible molasses syrups are often blends with maple syrup, invert sugars, or corn syrup.

The four-digit standard industrial classification (SIC) code for the manufacture of raw sugar, syrup, and finished (granulated) cane sugar from sugarcane is 2061. For those facilities that refine purchased raw cane sugar and sugar syrup, the SIC code is 2062.

In this document, unrefined or raw sugar is referred to as “cane sugar.” Following refining, the sugar is referred to as “refined sugar.”

2.1 INDUSTRY CHARACTERIZATION[1,2,4,5]

Sugarcane is produced and harvested for two purposes: production of cane sugar and use as seed for subsequent plantings. In the United States, sugarcane is produced, harvested, and processed in four states: Florida, Louisiana, Texas, and Hawaii. In 1994, a total of 937,000 acres were harvested, of which 882,000 were for the production of cane sugar and 55,000 were for seed. The yield of cane for sugar production averages about 33 to 34 tons per acre; the yield of cane for seed averages about 26 to 28 tons per acre. Total production of sugarcane for sugar production in 1994 was 29.41 million tons. Using 1993 raw sugar production as a basis, production of raw sugar in 1994 is estimated to be 3.453 million tons. For refined (granulated) sugar, 100 pounds of raw sugar are required to produce 93.46 pounds of refined sugar. For the 1993/1994 growing season, the U.S. ranked 8th among all countries in terms of worldwide sugarcane production.

In the U.S., the leading sugarcane production state is Florida, followed by Louisiana, Hawaii, and Texas; Puerto Rico also produces sugarcane. In 1995, Florida harvested 437,000 acres with a yield of about 15.12 million tons of sugarcane. Louisiana produced about 10.24 million tons, followed by Hawaii with about 4.07 million tons and Texas with about 1.36 million tons. No data were available for Puerto Rico, but it produces relatively small quantities compared to the four States. In Hawaii, sugarcane harvest continues throughout the year and production statistics are on a calendar year basis. In other States, harvest is seasonal and the production statistics relates to the year in which the season begins. In 1992, the employment figure for the sugarcane processing facilities in the four States was 7,000, which represented an increase of 13 percent over 1991. In 1996, 33 U.S. mills produced cane sugar, and 11 U.S. refineries produced refined sugar. Of the 33 mills, 7 were located in Florida, 19 in Louisiana, 1 in Texas, and 6 in Hawaii. Of the 11 refineries, 2 were located in Florida, 2 in Louisiana, 2 in New York, and 1 each in Texas, Hawaii, California, Maryland, and Georgia.

2.2 PROCESS DESCRIPTION[3-5]

Sugarcane is a tropical grass belonging to the same family as sorghum, johnsongrass, and corn (maize). Modern sugarcane is a complex hybrid of two or more of the five species of the genus *Saccharum*. The production of cane sugar from sugarcane has three major steps: harvesting, cane sugar production, and refined sugar production.

2.2.1 Harvesting

The primary goal of harvesting is to deliver to the processing mill good quality sugarcane stalks with a minimum of trash. During harvesting, the cane tops and leaves are removed because they contain little sucrose but are high in starch and reducing sugars, which reduces sugar yields. Cane leaves also have a high silica content which contributes to mill roll wear. Cane tops and leaves can be removed either by hand trimming after harvesting or by burning the green cane prior to harvesting.

Hand cutting is the most common harvesting method throughout the world but some locations (e.g., Florida, Louisiana, and Hawaii) have used mechanical harvesters for several years. After cutting, the cane is loaded by hand, mechanical grab loaders, or continuous loaders. Cane is transported to the mills using trailers, trucks, railcars, or barges, depending upon the relative location of the cane fields and the processing plants. When the cane is cut, rapid deterioration of the cane begins by enzymic, chemical, and microbial processes. Therefore, unlike sugarbeets, sugarcane cannot be stored for later processing without excessive deterioration of the sucrose content; the cane must be processed within a short time after cutting.

2.2.2 Cane Sugar Production

A simplified process flow diagram for a typical cane sugar production plant is shown in Figure 2-1. The cane is received at the mill and prepared for extraction of the juice. At the mill, the cane is mechanically unloaded and placed in a large pile. Prior to milling, the cane is cleaned, usually with high pressure water; a dry cleaning process is used in Hawaii. The milling process occurs in two steps: breaking the hard structure of the cane and grinding the cane. Breaking the cane uses revolving knives, shredders, crushers, or a combination of these processes. For the grinding, or milling, of the crushed cane, a three-roller mill is most commonly used although some mills consist of four, five, or six rollers in a single mill. Multiple sets of mills are used with combinations of 15 to 18 rollers being predominant. Conveyors transport the crushed cane from one mill to the next. Imbibition is the process in which water or juice is applied to the crushed cane to enhance the extraction of the juice at the next mill. The common procedure is to send the juice from the crusher and the first two mills for further processing. In imbibition, water or juice from other processing areas is introduced into the last mill and transferred from mill to mill towards the first two mills while the crushed cane travels from the first to the last mill. The crushed cane exiting the last mill is called bagasse. A diffusion process, consisting of treating the crushed or shredded cane with water to extract the juice, pressing the cane, and treating the press water, is used in some processing facilities but handling the large amounts of press water is a major problem

The juice from the mills or diffuser is strained to remove large particles and then clarified. In raw sugar production, clarification is done almost exclusively with heat and lime (as milk of lime or lime saccharate); small quantities of soluble phosphate also may be added. The lime is added to neutralize the organic acids and the temperature of the juice raised to about 95°C (200°F). A heavy precipitate forms which is separated from the juice in the clarifier. The phosphate acts as a flocculating agent. There are many different forms of clarifiers, many variations of the clarification process, and many different additives used as clarification aides. The insoluble particulate mass, called "mud", is separated from the

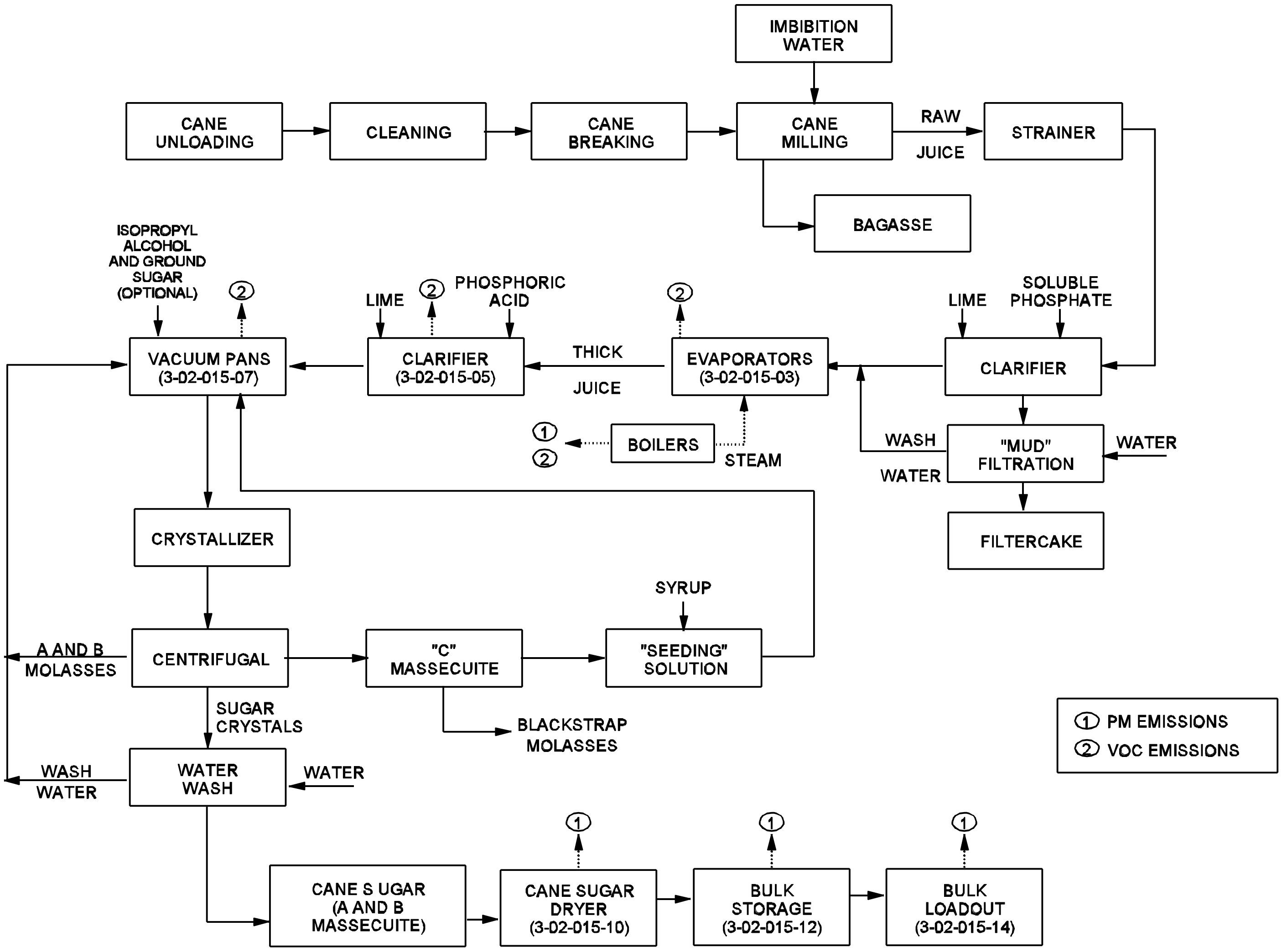


Figure 2-1. Simplified process flow diagram for cane sugar production.
(Source Classification Code in parentheses.)

limed juice by gravity or centrifuge. Clarified juice goes to the evaporators without additional treatment. The mud is filtered and the filtercake is washed with water; the wash water is added to the juice recovered during filtration. These juices may require further clarification before going to the evaporators.

Evaporation is performed in two stages: initially in an evaporator station to concentrate the juice and then in vacuum pans to crystallize the sugar. The clarified juice is passed through heat exchangers to preheat the juice and then to the evaporator stations. Evaporator stations consist of a series of evaporators, termed multiple-effect evaporators. This process typically uses 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 heat transfer process continues through the five evaporators and as the temperature decreases (due to heat loss) from evaporator to evaporator, the pressure inside each evaporator also decreases which allows the juice to boil at the lower temperatures in the subsequent evaporator. Some steam is released from the first three evaporators, and this steam is used in various process heaters in the plant. The evaporator station in raw sugar manufacture typically produces a syrup with about 65 percent solids and 35 percent water. Following evaporation, the syrup is clarified by adding lime, phosphoric acid, and a polymer flocculent, aerated, and filtered in the clarifier. From the clarifier, the syrup goes to the vacuum pans for crystallization.

Crystallization of the sugar starts in the vacuum pans, whose function is to produce sugar crystals from the syrup. There are several pan designs, each with different models and sizes. Pan boilings may be batch or continuous processes; batch systems use a sequence of multiple (2 or 3) pan boilings. In the pan boiling process, the syrup is evaporated until it reaches the supersaturation stage. At this point, the crystallization process is initiated by "seeding" or "shocking" the solution. When the volume of the mixture of liquor and crystals, known as massecuite, reaches the capacity of the pan, the evaporation is allowed to proceed until the final massecuite is formed. At this point, the contents of the vacuum pans (called "strike") are discharged to the crystallizer. Some mills seed the vacuum pans with isopropyl alcohol and ground sugar (or other similar seeding agent) rather than with crystals from the process. The function of the crystallizer is to maximize the sugar crystal removal from the massecuite. From the crystallizer, the massecuite (A massecuite) is transferred to high-speed centrifugal machines (centrifugals), in which the mother liquor (termed "molasses") is centrifuged to the outer shell and the crystals remain in the inner centrifugal basket. The crystals are washed with water and the wash water centrifuged from the crystals.

The liquor (A molasses) from the first centrifugal is returned to a vacuum pan and reboiled to yield a second massecuite (B massecuite), that in turn yields a second batch of crystals. The B massecuite is transferred to the crystallizer and then to the centrifugal, and the cane sugar is separated from the molasses. This cane sugar is combined with the first crop of crystals. The molasses from the second boiling (B molasses) is of much lower purity than the first molasses. It is reboiled to form a low grade massecuite (C massecuite) which goes to a crystallizer and then to a centrifugal. This low-grade cane sugar is mingled with syrup and used in the vacuum pans as a "seeding" solution. The final molasses from the third stage (blackstrap) is a heavy, viscous material used primarily as a supplement in cattle feed. The cane sugar from the combined A and B massecuites is dried in fluidized bed or spouted bed driers and cooled. After cooling, the cane sugar is transferred to packing bins and then sent to bulk storage; cane sugar is bagged in some areas. Cane sugar is then generally bulk loaded to trucks, railcars, or barges. A large bulk sugar carrier is used to transport cane sugar from Hawaii to the U.S. mainland.

2.2.3 Refined Sugar Production

A simplified process flow diagram for refined sugar production is shown in Figure 2-2. Cane sugar is refined either at the same location where it was produced as part of an integrated facility or at separate raw sugar refineries. The majority of the impurities in cane sugar are contained in a thin molasses film adhering to the sugar crystal surface; only very small quantities are occluded in the crystal. The initial step in cane sugar refining is washing the sugar, called affination, to remove the molasses film. The washing involves mingling the crystals with warm, almost saturated syrup to loosen the film. The crystals are then separated from the syrup in a centrifugal and washed (in the centrifugal) with hot water or a high purity sweetwater. If the refinery is part of the cane sugar production facility, the cane sugar may be washed more heavily in previous steps and the affination step omitted.

The washed raw sugar is sent to a premelter and then to a melter, where it is mixed with high-purity sweetwaters from other refinery steps and is steam heated. The resultant syrup is passed through a screen to remove any particulate in the syrup and sent to the clarification step. The syrup from the crystal washing, called affination syrup, is transferred to a remelt processing station or reused in the raw sugar washing step. In the remelt station, the syrup volume is reduced to form the massecuite and the sugar crystals are separated from the syrup. The separated liquor is blackstrap molasses. The sugar crystals are sent to a melter and then to the clarification step. Sugar liquors from the melter are filtered to remove course material and then sent to the clarification step. Two clarification methods are commonly used: pressure filtration and chemical treatment. Because pressure filtration is labor intensive and costly, chemical clarification is the preferred method. Two chemical methods are commonly used: phosphatation and carbonation; both processes require the addition of lime. The phosphatation uses phosphoric acid, lime (as lime sucrate to increase solubility), and polyacrylamide flocculent to produce a calcium phosphate floc. Air flotation is usually used to separate the floc from the liquor and the floc skimmed from the liquor surface. Carbonation consists of adding lime to the raw melter liquid and then bubbling carbon dioxide (CO_2) through the liquor to produce a voluminous calcium carbonate precipitate. The source of CO_2 is boiler flue gas, which contains about 12 percent CO_2 by volume. For oil or coal-fired boilers, the flue gas is scrubbed twice (water and Na_2CO_3 solution) to remove sulfur compounds; for bagasse-fired boilers, only water scrubbing is used. The clarifier systems yield either presscakes, muds, or scums which are treated to remove entrapped sugar, and then sent to disposal.

Clarification and filtration remove suspended solids and colloidal matter; decolorization removes soluble impurities by adsorption. Carbonaceous adsorbents made from naturally occurring materials and synthetic resins are used as media for decolorization. The two most common adsorbents are granular activated carbon and bone char, manufactured from degreased cattle bones. Powdered carbon and synthetic resins are less commonly used. Bone char or activated carbon are used in either fixed or moving bed systems. With fixed beds, the sugar liquor is cycled through a series of beds until the final liquor color reaches a predetermined level. At the end of the cycle, liquor remaining on the bed is removed by flushing the bed with water (termed "sweetening off"). A moving bed system operates continuously rather than cyclic and the adsorbent moves countercurrent to the flow of the sugar liquor. Spent adsorbent is removed from the bed, regenerated (dried in kilns), and the regenerated adsorbent is transferred by conveyor to storage or to the decolorization beds.

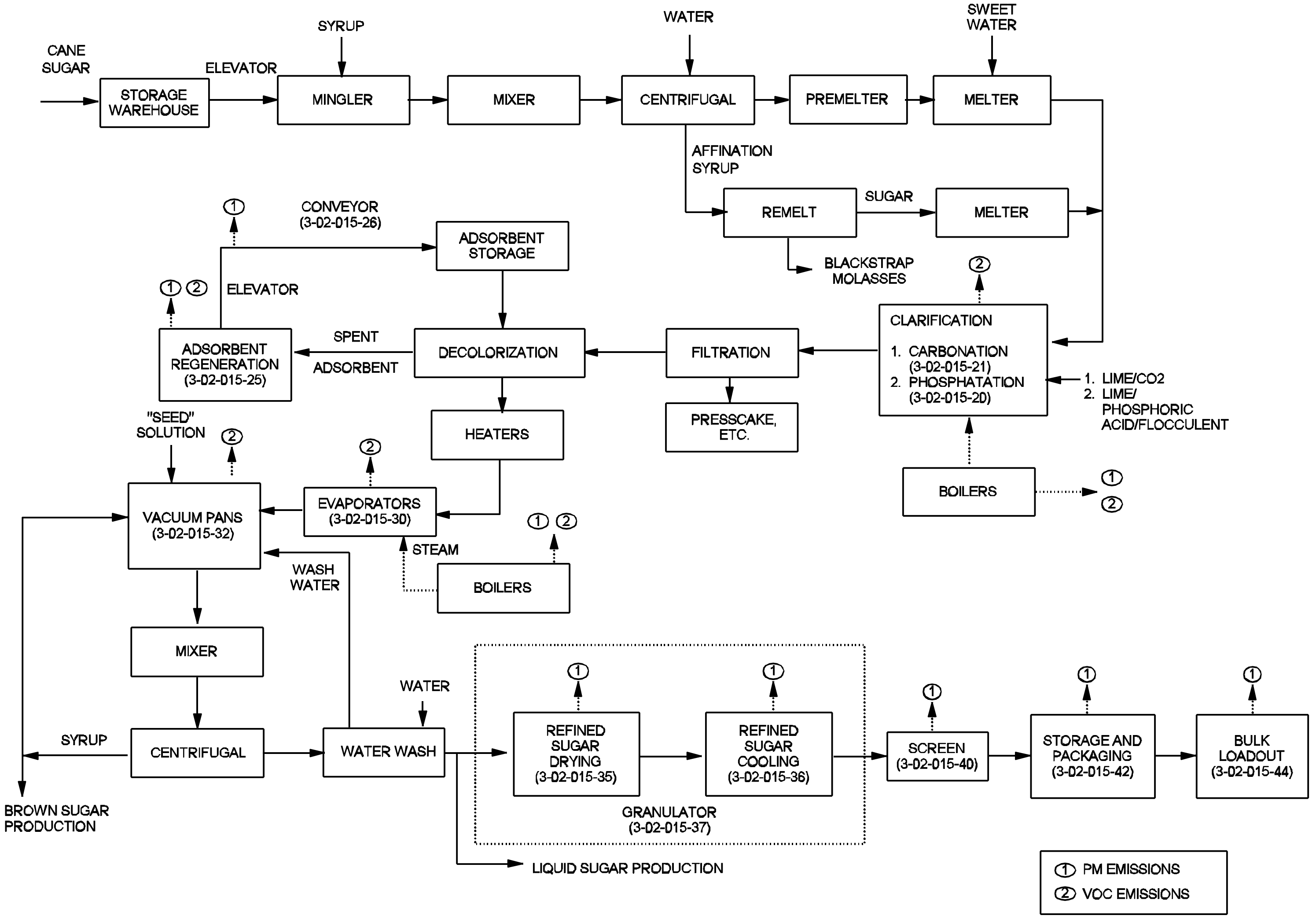


Figure 2-2. Simplified process flow diagram for refined sugar production.
(Source Classification Code in parentheses.)

The decolorized sugar liquor is sent to heaters (not at all refineres), followed by multiple-effect evaporators, and then to the vacuum pans; this is the same sequence used in cane sugar manufacture. Basic operation of the evaporators and vacuum pans is the same as for cane sugar. An evaporator station consisting of five evaporators is commonly used. The sugar liquor from the evaporators (thick juice) is transferred to the vacuum pans to further reduce the liquor volume and form the massecuite. In refined sugar production, the most common boiling system is the four-strike system. When the liquor in the pans has reached the desired level of supersaturation, the liquor is "seeded" to initiate formation of sugar crystals. The seed is usually sugar ground in a mill with isopropyl alcohol or a saturated syrup. Crystallization proceeds to produce a massecuite with a sugar content as high as the centrifugal can handle. At this point, the strike is discharged to a mixer and then to the centrifugal. In the centrifugal, the white sugar is retained in the inner basket and the liquor centrifuged to the outer shell. The sugar liquor is returned to a vacuum pan for further volume reduction and white or brown sugar production. The white sugar is washed one time in the centrifugal; the separated wash water, containing liquor and dissolved sugar, is returned to the vacuum pans. The moist sugar from the centrifugals contains about one percent water by weight.

White sugar designed for dry, refined granulated sugar is transported by conveyors and bucket elevators to the sugar dryers. Granulated sugar represents the largest part of all refinery production capacity and the entire capacity of many small refineries. Production of other sugar products is briefly discussed at the end of this section.

The most common sugar dryer is the granulator, which consists of two drums in series. One drum dries the sugar and the other cools the dried sugar crystals. Dryer drums typically operate at a temperature of about 110°C (230°F). Fluidized bed dryers/coolers are used at some facilities in place of the conventional rotary drum granulators. From the granulators, the dried white sugar crystals are mechanically screened by particle size using a sloping, gyrating wire mesh screen or perforated plate. After screening, the finished, refined granulated sugar is sent to conditioning bins, and then to storage bins prior to packaging or bulk loadout. Almost all packaged sugar uses either multiwall paper containers, cardboard cartons, or polyethylene bags; bulk loadout is the loadout of the sugar to special bulk hopper cars or tank trucks.

In addition to granulated sugar, other common refined sugar products include confectioners' (powdered) sugar, brown sugar, liquid sugar, and edible molasses. There are about six other less common sugar products. Confectioners' sugar results from grinding granulated sugar in specially designed hammermills. Brown sugar is a soft sugar produced by treating various purified and low purity syrups in vacuum pans followed by the same processing sequence as white granulated sugar (i.e., volume reduction, seeding, massecuite formation, mixing, centrifugation). After cooling, the soft sugars are packaged in moisture-proof containers while still moist. The brown coloration is enhanced by adding a colored, molasses-flavored syrup. There are two basic types of liquid sugars: one essentially all sucrose and the other where about half of the sucrose has been converted to reducing sugars. Liquid sucrose is produced either from melted granulated sugar or from decolorized, high-grade refinery process liquors. Liquid sugars are shipped in rubber containers in freight trailers, railroad tankcars, or by barge. Edible molasses is the concentrated extract of sugarcane that has been clarified and concentrated. It often is a blend of various molasses from the sugar production process designed to produce a specific flavor.

2.3 EMISSIONS

Particulate matter (PM), combustion products, and volatile organic compounds (VOC) are the primary pollutants emitted from the sugarcane processing industry. Combustion products include nitrogen oxides (NO_x), carbon monoxide (CO), CO_2, and sulfur oxides (SO_x). Potential emission sources include the sugar granulators, sugar conveying and packaging equipment, bulk loadout operations, boilers, granular carbon and char regeneration kilns, regenerated adsorbent transport systems, lime kilns and handling equipment, carbonation tanks, multi-effect evaporator stations, and vacuum boiling pans. Emissions from lime kilns and boilers are addressed in AP-42 Section 11.15 (Lime Manufacturing) and Sections 1.1 through 1.4 and 1.8 (Combustion), respectively, and are not included in this discussion. It should be noted that many facilities purchase lime and do not operate lime kilns. Combustion of bagasse in boilers in sugar mills is addressed in AP-42 Section 1.8 (5th Edition). Potential sources of PM emissions include the granular carbon and char (adsorbent) regeneration kilns, regenerated adsorbent transporting systems, sugar granulators, granulated sugar transport systems, sugar packaging operations, and bulk loadout operations. The multi-effect evaporators and vacuum boiling pans are a potential source of small amounts of VOC emissions. However, only the first three of five evaporators (in a typical five-stage evaporator) release exhaust gases, and the gases are used as a heat source for various process heaters before release to the atmosphere. Emissions from the carbonation tanks are primarily water vapor but may contain small quantities of VOC and may also include CO_2 and other combustion gases from the boilers.

2.4 EMISSION CONTROL TECHNOLOGY[3,4]

The exhaust from granulators typically is vented to cyclones to remove large particles and is then passed through a wet cyclone system (e.g., Rotoclone) to remove smaller particles. Fabric filters are sometimes used to control PM emissions from sugar handling operations and from fluidized bed drying and cooling systems. Particulate matter emissions from boilers typically are controlled with cyclones. Wet scrubbers are sometimes used as primary or secondary control devices for boilers. Some natural gas-fired boilers are not equipped with controls. Emissions from the carbonation tanks, evaporators, and vacuum boiling pans typically are not controlled.

REFERENCES FOR SECTION 2

1. *Sugar and Sweetener Yearbook*, U.S. Department of Agriculture, Economic Research Service, Washington, DC, June 1995.

2. *1992 Census of Manufacturers; Industry Series: Sugar and Confectionery Products*, U.S. Department of Commerce, Bureau of the Census, Washington, DC, April 1995.

3. J.C.P. Chen and C. Chou, *Cane Sugar Handbook, Twelfth Edition*, John Wiley and Sons, Inc., New York, 1993.

4. Written communication for P. Wesson, Golder Associates, Gainesville, FL, to D. Safriet, U. S. Environmental Protection Agency, Research Triangle Park, NC, March 20, 1997.

5. Written communication for T. King, Domino Sugar Corporation, Arabi, LA, to D. Safriet, U. S. Environmental Protection Agency, Research Triangle Park, NC, March 21, 1997.

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 Branch (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 *Census of Manufactures,* and other sources. 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 sugarcane processing industry. Copies of these test reports were obtained from the files of the Emission Measurement Center (EMC). The EPA library was searched for additional test reports. Using information obtained on plant locations, 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 sugarcane industry. In addition, representative trade associations were contacted for assistance in obtaining information about the industry and emissions.

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 tests that were performed on the same source using sound methodology and reported in enough detail for adequate validation. These tests do not necessarily conform to the methodology specified in 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 untested or new methodology or that lacked a significant amount of background data.

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

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

1. Source operation. The manner in which the source was operated is well documented in the report. The source was operating within typical parameters during the test.

2. Sampling procedures. The sampling procedures conformed to a generally acceptable methodology. If actual procedures deviated from accepted methods, the deviations are well documented. When this occurred, an evaluation was made of the extent to which such alternative procedures could influence the test results.

3. Sampling and process data. Adequate sampling and process data are documented in the report, 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 only from A- and B-rated test data taken from many randomly chosen facilities in the industry population. The source category is specific enough so that variability within the source category population may be minimized.

B—Above average: Developed only from A- and B-rated test data from a reasonable number of facilities. Although no specific bias is evident, it is not clear if the facilities tested represent a random sample of the 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. POLLUTANT EMISSION FACTOR DEVELOPMENT

This section describes the references and test data that were evaluated to determine if pollutant emission factors could be developed for AP-42 Section 9.10.1.1, Sugarcane Processing.

4.1 REVIEW OF SPECIFIC DATA SETS

Only one emission source test report was identified for sugarcane processing operations other than boiler emissions, which are addressed in AP-42 Sections 1.1 through 1.4 and 1.8 (Combustion).

4.1.1 Reference 1

This report documents a compliance test conducted at the Amstar Sugar Corporation (now Domino Sugar Corporation) in Arabi, Louisiana, on February 15 and 16, 1989. This facility refines raw cane sugar into various granulated and liquid sugar products. Ducts from two granulators equipped with Rotoclone controls were tested for filterable particulate matter (PM). Particulate matter was quantified using EPA Method 5 (front-half only). Granulator sugar throughput during the tests was determined by batch centrifuge event recorders. According to the report, the PM, predominantly sucrose, was difficult to sample and handle because it is emitted in a syrup form, apparently due to the water sprays associated with the Rotoclone. The report stated that the form of the emissions (syrup) may explain the low particulate emission rates. For one Rotoclone duct (#4), combining PM emission rates and sugar throughput rates gives an average PM emission factor of 0.059 lb/ton of sugar processed. Tests in the other duct (#3) showed an average PM emission factor of 0.13 lb/ton of sugar processed. The average emission factor for the two ducts is 0.095 lb/ton.

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 sampling and handling problems due to the hygroscopic nature of the sucrose apparently impacted the accuracy of the results. Pertinent test data and process data are provided in Appendix A.

4.1.2 Reference 2

This report documents a compliance test conducted at the Domino Sugar Corporation Chalmette Refinery in Arabi, Louisiana, on January 27 and 28, 1997. The test included filterable PM measurements at the outlet of a gravity dust collector that controls PM emissions from a conveyor transfer point and at the outlet of a fabric filter that controls PM emissions from a hammermill (that produces powdered sugar). Three EPA Method 5 test runs were conducted for each source. Process rates are not provided in the report. However, Mr. Terry King of Domino Sugar provided process data for the char conveyor transfer point. Process data are not available for the hammermill. Therefore, only the conveyor transfer point data are discussed here. The isokinetic variation for two of the three test runs (Runs 1 and 3) was slightly below 90 percent, which is the lower limit required by EPA Method 5. The results of these two test runs are potentially biased high. The emission factors for the three conveyor transfer point test runs are: Run 1--0.011 lb/ton of char transferred, Run 2--0.060 lb/ton, and Run 3--0.71 lb/ton. The average emission factor for this test is 0.26 lb/ton of char transferred.

The test data for the conveyor transfer point are assigned a C rating because of the low isokinetics. Otherwise, the test methodology was sound, the report included adequate detail, and no problems were reported. The hammermill test data are not rated because process data are not available for the test. Pertinent test data and process data are provided in Appendix B.

4.2 DEVELOPMENT OF CANDIDATE EMISSION FACTORS

Two emission test reports were identified for sugarcane processing. Both tests were conducted at sugar refineries. The first test report documents testing of a sugar granulator that is controlled by a Rotoclone wet cyclone system. The average filterable PM emission factor for the granulator is 0.095 lb/ton. The second test report includes measurements of filterable PM emissions at the outlet of a gravity collector that controls PM emissions from a bone char conveyor tranfer point. The average emission factor for this test is 0.26 lb/ton of char transferred. These emission factors are assigned E ratings because they are based on single tests.

In AP-42 Section 9.10.1.2, Sugarbeet Processing, the emission factor for filterable PM emissions from a sugar granulator equipped with a Rotoclone control was 0.064 lb/ton of sugar processed. Because the granulators in cane sugar and beet sugar production are expected to be similar, it is not surprising that the two emission factors are comparable.

4.3 SUMMARY OF CHANGES TO SECTION NARRATIVE

The process description was revised using the most recent available references to describe the current process for the processing of sugarcane to form cane sugar products. Simplified process flow diagrams for typical sugarcane processing facilities were also added.

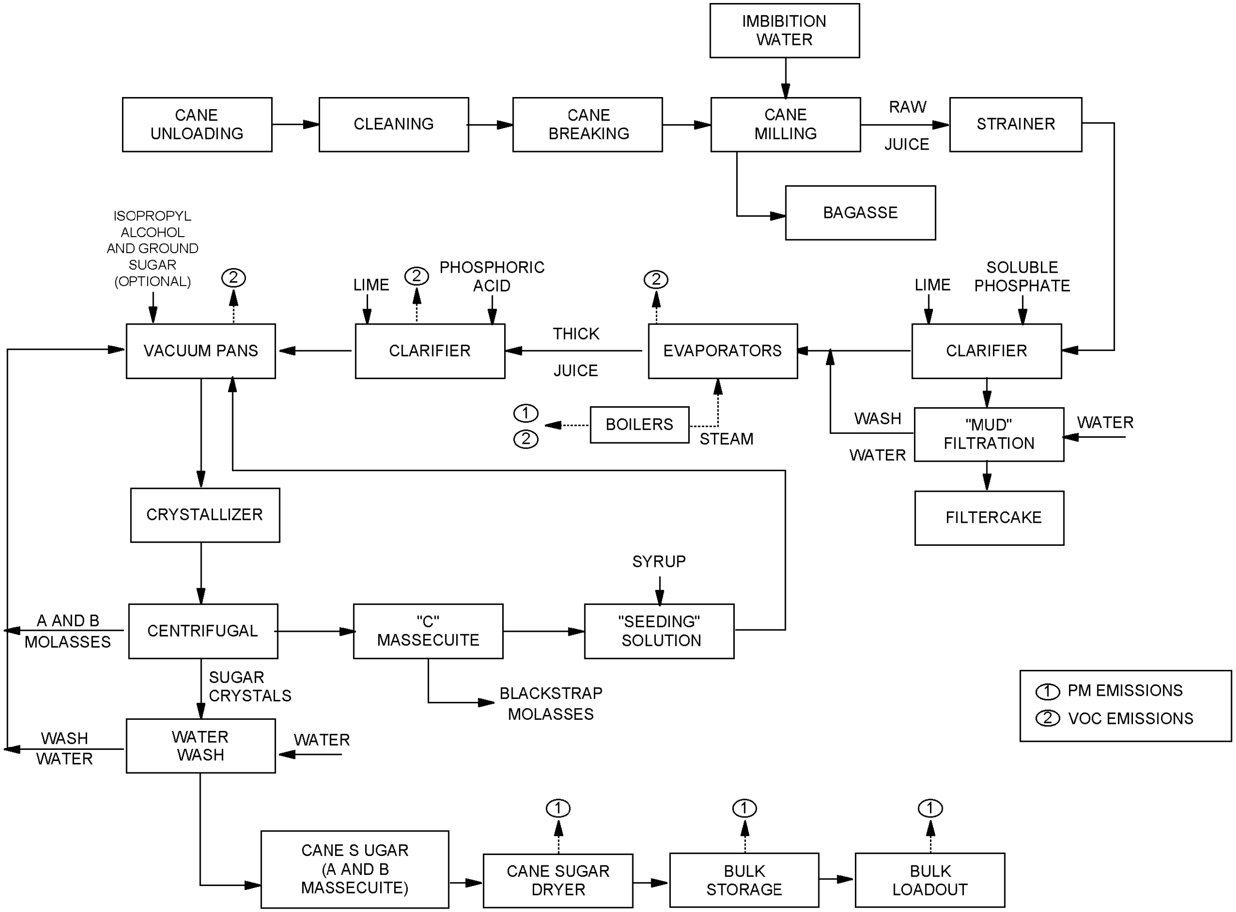
REFERENCE FOR SECTION 4

1. *Regulatory Compliance Source Test: Particulate Emissions Test of Panhouse at Amstar Sugar Corporation, Arabi, Louisiana*, Waldemar S. Nelson and Company, Inc., New Orleans, LA, April 1989.

2. *Emission Compliance Tests, Char Dust Collector #1 and #4 ACM Mill Exhaust, Domino Sugar Corporation Chalmette Refinery, Arabi, Louisiana*, Emission Testing Services, Baton Rouge, LA, January 27-28, 1997.

5. PROPOSED AP-42 SECTION

The proposed AP-42, Section 9.10.1.1, Sugarcane Processing, is presented on the following pages as it would appear in the document.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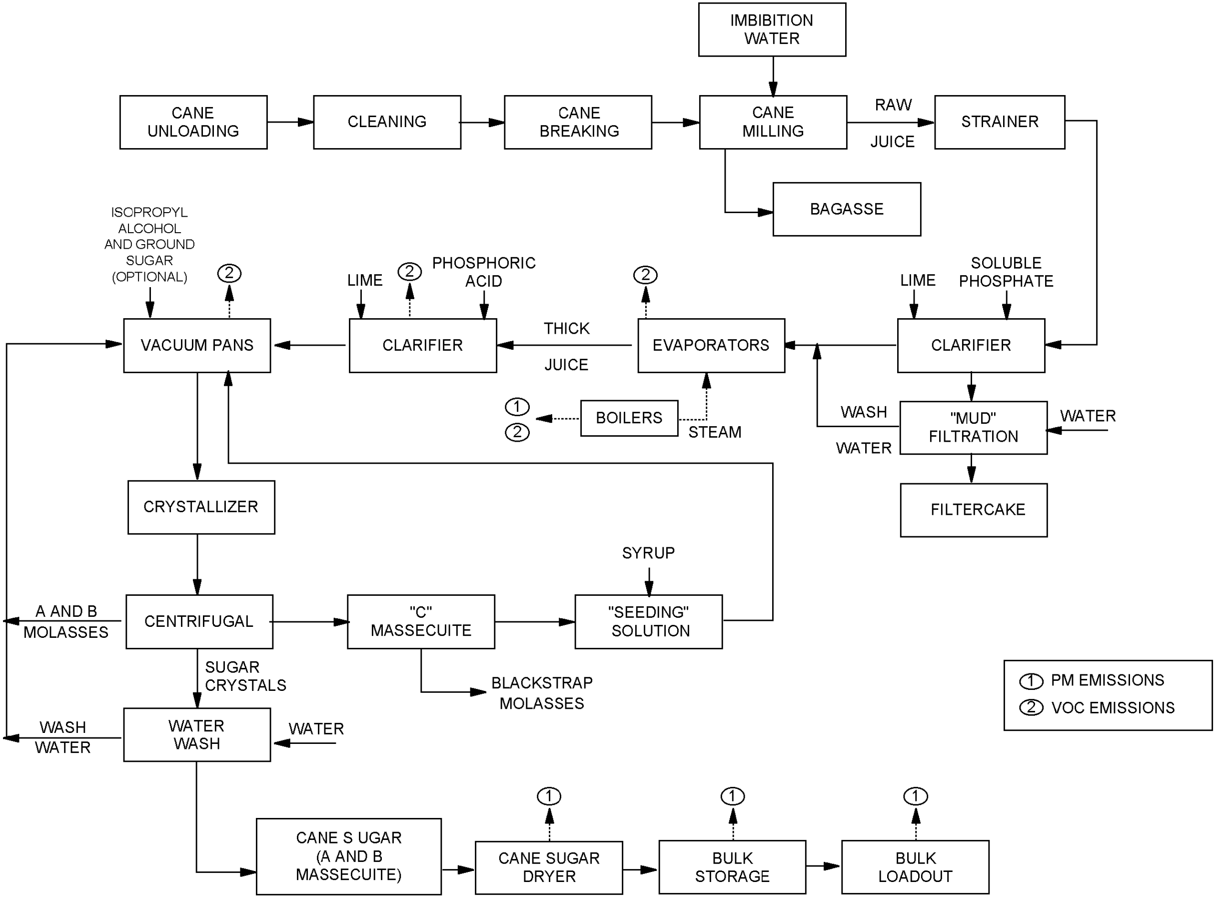
CLEANING
CANE BREAKING
CANE MILLING
RAW JUICE
STRAINER
BAGASSE
ISOPROPYL ALCOHOL AND GROUND SUGAR (OPTIONAL)
②
LIME
②
PHOSPHORIC ACID
②
LIME
SOLUBLE PHOSPHATE
VACUUM PANS
CLARIFIER
THICK JUICE
EVAPORATORS
CLARIFIER
①
②
BOILERS
STEAM
WASH WATER
"MUD" FILTRATION
WATER
FILTERCAKE
CRYSTALLIZER
SYRUP
A AND B MOLASSES
CENTRIFUGAL
"C" MASSECUITE
"SEEDING" SOLUTION
SUGAR CRYSTALS
BLACKSTRAP MOLASSES
WASH WATER
WATER WASH
WATER
① PM EMISSIONS
② VOC EMISSIONS
①
①
①
CANE S UGAR (A AND B MASSECUITE)
CANE SUGAR DRYER
BULK STORAGE
BULK LOADOUT


IMBIBITION WATER
CANE UNLOADING
CLEANING
CANE BREAKING
CANE MILLING
RAW JUICE
STRAINER
BAGASSE
ISOPROPYL ALCOHOL AND GROUND SUGAR (OPTIONAL)
②
LIME
②
PHOSPHORIC ACID
②
LIME
SOLUBLE PHOSPHATE
VACUUM PANS
CLARIFIER
THICK JUICE
EVAPORATORS
CLARIFIER
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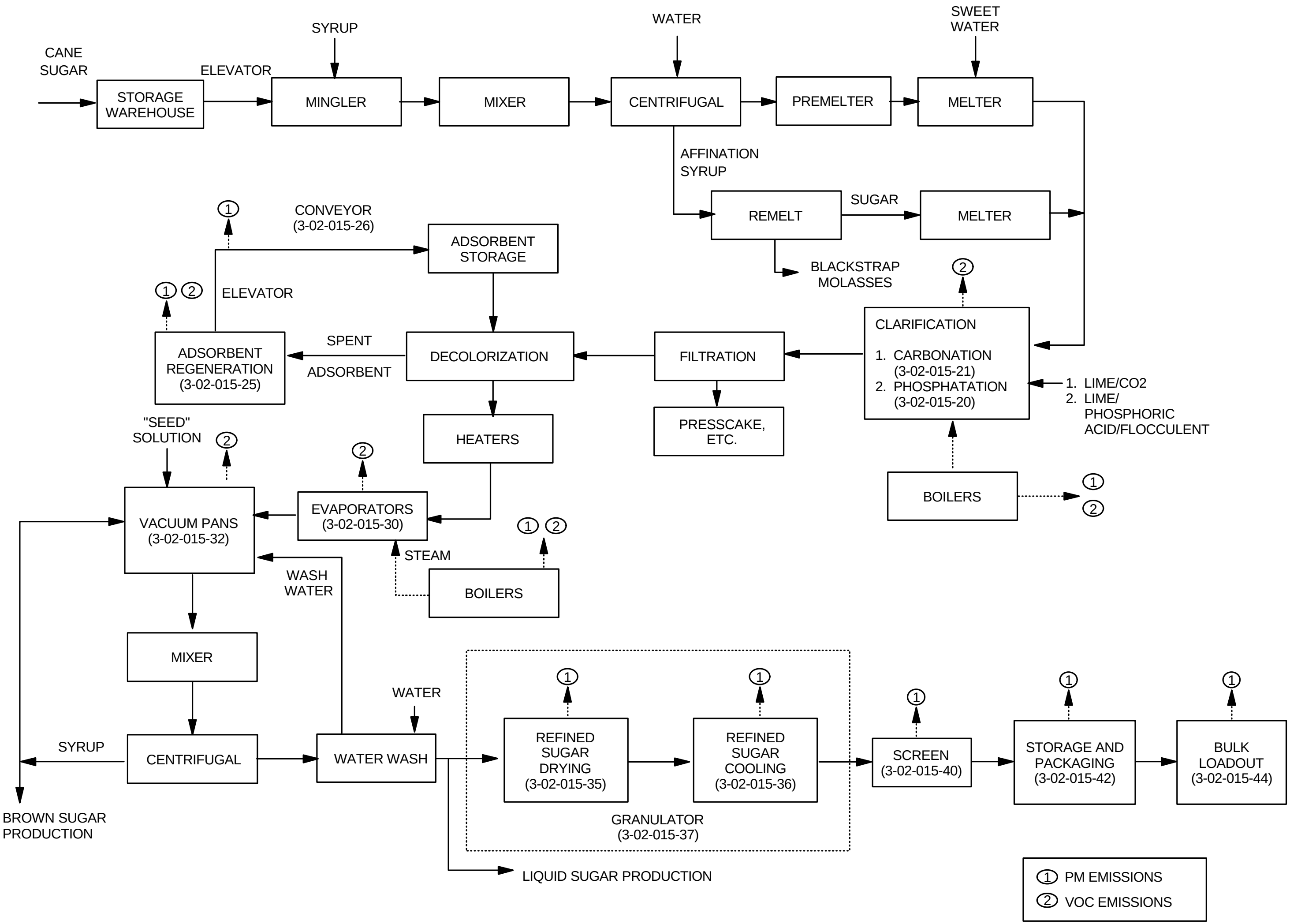
BOILERS
STEAM
WASH WATER
"MUD" FILTRATION
WATER
FILTERCAKE
CRYSTALLIZER
SYRUP
A AND B MOLASSES
CENTRIFUGAL
"C" MASSECUITE
"SEEDING" SOLUTION
SUGAR CRYSTALS
BLACKSTRAP MOLASSES
WASH WATER
WATER WASH
WATER
① PM EMISSIONS
② VOC EMISSIONS
①
①
①
CANE S UGAR (A AND B MASSECUITE)
CANE SUGAR DRYER
BULK STORAGE
BULK LOADOUT


CANE SUGAR
STORAGE WAREHOUSE
ELEVATOR
SYRUP
MINGLER
MIXER
WATER
CENTRIFUGAL
PREMELTER
SWEET WATER
MELTER
AFFINATION SYRUP
REMELT
SUGAR
MELTER
BLACKSTRAP MOLASSES
①
CONVEYOR (3-02-015-26)
ADSORBENT STORAGE
① ②
ELEVATOR
ADSORBENT REGENERATION (3-02-015-25)
SPENT ADSORBENT
DECOLORIZATION
FILTRATION
②
CLARIFICATION
1. CARBONATION (3-02-015-21)
2. PHOSPHATATION (3-02-015-20)
1. LIME/CO2
2. LIME/ PHOSPHORIC ACID/FLOCCULENT
HEATERS
PRESSCAKE, ETC.
"SEED" SOLUTION
②
②
VACUUM PANS (3-02-015-32)
EVAPORATORS (3-02-015-30)
BOILERS
① ②
① ②
STEAM
WASH WATER
BOILERS
MIXER
SYRUP
CENTRIFUGAL
BROWN SUGAR PRODUCTION
WATER
WATER WASH
①
REFINED SUGAR DRYING (3-02-015-35)
①
REFINED SUGAR COOLING (3-02-015-36)
GRANULATOR (3-02-015-37)
①
SCREEN (3-02-015-40)
①
STORAGE AND PACKAGING (3-02-015-42)
①
BULK LOADOUT (3-02-015-44)
LIQUID SUGAR PRODUCTION
① PM EMISSIONS
② VOC EMISSIONS