

9.10.1.1 Sugarcane Processing

9.10.1.1.1 General¹⁻⁵

Sugarcane processing is focussed on the production of cane sugar (sucrose) 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 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 is used to produce ethanol, compressed yeast, citric acid, and rum. Edible molasses syrups are often blends with maple syrup, invert sugars, or corn syrup.

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. Cane sugar is refined in eight states: Florida, Louisiana, Texas, Hawaii, California, New York, Maryland, and Georgia.

In the following sections, unrefined, or raw sugar is referred to as “cane sugar”. Following refining, the sugar is called “refined sugar”.

9.10.1.1.2 Process Description³

9.10.1.1.2.1 Cane Sugar Production -

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. Therefore, unlike sugarbeets, sugarcane cannot be stored for later processing without excessive deterioration of the sucrose content.

A simplified process flow diagram for a typical cane sugar production plant is shown in Figure 9.10.1.1-1. The cane is received at the mill and prepared for extraction of the juice. At the mill, the cane is mechanically unloaded, placed in a large pile, and, prior to milling, the cane is cleaned. 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, multiple sets of three-roller mills are most commonly used although some mills consist of four, five, or six rollers in multiple sets. 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. 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. The juice from the mills 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

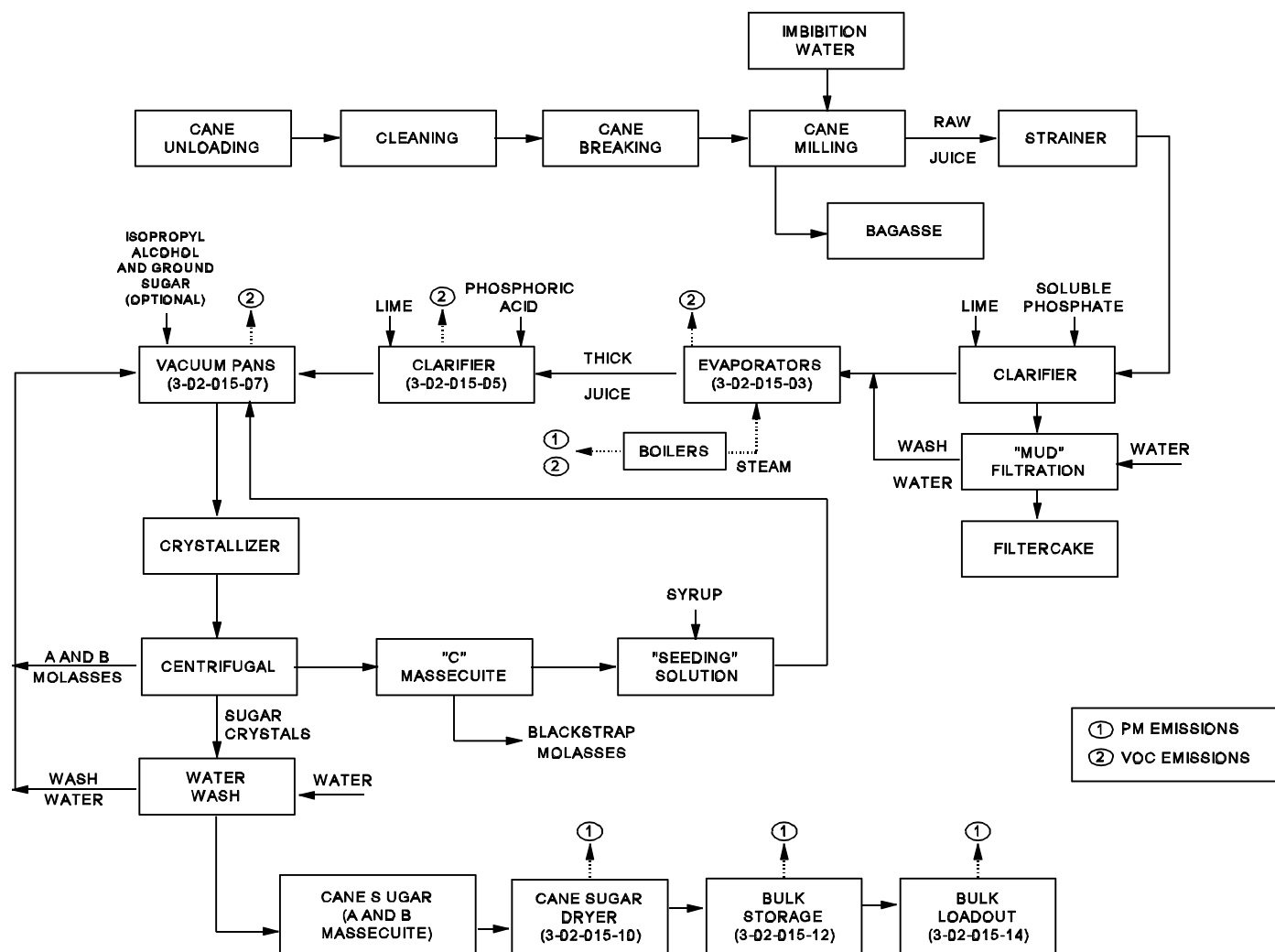


Figure 9.10.1.1-1. Simplified process flow diagram for cane sugar production.
(Source Classification Codes in parentheses.)

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 insoluble particulate mass, called “mud”, is separated from the 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.

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; typically 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 cane 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. 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, whose function is to maximize the sugar crystal removal from the massecuite. Some mills seed the vacuum pans with isopropyl alcohol and ground sugar (or other similar seeding agent) rather than with crystals from the process. 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 raw sugar is separated from the molasses. This raw 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 is sometimes used in the vacuum pans as a “seeding” solution. The final molasses from the third stage (blackstrap molasses) 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 then generally bulk loaded to trucks, railcars, or barges.

9.10.1.1.2.2 Refined Sugar Production -

A simplified process flow diagram for refined sugar production is shown in Figure 9.10.1.1-2. 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 initial step in cane sugar refining is washing the sugar, called affination, with warm, almost saturated syrup to loosen the molasses film. This is followed by separation of the crystals from the syrup in a centrifugal and washing of the separated crystals with hot water or a high

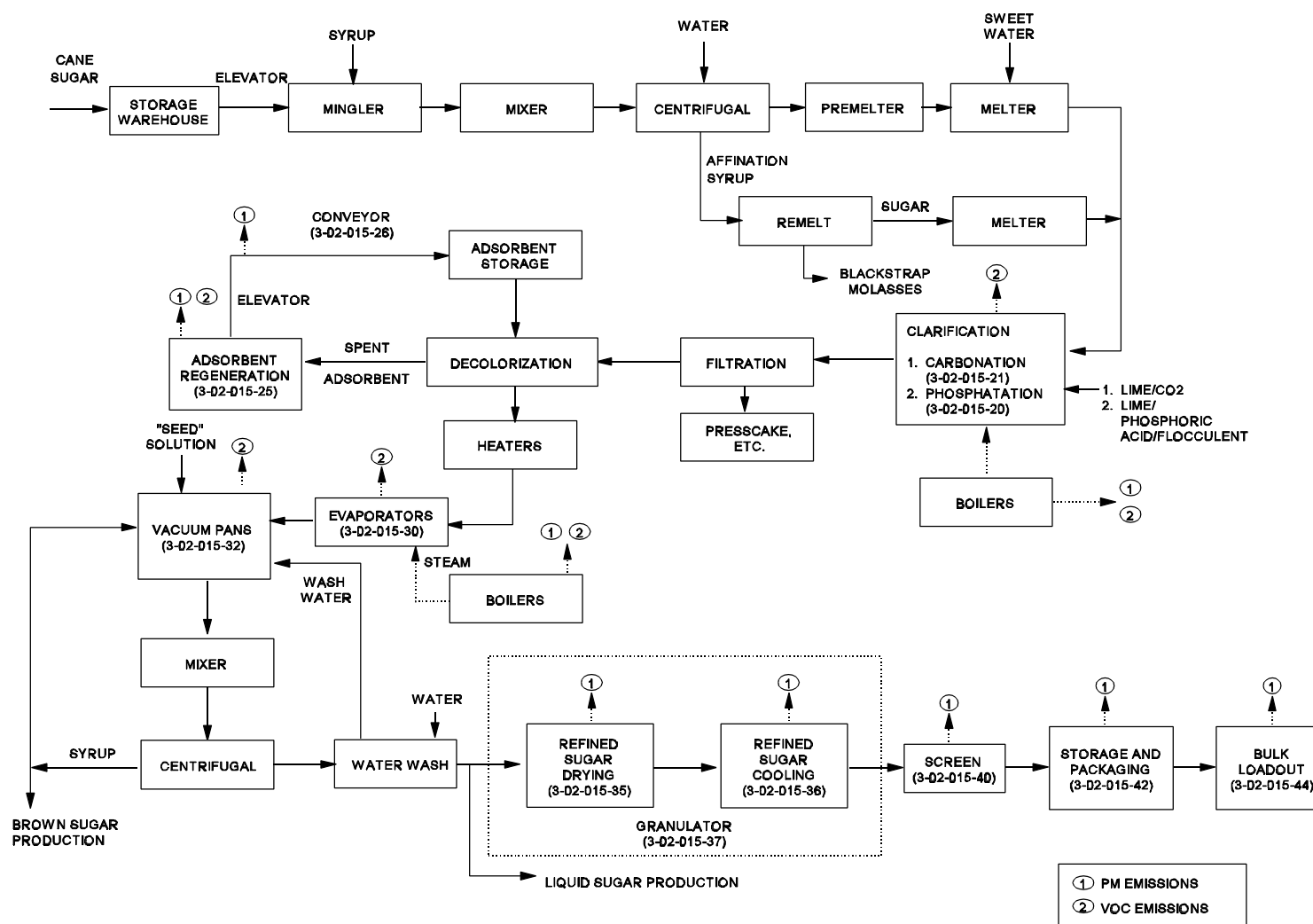


Figure 9.10.1.1-2. Simplified process flow diagram for refined sugar production.
(Source Classification Codes in parentheses.)

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. Two clarification methods are commonly used: pressure filtration and chemical treatment; 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 sucate 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 calcium carbonate precipitate. The source of CO_2 is boiler flue gas, which contains about 12 percent CO_2 by volume. The clarifier systems yield either presscakes, muds, or scums which are treated to remove entrapped sugar, and then sent to disposal.

The next step is decolorization, which removes soluble impurities by adsorption. 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. Spent adsorbent is removed from the bed, regenerated, and stored for reuse.

The decolorized sugar liquor is sent to heaters (at some refineries), 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. 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. 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 1 percent water by weight.

To produce refined granulated sugar, white sugar is transported by conveyors and bucket elevators to the sugar dryers. 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 specially designed 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.

9.10.1.1.3 Emissions and Controls³⁻⁷

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), CO₂, 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 (at some facilities), carbonation tanks, multi-effect evaporator stations, and vacuum boiling pans. Potential 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. Potential sources of PM emissions include the granular carbon and char regeneration kilns, regenerated adsorbent transporting systems, sugar granulators, granulated sugar transport systems, and sugar packaging operations. The multi-effect evaporators and vacuum boiling pans are a potential source of VOC emissions from the juice. 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 CO₂ and other combustion gases from the boilers.

The exhaust from granulators typically is vented to cyclones to remove large PM 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 typically are not controlled.

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 (SCC 3-02-015-37) is 0.095 lb/ton. In AP-42 Section 9.10.1.2, Sugarbeet Processing, the filterable PM emission factor for a granulator equipped with a Rotoclone control was 0.064 lb/ton. 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. 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 transfer point (SCC 3-02-015-26). The average emission factor for this test is 0.26 lb/ton of char transferred.

The use of emission factors based on a single test is not recommended. If necessary, the average filterable PM emission factors can be used, but would be rated E.

References For Section 9.10.1.1

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