9.13.2 Coffee Roasting

9.13.2.1 General

The coffee roasting industry involves the processing of green coffee beans into roasted coffee products, including whole and ground beans and soluble coffee products. The Standard Industrial Classification (SIC) code for coffee roasting is 2095.

9.13.2.2 Process Description[1-6]

The coffee roasting process consists essentially of cleaning, roasting, cooling, grinding, and packaging operations. Figure 9.13.2-1 shows a process flow diagram for a typical coffee roasting operation. Bags of green coffee beans are hand- or machine-opened, dumped into a hopper, and screened to remove debris. The green beans are then weighed and transferred by belt or pneumatic conveyor to storage hoppers. From the storage hoppers, the green beans are conveyed to the roaster. Roasters typically operate at temperatures between 370° and 540°C (698° and 1004°F), and the beans are roasted for a period of time ranging from a few minutes to about 30 minutes. Roasters are typically horizontal rotating drums that tumble the green coffee beans in a current of hot combustion gases; the roasters operate in either batch or continuous modes and can be indirect- or direct-fired. Indirect-fired roasters are roasters in which the burner flame does not contact the coffee beans, although the combustion gases from the burner do contact the beans. Direct-fired roasters contact the beans with the burner flame and the combustion gases. At the end of the roasting cycle, water sprays are used to "quench" the beans. Following roasting, the beans are cooled and run through a "destoner". Destoners are air classifiers that remove stones, metal fragments, and other waste not removed during initial screening from the beans. The destoners pneumatically convey the beans to a hopper, where the beans are stabilize and dry (small amounts of water from quenching exist on the surface of the beans). This stabilization process is called equilibration. Following equilibration, the roasted beans are ground, usually by multi-stage grinders. Some roasted beans are packaged and shipped as whole beans. Finally, the ground coffee is vacuum sealed and shipped.

Additional operations associated with processing green coffee beans include decaffeination and instant (soluble) coffee production. Decaffeination is the process of extracting caffeine from green coffee beans prior to roasting. The most common decaffeination process used in the United States is supercritical carbon dioxide (CO_2) extraction. In this process, moistened green coffee beans are contacted with large quantities of supercritical CO_2 (CO_2 maintained at a pressure of about 4,000 pounds per square inch and temperatures between 90° and 100°C [194° and 212°F]), which removes about 97 percent of the caffeine from the beans. The caffeine is then recovered from the CO_2, typically using an activated carbon adsorption system. Another commonly used method is solvent extraction, typically using oil (extracted from roasted coffee) or ethyl acetate as a solvent. In this process, solvent is added to moistened green coffee beans to extract most of the caffeine from the beans. After the beans are removed from the solvent, they are steam-stripped to remove any residual solvent. The caffeine is then recovered from the solvent, and the solvent is re-used. Water extraction is also used for decaffeination, but little information on this process is available. Decaffeinated coffee beans have a residual caffeine content of about 0.1 percent on a dry basis. Not all facilities have decaffeination operations, and decaffeinated green coffee beans are purchased by many facilities that produce decaffeinated coffee.

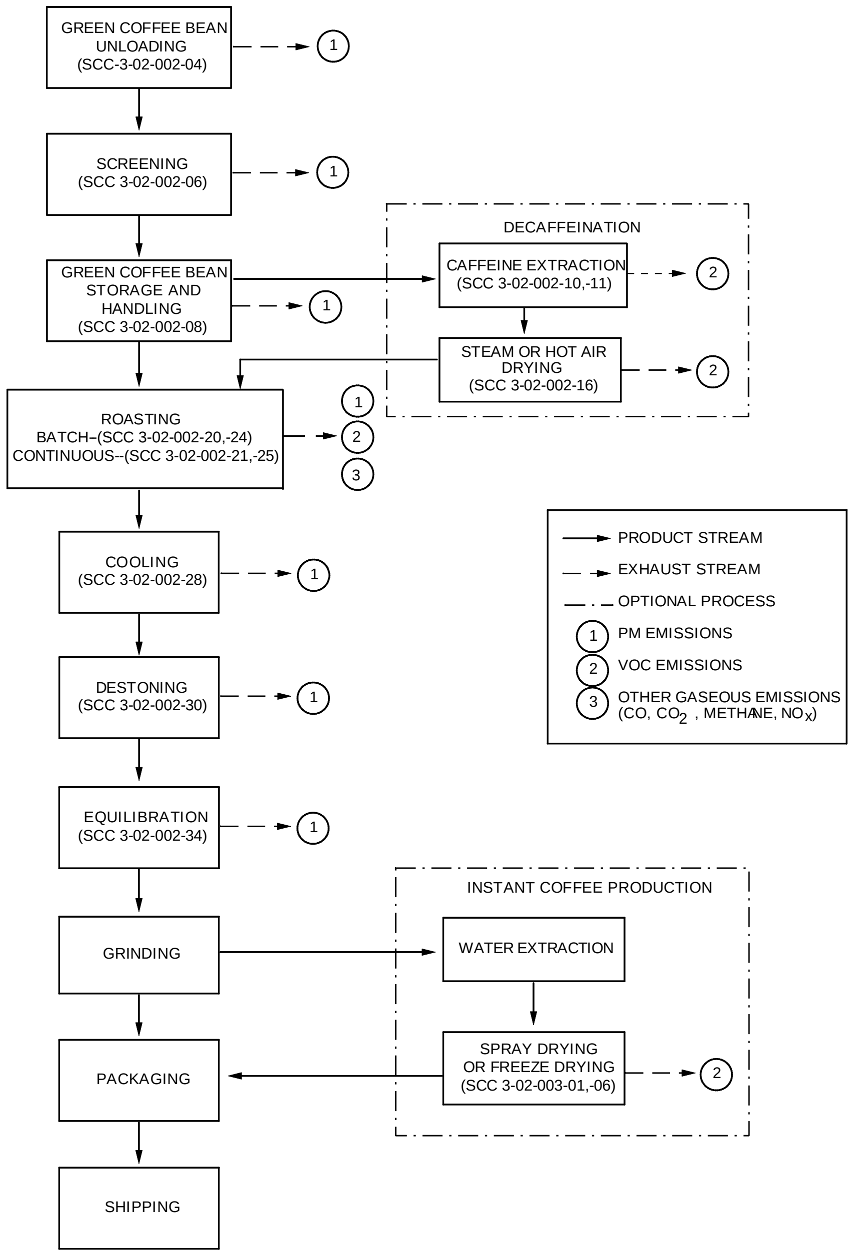

Figure 9.13.2-1. Typical coffee roasting operation.
(Source Classification Codes in parentheses.)

In the manufacture of instant coffee, extraction follows the roasting and grinding operations. The soluble solids and volatile compounds that provide aroma and flavor are extracted from the coffee beans using water. Water heated to about 175°C (347°F) under pressurized conditions (to maintain the water as liquid) is used to extract all of the necessary solubles from the coffee beans. Manufacturers use both batch and continuous extractors. Following extraction, evaporation or freeze-concentration is used to increase the solubles concentration of the extract. The concentrated extracts are then dried in either spray dryers or freeze dryers. Information on the spray drying and freeze drying processes is not available.

9.13.2.3 Emissions And Controls

Particulate matter (PM), volatile organic compounds (VOC), organic acids, and combustion products are the principal emissions from coffee processing. Several operations are sources of PM emissions, including the cleaning and destoning equipment, roaster, cooler, and instant coffee drying equipment. The roaster is the main source of gaseous pollutants, including alcohols, aldehydes, organic acids, and nitrogen and sulfur compounds. Because roasters are typically natural gas-fired, carbon monoxide (CO) and carbon dioxide (CO_2) emissions are expected as a result of fuel combustion. Decaffeination and instant coffee extraction and drying operations may also be sources of small amounts of VOC. Emissions from the grinding and packaging operations typically are not vented to the atmosphere.

Particulate matter emissions from the receiving, storage, cleaning, roasting, cooling, and stoning operations are typically ducted to cyclones before being emitted to the atmosphere. Gaseous emissions from roasting operations are typically ducted to a thermal oxidizer or thermal catalytic oxidizer following PM removal by a cyclone. Some facilities use the burners that heat the roaster as thermal oxidizers. However, separate thermal oxidizers are more efficient because the desired operating temperature is typically between 650°C and 816°C (1200°F and 1500°F), which is 93°C to 260°C (200°F to 500°F) more than the maximum temperature of most roasters. Some facilities use thermal catalytic oxidizers, which require lower operating temperatures to achieve control efficiencies that are equivalent to standard thermal oxidizers. Catalysts are also used to improve the control efficiency of systems in which the roaster exhaust is ducted to the burners that heat the roaster. Emissions from spray dryers are typically controlled by a cyclone followed by a wet scrubber.

Table 9.13.2-1 presents emission factors for filterable PM and condensible PM emissions from coffee roasting operations. Table 9.13.2-2 presents emission factors for volatile organic compounds (VOC), methane, CO, and CO_2 emissions from roasting operations. Emissions from batch and continuous roasters are shown separately, but with the exception of CO emissions, the emissions from these two types of roasters appear to be similar.

Table 9.13.2-1. EMISSION FACTORS FOR COFFEE ROASTING OPERATIONS[a]

EMISSION FACTOR RATING: D

Source	Filterable PM, lb/ton	Condensible PM lb/ton
Batch roaster with thermal oxidizer[b] (SCC 3-02-002-20)	0.12	ND
Continuous cooler with cyclone[c] (SCC 3-02-002-28)	0.028	ND
Continuous roaster[d] (SCC 3-02-002-21)	0.66	ND
Continuous roaster with thermal oxidizer (SCC 3-02-002-21)	0.092[e]	0.10[c]
Green coffee bean screening, handling, and storage system with fabric filter[f] (SCC 3-02-002-08)	0.059	ND
Destoner (SCC 3-02-002-30)	ND	ND
Equilibration (SCC 3-02-002-34)	ND	ND

[a] Emission factors are based on green coffee bean feed. Factors represent uncontrolled emissions unless noted. SCC = Source Classification Code. ND = no data. D-rated and E-rated emission factors are based on limited test data; these factors may not be representative of the industry.
[b] References 12,14.
[c] Reference 15.
[d] References 8-9.
[e] References 7-9,11,15. Includes data from thermal catalytic oxidizers.
[f] Reference 16. EMISSION FACTOR RATING: E.

Table 9.13.2-2. EMISSION FACTORS FOR COFFEE ROASTING OPERATIONS[a]

EMISSION FACTOR RATING: D

Source	VOC[b], lb/ton	Methane, lb/ton	CO, lb/ton	CO_2, lb/ton
Batch roaster[c] (SCC 3-02-002-20)	0.86	ND	ND	180
Batch roaster with thermal oxidizer (SCC 3-02-002-20)	0.047[d]	ND	0.55[d]	530[e]
Continuous roaster (SCC 3-02-002-21)	1.4[f]	0.26[g]	1.5[h]	120[j]
Continuous roaster with thermal oxidizer (SCC 3-02-002-21)	0.16[k]	0.15[m]	0.098[k]	200[n]
Decaffeination: solvent or supercritical CO_2 extraction (SCC 3-02-002-10,-11)	ND	ND	ND	ND
Steam or hot air dryer (SCC 3-02-002-16)	ND	ND	ND	ND
Spray drying (SCC 3-02-003-01)	ND	ND	ND	ND
Freeze drying (SCC 3-02-003-06)	ND	ND	ND	ND

[a] Emission factors are based on green coffee bean feed. Factors represent uncontrolled emissions unless noted. SCC = Source Classification Code. ND = no data. D-rated and E-rated emission factors are based on limited test data; these factors may not be representative of the industry.
[b] Volatile organic compounds as methane. Measured using GC/FID.
[c] Reference 14.
[d] References 12-14.
[e] References 12,14.
[f] References 8-9,11,15.
[g] References 8-9,11,15. EMISSION FACTOR RATING: E.
[h] References 8-9,15.
[j] References 8-9,11,15. EMISSION FACTOR RATING: C.
[k] References 8-9,11,15. Includes data from thermal catalytic oxidizers.
[m] References 8-9,11,15. Includes data from thermal catalytic oxidizers. EMISSION FACTOR RATING: E.
[n] References 9,11,15. Includes data from thermal catalytic oxidizers.

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