11.31 Abrasives Manufacturing

11.31.1 General[1]

The abrasives industry is composed of approximately 400 companies engaged in the following separate types of manufacturing: abrasive grain manufacturing, bonded abrasive product manufacturing, and coated abrasive product manufacturing. Abrasive grain manufacturers produce materials for use by the other abrasives manufacturers to make abrasive products. Bonded abrasives manufacturing is very diversified and includes the production of grinding stones and wheels, cutoff saws for masonry and metals, and other products. Coated abrasive products manufacturers include those facilities that produce large rolls of abrasive-coated fabric or paper, known as jumbo rolls, and those facilities that manufacture belts and other products from jumbo rolls for end use.

The six-digit Source Classification Codes (SCC) for the industry are 3-05-035 for abrasive grain processing, 3-05-036 for bonded abrasives manufacturing, and 3-05-037 for coated abrasives manufacturing.

11.31.2 Process Description[1-7]

The process description is broken into three distinct segments discussed in the following sections: production of the abrasive grains, production of bonded abrasive products, and production of coated abrasive products.

Abrasive Grain Manufacturing -

The most commonly used abrasive materials are aluminum oxides and silicon carbide. These synthetic materials account for as much as 80 to 90 percent of the total quantity of abrasive grains produced domestically. Other materials used for abrasive grains are cubic boron nitride (CBN), synthetic diamonds, and several naturally occurring minerals such as garnet and emery. The use of garnet as an abrasive grain is decreasing. Cubic boron nitride is used for machining the hardest steels to precise forms and finishes. The largest application of synthetic diamonds has been in wheels for grinding carbides and ceramics. Natural diamonds are used primarily in diamond-tipped drill bits and saw blades for cutting or shaping rock, concrete, grinding wheels, glass, quartz, gems, and high-speed tool steels. Other naturally occurring abrasive materials (including garnet, emery, silica sand, and quartz) are used in finishing wood, leather, rubber, plastics, glass, and softer metals.

The following paragraphs describe the production of aluminum oxide, silicon carbide, CBN, and synthetic diamond.

1. Silicon carbide. Silicon carbide (SiC) is manufactured in a resistance arc furnace charged with a mixture of approximately 60 percent silica sand and 40 percent finely ground petroleum coke. A small amount of sawdust is added to the mix to increase its porosity so that the carbon monoxide gas formed during the process can escape freely. Common salt is added to the mix to promote the carbon-silicon reaction and to remove impurities in the sand and coke. During the heating period, the furnace core reaches approximately 2200°C (4000°F), at which point a large portion of the load crystallizes. At the end of the run, the furnace contains a core of loosely knit silicon carbide crystals surrounded by unreacted or partially reacted raw materials. The silicon carbide crystals are removed to begin processing into abrasive grains.

2. Aluminum oxide. Fused aluminum oxide (Al_2O_3) is produced in pot-type, electric-arc furnaces with capacities of several tons. Before processing, bauxite, the crude raw material, is calcined at about 950°C (1740°F) to remove both free and combined water. The bauxite is then mixed with ground coke (about 3 percent) and iron borings (about 2 percent). An electric current is applied and the intense heat, on the order of 2000°C (3700°F), melts the bauxite and reduces the impurities that settle to the bottom of the furnace. As the fusion process continues, more bauxite mixture is added until the furnace is full. The furnace is then emptied and the outer impure layer is stripped off. The core of aluminum oxide is then removed to be processed into abrasive grains.

3. Cubic boron nitride. Cubic boron nitride is synthesized in crystal form from hexagonal boron nitride, which is composed of atoms of boron and nitrogen. The hexagonal boron nitride is combined with a catalyst such as metallic lithium at temperatures in the range of 1650°C (3000°F) and pressures of up to 6,895,000 kilopascals (kPa) (1,000,000 pounds per square inch [psi]).

4. Synthetic diamond. Synthetic diamond is manufactured by subjecting graphite in the presence of a metal catalyst to pressures in the range of 5,571,000 to 13,100,000 kPa (808,000 to 1,900,000 psi) at temperatures in the range of 1400 to 2500°C (2500 to 4500°F).

Abrasive Grain Processing -

Abrasive grains for both bonded and coated abrasive products are made by graded crushing and close sizing of either natural or synthetic abrasives. Raw abrasive materials first are crushed by primary crushers and are then reduced by jaw crushers to manageable size, approximately 19 millimeters (mm) (0.75 inches [in]). Final crushing is usually accomplished with roll crushers that break up the small pieces into a usable range of sizes. The crushed abrasive grains are then separated into specific grade sizes by passing them over a series of screens. If necessary, the grains are washed in classifiers to remove slimes, dried, and passed through magnetic separators to remove iron-bearing material, before the grains are again closely sized on screens. This careful sizing is necessary to prevent contamination of grades by coarser grains. Sizes finer than 0.10 millimeter (mm) (250 grit) are separated by hydraulic flotation and sedimentation or by air classification. Figure 11.31-1 presents a process flow diagram for abrasive grain processing.

Bonded Abrasive Products Manufacturing -

The grains in bonded abrasive products are held together by one of six types of bonds: vitrified or ceramic (which account for more than 50 percent of all grinding wheels), resinoid (synthetic resin), rubber, shellac, silicate of soda, or oxychloride of magnesium. Figure 11.31-2 presents a process flow diagram for the manufacturing of vitrified bonded abrasive products.

Measured amounts of prepared abrasive grains are moistened and mixed with porosity media and bond material. Porosity media are used for creating voids in the finished wheels and consist of filler materials, such as paradichlorobenzene (moth ball crystals) or walnut shells, that are vaporized during firing. Feldspar and clays generally are used as bond materials in vitrified wheels. The mix is moistened with water or another temporary binder to make the wheel stick together after it is pressed. The mix is then packed and uniformly distributed into a steel grinding wheel mold, and compressed in a hydraulic press under pressures varying from 1,030 to 69,000 kPa (150 to 10,000 psi). If there is a pore-inducing media in the mix such as paradichlorobenzene, it is removed in a steam autoclave. Prior to firing, smaller wheels are dried in continuous dryers; larger wheels are dried in humidity-controlled, intermittent dry houses.

Most vitrified wheels are fired in continuous tunnel kilns in which the molded wheels ride through the kiln on a moving belt. However, large wheels are often fired in bell or periodic kilns. In the firing process, the wheels are brought slowly to temperatures approaching 1400°C (2500°F)

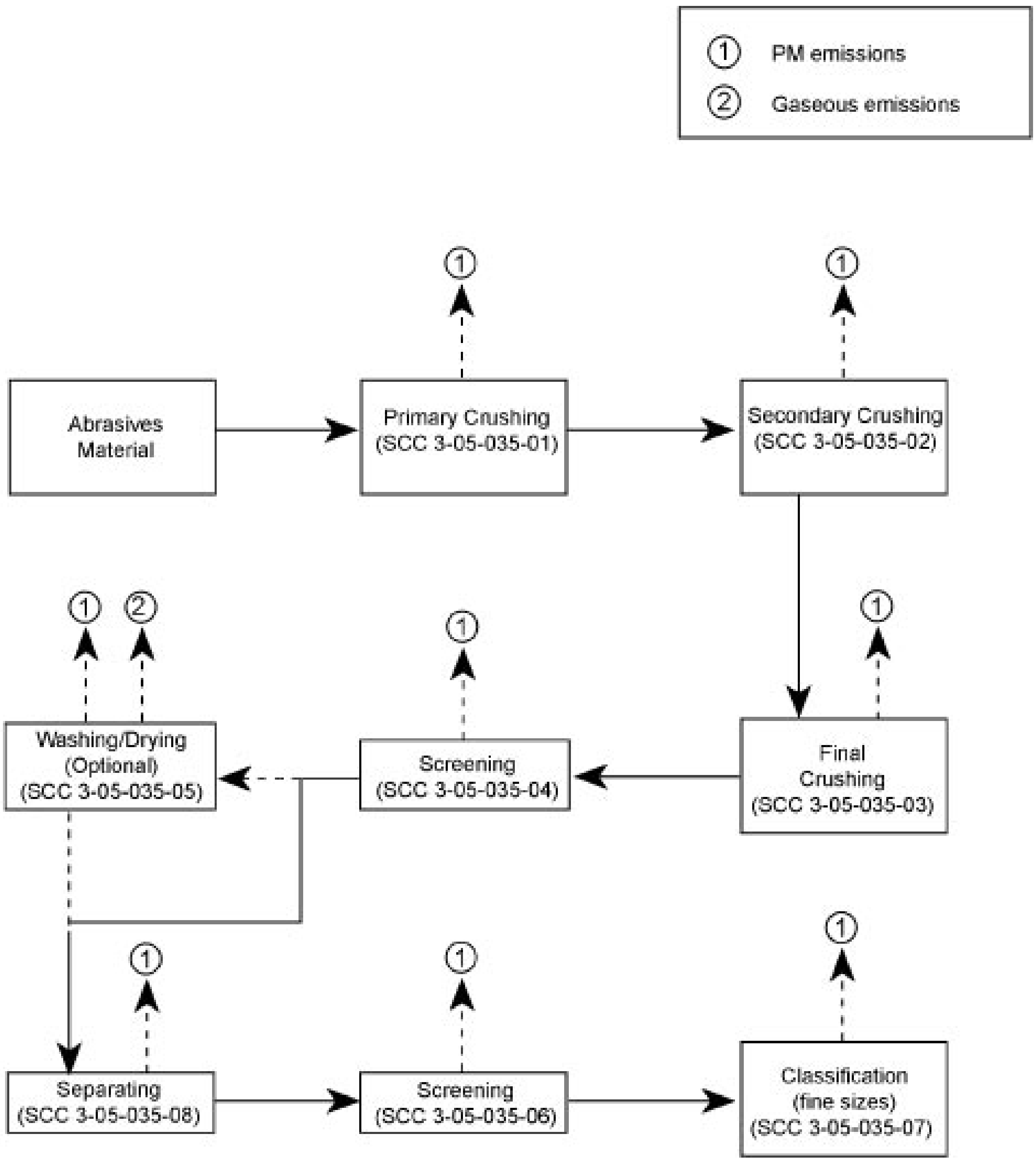

Figure 11.31-1. Process flow diagram for abrasive grain processing.
(Source Classification Codes in parentheses.)

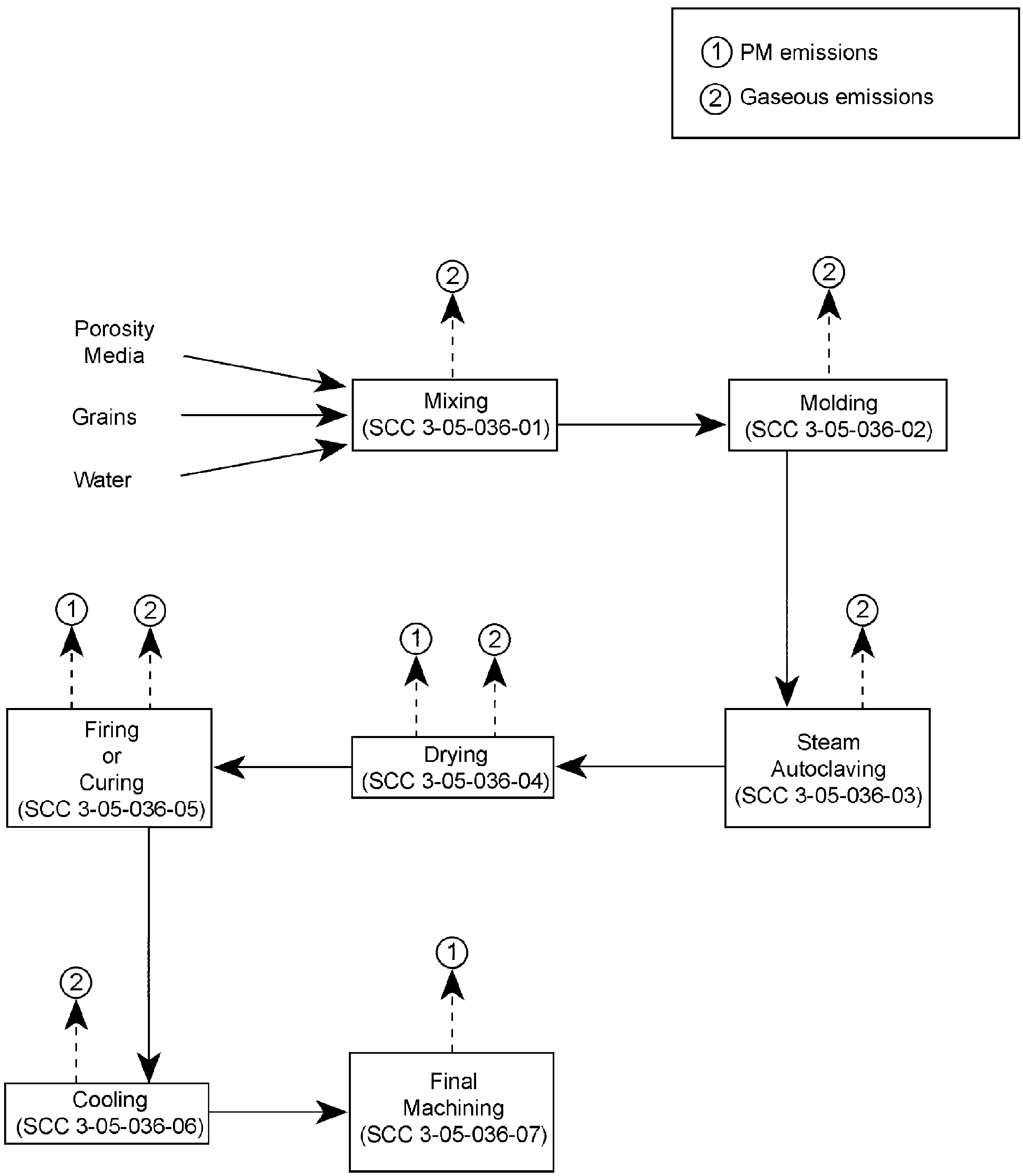

Figure 11.31-2. Process flow diagram for the manufacturing of vitrified bonded abrasive products. (Source Classification Codes in parentheses.)

for as long as several days depending on the size of the grinding wheels and the charge. This slow temperature ramp fuses the clay bond mixture so that each grain is surrounded by a hard glass-like bond that has high strength and rigidity. The wheels are then removed from the kiln and slowly cooled.

After cooling, the wheels are checked for distortion, shape, and size. The wheels are then machined to final size, balanced, and overspeed tested to ensure operational safety. Occasionally wax and oil, rosin, or sulfur are applied to improve the cutting effectiveness of the wheel.

Resin-bonded wheels are produced similarly to vitrified wheels. A thermosetting synthetic resin, in liquid or powder form, is mixed with the abrasive grain and a plasticizer (catalyst) to allow the mixture to be molded. The mixture is then hydraulically pressed to size and cured at 150 to 200°C (300 to 400°F) for a period of from 12 hours to 4 or 5 days depending on the size of the wheel. During the curing period, the mold first softens and then hardens as the oven reaches curing temperature. After cooling, the mold retains its cured hardness. The remainder of the production process is similar to that for vitrified wheels.

Rubber-bonded wheels are produced by selecting the abrasive grain, sieving it, and kneading the grain into a natural or synthetic rubber. Sulfur is added as a vulcanizing agent and then the mix is rolled between steel calendar rolls to form a sheet of the required thickness. The grinding wheels are cut out of the rolled sheet to a specified diameter and hole size. Scraps are kneaded, rolled, and cut out again. Then the wheels are vulcanized in molds under pressure in ovens at approximately 150 to 175°C (300 to 350°F). The finishing and inspection processes are similar to those for other types of wheels.

Shellac-bonded wheels represent a small percentage of the bonded abrasives market. The production of these wheels begins by mixing abrasive grain with shellac in a steam-heated mixer, which thoroughly coats the grain with the bond material (shellac). Wheels 3 mm (0.125 in.) thick or less are molded to exact size in heated steel molds. Thicker wheels are hot-pressed in steel molds. After pressing, the wheels are set in quartz sand and baked for a few hours at approximately 150°C (300°F). The finishing and inspection processes are similar to those for other types of wheels.

In addition to grinding wheels, bonded abrasives are formed into blocks, bricks, and sticks for sharpening and polishing stones such as oil stones, scythe stones, razor and cylinder hones. Curved abrasive blocks and abrasive segments are manufactured for grinding or polishing curved surfaces. Abrasive segments can also be combined into large wheels such as pulpstones. Rubber pencil and ink erasers contain abrasive grains; similar soft rubber wheels, sticks, and other forms are made for finishing soft metals.

Coated Abrasive Products Manufacturing -

Coated abrasives consist of sized abrasive grains held by a film of adhesive to a flexible backing. The backing may be film, cloth, paper, vulcanized fiber, or a combination of these materials. Various types of resins, glues, and varnishes are used as adhesives or bonds. The glue is typically animal hide glue. The resins and varnishes are generally liquid phenolics or ureas, but depending on the end use of the abrasive, they may be modified to yield shorter or longer drying times, greater strength, more flexibility, or other required properties. Figure 11.31-3 presents a process flow diagram for the manufacturing of coated abrasive products.

The production of coated abrasive products begins with a length of backing, which is passed through a printing press that imprints the brand name, manufacturer, abrasive, grade number, and other identifications on the back. Jumbo rolls typically are 1.3 m (52 in.) wide by 1,372 m (1,500 yards

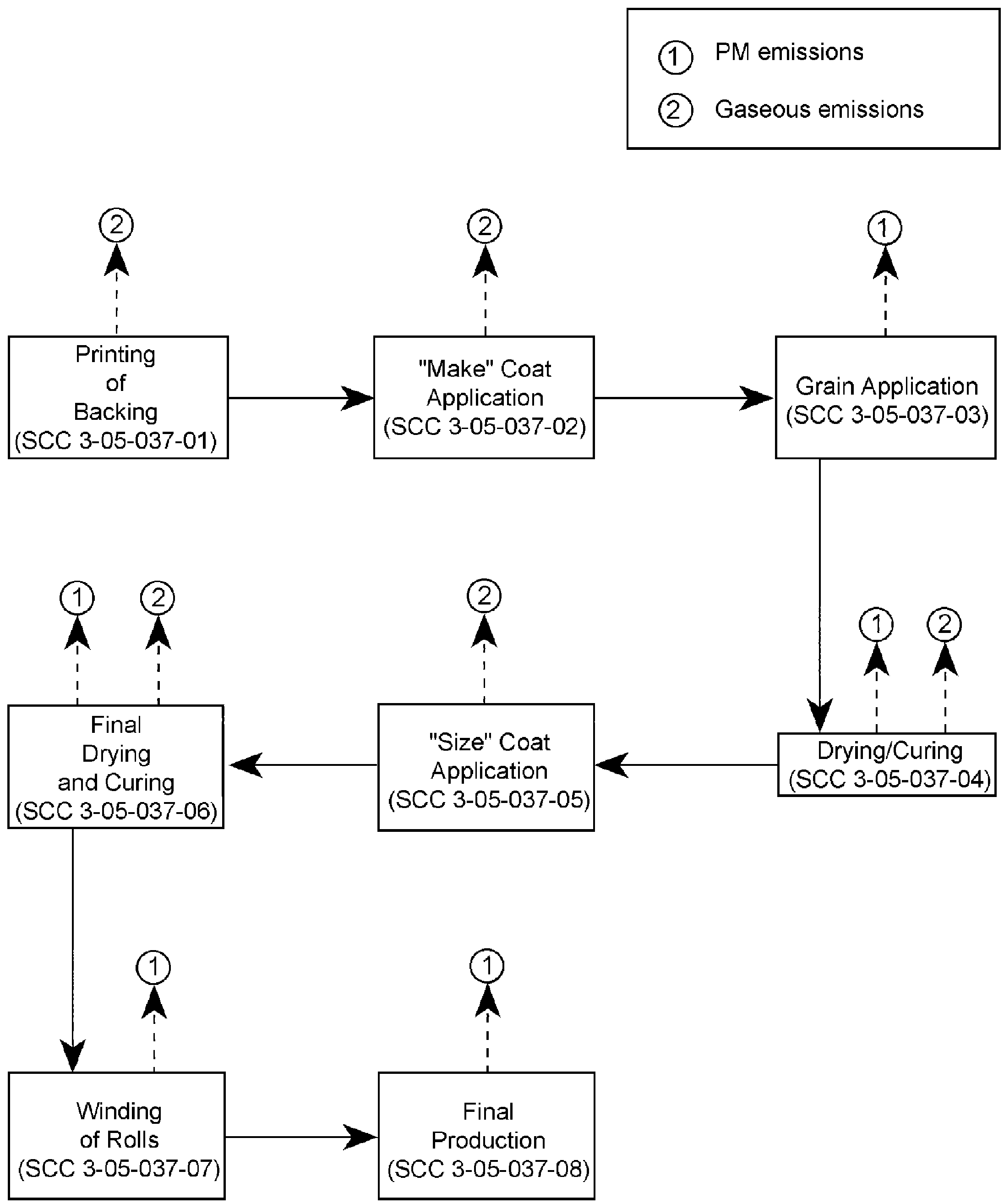

Figure 11.31-3. Process flow diagram for the manufacturing of coated abrasive products. (Source Classification Codes in parentheses.)

[yd]) to 2,744 m (3,000 yd) in length. The shorter lengths are used for fiber-backed products, and the longer lengths are used for film-backed abrasives. Then the backing receives the first application of adhesive bond, the "make" coat, in a carefully regulated film, varying in concentration and quantity according to the particle size of the abrasive to be bonded. Next, the selected abrasive grains are applied either by a mechanical or an electrostatic method. Virtually all of the abrasive grain used for coated abrasive products is either silicon carbide or aluminum oxide, augmented by small quantities of natural garnet or emery for woodworking, and minute amounts of diamond or CBN.

In mechanical application, the abrasive grains are poured in a controlled stream onto the adhesive-impregnated backing, or the impregnated backing is passed through a tray of abrasive thereby picking up the grains. In the electrostatic method, the adhesive-impregnated backing is passed adhesive-coated side down over a tray of abrasive grains, while at the same time passing an electric current through the abrasive. The electrostatic charge induced by the current causes the grains to imbed upright in the wet bond on the backing. In effect the sharp cutting edges of the grain are bonded perpendicular to the backing. It also causes the individual grains to be spaced more evenly due to individual grain repulsion. The amount of abrasive grains deposited on the backing can be controlled extremely accurately by adjusting the abrasive stream and manipulating the speed of the backing sheet through the abrasive.

After the abrasive is applied, the product is carried by a festoon conveyor system through a drying chamber to the sizing unit, where a second layer of adhesive, called the size coat or sand size, is applied. The size coat unites with the make coat to anchor the abrasive grains securely. The coated material is then carried by another longer festoon conveyor through the final drying and curing chamber in which the temperature and humidity are closely controlled to ensure uniform drying and curing. When the bond is properly dried and cured, the coated abrasive is wound into jumbo rolls and stored for subsequent conversion into marketable forms of coated abrasives. Finished coated abrasives are available as sheets, rolls, belts, discs, bands, cones, and many other specialized forms.

11.31.3 Emissions And Controls[1,7]

Little information is available on emissions from the manufacturing of abrasive grains and products. However, based on similar processes in other industries, some assumptions can be made about the types of emissions that are likely to result from abrasives manufacturing.

Emissions from the production of synthetic abrasive grains, such as aluminum oxide and silicon carbide, are likely to consist primarily of particulate matter (PM), PM less than 10 micrometers (PM-10), and carbon monoxide (CO) from the furnaces. The PM and PM-10 emissions are likely to consist of filterable, inorganic condensable, and organic condensable PM. The addition of salt and sawdust to the furnace charge for silicon carbide production is likely to result in emissions of chlorides and volatile organic compounds (VOC). Aluminum oxide processing takes place in an electric arc furnace and involves temperatures up to 2600°C (4710°F) with raw materials of bauxite ore, silica, coke, iron borings, and a variety of minerals that include chromium oxide, cryolite, pyrite, and silane. This processing is likely to emit fluorides, sulfides, and metal constituents of the feed material. In addition, nitrogen oxides (NO_x) are emitted from the Solgel method of producing aluminum oxide.

The primary emissions from abrasive grain processing consist of PM and PM-10 from the crushing, screening, classifying, and drying operations. Particulate matter also is emitted from materials handling and transfer operations. Table 11.31-1 presents emission factors for filterable PM and CO_2 emissions from grain drying operations in metric and English units. Table 11.31-2

Table 11.31-1 (Metric And English Units). EMISSION FACTORS FOR ABRASIVE MANUFACTURING[a]

EMISSION FACTOR RATING: E

Process	Filterable PM[b]		CO_2	
	kg/Mg	lb/ton	kg/Mg	lb/ton
Rotary dryer, sand blasting grit, with wet scrubber (SCC 3-05-035-05)	ND	ND	22[c]	43[c]
Rotary dryer, sand blasting grit, with fabric filter (SCC 3-05-035-05)	0.0073[d]	0.015[d]	ND	ND

[a] Emission factors in kg/Mg and lb/ton of grit fed into dryer. SCC = Source Classification Code. ND = no data.
[b] Filterable PM is that PM collected on or prior to the filter of an EPA Method 5 (or equivalent) sampling train.
[c] Reference 9.
[d] Reference 8.

Table 11.31-2 (Metric And English Units). EMISSION FACTORS FOR ABRASIVE MANUFACTURING[a]

EMISSION FACTOR RATING: E

Source	Pollutant	Emission Factor	
		kg/Mg	lb/ton
Rotary dryer: sand blasting grit, with wet scrubber (SCC 3-05-035-05)	Antimony	4.0×10^{-5}	8.1×10^{-5}
	Arsenic	0.00012	0.00024
	Beryllium	4.1×10^{-6}	8.2×10^{-6}
	Lead	0.0022	0.0044
	Cadmium	0.00048	0.00096
	Chromium	0.00023	0.00045
	Manganese	3.1×10^{-5}	6.1×10^{-5}
	Mercury	8.5×10^{-7}	1.7×10^{-6}
	Thallium	4.0×10^{-5}	8.1×10^{-5}
	Nickel	0.0013	0.0026

[a] Reference 9. Emission factors in kg/Mg and lb/ton of grit fed into dryer. SCC = Source Classification Code.

presents emission factors developed from the results of a metals analysis conducted on a rotary dryer controlled by a wet scrubber.

Emissions generated in the production of bonded abrasive products may involve a small amount of dust generated by handling the loose abrasive, but careful control of sizes of abrasive particles limits the amount of fine particulate that can be entrained in the ambient air. However, for products made from finer grit sizes--less than 0.13 mm (200 grit)--PM emissions may be a significant problem. The main emissions from production of grinding wheels are generated during the curing of the bond structure for wheels. Heating ovens or kilns emit various types of VOC depending upon the composition of the bond system. Emissions from dryers and kilns also include products of combustion, such as CO, carbon dioxide (CO_2), nitrogen oxides (NO_x), and sulfur oxides (SO_x), in addition to filterable and condensable PM. Vitrified products produce some emissions as filler materials included to provide voids in the wheel structure are vaporized. Curing resins or rubber that is used in some types of bond systems also produce emissions of VOC. Another small source of emissions may be vaporization during curing of portions of the chloride- and sulfur-based materials that are included within the bonding structure as grinding aids.

Emissions that may result from the production of coated abrasive products consist primarily of VOC from the curing of the resin bonds and adhesives used to coat and attach the abrasive grains to the fabric or paper backing. Emissions from dryers and curing ovens also may include products of combustion, such as CO, CO_2, NO_x, and SO_x, in addition to filterable and condensable PM. Emissions that come from conversion of large rolls of coated abrasives into smaller products such as sanding belts consist of PM and PM-10. In addition, some VOC may be emitted as a result of the volatilization of adhesives used to form joints in those products.

Fabric filters preceded by cyclones are used at some facilities to control PM emissions from abrasive grain production. This configuration of control devices can attain controlled emission concentrations of 37 micrograms per dry standard cubic meter (0.02 grains per dry standard cubic foot) and control efficiencies in excess of 99.9 percent. Little other information is available on the types of controls used by the abrasives industry to control PM emissions. However, it is assumed that other conventional devices such as scrubbers and electrostatic precipitators can be used to control PM emissions from abrasives grain and products manufacturing.

Scrubbers are used at some facilities to control NO_x emissions from aluminum oxide production. In addition, thermal oxidizers are often used in the coated abrasives industry to control emissions of VOC.

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