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Appendix A
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Ref # 7

Air Pollution Control Techniques for Non-Metallic Minerals Industry

Emission Standards and Engineering Division

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August 1981

1. INTRODUCTION

This document presents information on the emission of particulates and their control at non-metallic mineral processing facilities. Emissions from both process sources, except combustion sources (i.e., dryers and calciners), and fugitive dust sources are considered. Applicable control techniques are identified and discussed in terms of performance, environmental impacts, energy requirements, and cost.

This document supersedes the document entitled Air Pollution Control Techniques for Crushed and Broken Stone Industry (EPA-450/3-80-019) which was published in May 1980. This document contains the information and emission test results previously presented for the crushed and broken stone industry in the above mentioned document.

1.1. INDUSTRY DESCRIPTION

The 17 non-metallic minerals selected for investigation in this study are:

Crushed and broken stone	Clay
Sand and gravel	Gypsum
Rock salt	Pumice
Gilsonite	Talc
Boron	Barite
Fluorspar	Feldspar
Diatomite	Perlite
Vermiculite	Mica
Kyanite	

Total domestic production of these non-metallic minerals for 1977 was about 1,790 million megagrams (1,975 million short tons).[1,2,3] Geographically, the non-metallic minerals industry is highly dispersed with all States reporting production of at least one of these 17 non-metallic minerals. The non-metallic mineral processing industry is highly diverse in terms of unit production capacities and end product uses.

Principal quarrying operations include drilling, blasting, secondary breakage, and the loading and hauling of broken rock to the non-metallic mineral processing plant. Emissions from drilling operations are caused by the removal of cuttings and dust from the bottom of the hole by air flushing. Generally, two control techniques are available: (1) water injection and (2) the aspiration of dry cuttings to a control device. Although largely uncontrollable, emissions from blasting can be minimized by using good blasting practices and scheduling blasts only under favorable meteorological conditions. If secondary breakage is required, drop-ball cranes are generally used and resulting emissions are relatively small. Emissions generated by the loading of broken rock into in-plant haulage vehicles by front-end loaders or shovels can be controlled by wetting down rock piles prior to loading. At most quarries, large haulage vehicles are used to transport broken rock from the quarry to the processing plant over unpaved roads. Emissions generated are proportional to the surface condition of the roads and the volume and speed of the vehicle traffic. Control measures include methods to improve road surfaces including watering, surface treatment with chemical dust suppressants, soil stabilization and paving, and operational changes to reduce traffic volume and vehicle speed.

The principal crushing and grinding process facilities include crushers, grinders, screens, and material handling and transfer equipment. Particulate emissions from process equipment are generally discharged at feed and process material discharge points, and emissions from material handling equipment at transfer points. Available emission control techniques for these plant-generated emissions include wet dust suppression, dry collection, and the combination of the two. Wet dust suppression consists of introducing moisture into the material flow to prevent or suppress the emission of fine particulates. Dry collection involves hooding and enclosing dust-producing points and venting emissions to a collection device. Combination systems utilize both methods at different stages throughout the processing plant.

Other particulate emission sources include windblown dust from open conveyors, stockpiles, and the plant yard. Control measures range from the use of dust suppression techniques to the erection of enclosures or windbreaks.

2.0 SOURCES AND TYPES OF EMISSIONS

2.1 GENERAL

There are many non-metallic minerals which are individually produced in a wide range of quantities. For example, the annual domestic demand for sand and gravel is quoted in millions of megagrams (tons), whereas the production of industrial diamonds and gem stones is measured in carats. Previous EPA studies have investigated some of these non-metallic minerals, namely, coal, phosphate rock, and asbestos. The 17 non-metallic minerals selected for this study are:

Crushed and Broken Stone	Clay
Sand and Gravel	Gypsum
Rock Salt	Pumice
Gilsonite	Talc
Boron	Barite
Fluorspar	Feldspar
Diatomite	Perlite
Vermiculite	Mica
Kyanite	

These 17 categories are based upon Bureau of Mines classifications and are the highest mined production segments of the non-metallic minerals industry which have crushing and grinding operations, excluding coal, phosphate rock, and asbestos.

Total domestic production of these non-metallic minerals for 1977 was about 1,790 million megagrams (1,975 million short tons). The estimated domestic production level of these minerals in 1985 has been projected to be 2,203 million megagrams (2,429 million short tons). The value of the minerals ranges from $1.10 per megagram ($1.00 per ton) for low grade clay, to $276 per megagram ($250 per ton) for high grade talc. Geographically, the non-metallic minerals industry is highly dispersed, with all states reporting production of at least one of these 17 non-metallic minerals. The industry is also extremely diverse in terms of production capacities per facility (from five to several thousand megagrams (tons per hour) and end product uses.

2.1.1 Industry Characteristics

Table 2.1 presents industry characteristics for each mineral under consideration. Crushed stone and sand and gravel are by far the largest segments, accounting for 1,708 million megagrams (1,883 million tons) of the 1,791 million megagrams (1,975 million tons) produced by the 17 industries. There are about 6,100 processing plants in the sand and gravel industry and about 5,100 quarries worked in the crushed stone industry. Each of the other industries has less than 100 processing plants, except for the clay industry which has about 120 plants.

Sand and gravel plants are located in every State. Crushed stone plants are located in every State except Delaware. Clay plants are located in every State except Vermont, Rhode Island, and Alaska. Processing plants for the other industries are usually distributed among a few States where those mineral deposits are located. One of the minerals is principally mined and processed in only one State: boron in California.

Projected growth rates are also presented in Table 2.1. The growth rates are projected to increase at compounded annual rates of up to 6 percent through the year 1985.

2.1.2 End Uses

End uses for the non-metallic minerals are many and diverse. The minerals may be used either directly in their natural state or processed into a variety of manufactured products. Generally, they can be classified as either minerals for the construction industry; minerals for the chemical and fertilizer industries; or clay, ceramic, refractory, and miscellaneous minerals. Minerals generally used for construction are crushed and broken stone, sand and gravel, gypsum, gilsonite, perlite, pumice, vermiculite, and mica. Minerals generally used in the chemical and fertilizer industries are barite, fluorspar, boron, and rock salt. Clay, feldspar, kyanite, talc, and diatomite can be generally classified as clay, ceramic, refractory, and miscellaneous minerals. Table 2.2 lists the major uses of each individual mineral.

TABLE 2.1 INDUSTRY CHARACTERISTICS

Mineral	1977 Production 1000 megagrams (1000 tons)	1977 Price (Dollars/Mg)	Annual growth rate (%)	Major producing States in order of production	Number of active operations
Crushed and broken stone	865,280 (954,000)	2.83	4.0	Texas Pennsylvania Illinois Florida Ohio	5177 (quarries)
Sand and gravel	842,785 (929,200)	2.40	1.0	California Alaska Texas Ohio Michigan	6179
Clay	48,250 (53,196)	1.10-221.00	3.3	Georgia Texas Ohio North Carolina	120
Rock Salt	13,565 (14,958)	10.06	2.0	Louisiana Texas New York	21
Gypsum (crude)	12,145 (13,390)	6.12	2.0	California Michigan Iowa Texas	69 (mines)
Pumice	3,635 (4,009)	3.29	3.5	Oregon New Mexico California Arizona	253
Gilsonite	90 (100)	-	2.0	Utah	2
Talc	1,100 (1,205)	5.50-276.00	4.0	Vermont Texas California	43

TABLE 2.1 (continued)

Mineral	1977 Production 1000 megagrams (1000 tons)	1977 Price (Dollars/Mg)	Annual growth rate (%)	Major producing States in order of production	Number of active operations
Boron	1,330 (1,469)	177	5.0	California	6
Barite	1,355 (1,494)	22.34	2.2	Nevada Missouri	30
Fluorspar	150 (169)	91-126	3.0	Illinois	15
Feldspar	665 (734)	25.81	4.0	North Carolina	16
Diatomite	590 (648)	108.67	5.5	California Nevada Oregon	15
Perlite	790 (871)	19.84	4.0	New Mexico	12
Vermiculite	325 (359)	57.06	4.0	Montana South Carolina	4
Mica	150 (163)	50.75	4.0	North Carolina New Mexico	22
Kyanite	85 (94)**	-	6.0	Virginia Georgia	3

**Estimates for 1974.

TABLE 2.2 MAJOR USES OF THE NON-METALLIC MINERALS

Mineral	Major uses
Crushed and broken stone	Construction, lime manufacturing
Sand and gravel	Construction
Clay	Bricks, cement, refractory, paper
Rock salt	Highway use, chlorine
Gypsum	Wallboard, plaster, cement, agriculture
Pumice	Road construction, concrete
Gilsonite	Asphalt paving
Talc	Ceramics, paint, toilet preparations
Boron	Glass, soaps, fertilizer
Barite	Drilling mud, chemicals
Fluorspar	Hydrofluoric acid, iron and steel, glass
Feldspar	Glass, ceramics
Diatomite	Filtration, filters
Perlite	Insulation, filter aid, plaster aggregate
Vermiculite	Concrete
Mica	Paint, joint cement, roofing
Kyanite	Refractories, ceramics

QUARRYING

Sources of particulate emissions from quarrying operations include drilling, blasting, secondary breakage, and the loading and hauling of the mineral to the processing plant. Not all non-metallic mineral deposits require drilling and blasting to fragment portions of the deposits into pieces of material of convenient size for further processing. Some mineral deposits can be removed without blasting by the use of power equipment such as front-end loaders, drag lines, and dredges.

Particulate emissions from drilling operations are primarily caused by the removal of cuttings and dust from the bottom of the hole by air flushing. Compressed air is released down the hollow drill center, forcing cuttings and dust up and out the annular space formed between the hole wall and drill.

Clays are a group of fine-grained non-metallic minerals which are mostly hydrous aluminum silicates that contain various amounts of organic and inorganic impurities. Clays are classified into six groups by the Bureau of Mines: kaolin, ball clay, fire clay, bentonite, fuller's earth, and miscellaneous (common) clay.

Kaolin is a clay in which the predominant clay mineral is kaolinite. Large quantities of high quality kaolin are found in Georgia. Ball clay consists principally of kaolinite, but has a higher silica-to-alumina ratio than is found in most kaolin, as well as larger quantities of mineral impurities and much organic material. Ball clays are mined in Kentucky, Tennessee, and New Jersey.

The terms "fire clay" and "stoneware clay" are based on refractoriness, or on intended usage (fire clay indicating potential use for refractories, and stoneware clay indicating uses for such items as crocks, jugs, and jars). Fire clays are basically kaolinitic but include other clay minerals and impurities. Included under the general term fire clay are the disapore, burley, and burley-flint clays. Fire clay deposits are widespread in the United States, with the greatest reserves being found in the Middle Atlantic region.

Bentonites are composed essentially of minerals of the montmorillonite group. The swelling type has a high sodium iron concentration, whereas the nonswelling types are usually high in calcium. Bentonite is presently produced in Wyoming and Montana.

Fuller's earths are essentially montmorillonite or attapulgite. A small area in Georgia and Florida contains the known reserve of attapulgite-type fuller's earth.

The term "miscellaneous (common) clay" is a statistical designation used by the Bureau of Mines to refer to clays and shales not included under the other five clay types. Miscellaneous clay may contain some kaolinite and montmorillonite, but illite usually predominates, particularly in the shales. Miscellaneous clay is widespread throughout the United States.

Rock salt consists of sodium chloride and is the chief source of all forms of sodium. Rock salt is mined on a large scale in Michigan, Texas, New York, Louisiana, Ohio, Utah, New Mexico, and Kansas.

Gypsum is a hydrous calcium sulfate normally formed as a chemical precipitate from marine waters of high salinity. Domestic reserves of gypsum are geographically distributed in 23 states. Areas deficient in gypsum reserves are Minnesota, Wisconsin, the Pacific Northwest, the New England States, the deep South to the east of Louisiana, and northern California.

Pumice is a rock of igneous origin, ranging from acidic to basic in composition, with a cellular structure formed by explosive or effusive volcanism. The commercial designation includes the more precise petrographic descriptions for pumice, pumicite (volcanic ash), volcanic cinders, and scoria. Deposits are mostly found in the Western States.

The mineral gilsonite is a variety of native asphalt which has many applications. Gilsonite occurs in large boulders, several inches across. It is black, lustrous mineral found in the Uintah basin in Utah and Colorado.

The mineral talc is a soft hydrous magnesium silicate, $3\ MgO{\cdot}4SiO_2{\cdot}H_2O$. The talc of highest purity is derived from magnesium-rich metamorphic carbonate rocks; less pure talc from metamorphosed ultra basic igneous rocks. Soapstone is a term used for a massive form of rock containing the mineral. Pyrophyllite ($Al_2O_3{\cdot}4SiO_2{\cdot}H_2O$) is a hydrous aluminum silicate similar to talc in properties. It is principally found in North Carolina. Talc-group minerals are principally produced in New York, Texas, Vermont, California, and Montana.

Boron is a versatile and useful element used mainly in the form of its many compounds, of which borax and boric acid are the best known. Many minerals contain boron, but only a few are commercially valuable as sources of boron. The principal boron minerals are borax, kernite, and colemanite. Half of the commercial world reserves are in southern California as bedded deposits of borax (sodium borate) and colemanite (calcium borate), or as solutions of boron minerals in Searles Lake brines.

Barite is almost pure barium sulfate ($BaSO_4$), and is the principal commercial mineral source of barium and barium compounds. The reserves are principally in Missouri and the southern Appalachian States, with the remainder in Arkansas, Nevada, and California.

Fluorine is derived from the mineral fluorite (CaF_2), commonly known as fluorspar. Fluorspar is principally found in deposits located in Kentucky and Illinois.

Feldspar is a general term used to designate a group of closely related minerals, especially abundant in igneous rocks and consisting essentially of aluminum silicates in combination with varying proportions of potassium, sodium, and calcium. The principal feldspar species are orthclase or microcline (both $K_2O \cdot Al_2O_3 \cdot 6SiO_2$), albite ($Na_2O \cdot Al_2O_3 \cdot 6SiO_2$) and anorthite ($CaO \cdot Al_2O_3 \cdot 2SiO_2$). North Carolina is the foremost domestic producer, followed in order of output by California, Connecticut, and Georgia.

Diatomite is a material of sedimentary origin consisting mainly of an accumulation of skeletons or frustules formed as a protective covering by diatoms, single-celled microscopic plants. The skeletons are essentially amorphous hydrated or opaline silica but occassionally are partly composed of alumina. The terms "diatomaceous earth" and "kieselguhr" are sometimes used interchangeably and are synonymous with diatomite. Diatomite is found only in the Western States with a substantial part of the total reserve found in the Lompoc, California area.

Perlite is chemically a metastable amorphous aluminum silicate with minor impurities and inclusions of various other metal oxides and minerals. Perlite is mostly found in the Western States.

Vermiculite is a micaceous mineral with a ferromagnesium-aluminum silicate composition and the property of exfoliating to a low-density material when heated. Presently, vermiculite is mined from deposits located in Montana and South Carolina.

Mica is a group name for a number of complex hydrous potassium aluminum silicate minerals differing in chemical composition and physical properties but characterized by excellent basal cleavage that facilitates splitting into thin, tough, flexible, elastic sheets. These minerals can be classified into four principal types named after the most common mineral in each group - muscovite (potassium mica), phlogopite (magnesium mica), biotite (iron mica), and lepidolite (lithium mica). The major producing regions in the United States are the Southeast and West.

Kyanite and the related minerals - andalusite, sillimanite, dumortierite, and topaz - are natural aluminum silicates which can be converted to mullite, a stable refractory raw material. Reserves of kyanite and the related minerals are mostly found in Virginia, North and South Carolina, Idaho, and Georgia.

2.2 NON-METALLIC MINERALS PROCESSING OPERATIONS AND THEIR EMISSIONS

2.2.1 Process Description

2.2.2 Sources of Emissions

Essentially all mining and mineral processing operations are potential sources of particulate emissions. Emissions may be categorized as either fugitive emissions or fugitive dust. Operations included within each category are listed in Table 2.4. Fugitive emission sources include those sources for which emissions are amenable to capture and subsequent control. Fugitive dust sources are not amenable to control using conventional control systems and generally involve the reentrainment of settled dust by wind or machine movement.

TABLE 2.3 POSSIBLE SOURCES OF EMISSIONS

Type of plant	Crushers	Screens	Transfer points	Grinders	Loading operation	Bagging operation	Dryers or calciners	Drilling operation
Crushed and broken stone	X	X	X		X			X
Sand & gravel	X	X	X		X			
Clay	X	X	X	X	X	X	X	
Gypsum	X	X	X	X		X	X	
Pumice	X	X	X	X		X	X	
Feldspar	X	X	X	X	X		X	
Boron	X	X	X	X	X	X	X	X
Talc	X	X	X	X	X	X	X	X
Barite	X	X	X	X		X		
Diatomite	X	X	X	X		X	X	
Perlite	X	X	X	X	X	X	X	
Rock salt	X	X	X					
Fluorspar	X	X	X	X			X	
Gilsonite	X	X					X	
Mica	X	X		X				
Kyanite	X			X			X	X
Vermiculite	X	X	X	X	X	X	X	X

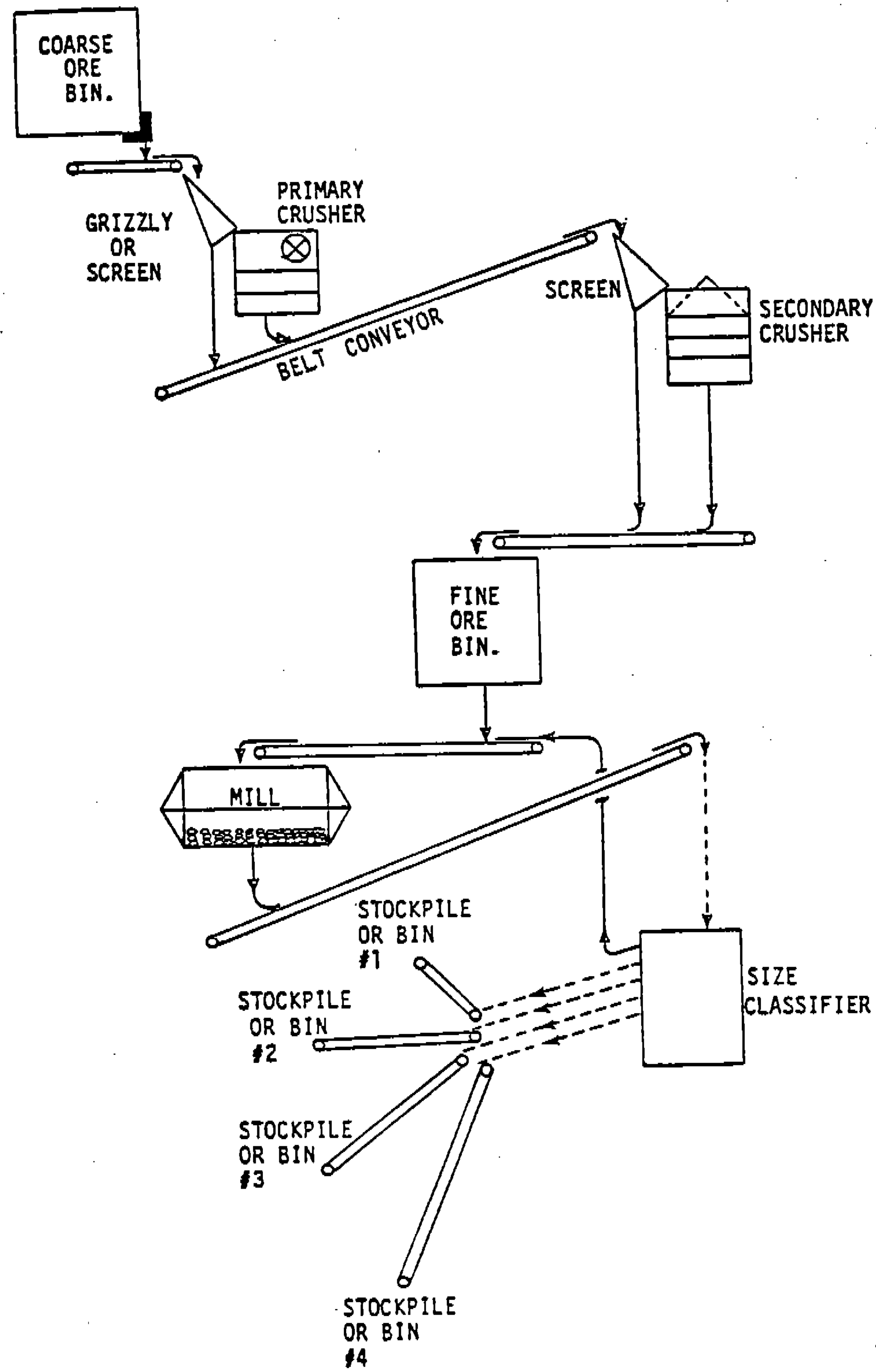

Figure 2.2 General Schematic for Non-Metallic Minerals Processing

TABLE 2.4. EMISSION SOURCES AT NON-METALLIC MINERAL FACILITIES

Fugitive Emissions	Fugitive Dust Sources
Drilling	Blasting
Crushing	Hauling
Screening	Haul Roads
Grinding	Stockpiles
Conveyor Transfer Points	Plant yard
Loading	Conveying

2.2.3 Factors that Affect Emissions from Mining and Process Operations

In general, the factors that affect emissions from most mineral processing operations include: the type of ore processed,[4] the type of equipment and operating practices employed, the moisture content of the ore, the amount of ore processed, and a variety of geographical and seasonal factors. These factors, discussed in more detail below, apply to both fugitive emission and fugitive dust sources associated with mining and processing plant operation.

The type of equipment and operating practices employed also affect uncontrolled emissions. In general, emissions from process equipment such as crushers, screens, grinders, and conveyors depend on the size distribution of the material and the velocity that is mechanically imparted to the material. For crushers, the particular type of crushing mechanism employed (compression or impaction) affects emissions. The effect of equipment type on uncontrolled emissions from all sources will be more fully discussed in subsequent sections of this report (see Sections 2.4 to 2.11).

Information is limited on the amount of emissions from non-metallic mineral processing operations. Table 2.5 presents information concerning the size of the particulates emitted from the processing of different non-metallic minerals based on testing using EPA Method 5.

TABLE 2.5 PARTICLE SIZE DATA FOR NON-METALLIC MINERAL PROCESSING

Mineral	Process	Percent of particle size less than				Median (μm)
		2 μm	5 μm	10 μm	20 μm	
Clay (kaolin)	Roller mill	22	70			3.5
	Impact mill	18	70			3.8
Feldspar	Ball mill (inlet 1)	14	25	37	50	20.0
	(inlet 2)	6	16	27	44	25.0
Clay (fuller's earth)	Fluid energy mill	65	92			1.5
	Raymond mill	3	18			7.0
Talc	Ball mill		37	59	82	5 to 10
Gypsum	Raymond mill	0	40	80	90	6
Talc	Processing plant[a] (inlet 1)	1	11	34	64	14
	(inlet 2)	0.3	28	85	99.6	7.5
	(inlet 3)	1	18	60	90	9
Crushed stone	Primary crusher	0.2	1			>10
	Primary screen	1	3			>10
	Primary crusher and hammermill	4	16	32	52	19
	Final screen	4	13	25	43	24
	Tertiary crusher and final screen	4	16	34	62	15

[a]Crushing, grinding, and bagging operations all ducted to one baghouse.

Blasting is used to displace solid rock from its quarry deposit and to fragment it into sizes which require a minimum of secondary breakage and which can be readily handled by loading and hauling equipment. The frequency of blasting ranges from several shots per day to one per week depending on the plant capacity and the size of individual shots. The effectiveness of a shot depends on the characteristics of the explosive and the rock. Emissions from blasting are evident from visual observations and are largely unavoidable. The emissions generated are affected by the blasting practices employed and are reduced during wet, low wind conditions.

If secondary breakage is required, drop-ball cranes are usually employed. Normally, a pear-shaped or spherical drop-ball, weighing several tons, is suspended by a crane and dropped on the oversize rock as many times as needed to break it. Emissions are slight.

The excavation and loading of broken rock is normally performed by shovels and front-end loaders. Whether the broken rock is dumped into a haulage vehicle for transport or directly into the primary crusher, considerable fugitive dust emissions may result. The most significant factor affecting these emissions is the wetness of the rock.

At most quarries, large capacity "off-the-road" haulage vehicles are used to transport broken rock from the quarry to the primary crusher over unpaved haul roads. The vehicle traffic on unpaved roads is responsible for a large portion of the fugitive dust generated by quarrying operations. Factors affecting fugitive dust emissions from hauling operations include the composition of the road surface, the wetness of the road, and the volume and speed of the vehicle traffic.

2.4 CRUSHING

Crushing is the process by which coarse material is reduced by mechanical energy and attrition to a desired size for mechanical separation (screening). The mechanical stress applied to rock fragments during crushing may be accomplished by either compression or impaction. These two methods of crushing differ in the duration of time needed to apply the breaking force. In impaction, the breaking force is applied very rapidly; in compression, the rock particle is slowly squeezed and forced to fracture. All types of crushers are both compression and impaction to varying degrees. Table 2.6 ranks crushers according to the predominant crushing mechanism used (from top to bottom, compression to impaction). In all cases, there is some reduction by the rubbing of stone on stone or on metal surfaces (attrition).

TABLE 2.6. RELATIVE CRUSHING MECHANISM UTILIZED BY VARIOUS CRUSHERS[5]

Compression	Double roll crusher
	Jaw crusher
	Gyratory crusher
	Single roll crusher
	Rod mill (low speed)
	Ball mill
	Rod mill (high speed)
	Hammermill (low speed)
	Impact breaker
Impaction	Hammermill (high speed)

The size of the product from compression type crushers is controlled by the space between the crushing surfaces compressing the rock particle. This type of crusher produces a relatively closely graded product with a small proportion of fines. Crushers that reduce by impact, on the other hand, produce a wide range of sizes and high proportion of fines.

Because the size reduction achievable by one machine is limited, reduction in stages is frequently required. As noted previously, the various stages include primary, secondary, and perhaps tertiary crushing. Basically, the crushers used in the non-metallic minerals industry are: jaw, gyratory, roll, and impact crushers.

Jaw Crushers

Jaw crushers consist of a vertical fixed jaw and a moving inclined jaw which is operated by a single toggle or a pair of toggles. Rock is crushed by compression as a result of the opening and closing action of the moveable jaw against the fixed jaw. Their principal application in the industry is for primary crushing.

The most commonly used jaw crusher is the Balke or double-toggle type. As illustrated in Figure 2.3, an eccentric shaft drives a Pitman arm that raises and lowers a pair of toggle plates to open and close the moving jaw which is suspended from a fixed shaft. In a single-toggle jaw crusher, the moving jaw is itself suspended from an eccentric shaft and the lower part of the jaw is supported by a rolling toggle plate (Figure 2.4). Rotation of the eccentric shaft produces a circular motion at the upper end of the jaw and an elliptical motion at the lower end. Other types, such as the Dodge and overhead eccentric are used on a limited scale.

The size of a jaw crusher is defined by its feed opening dimensions and may range from about 15 x 30 centimeters to 213 x 168 centimeters (6 x 12 inches to 84 x 66 inches). The size reduction obtainable may range from 3:1 to 10:1 depending on the nature of the rock. Capacities are quite variable depending on the unit and its discharge setting. Table 2.7 presents approximate capacities for a number of jaw crusher sizes at both minimum and maximum discharge settings.

Gyratory Crushers

Simply, a gyratory crusher may be considered to be a jaw crusher with circular jaws between which the material flows and is crushed. As indicated in Table 2.8, however, a gyratory crusher has a much greater capacity than a jaw crusher with an equivalent feed opening.

There are basically three types of gyratory crushers: the pivoted spindle, fixed spindle, and cone. The fixed and pivoted spindle gyratories are used for primary and secondary crushing, and cone crushers are used for secondary and tertiary crushing. The larger gyratories are sized according to feed opening and the small units are sized by cone diameters.

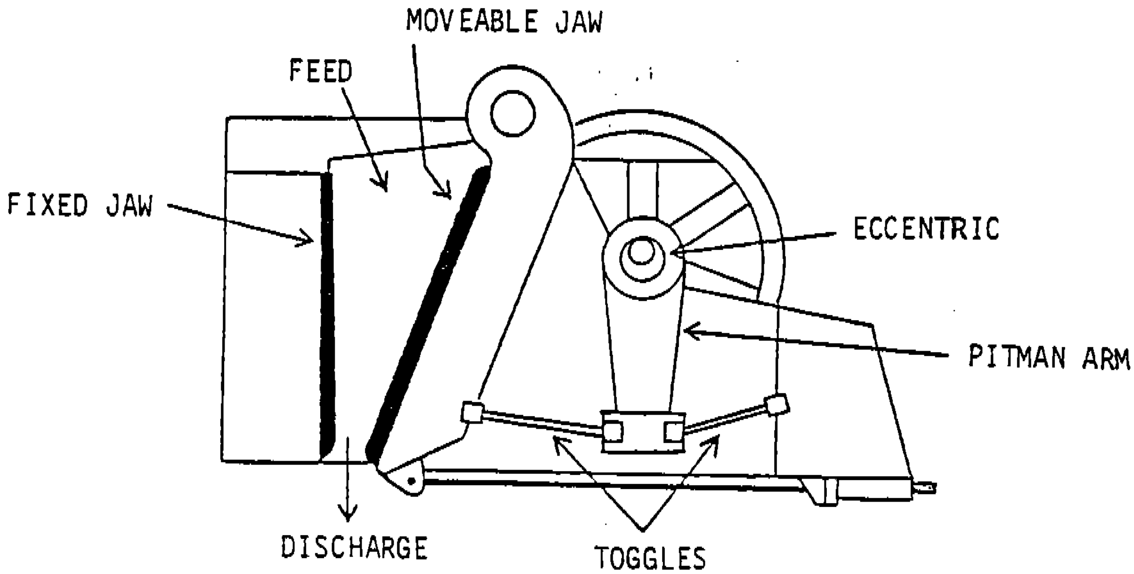

Figure 2.3 Double-toggle Jaw Crusher

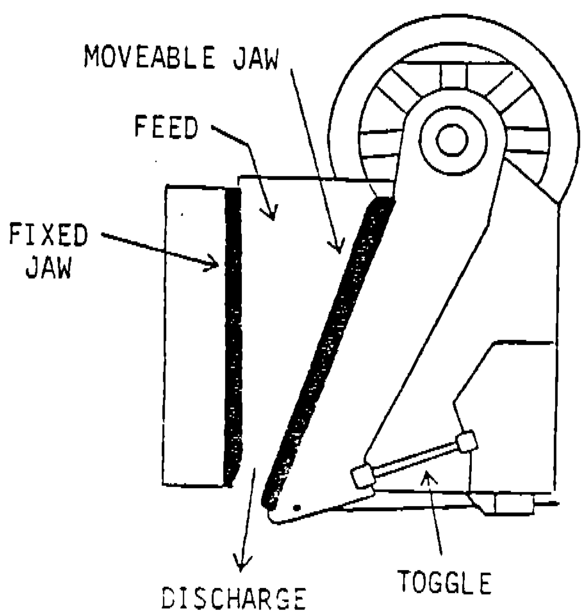

Figure 2.4 Single-toggle Jaw Crusher

TABLE 2.7 APPROXIMATE CAPACITIES OF JAW CRUSHERS(7)
(Discharge opening - closed)

Size [cm.(in.)]	Smallest discharge opening [cm.(in.)]	Capacity* [Mg/hr (tons/hr)]	Largest discharge opening [cm.(in.)]	Capacity [Mg/hr (tons/hr)]
91 x 61 (36 x 24)	>6 (3)	68 (75)	15.2 (6)	145 (160)
107 x 152 (42 x 60)	10.2 (4)	118 (130)	20.3 (8)	181 (200)
122 x 107 (48 x 42)	12.7 (5)	159 (175)	20.3 (8)	250 (275)
152 x 122 (60 x 48)	12.7 (5)	218 (240)	22.9 (9)	408 (450)
213 x 168 (84 x 66)	20.3 (8)	363 (400)	30.5 (12)	544 (600)

*Based on rock weighing 1600 kg/m³ (100 lb/cu ft.)

TABLE 2.8 APPROXIMATE CAPACITIES OF GYRATORY CRUSHERS (8)
(Discharge opening - open)

Size [cm. (in.)]	Smallest discharge opening [cm.(in.)]	Capacity* [Mg/hr. (tons/hr)]	Largest discharge opening [cm.(in.)]	Capacity [Mg/hr. (tons/hr)]
76 (30)	10.2 (4)	181 (200)	16.5 (6.5)	408 (450)
91 (36)	11.4 (4.5)	336 (370)	17.8 (7)	544 (600)
107 (42)	12.7 (5)	381 (420)	19.1 (7.5)	635 (700)
122 (48)	14.0 (5.5)	680 (750)	22.9 (9)	1088 (1,200)
137 (54)	16.5 (6.5)	816 (900)	24.1 (9.5)	1451 (1,600)
152 (60)	17.8 (7)	1088 (1,200)	25.4 (10)	1814 (2,000)
183 (72)	22.9 (9)	1814 (2,000)	30.5 (12)	2721 (3,000)

*Based on rock weighing 1600 kg/m³ (100 lb/cu ft.)

The pivoted spindle gyratory (Figure 2.5) has the crushing head mounted on a shaft that is suspended from above and free to pivot. The bottom of the shaft is seated in an eccentric sleeve which revolves, thus causing the crusher head to gyrate in a circular path within a stationary concave circular chamber. The crushing action is similar to that of a jaw crusher in that the crusher element reciprocates to and from a fixed crushing plate. Because some part of the crusher head is working at all times, the discharge from the gyratory is continuous rather than intermittent as in a jaw crusher. The crusher setting is determined by the wide-side opening at the discharge end and is adjusted by raising or lowering the crusher head.

Unlike the pivoted spindle gyratory, the fixed spindle gyratory has its crushing head mounted on an eccentric sleeve fitted over a fixed shaft. This produces a uniform crushing stroke from the top to the bottom of the crushing chamber.

For fine crushing, the gyratory is equipped with flatter heads and converted to a cone crusher (Figure 2.6). Commonly, in the lower section a parallel zone exists. This results in a larger discharge-to-feed area ratio which makes it extremely suitable for fine crushing at high capacity. Also, unlike regular gyratories, the cone crusher sizes at the closed side setting and not the open side (wide-side) setting. This assures that the material discharge will have been crushed at least once at the closed side setting. Cone crushers yield a cubical product and a high percentage of fines due to interparticle crushing (attrition). They are the most commonly used crusher in the industry for secondary and tertiary reduction. Table 2.9 presents performance data for typical cone crushers.

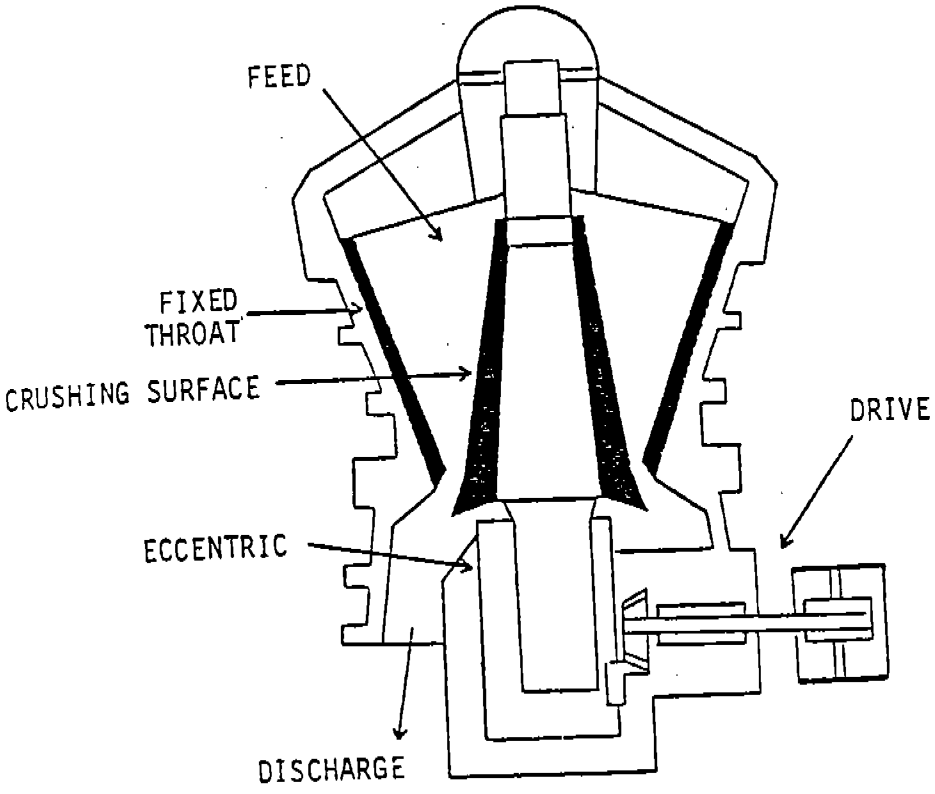

Figure 2.5 The Pivoted Spindle Gyratory

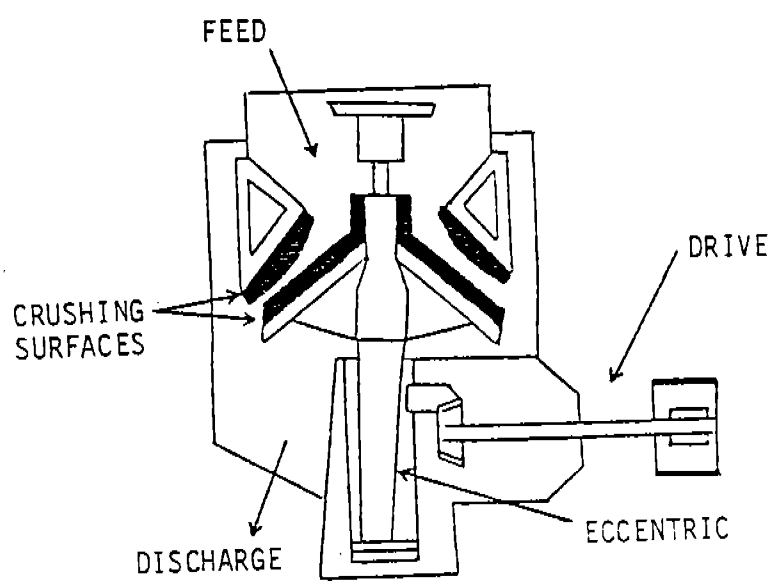

Figure 2.6 Cone Crusher

TABLE 2.9. PERFORMANCE DATA FOR CONE CRUSHERS[8]

Size of crusher (m (ft))	Capacity (Mg/hr (tons/hr)) discharge setting (cm (in))									
	1.0	(3/8)	1.3	(1/2)	1.9	(3/4)	2.5	(1)	3.8	(1.5)
0.6 (2)	18	(20)	23	(25)	23	(25)		-		-
0.9 (3)	32	(35)	36	(40)	64	(70)		-		-
1.2 (4)	54	(60)	73	(80)	109	(120)	136	(150)		-
1.7 (5.5)		-		-	181	(200)	250	(275)	308	(340)
2.1 (7)		-		-	229	(330)	408	(450)	544	(600)

Roll Crushers

These machines are utilized primarily at intermediate or final reduction stages and are often used at portable plants. There are essentially two types, the single-roll and the double-roll. As illustrated in Figure 2.7, the double-roll crusher consists of two heavy parallel rolls which are turned toward each other at the same speed. Roll speeds range from 50 to 300 rpm. Usually, one roll is fixed and the other set by springs. Typically, roll diameters range from 61 to 198 centimeters (24 to 78 inches) and have narrow face widths (about half the roll diameter). Rock particles are caught between the rolls and crushed almost totally by compression. Reduction ratios are limited and range from 3 or 4 to 1. These units produce few fines and no oversize. They are used especially for reducing hard rock to a final product ranging from 1/4 inch to 20 mesh.

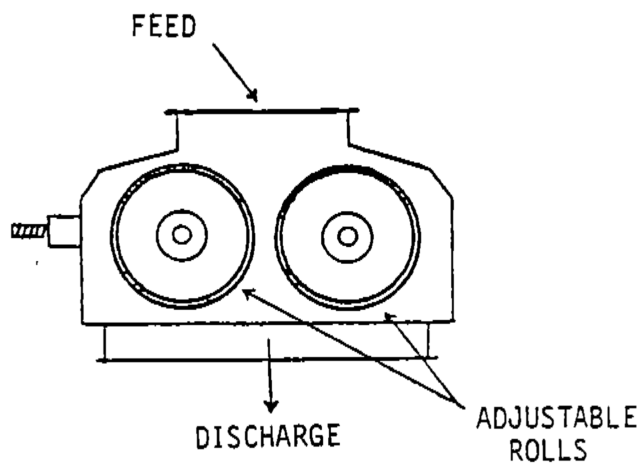

Figure 2.7 Double-roll Crusher

The working elements of a single-roll crusher include a toothed or knobbed roll and a curved crushing plate which may be corrugated or smooth. The crushing plate is generally hinged at the top and its setting is held by a spring at the bottom. A toothed-roll crusher is depicted in Figure 2.8. The feed caught between the roll and crushing plate is broken by a combination of compression, impact, and shear. These units may accept feed sizes up to 51 centimeters (20 inches) and have capacities up to 454 megagrams per hour (500 tons/hr). In contrast with the double-roll, the single-roll crusher is principally used for reducing soft materials.

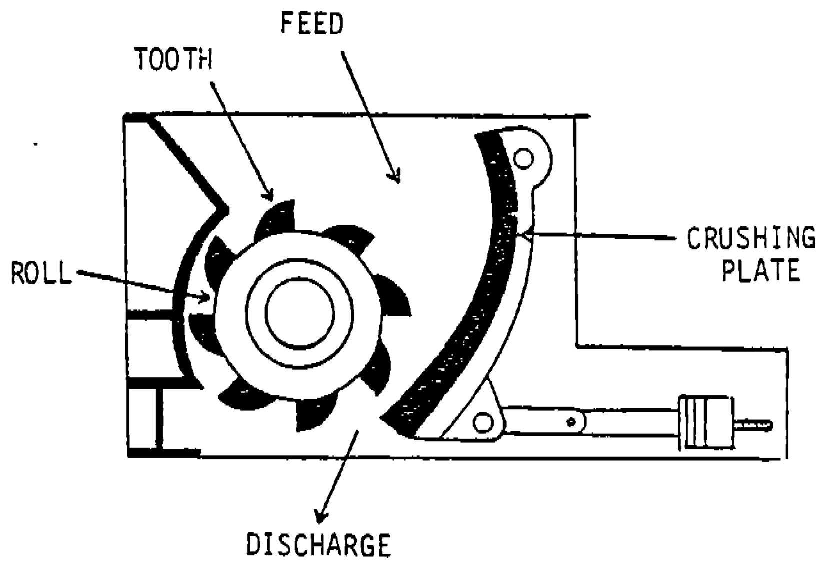

Figure 2.8 Single roll Crusher

Impact Crushers

Impact crushers, including hammermills and impactors, use the force of fast rotating massive impellers or hammers to strike and shatter free falling rock particles. These units have extremely high reduction and produce a cubical product spread over a wide range of particle sizes with a large proportion of fines.

A hammermill consists of a high-speed horizontal rotor with several rotor discs to which sets of swing hammers are attached (Figure 2.9). As rock particles are fed into the crushing chamber, they are impacted and shattered by the hammers which attain tangential speeds as high as 76 meters (250 feet) per second. The shattered rock then collides with a steel breaker plate and is fragmented even further. A cylindrical grating or screen positioned at the discharge opening restrains oversize material until it is reduced to a size small enough to pass the grate bars. Rotor speeds range from 250 to 1800 rpm and capacities can reach over 907 megagrams per hour (1,000 tons/hr). Product size is controlled by the rotor speed, the spacing between the grate bars, and by hammer length.

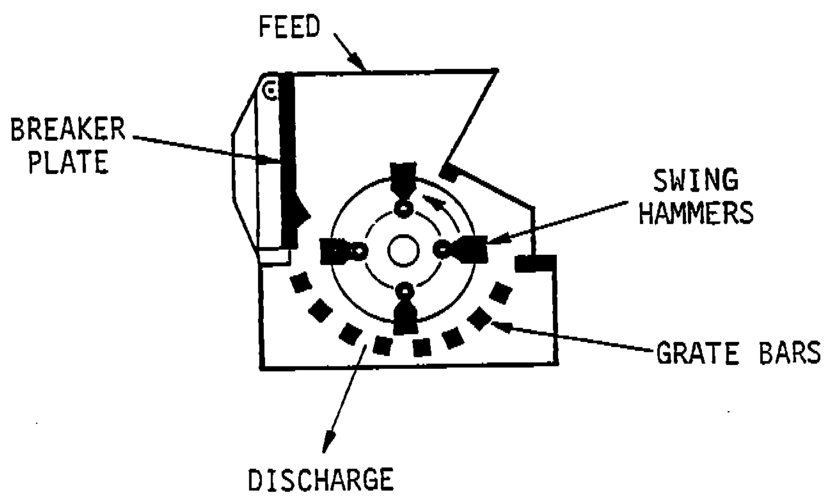

Figure 2.9 Hammermill

An impact breaker (Figure 2.10) is similar to a hammermill except that it has no grate or screen to act as a restraining member. Feed is broken by impact alone. Adjustable breaker bars are used instead of plates to reflect material back into the path of the impellers. Primary-reduction units are available which can reduce quarry-run material at over 907 megagrams per hour (1,000 tons/hr) capacity to about 2.5 centimeters (1 inch). These units are not appropriate for hard abrasive materials, but are ideal for soft rocks.

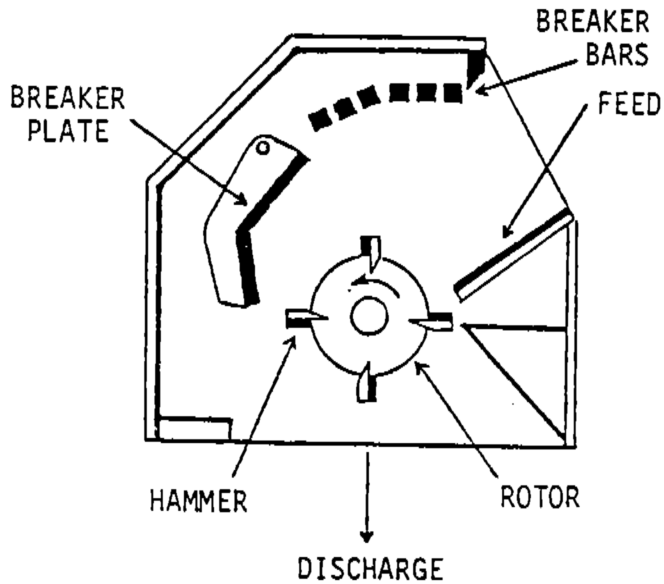

Figure 2.10 Impact Crusher

Sources of Emissions

The generation of particulate emissions is inherent in the crushing process. Emissions are most apparent at crusher feed and discharge points. Emissions are influenced predominantly by the type of rock processed, the moisture content of the rock, and the type of crusher used.

The most important elements influencing emissions from crushing equipment, as previously mentioned, are the type of rock and the moisture content of the mineral being crushed. The crushing mechanism employed has a substantial affect on the size reduction that a machine can achieve, the particle size distribution of the product (especially the proportion of fines produced), and the amount of mechanically induced energy which is imparted to fines.

Crushing units utilizing impaction rather than compression produce a larger proportion of fines as noted above. In addition to generating more fines, impact crushers also impart higher velocity to them as a result of the fan-like action produced by the fast, rotating hammers. Because of this and the high proportion of fines produced, impact crushers generate larger quantities of uncontrolled particulate emissions per ton of material processed than any other crusher type.

The level of uncontrolled emissions from jaw, gyratory, cone, and roll crushers closely parallels the reduction stage to which they are applied. Emissions increase progressively from primary to secondary to tertiary crushing. Factors other than the type of crushing mechanism (compression, impact) also affect emissions. In all likelihood, primary jaw crushers produce greater emissions than comparable gyratory crushers because of the bellows effect of the jaw, and because gyratory crushers are usually choke-fed to minimize the open spaces from which dust may be emitted. For subsequent reduction stages, cone crushers produce more fines as a result of attrition and consequently generate more dust.

2.5 SCREENING OPERATIONS

Screening is the process by which a mixture of rocks is separated according to size. In screening, material is dropped into a mesh surface with openings of desired size and separated into two fraction: undersize, which passes through the screen opening, and oversize, which is retained on the screen surface. When material is passed over and through multiple screening surfaces, it is separated into fractions of known particle size distribution. Screening surfaces may be contructed of metal bars, perforated or slotted metal plates, or woven wire cloth.

The capacity of a screen is primarily determined by the open area of the screening surface and the physical characteristics of the feed. It is usually expressed in tons of material per hour per square foot of screen area. Although screening may be performed wet or dry, dry screening is the more common.

Screening equipment commonly used in the non-metallic minerals industry includes grizzlies, shaking screens, vibrating screens, and revolving screens.

Grizzlies

Grizzlies consist of a set of uniformly-spaced bars, rods or rails. The bars may be horizontal or inclined and are usually wider in cross section at the top than the bottom. This prevents the clogging or wedging of stone particles between bars. The spacing between the bars ranges from 5 to 20 centimeters (2 to 8 inches). Bars are usually constructed of manganese steel or other highly abrasion-resistant material.

Grizzlies are primarily used to remove fines prior to primary crushing, thus reducing the load on the primary crusher. Grizzlies may be stationary cantilevered (fixed at one end with the discharge end free to vibrate) or mechanically vibrated. Vibrating grizzlies are simple bar grizzlies mounted on eccentrics (Figure 2-11). The entire assembly is moved forward and backward at about 100 strokes a minute, resulting in better flow through and across the grizzly surface.

Shaking Screens

The shaking screen consists of a rectangular frame with perforated plate or wire cloth screening surfaces, usually suspended by rods or cables and inclined at an angle of 14 degrees. The screens are mechanically shaken parallel to the plane of material flow at speeds ranging from 60 to 800 strokes per minute and at amplitudes ranging from 2 to 23 centimeters (3/4 to 9 inches).[9] Generally, they are used for screening coarse material, 1.3 centimeters (1/2-inch) or larger.

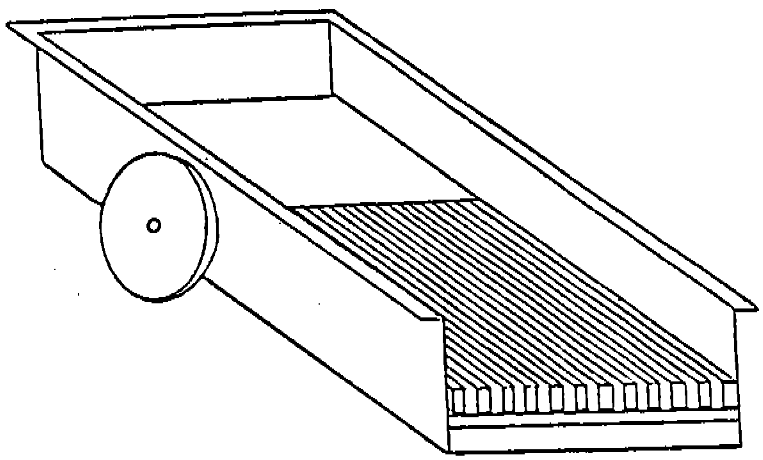

Figure 2.11 Vibrating Grizzly

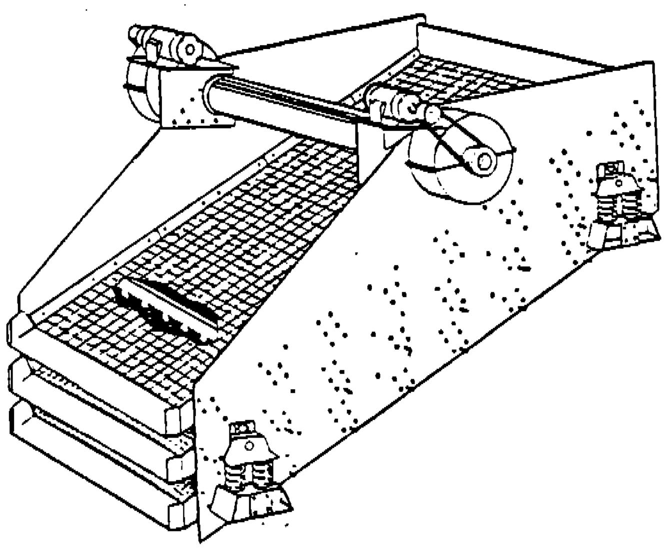

Figure 2.12 Vibrating Screen

Vibrating Screens

Where large capacity and high efficiency are desired, the vibrating screen has practically replaced all other screen types. It is by far the most commonly used screen type in the non-metallic minerals industry. A vibrating screen (Figure 2.12) essentially consists of an inclined flat or slightly convex screening surface which is rapidly vibrated in a plane normal or nearly normal to the screen surface. The screening motion is of small amplitude but high frequency, normally in excess of 3,000 cycles per minute. The vibrations may be generated either mechanically by means of an eccentric shaft, unbalanced fly wheel, cam and tappet assembly, or electrically by means of an electromagnet.

Mechanically-vibrated units are operated at about 1,200 to 1,800 rpm and at amplitudes of about 0.3 to 1.3 centimeters (1/8 to 1/2 inch). Electrically vibrated screens are available in standard sizes from 30 to 180 centimeters (12 inches to 6 feet) wide and 0.76 to 6.1 meters (2-1/2 to 20 feet) long. A complete screening unit may have one, two or three decks.

Revolving Screens

This screen type consists of an inclined cylindrical frame around which is wrapped a screening surface of wire cloth or perforated plate. Feed material is delivered at the upper end and, as the screen is rotated, undersized material passes through the screen openings while the oversized is discharged at the lower end. Revolving screens are available up to 1.2 meters (4 feet) in diameter and usually run at 15 to 20 rpm.[10]

Source of Emissions

Dust is emitted from screening operations as a result of the agitation of dry material. The level of uncontrolled emissions depends on the quantity of fine particles contained in the material, the moisture content of the material, and the type of screening equipment. Generally, the screening of fines produces higher emissions than the screening of coarse materials. Also, screens agitated at large amplitudes and high frequency emit more dust than those operated at small amplitudes and low frequencies.

2.6 MATERIAL HANDLING

Material handling devices are used to convey materials from one point to another. The most common include feeders, belt conveyors, bucket elevators, screw conveyors, and pneumatic systems.

Feeders

Feeders are relatively short, heavy-duty conveyance devices used to receive material and deliver it to process units, especially crushers, at a uniformly regulated rate. The various types used are the apron, belt, reciprocating plate, vibrating, and wobbler feeders.

Apron feeders are composed of overlapping metal pans or aprons which are hinged or linked by chains to form an endless conveyor supported by rollers and spaced between a head and tail assembly. These feeders are constructed to withstand high impact and abrasion and are available in various widths (18 to 27 inches) and lengths.

Belt feeders are essentially short, heavy duty belt conveyors equipped with closely spaced support rollers. Adjustable gates are used to regulate feed rates. Belt feeders are available in 46 to 122 centimeter (18 to 48 inch) widths and 0.9 to 3.7 meter (3 to 12 foot) lengths and are operated at speeds of 12.2 to 30.5 meters (40 to 100 feet) per minute.

Reciprocating plate feeders consist of a heavy-duty horizontal plate which is driven in a reciprocating motion causing material to move forward at a uniform rate. The feed rate is controlled by adjusting the frequency and length of the stroke.

Vibrating feeders operate at a relatively high frequency and low amplitude. Their feed rate is controlled by the slope of the feeder bed and the amplitude of the vibrations. These feeders are available in a variety of sizes, capacities, and drives. When combined with a grizzly, both scalping and feeding functions are performed.

Wobbler feeders also perform the dual task of scalping and feeding. These units consist of a series of closely spaced elliptical bars which are mechanically rotated, causing oversize material to tumble forward to the discharge and undersize material to pass through the spaces. The feed rate is controlled by the bar spacing and the speed of rotation.

Belt Conveyors

Belt conveyors are the most widely used means of transporting, elevating and handling materials in the non-metallic minerals industry. As illustrated in Figure 2.13, belt conveyors consist of an endless belt which is carried on a series of idlers usually arranged so that the belt forms a trough. The belt is stretched between a drive or head pulley and a tail pulley. Although belts may be constructed of other material, reinforced rubber is the most commonly used. Belt widths may range from 36 to 152 centimeters (14 to 60 inches), with 76 to 91 centimeter (30 to 36 inch) belts the most common. Normal operating speeds may range from 60 to 120 meters per minute (200 to 400 feet/minute). Depending on the belt speed, belt width, and rock density, load capacities may be in excess of 1360 megagrams (1,500 tons) per hour.

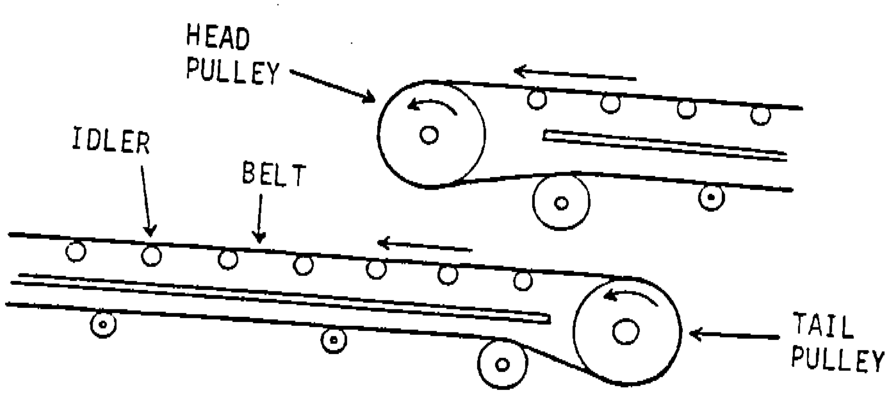

Figure 2.13 Conveyor Belt Transfer Point

Elevators

Bucket elevators are utilized where substantial elevation is required within a limited space. They consist of a head and foot assembly which supports and drives an endless single or double strand chain or belt to which buckets are attached. Figure 2.14 depicts the three types most commonly used: the high-speed centrifugal-discharge, the slow speed positive or perfect-discharge, and the continuous-bucket elevator.

The centrifugal-discharge elevator has a single strand of chain or belt to which the spaced buckets are attached. As the buckets round the tail pulley, which is housed within a suitable curved boot, the buckets scoop up their load and elevate it to the point of discharge. The buckets are so spaced so that at discharge, the material is thrown out by the centrifugal action of the bucket rounding the head pulley. The positive-discharge type also utilizes spaced buckets but differs from the centrifugal type in that it has a double-strand chain and a different discharge mechanism. An additional sprocket, set below the head pulley, effectively bends the strands back under the pulley causing the bucket to be totally inverted resulting in a positive discharge.

The continuous-bucket elevator utilizes closely-spaced buckets attached to a single-or double-strand belt or chain. Material is loaded directly into the buckets during ascent and is discharged gently as a result of using the back of the precluding bucket as a discharge chute.

Screw Conveyors

Screw conveyors are comprised of a steel shaft with a spiral or helical fin which, when rotated, pushes material along a trough. Since these conveyors are usually used with wet classification, no significant emission problem is experienced.

Pneumatic Conveyors

Pneumatic conveyors are comprised of tubes or ducts through which material is conveyed. Pneumatic conveyors are divided into two classes termed by their operating principles: pressure systems and vacuum (suction) systems.

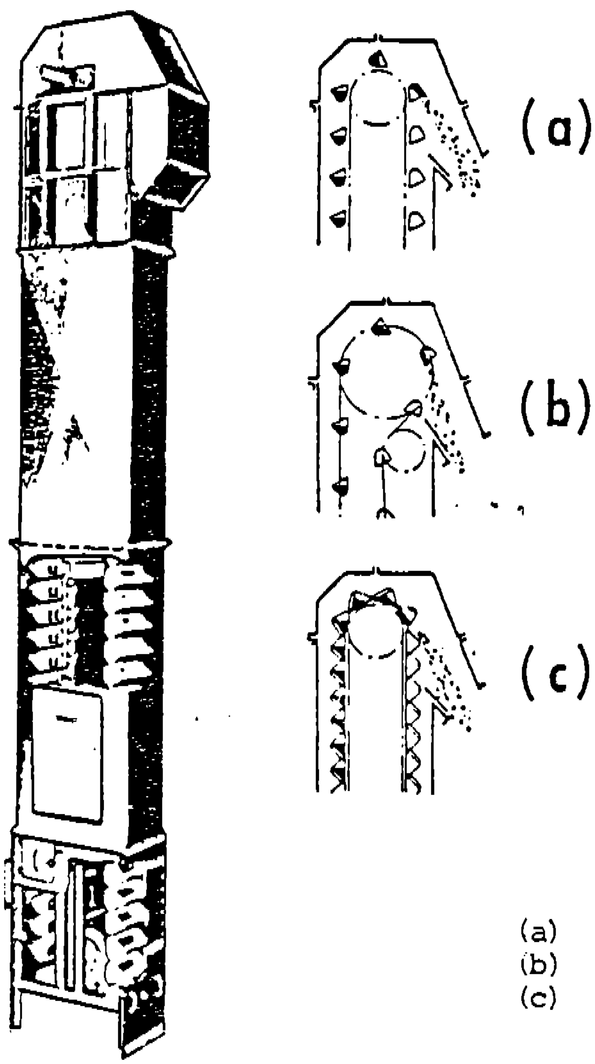

Figure 2.14 Bucket Elevator Types

Pressure systems are further classified into low pressure and high pressure types, and vacuum systems into low-, medium-, and high-vacuum types. Pressure and vacuum systems occasionally are used in combination for special requirements.

Pressure systems operate at pressure obtainable from a fan (low-pressure systems) or a compressed air system (high-pressure systems). Normally, the airstream functions in a 20 to 31 centimeters (8 to 12 inches) diameter pipeline. Into this line, material is fed from a hopper or other device at controlled rates. The airstream immediately suspends this material and conveys it to a cyclone-type or filter-type collector for deposit. Conveying air escapes via the cyclone vent or through the filter.

Vacuum systems offer the advantage of clean, efficient pickup from railcars, trucks or bins for unloading or in-plant conveying operations. Cyclone receivers or combination receiver-filters are used at the terminal of the system to separate the material being conveyed from the air. Below the receiver, either a rotary feeder or gatelock (trap door feeder) is employed as a discharge air lock. Positive displacement blowers are used as exhausters to provide the necessary conveying air at the operating vacuum. Generally, the vacuum system is most applicable where the feed-in point must be flexible, such as unloading railroad cars, barges, ships, or reclaiming material from open warehouse storage, or where it is desirable to pick up material from a multiplicity of stations.

Source of Emissions

Particulates may be emitted from any of the material handling and transfer operations. As with screening, the level of uncontrolled emissions depends on the material being handled, the size of the material handled, the degree of agitation of the material, and the moisture content of the material. Perhaps the largest emissions occur at conveyor belt transfer points. Depending on the conveyor belt speed and the free fall distance between transfer points, substantial emissions may be generated.

2.7 GRINDING OPERATION

Grinding is a further step in the reduction of material to particle sizes smaller than those attainable by crushers. Because the material to be treated has already been reduced to small sizes, and the force to be applied to each particle is comparatively small, the machines used in grinding are of a different type, and may operate on a different principle, from those used in more coarse crushing.

Many types of grinding mills are manufactured for use by various industries. The principal types of mills used are: (1) hammer, (2) roller, (3) rod, (4) pebble and ball, and (5) fluid energy. Each of these types of mills is discussed separately below.

Hammermills

A hammermill consists of a high-speed horizontal rotor with several rotor discs, to which sets of swing hammers are attached. As rock particles are fed into the grinding chamber, they are impacted and shattered by the hammers which attain peripheral speeds greater than 4,572 meters per minute (250 feet per second). The shattered rock then collides with a steel breaker plate and is fragmented even further. A cylindrical grating or screen positioned at the discharge opening restrains oversize material until it is reduced to a size small enough to pass between the grate bars. Product size is controlled by the rotor speed, the spacing between the grate bars, and by hammer length. These mills are used for nonabrasive materials and can accomplish a size reduction of up to 12:1.

Roller Mill

The roller mill, also known as a Raymond Roller Mill, with its integral whizzer separator, can produce ground material ranging from 20 mesh to 325 mesh or finer. The material is ground by rollers that travel along the inside of a horizontal stationary ring. The rollers swing outward by centrifugal force, and trap the material between them and the ring. The material is swept out of the mill by a stream of air to a whizzer separator, located directly on top of the mill, where the oversize is separated and dropped back for further grinding while the desired fines pass up through the whizzer blades into the duct leading to the air separator (cyclone). A typical roller mill is shown in Figure 2.15.

Rod Mill

The rod mill is generally considered as a granular grinding unit, principally for handling a maximum feed size of 2 to 4 centimeters (1 to 2 inches), and grinding to a maximum of 65 mesh. It is normally used in a closed circuit with a sizing device, such as a classifier or screen, and for wet or dry grinding. It will grind with the minimum of the finer sizes, such as 100 or 200 mesh, and will handle relatively high moisture material without packing.

The mill in its general form consists of a horizontal, slow-speed rotating, cylindrical drum. The grinding media consists of a charge of steel rods, slightly shorter than the mill's inside length and from 5 to 13 centimeters (2 inches to 5 inches) in diameter. The rods roll freely inside the drum during its rotation to give the grinding action desired.

Pebble and Ball Mills

The simplest form of a ball mill is a cylindrical, horizontal, slow-speed rotating drum containing a mass of balls as grinding media. When other types of grinding media such as a flint or various ceramic pebbles are used, it is known as a pebble mill. The ball mill uses steel, flint, porcelain, or cast iron balls. A typical ball mill is shown in Figure 2.16.

The diameter of balls or pebbles as the initial charge in a mill is determined by the size of the feed material and the desired fineness of the product. Usually the larger diameter ranges are used for preliminary grinding and the smaller for final grinding. Ball mills reduce the size of the feed mostly by impact. These grinders normally have a speed of 10 to 40 revolutions per minute. If the shell rotates too fast, centrifugal force keeps the balls against the shell and minimal grinding occurs.

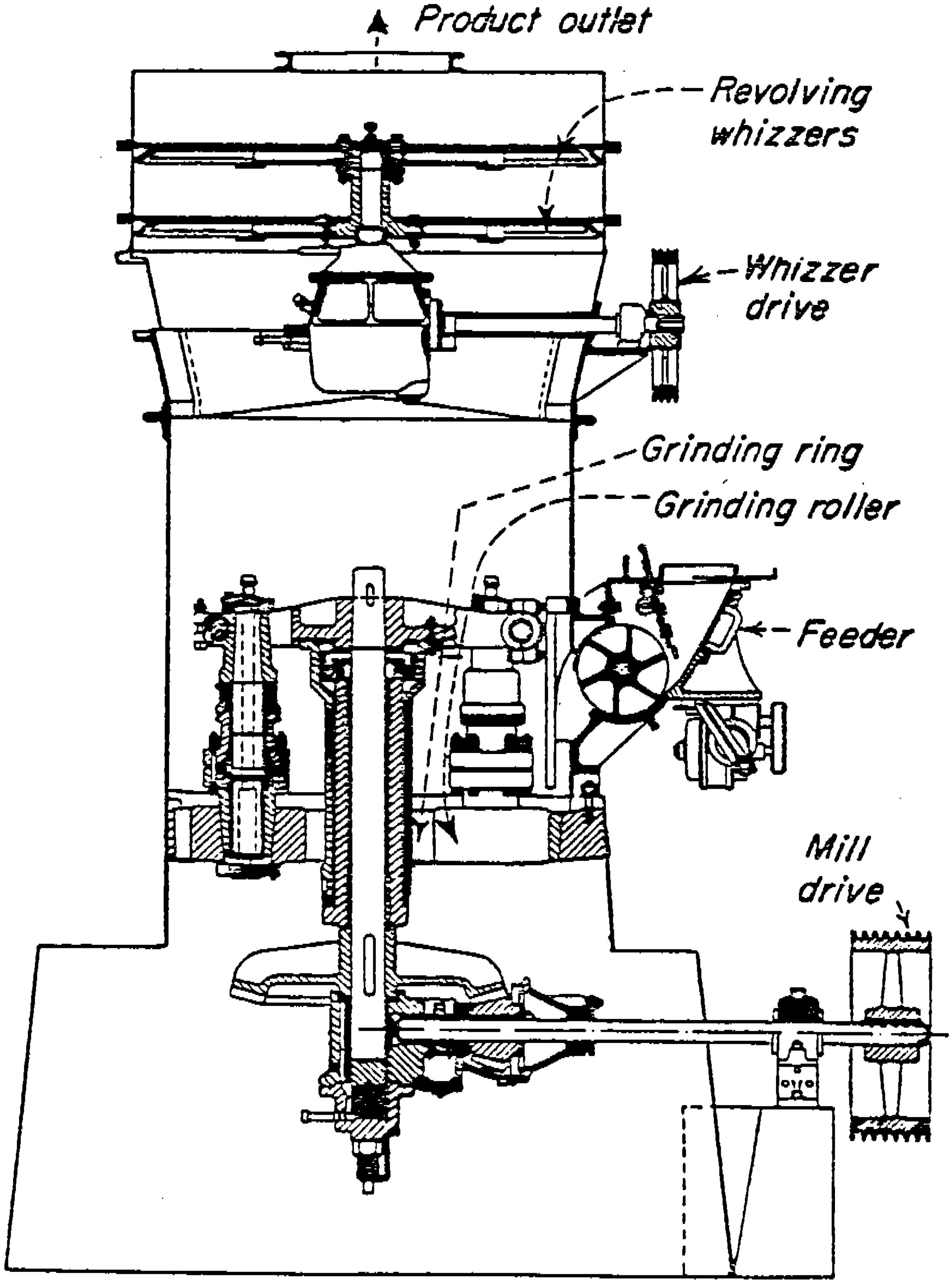

Figure 2.15 Roller Mill

Fluid Energy Mills

When the desired material size is in the range of 1 to 20 microns, an ultrafine grinder such as the fluid energy mill is required. A typical fluid energy mill is shown in Figure 2.17. In this type of mill, the particles are suspended and conveyed by a high velocity gas stream in a circular or elliptical path. Size reduction is caused by impaction and rubbing against mill walls, and by interparticle attrition. Classification of the particles takes place at the upper bend of the loop shown in Figure 2.17. Internal classification occurs because the smaller particles are carried through the outlet by the gas stream while the larger particles are thrown against the outer wall by centrifugal force. Product size can be varied by changing the gas velocity through the grinder.

Fluid energy mills can normally reduce up to 0.91 megagrams/hr (1 ton/hr) of solids from 0.149 mm (100 mesh) to particles averaging 1.2 to 10 microns in diameter. Typical gas requirements are 0.45 and 1.8 kg (1 to 4 pounds) of steam or 2.7 to 4.1 kg (6 to 9 pounds) of air admitted at about 0.07 kPa (100 psig) per 0.45 kg (1 pound) of product. The grinding chambers are about 2.5 to 20 cm (1 to 8 inches) in diameter and the equipment is 1.2 to 2.4 meters (4 to 8 feet) high.

Source of Emissions

As with crushers, the most important element influencing emissions from grinding mills is the reduction mechanism employed, compression or impaction. Grinding mills generally utilize impaction rather than compression. Reduction by impaction will produce a larger proportion of fines. Particulate emissions are generated from grinding mills at the grinder's inlet and outlet. Gravity type grinding mills accept feed from a conveyor and discharge product into a screen or classifier or onto a conveyor. These transfer points are the source of particulate emissions. The outlet has the highest emissions potential because of the finer material. Air-swept mills include an air conveying system and an air separator, a classifier, or both. The air separator and classifier are generally cyclone collectors. In some systems, the air just conveys the material to a separator for deposit into a storage

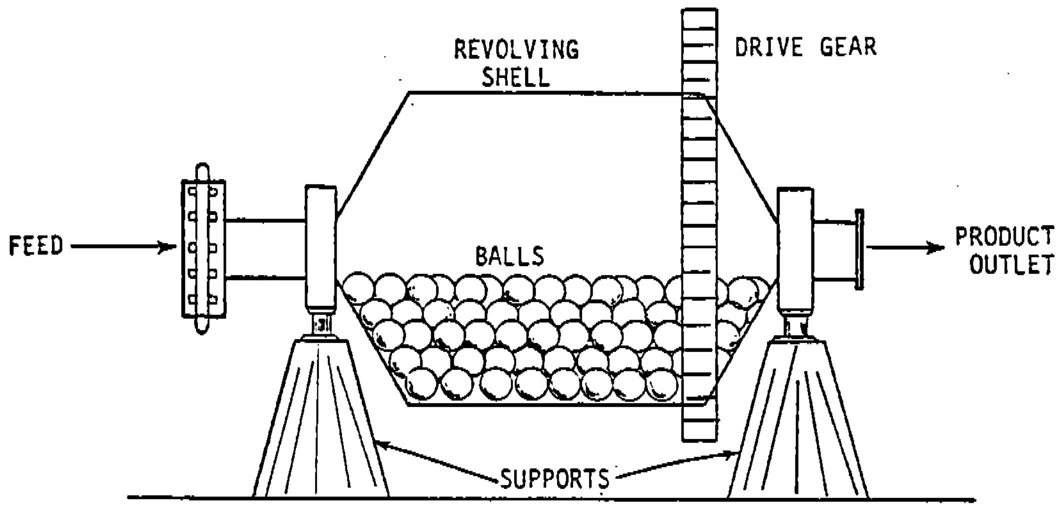

Figure 2.16 Ball Mill

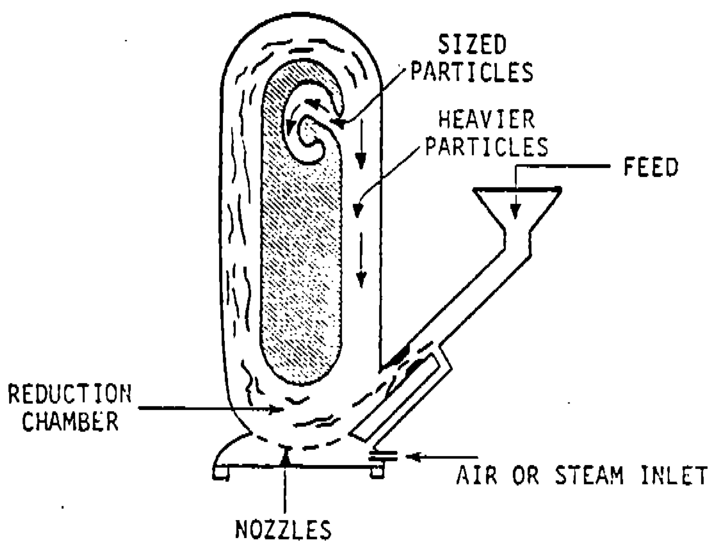

Figure 2.17 Fluid-energy Mill

bin with the conveying air escaping via the cyclone vent. In other grinding systems, the air is continuously recirculated. Maintaining this circulating air system under suction keeps the mill dustless in operation, and any surplus air drawn into the system due to the suction created by the fan is released through a vent. In both cases the vent gases will contain a certain amount of particulate matter.

2.8 SEPARATING AND CLASSIFYING

Mechanical air separators of the centrifugal type cover a distinct field and find wide acceptance for the classification of dry materials in a relatively fine state of subdivision. In commercial practice the separator may be said to begin where the impact of vibrating screens leave off,[11] extending from about 40 to 60 mesh down.

Briefly stated, the selective action of the centrifugal separator is the result of an ascending air current generated within the machine by means of a fan, which lifts the finer particles against the combined effect of centrifugal force and gravity. In operation the feed opening allows the material to drop on the lower or distributing plate where it is spread and thrown off by centrifugal force, the larger and heavier particles being projected against an inner casing, while the smaller and lighter particles are picked up by the ascending air current created by the fan. These fines are carried over into an outer cone and deposited. Concurrently, the rejected coarse material drops into the inner cone, passes out through a spout, and is recycled back to the grinding mill.

The air, after dropping the major portion of its burden, is either recirculated back to the grinding mill or vented. In the case of the recirculated air, a small amount of extraneous air is entrained in the feed and frequently builds up pressure in the separator, in which case the excess air may be vented off. Both vent gases are a source of particulate matter.

2.9 BAGGING AND BULK LOADING OPERATIONS

In the non-metallic minerals industry, the valve-type paper bag, either sewn or pasted together, is widely used for shipping fine materials. The valve bag is "factory closed," that is, the top and bottom are closed either by sewing or by pasting, and a single small opening is left on one corner. Materials are discharged into the bag through the valve. The valve closes automatically due to the internal pressure of the contents of the bag as soon as it is filled.

The valve type bag is filled by means of a packing machine designed specifically for this purpose. The material enters the bag through a nozzle inserted in the valve opening, and the valve closes automatically when the filling is completed.

Bagging operations are a source of particulate emissions. Dust is emitted during the final stages of filling when dust-laden air is forced out of the bag. The fugitive emissions due to bagging operation are generally localized in the area of the bagging machine.

Fine product materials that are not bagged for shipment are either bulk-loaded in tank trucks or enclosed railroad cars. The usual method of loading is gravity feeding through plastic or fabric sleeves. Bulk loading of fine material is a source of particulate because, as in the bagging operation, dust-laden air is forced out of the truck or railroad car during the loading operation.

2.10 WASHING

To meet specifications, some aggregate products, such as concrete aggregate, require washing to remove fines. Although a variety of equipment is available, washing screens are generally used. A washing screen is a standard, inclined, vibrating screen with high-pressure water-spray bars installed over the screening surface. Rocks passing over the screen are washed and classified. Because it is a wet process, it essentially produces no particulate emissions.

2.11 PORTABLE PLANTS[12]

A portable plant may consist of a single chassis on which one or several processing units may be mounted; or it may consist of a combination of chassis on which various types of units are mounted to provide a sequence of operations such as feeding, crushing, screening, sizing, washing, and loading. The processing steps for crushed and broken stone and sand and gravel are the same in both fixed and portable plants. In a portable plant, however, the processing units are squeezed into a very restricted space. Thus, the entire plant can be readily moved from one quarry site to another.

Portable plants come in various designs and are adaptable to practically any process conditions and product specifications. They may be grouped into three categories: simple, duplex, and combination. In the simple portable plant a single screen receives material from a feed conveyor. The oversized material is scalped to a jaw crusher, where it is reduced before it is returned to the feed conveyor. The material that passes through the scalping screen is the lone product that is collected in a truck or bin directly underneath the screen.

Additional product sizes may be produced by adding a secondary crusher and modifying the screening arrangement. This grouping that is commonly mounted on a single chassis is known as a duplex plant. As shown in Figure 2.18, pit material is fed to the top of a triple-deck, inclined, vibrating screen capable of producing three product sizes and oversize which is reduced by a jaw crusher. Material that is passed to the second screening deck is delivered to a double- or triple-roll crusher for secondary reduction. The output from both crushers is conveyed to a rotating drum-type elevator that returns the material to the feed conveyor. Material passing through the second screen to the third is classified by size, collected in bins, and conveyed to storage piles. Combination plants have two or more chassis with various combinations of processing units.

Portable plants may be used as auxiliary units to large stationary primary crushers in quarries that produce pit material too large for the portable plant to handle alone. The ability of some portable plants, however, is too limited to accept the feed from the larger primary crushers. Therefore, a secondary or intermediate crusher, which may also be a portable unit, is required to take full advantage of the capability of the primary crusher.

Conversely, some process conditions preclude the need for an intermediate crusher, and the flexibility of individual portable processing units allows the user to meet his product requirements simply by arranging the units in the most efficient combination.

Emissions from each processing unit in a portable plant are the same as those from a unit of equivalent size in a stationary plant.

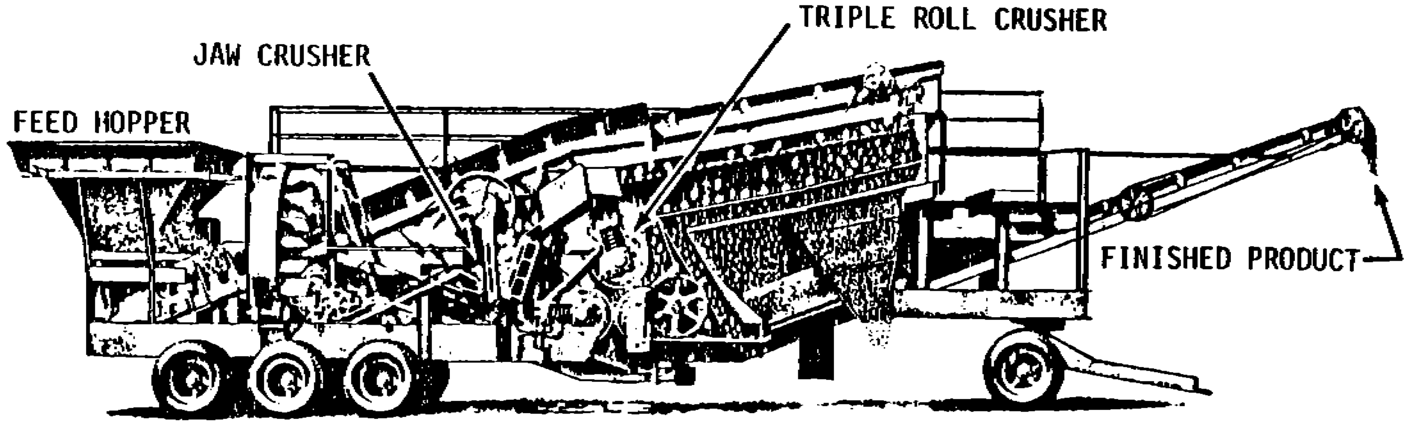

Figure 2.18 Portable Plant (courtesy of Pit and Quarry Handbook)

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3.0 EMISSION CONTROL TECHNIQUES

The emission control techniques that are generally applicable for the control of particulate emissions from fugitive dust and fugitive process sources at non-metallic mineral processing plants are discussed in this chapter. Sources of fugitive dust emissions include drilling, blasting, mine loading, haul roads, conveyor systems, stockpiles, and wastepiles. Sources of fugitive process emissions include crushers, screens, grinders, storage bins, conveyor transfer points, product loading, and product bagging. The control techniques discussed in this chapter are applicable for the control of particulate emissions from both fixed mineral processing plants and portable mineral processing plants.

The diversity of the particulate emission sources involved in mining and processing non-metallic minerals requires use of a variety of emission control techniques. Dust suppression techniques, designed to prevent particulate matter from becoming airborne, are applicable to both fugitive dust and fugitive process sources. Where particulate emissions can be contained and captured, dry collection systems are usually used. Emission sources and applicable emission control techniques are listed in Table 3.1.

3.1 CONTROL OF FUGITIVE DUST SOURCES[1]

3.1.1 Drilling Operations

The two methods that are generally applicable for the control of fugitive dust emissions from drilling operations are water injection and dry collection systems. Water injection is a technique in which water or water plus a surfactant (wetting agent) is combined with the compressed air stream that flushes the drill cuttings from the drill hole. The injection of fluid into the air stream produces a mist that dampens the drill cuttings and causes them to agglomerate. Most of the dampened drill cuttings will settle out at the drill collar when blown from the drill hole.

TABLE 3.1. PARTICULATE EMISSION SOURCES AND APPLICABLE EMISSION CONTROL TECHNIQUES

Fugitive dust		Fugitive process	
Emission source	Applicable emission control technique	Emission source	Applicable emission control technique
Drilling	a. Injection of water or water plus surfactant b. Dry collection system	Crushers	a. Wet dust suppression b. Dry collection system
Blasting	a. Good blasting practices	Screens	Same as crushers
Quarry loading	a. Wetting with water or water plus surfactant	Grinders	Same as crushers
Haul roads	a. Wetting with water or water plus surfactant b. Soil stabilization c. Paving d. Traffic control	Storage bins	Same as crushers
Conveyor systems	a. Coverings b. Wet dust suppression	Conveyor transfer points	Same as crushers
Stockpiles	a. Stone ladders b. Stacker conveyors c. Water sprays at conveyor discharge	Product loading	Same as crushers
Windblown dust from stockpiles	a. Wetting with water or water plus surfactant b. Coverings c. Windbreaks	Product bagging	a. Dry collection system

The addition of a surfactant increases the wetting ability of untreated water by reducing its surface tension.[2] This reduces the amount of water required for effective control. The amount of solution required is dependent upon the size of the hole, the drilling rate, and the type of material being drilled. A typical injection rate for an 8.9 centimeters (3.5 inches) diameter hole is approximately 26.6 liters (7 gallons) per hour. The effective application of water injection to a drilling operation should eliminate visible emissions.

Dry collection systems are also used to control emissions from drilling operations. A shroud or hood encircles the drill rod at the drill hole collar. A vacuum captures emissions and vents them through a flexible duct to a control device for collection. The control devices most commonly used are cyclones or baghouses preceded by a settling chamber. Cyclone collection efficiencies usually are not high. Although designed for the collection of coarse-to-medium-sized particles (15 to 40 microns or larger), cyclones are generally unsuitable for fine particulates (10 microns and smaller). Cyclone collection efficiencies seldom exceed 80 percent in the smaller particulate size range. However, baghouses exhibit collection efficiencies in excess of 99 percent through the submicron particle range.[3] Air volumes required for effective control may range from 15 to 45 cubic meters (500 to 1500 cubic feet) per minute depending on the type of rock drilled, drill hole size, and penetration rate. A rotary drill equipped with a baghouse was tested for visible emissions from the capture system and the baghouse outlet. For more than 75 percent of the time, the opacity was less than 20 percent at the capture point. Readings at the baghouse ranged from 0 to 5 percent.

3.1.2 Blasting Operations

No effective method is available for controlling particulate emissions from blasting. Good blasting practices can minimize noise, vibration, and air shock. Multidelay detonation devices, which detonate the explosive charges in millisecond time intervals, can reduce these effects. Scheduling blasting operations so that they occur only during conditions of low wind and low inversion potential can substantially reduce the impact of fugitive dust emissions from this source.

3.1.3 Quarry Loading Operations

Particulate emissions from the loading of broken rock by loaders or shovels are estimated to be 25 grams per megagram (0.05 pound per ton) stone. These emissions are difficult to control. However, some control may be attained by using water trucks equipped with hoses or portable watering systems to wet down the piles prior to loading.

3.1.4 Haul Roads

A large portion of the fugitive dust generated by quarrying operations results from the transportation of material from the quarry to the processing plant over unpaved haul roads.[4] Emissions from hauling operations are a function of the condition of the road surface and the volume and speed of vehicular traffic. Consequently, control measures include methods to improve road surfaces or suppress fugitive dust and operational changes to minimize the effect of vehicular traffic.

Various treatment methods applied to control fugitive dust emissions from haul roads include watering, surface treatment with chemical dust suppressants, soil stabilization, and paving. The most common method is watering. Water is applied to the road in a controlled manner by operators of water trucks equipped with either gravity-fed spray bars or pressure sprays. The amount of water required, frequency of application, and effectiveness are dependent on climatic conditions, the conditions of the roadbed, and vehicular traffic.

Fugitive dust from haul roads can also be controlled by periodic application of wet or dry surface treatment chemicals for dust suppression. Road surfaces are commonly treated with oil, usually supplemented by watering. Waste oils, such as crankcase drainings, are spread over roadways at a rate of about 0.24 liter per square meter (0.05 gallon per square yard) of roadway.[5] The frequency of application may range from once per week to only several times per season, depending on the ambient temperature, wind, and rainfall in the area.

Other haul road fugitive dust suppression treatments include the application of hygroscopic chemicals (substances that absorb moisture) such as organic sulfonates and calcium chloride. When spread directly over unpaved road surfaces, these chemicals dissolve in the moisture they adsorb and form a clear liquid that is resistant to evaporation. Consequently, they are most effective in areas of relatively high humidity. Because the chemicals are water soluble, however, they may have to be applied repeatedly in areas with frequent rainfall.

An alternative to surface treatment is soil stabilization. Stabilizers usually consist of a water dilutable emulsion of either synthetic or petroleum resins that act as an adhesive or binder. Quarry operators in California and Arizona report substantial success with one such agent.[6,7] This product is a nonvolatile emulsion containing about 60 percent natural petroleum resins and 40 percent wetting solution. Its use in the initial treatment of new haul roads depends on the characteristics of the road bed and the penetration depth required. For most roads, an effective dilution is one part stabilizer to four parts of water (1:4) applied at a rate of about 9.5 to 23.8 liters per square meter (2 to 5 gallons per square yard). Once the road has been stabilized by repeated application and compaction of vehicle traffic, the dilution may be increased to 1:7 to 1:20 for daily maintenance. Usually, one pass per day is considered sufficient for effective dust control.

Paving is probably the most effective means for reducing fugitive dust emissions from haul roads. Initial paving costs may exceed $12,400 per kilometer ($20,000 per mile) of haul road for a 7.7 centimeters (3 inches) thick bituminous surface. Maintenance and repair may be relatively high due to the damage caused by heavy vehicle traffic.[8] In addition, the paved roads would have to be periodically vacuumed or cleaned due to accumulation of soil and dust on the roadway.

Operational measures that would reduce fugitive dust emissions include the reduction of traffic volume and control of traffic speed. Replacing smaller haul vehicles with larger capacity units would minimize the number of trips required and should reduce the total fugitive dust emissions generated per megagram (ton) of material hauled. A stringent program to control traffic speed would also reduce dust emissions. According to a study of emissions from conventional vehicle traffic on unpaved roads, a reduction in the average vehicle speed from 48 kilometers (30 miles) per hour to 40, 32, and 24 kilometers (25, 20, and 15 miles) per hour reduced emissions by 25, 33, and 40 percent, respectively. Although the situations may not be completely analogous, it can be concluded that an enforced speed limit of 8 to 16 kilometers (5 to 10 miles) per hour would reduce fugitive dust emissions from quarry vehicle traffic.

3.1.5 Conveyor Systems

Fugitive dust emissions are generated by the wind blowing across the material being transferred from one process operation to another on nonenclosed conveyor systems. The two methods available for the control of fugitive dust emissions from conveyor systems are coverings or wet dust suppression. Coverings can consist of enclosing the entire conveyor system with sheet metal or the use of plastic or canvas sheets which block the action of the wind across the conveyor system. The use of wet dust suppression would require the installation of spray bars at various intervals along the conveyor systems.

3.1.6 Stockpiles

Significant fugitive dust emissions, as judged by visible emissions, may result during the formation of new aggregate piles and the erosion of previously formed piles. During the formation of stockpiles by stacking conveyors, particulate emissions are generated by wind blowing across the streams of falling stone and segregating fine particles from coarse particles. Emissions are also produced when the falling stone impacts on the piles. Control methods include wet dust suppression and devices designed to minimize the free-fall distance to which the material is subjected, thus lessening its exposure to wind and reducing emissions generated upon impact.

The wet dust-suppression effect is carried over at plants that spray the discharge from the final crushing or screening operations, after which no new surfaces are created nor the material tumbled. Control devices that are applied include stone ladders, telescopic chutes, and hinged-boom stacker conveyors. A stone ladder simply consists of a section of vertical pipe into which stone from the stacking conveyor is discharged. At different levels the pipe has square or rectangular openings through which the material may flow. This reduces the effective free-fall distance and affords wind protection. Another approach is the telescopic chute. Material is discharged to a retractable chute and falls freely to the top of the pile. As the height of the stockpile increases or decreases, the chute is gradually raised or lowered accordingly. A similar approach is provided by a stacker conveyor equipped with an adjustable hinged boom that raises or lowers the conveyor according to the height of the stockpile.

Watering is the most commonly used technique for controlling windblown emissions from active stockpiles. A water truck equipped with a hose or other spray device may be used.

Locating stockpiles behind natural or manufactured windbreaks also aids in reducing windblown dust. Also, the working area of active piles should be located on the leeward side of the pile. Very fine materials or materials that must be stored dry can be controlled effectively only through the use of suitable stockpile enclosures or silos, even though these may create load-out problems.

The application of soil stabilizers, which are primarily petroleum or synthetic resins in emulsion, has been reasonably effective for storage piles that are inactive for long periods of time and for permanent waste piles or spoil banks. These chemical binders cause the surface particles to adhere to one another, forming a durable wind-and rain-resistant crust (relatively insoluble in water). As long as this crust remains intact, the stockpile is protected from wind erosion. It should be noted that chemical binders applied to the stockpiles may contaminate the material being stockpiled.

3.2 CONTROL OF FUGITIVE PROCESS SOURCES

A non-metallic mineral processing plant can consist of crushers, grinders, screens, conveyor transfer points, and storage, loading, and bagging facilities. Effective emission control can present a number of problems due to the multiplicity of dust-producing sources at the plant. Methods utilized to reduce fugitive process emissions include wet dust suppression, dry collection systems, and a combination of the two. Wet dust suppression consists of introducing moisture into the material flow, causing fine particulate matter to be confined and remain with the material flow rather than becoming airborne. Dry collection systems involve hooding and enclosing dust-producing points and exhausting emissions to a control device. Combination systems utilize both methods at different stages throughout the processing plant. In addition to these control techniques, the use of enclosed structures to house process equipment may also be effective in reducing fugitive process emissions.

3.2.1 Wet Dust Suppression

In a wet dust suppression system, dust emissions are controlled by applying moisture in the form of water or water plus a surfactant sprayed at critical dust producing points in the process flow. This causes dust particles to adhere to larger mineral pieces or to form agglomerates too heavy to become or remain airborne. The objective of wet dust suppression is not to fog an emission source with a fine mist to capture and remove particulates emissions, but rather to keep the material moist at all process stages.

The addition of 5.0 to 8.0 percent moisture (by weight), or greater, may be required to adequately suppress dust.[9] In many installations this may not be acceptable because excess moisture may cause screening surfaces to blind, thus reducing both their capacity and effectiveness, or result in the coating of mineral surfaces yielding a marginal or non-specification product. To counteract these deficiencies, small quantitities of specially formulated surfactants are blended with the water to reduce its surface tension and consequently improve its wetting efficiency so that dust particles may be suppressed with a minimum of added moisture. Although these agents may vary in composition, they are characteristically composed of a hydrophobic group (usually a long chain hydrocarbon) and a hygroscopic group (usually a sulfate, sulfonate, hydroxide, or ethylene oxide). When introduced into water, these agents cause an appreciable reduction in its surface tension.[10] The dilution of such an agent in minute quantities in water (1 part wetting agent to 1,000 parts water) is reported to make dust control practical throughout an entire non-metallic mineral processing plant.[11]

In adding moisture to the process material, several application points are normally required. Because the time required for the proper distribution of the added moisture on the mineral is critical to achieving effective dust control, treatment normally begins as soon as possible after the material to be processed is introduced into the plant. As such, the initial application point is commonly made at the primary crusher truck dump. In addition to introducing moisture prior to processing, this application contributes to reducing intermittent dust emissions generated during dumping operations. Spray bars are located either on the periphery of the dump hopper or above it. Applications are also made at the discharge of the primary crusher and at all secondary and tertiary crushers where new dry surfaces and dust are generated by the fracturing of minerals. Further wetting of the material at screens, conveyor transfer points, conveyor and screen discharges to bins, and conveyor discharges to storage piles may also be necessary. The wetted material may exhibit a carryover dust control effect that may suppress the dust through a number of material handling operations. The amount of moisture required at each application point is dependent on a number of factors including the wetting agent used, its dilution ratio in water, the type and size of process equipment, and the characteristics of the material processed (type, size distribution, feed rate, and moisture content).

A typical wet dust suppression system, such as the system illustrated in Figure 3.1, contains a number of basic components and features including a dust control agent, liquid proportioning equipment, a distribution system, and control actuators. A proportioner and pump are necessary to proportion the surfactant and water at the desired ratio and to provide moisture in sufficient quantity and adequate pressure to meet the demands of the overall system.

Distribution of the liquid is accomplished by spray headers fitted with pressure spray nozzles. One or more headers are used to apply the dust suppressant mixture at each treatment point at the rate and spray configuration required to effect dust control. A variety of nozzle types may be used

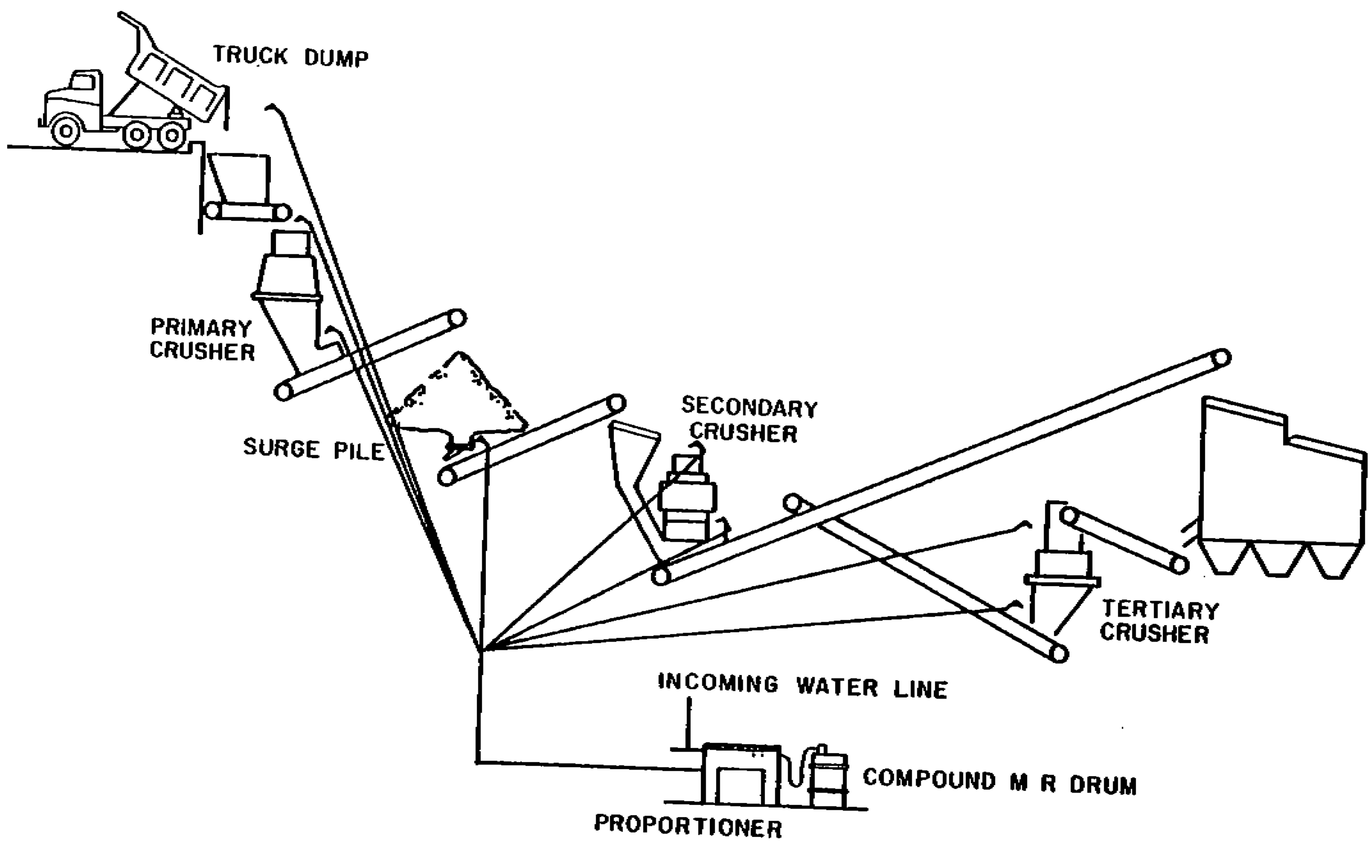

Figure 3.1 Wet dust suppression system.[12]

including hollow-cone, solid cone, or gas nozzles, depending on the spray pattern desired. To prevent nozzle plugging, screen filters are used. Figure 3.2 shows a typical arrangement for the control of fugitive process emissions at a crusher discharge.

Spray actuation and control is important to prevent waste and undesirable muddy conditions, especially when the material flow is intermittent. Spray headers at each application point are normally equipped with an on-off controller which is interlocked with a sensing mechanism so that sprays will be operative only when there is material actually flowing. In addition, systems are sometimes designed to operate under all weather conditions. To provide protection from freezing, exposed pipes are usually traced with heating wire and insulated. When the system is not is use, it should be drained to insure that no water remains in the lines. During prolonged periods when the ambient temperature remains below $0^{o}C$ ($32^{o}F$), wetted raw materials will freeze into large blocks and adhere to cold surfaces such as hopper walls.[13]

3.2.2 Dry Collection Systems

Particulate emissions generated at plant process operations (crushers, screens, grinders, conveyor transfer points, product loading operations, and bagging operations) may be controlled by capturing and exhausting potential emissions to a control device. Depending on the physical layout of the plant, emission sources may be either manifolded to a single centrally located control device or ducted to a number of individual control devices. Control systems consist of an exhaust system utilizing hoods and enclosures to capture and confine emissions, ducting and fans to convey the captured emissions to a control device, and the control device for particulate removal prior to exhausting the air stream to the atmosphere.

3.2.2.1 Exhaust Systems and Ducting

If a control system is to effectively prevent particulate emissions from being discharged to the atmosphere at the locations where emissions are generated, local exhaust systems including hooding and ducting must be properly designed and balanced. (Balancing refers to adjusting the static

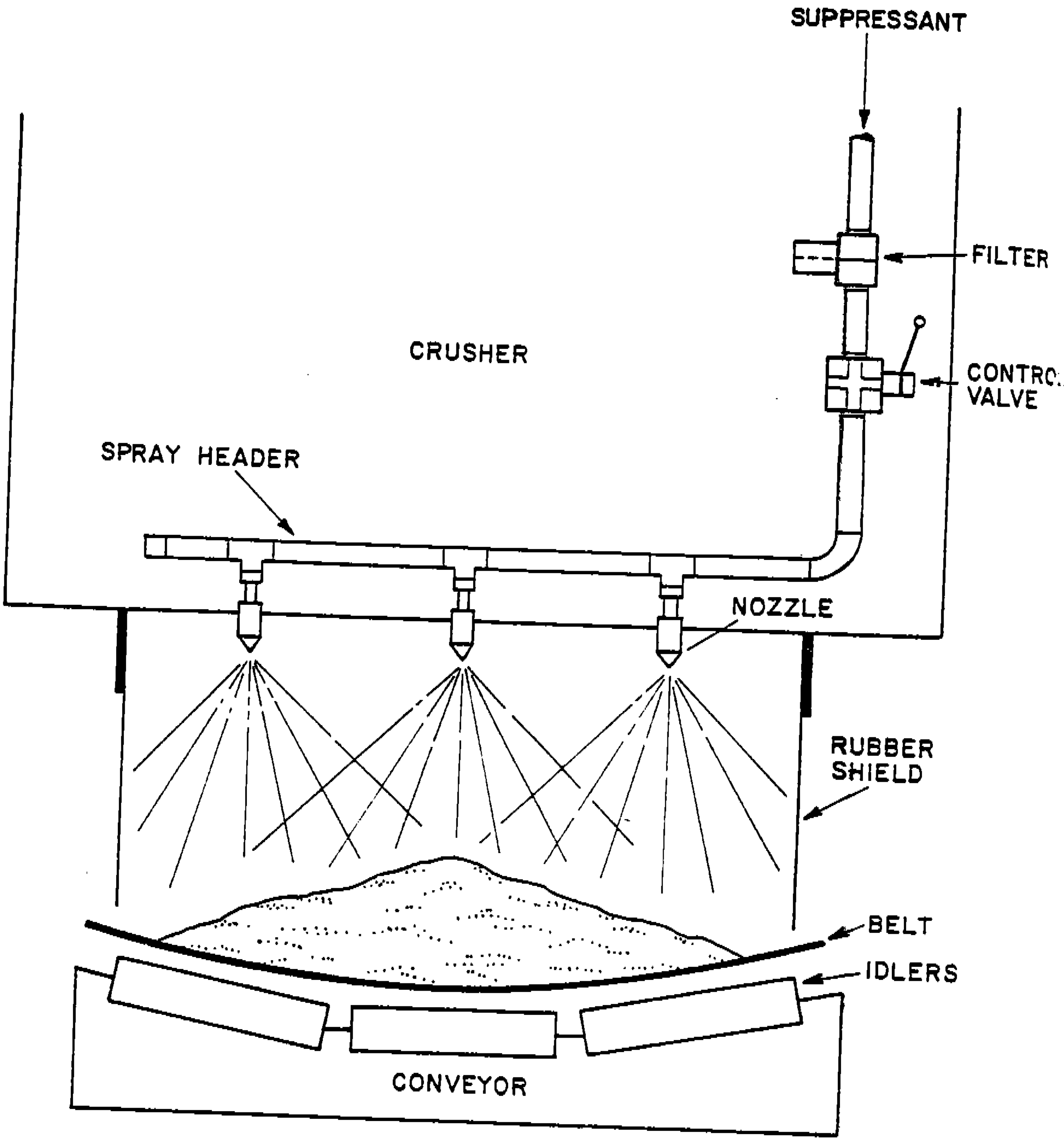

Figure 3.2 Dust suppression application at crusher discharge.

pressure balance, which exists at the junction of two branches, to obtain the desired volume in each branch). Process equipment should be enclosed as completely as practicable, allowing for access for operation, routine maintenance, and inspection requirements. For crushing facilities, recommended hood capture velocities range from 60 to 150 meters (200 to 500 feet) per minute.[14,15] In general, a minimum indraft velocity of 61 meters (200 feet) per minute should be maintained through all open hood areas. Proper design of hood and enclosures will minimize exhaust volumes required and, consequently, power consumption. In addition, proper hooding will minimize the effects of cross drafts (wind) and the effects of induced air (i.e., air placed in motion as a result of machine movement or falling material). A well-designed enclosure can be defined as a housing which minimizes open areas between the operation and the hood and contains all dust dispersion action.

Good duct design dictates that adequate conveying velocities be maintained so that the transported dust particles will not settle in the ducts along the way to the collection device. Based on information for crushed stone, conveying velocities recommended for mineral particles range from 1,050 to 1,350 meters (3,500 to 4,500 feet) per minute.[16,17]

Adequate design and construction specifications are available and have been utilized to produce efficient, long-lasting systems. Various guidelines establishing minimum ventilation rates required for the control of crushing plant operations, and upon which the ventilation rates most commonly utilized in the industry are based, are discussed briefly below.

Crushers and Grinders

Hooding and air volume requirements for the control of fugitive process emissions from crushers and grinders are quite variable depending upon the size and shape of the emission source, the hood's position relative to the points of emission, and the velocity, nature, and quantity of the released particles. The only established criterion is that a minimum indraft velocity of 61 meters (200 feet) per minute be maintained through all open hood areas. To achieve this, capture velocities in excess of 150 meters (500 feet) per minute may be necessary to overcome induced air motion, resulting from the material feed and discharge velocities and the mechanically induced velocity (fan action) of a particular equipment type.[18] To achieve effective emission control, ventilation should be applied at both the upper portion (feed end) of the equipment and the discharge point. An exception to this would be at primary jaw or gyratory crushers because of the necessity to have ready access to dislodge large rocks which may get stuck in the crusher feed opening. Where access to a device is required for maintenance, removable hood sections may be utilized.

In general, the upper portion of the crusher or grinder should be enclosed as completely as possible, and exhausted according to the criteria established for transfer points. The discharge to the conveyor should also be enclosed as completely as possible. The exhaust rate varies considerably depending on crusher type. For impact crushers or grinders, exhaust volumes may range from 120 to 240 cubic meters (4,000 to 8,000 cubic feet) per minute.[19] For compression type crushers, an exhaust rate of 50 cubic meters per minute per meter (500 cubic feet per minute per foot) of discharge opening should be sufficient.[20] The width of the discharge opening will approximate the width of the receiving conveyor. For either impact crushers or compression type crushers, pick-up should be applied downstream of the crusher for a distance of at least 3.5 times the width of the receiving conveyor.[21] A typical hood configuration used to control particulate emissions from a cone crusher is depicted in Figure 3.3.

Grinding or milling circuits which employ air conveying systems operate at slightly negative pressure to prevent the escape of air containing the ground rock. Because the system is not airtight, some air is drawn into the system and must be vented. This vent stream can be controlled by discharging it through a control device.

<u>Screens</u>

A number of exhaust points are usually required to achieve effective control at screening operations. A full coverage hood, as depicted in Figure 3.4, is generally used to control emissions generated at actual screening surfaces. Required exhaust volumes vary with the surface area of

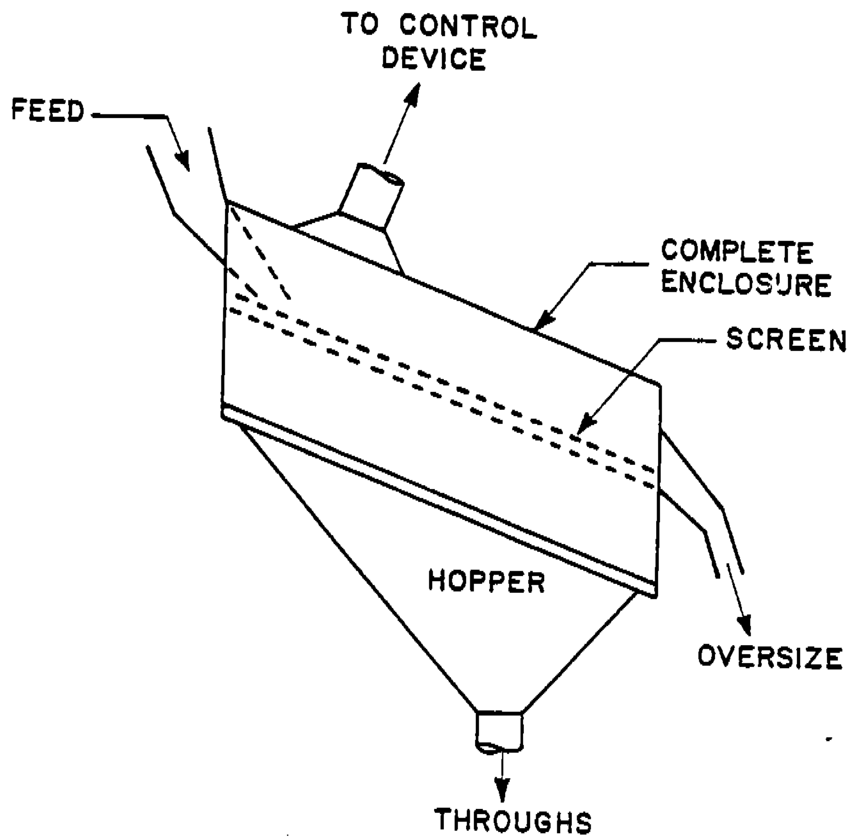

Figure 3.4 Hood configuration for vibrating screen.

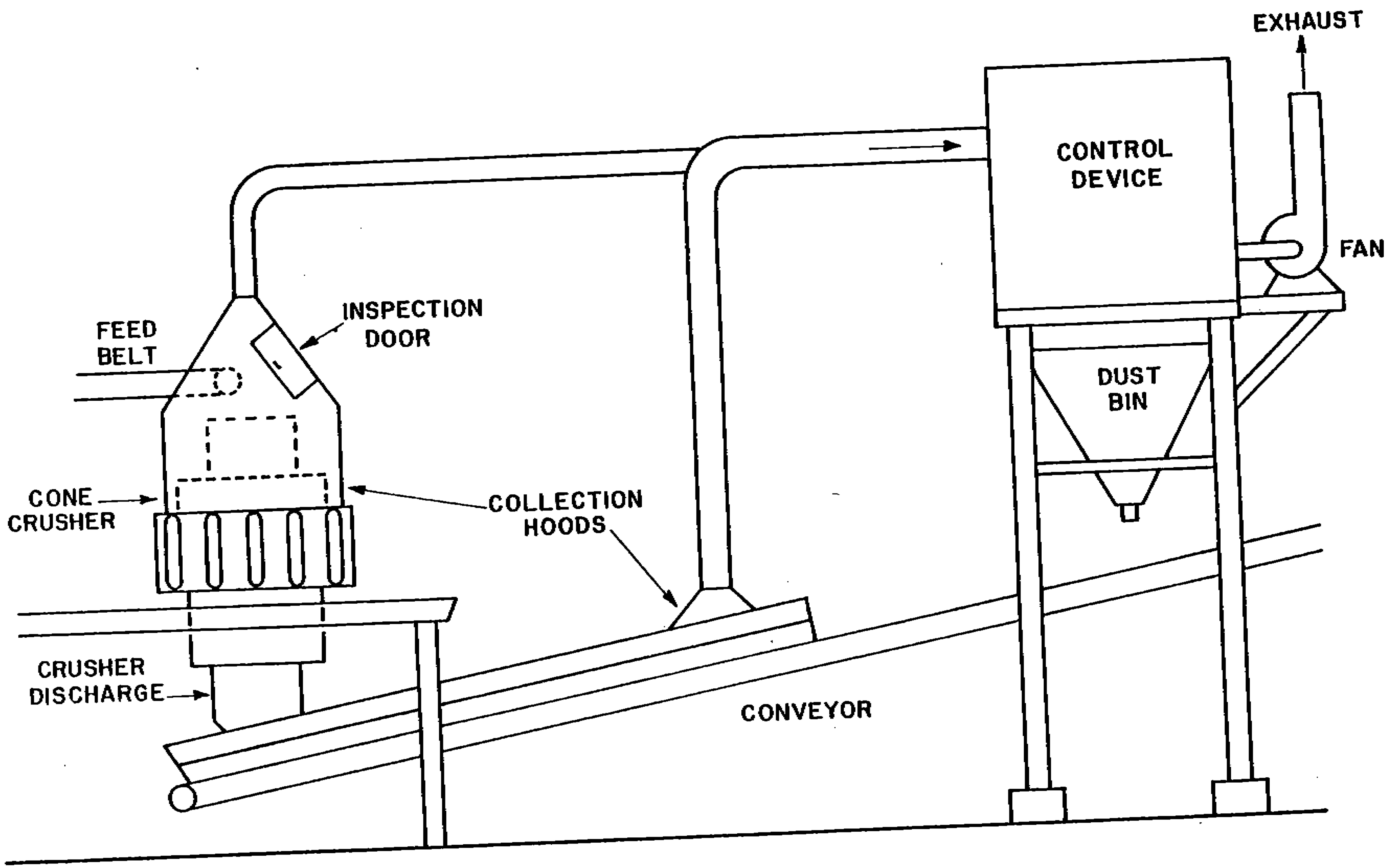

Figure 3.3 Hood configuration used to control a cone crusher.

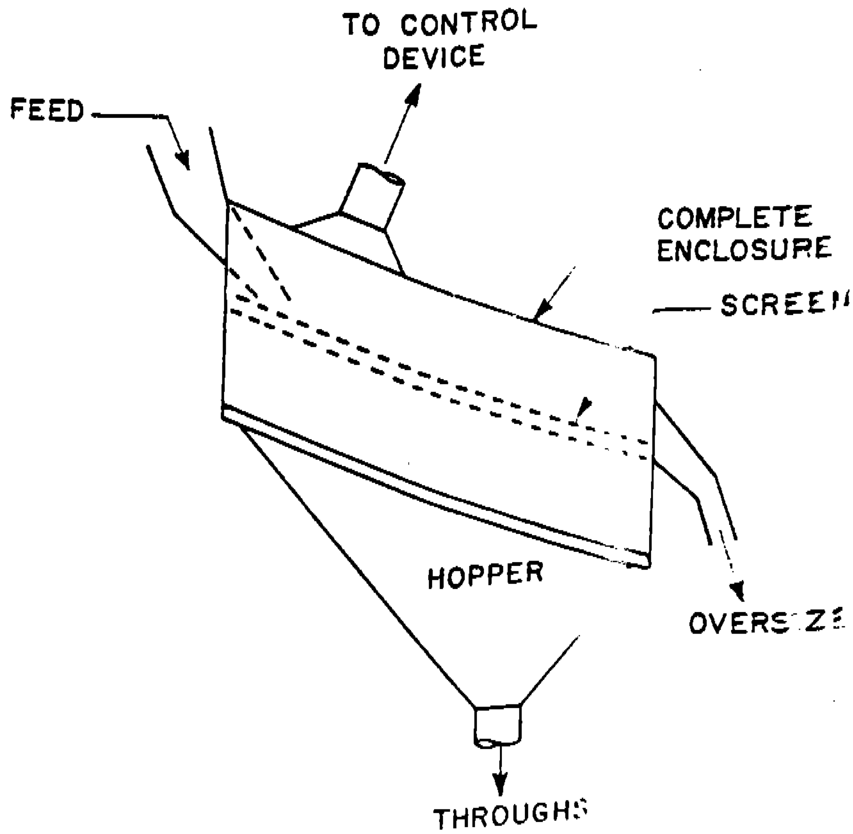

Figure 3.4 Hood configuration for [illegible]

the screen and the amount of open area around the periphery of the enclosure. A well-designed enclosure should have a space of no more than 5 to 10 centimeters (2 to 4 inches) around the periphery of the screen. A minimum exhaust rate of 15 cubic meters per minute per square meter (50 cubic feet per minute per square foot) of screen area is commonly used with no increase for multiple decks.[22] Additional ventilation air may be required at the discharge chute to conveyor or bin transfer points. If ventilation is needed, these points are treated as regular transfer points and exhausted accordingly.

Conveyor Transfer Points

At conveyor to conveyor transfer points, hoods should be designed to enclose both the head pulley of the upper conveyor and the tail pulley of the lower conveyor as completely as possible. With careful design, the open area should be reduced to about 0.15 square meter per meter (0.5 square foot per foot) of conveyor width.[23] Factors affecting the air volume to be exhausted include the conveyor speed and the free-fall distance to which the material is subjected. Recommended exhaust rates are 35 cubic meters per minute per meter (350 cubic feet per minute per foot) of conveyor width for conveyor speeds less than 60 meters (200 feet) per minute and 50 cubic meters per minute per meter (500 cubic feet per minute per foot) for conveyor speeds exceeding 60 meters (200 feet) per minute.[24] For a conveyor-to-conveyor transfer with less than 0.91 meter (3 feet) fall, the enclosure illustrated in Figure 3.5 is commonly used.

For conveyor-to-conveyor transfers with a free-fall distance greater than 0.91 meter (3 feet) and for chute-to-belt transfers, an arrangement similar to that depicted in Figure 3.6 is commonly used. The exhaust connection should be made as far downstream as possible to maximize dust fallout and thus minimize needless dust entrainment. For very dusty material, additional exhaust air may be required at the tail pulley of the receiving conveyor. Recommended air volumes are 21 cubic meters (700 cubic feet) per minute for conveyors 0.91 meter (3 feet) wide and less, and 30 cubic meters (1,000 cubic feet) per minute for conveyors wider than 0.91 meter (3 feet).[25]

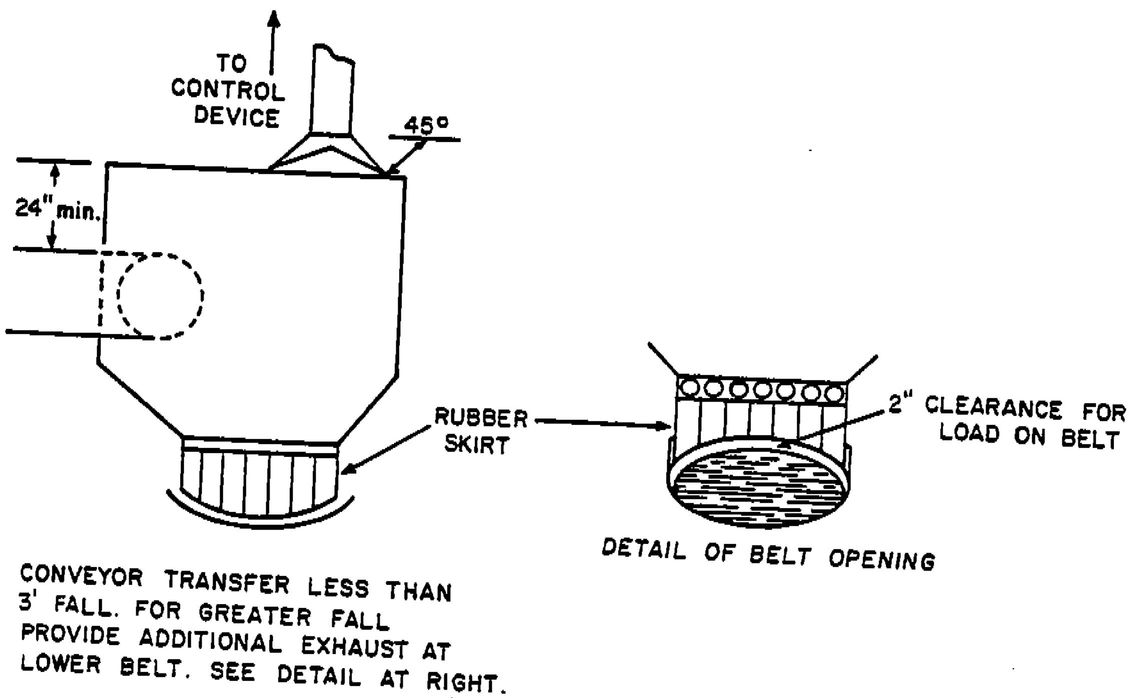

Figure 3.5 Hood configuration for conveyor transfer less than 0.91 meter (3 feet) fall.

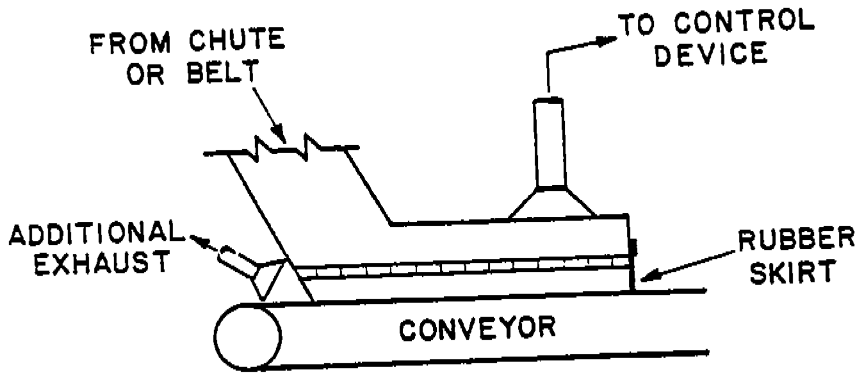

Figure 3.6 Hood configuration for a chute to belt or conveyor transfer greater than 0.91 meter (3 feet) fall.

Conveyor or chute-to-bin transfer points differ from the usual transfer operation in that there is no open area downstream of the transfer point. Thus, emissions are generated only at the loading point. As illustrated in Figure 3.7, the exhaust connection is normally located at some point remote from the loading point and exhausted at a minimum rate of 67 cubic meters per minute per square meter (200 cubic feet per minute per square foot) of open area.[26]

Product Loading and Bagging

Particulate emissions from truck and railcar loading of coarse material can be minimized by reducing the open height that the material must fall from the silo or bin to the shipping vehicle. Shrouds, telescoping feed tubes, and windbreaks can further reduce the fugitive process emissions from this intermittent source. Particulate emissions from loading of fine material into either trucks or railcar can be controlled by an exhaust system vented to a baghouse. The system is similar to the system described above for controlling bin or hopper transfer points (see Figure 3.7). The material is fed through one of the vehicle's openings and the exhaust connection is normally at another opening. The system should be designed with a minimum amount of open area around the periphery of the feed chute and the exhaust duct.

Bagging operations are controlled by local exhaust systems and vented to a baghouse for product recovery. Hood face velocities on the order of 150 meters (500 feet) per minute should be used. An automatic bag filling operation and vent system is shown in Figure 3.8.

3.2.2.2 Control Devices

Baghouse

The most efficient dry collection devices used in the non-metallic mineral industry are baghouses (fabric filters). For most non-metallic mineral processing plant applications, mechanical shaker type baghouses which require periodic shutdown for cleaning after four or five hours of operation are usually used. These units are normally equipped with

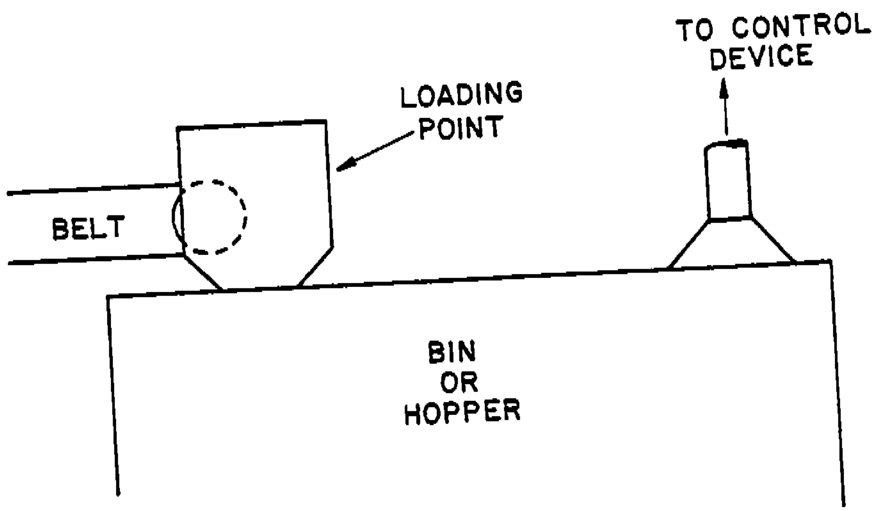

Figure 3.7 Exhaust configuration at bin or hopper.

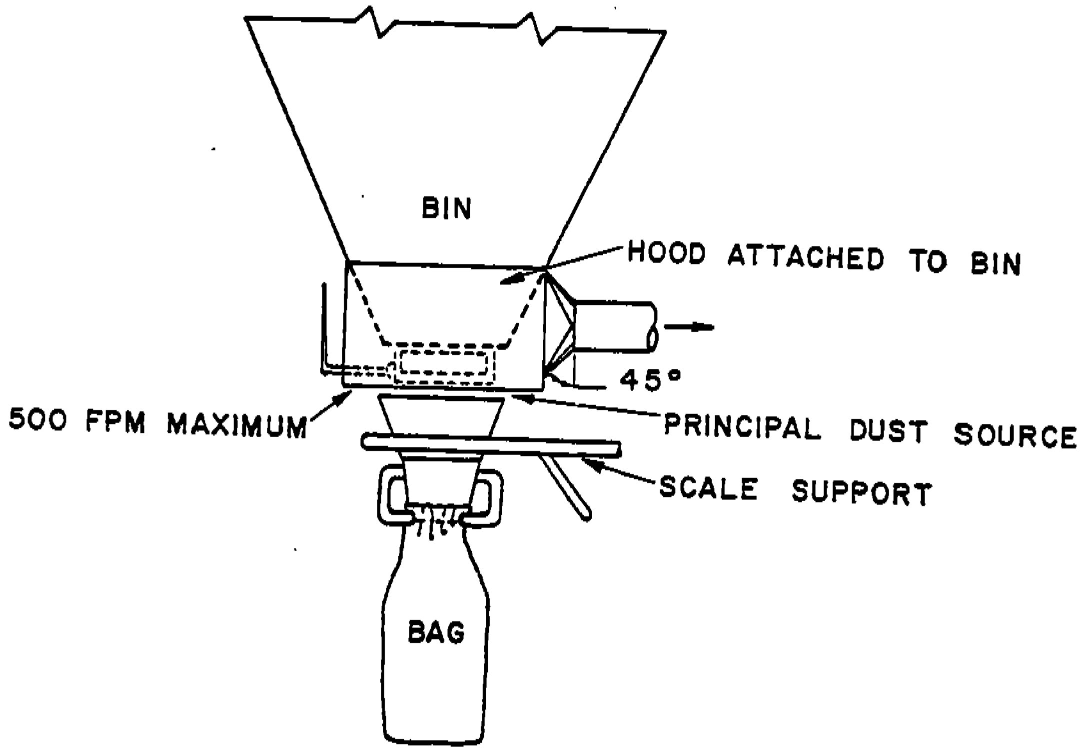

Figure 3.8 Bag filling vent system.[27]

cotton sateen bags and operated at an air-to-cloth ratio of 2:1 or 3:1. A cleaning cycle usually requires no more than two to three minutes of bag shaking and is normally actuated automatically when the exhaust fan is turned off. A typical baghouse is illustrated in Figure 3.9.

Another method of bag cleaning is to use reverse airflow down the tubes at such a rate that there is no net movement of air through the bag. This causes the bag to collapse which results in the filter cake breaking-up and falling off the bag. A final method is reverse air pulsing where a perforated ring travels up and down each bag or sleeve. Air jets in the ring force the bag to collapse, then reopen, breaking the filter cake apart. These two methods are shown in Figure 3.10.

For applications where it may be impractical to turn off the control system, baghouses with continuous cleaning are employed. Although compartmented mechanical shaker types may be used, jet pulse units are predominantly used by the industry. These units usually use wool or synthetic felted bags for a filtering media and may be operated at an air-to-cloth ratio of as high as 6:1 to 10:1. Regardless of the baghouse type used, jet pulse or shaker, greater than 99 percent efficiency can be attained even on submicron particle sizes.[28] Two baghouses tested by EPA for both inlet and outlet emission levels had collection efficiencies of 99.8 percent.[29,30]

Another major parameter considered in designing baghouses is the air-to-cloth ratio or filter ratio defined as the ratio of gas filtered in cubic meters (feet) per minute to the area of the filtering media in square meters (feet). A high ratio results in possible blinding or clogging of the bags and a resultant decrease in the baghouse collection efficiency and an increase in bag material wear.

The frequency of cleaning can be continuous in which a section of the baghouse is removed from operation and cleaned before going on to another section. Alternatively, intermittent cleaning consisting of timed cycles of cleaning and operation is used. Sensors can be installed that start the cleaning cycle when some specified pressure drop across the system occurs because of the buildup of the filter cake.

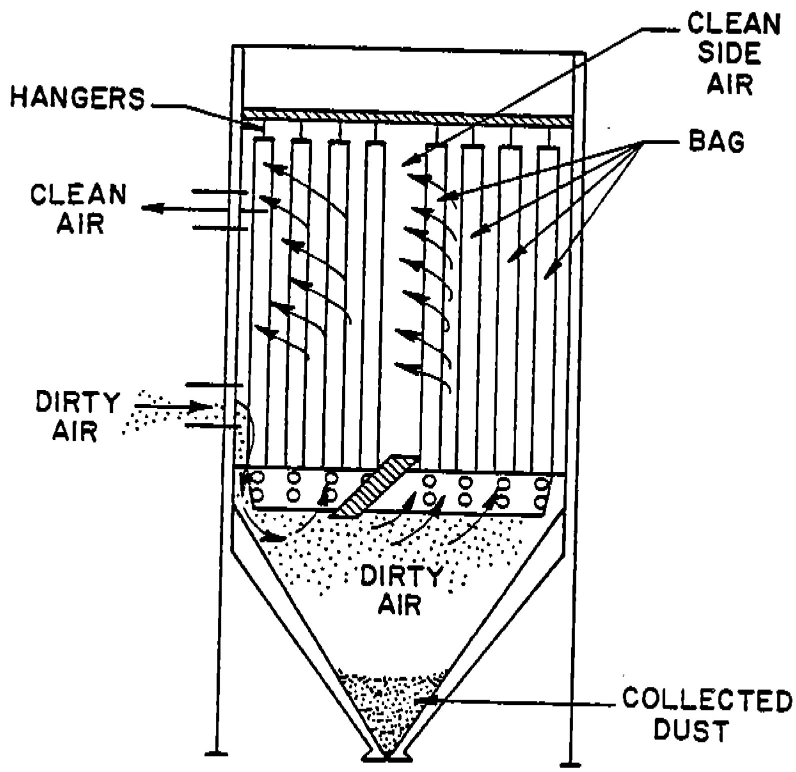

Figure 3.9 Typical baghouse operation.

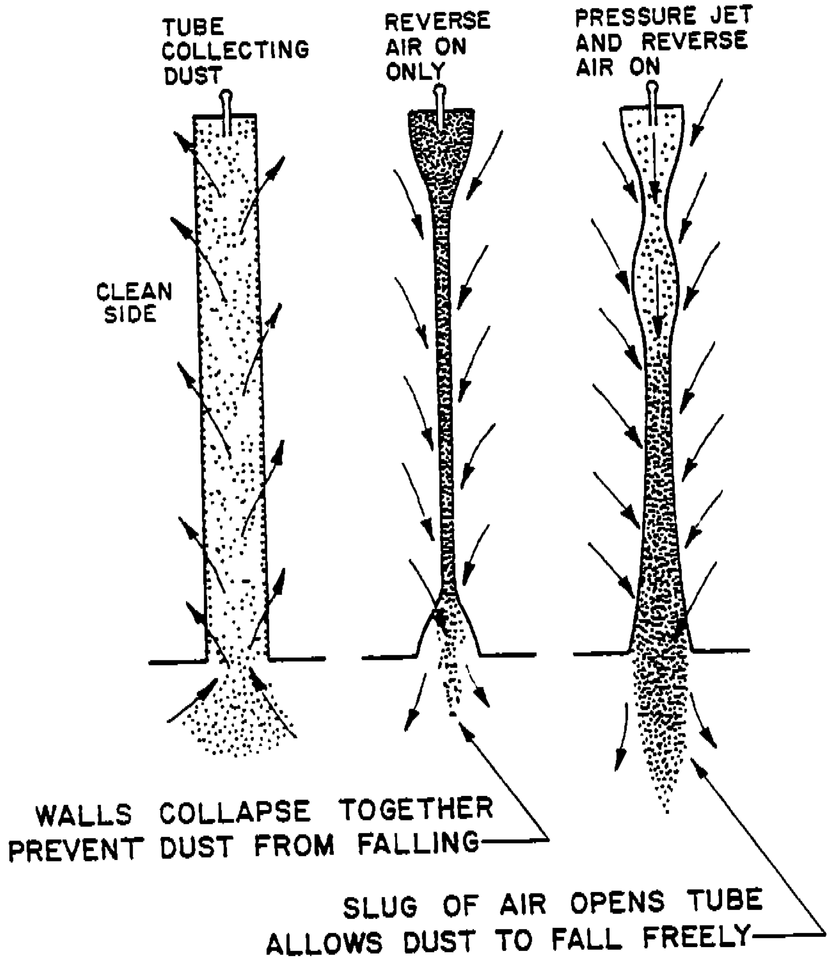

Figure 3.10 Baghouse cleaning methods.[32]

Materials used in bag construction include cotton, Teflon, glass, Orlon, Nylon, Dacron, wool, Dynel, and others. Temperature and other operating parameters must be taken into account in the selection of fabric material, though most industry processes are at ambient conditions. The most popular materials in terms of wear and performance are the synthetic fabrics or cotton sateen. Other parameters considered in the design of baghouse and fabric selection include frequency of cleaning, cloth resistances to corrosion, and ore moisture.

Other control devices used in the industry include cyclones and low energy scrubbers. Although these control devices may demonstrate efficiencies of 95 to 99 percent for coarse particles (40 microns and larger), their efficiencies are less than 85 percent for medium and fine particles (20 microns and smaller).[31] Although high energy scrubbers and electrostatic precipitators could conceivably achieve results similar to that of a baghouse, these methods are not commonly used to control particulate emissions in the industry.

Wet Capture Devices

The principal of collection in wet capture devices involves contacting dust particles with liquid droplets in some way and then having the wetted particles impinge upon a collecting surface where they can be flushed away with water. The method of contacting the dust has many variations depending on the equipment manufacturer. The major types of wet collectors are cyclones, mechanical scrubbers, mechanical-centrifugal scrubbers, and venturi scrubbers.[32] These devices are more efficient than inertial separators. Wet capture devices can also handle high temperature gases or mist-containing gases. Costs and efficiencies also vary with equipment selection and operating conditions. Efficiencies are higher at lower particle size ranges than with dry cyclones.

As with dry cyclones, wet cyclones impart a centrifugal force to the incoming gas stream causing it to increase in velocity. The principal difference here is that atomized liquids are introduced to contact and carry away dust particles. The dust impinges upon the collector walls with clean air remaining in the central area of the device. Efficiencies in this type of equipment average in the vicinity of 98.2 percent.

Mechanical scrubbers have a water spray created by a rotating disc or drum contacting the dust particles. Extreme turbulence is created which insures this required contact. Efficiencies are about the same as wet cyclone scrubbers.

Mechanical-centrifugal scrubbers with water sprays are similar to their dry counterparts with the exception that a water spray is located at the gas inlet so that the particulate matter is moistened before it reaches the blades. The water droplets containing particulate are impinged on the blades while the clean air is exhausted. This is depicted in Figure 3.11. In this case, the spray not only keeps the blades wet so that dust will impinge upon them, but it also serves as a medium to carry away particles. Some types of scrubbers use high pressure-sprays, consuming more energy and water, but have higher efficiencies than other wet capture devices.

Venturi scrubbers rely on an impaction mechanism and extreme turbulence for dust collection. Gas velocities in the throat of the venturi tube are 4,500 to 6,000 meters (15,000 to 20,000 feet) per minute. It is at this point that low pressure water sprays are placed. The extreme turbulence causes excellent contact of water and particulate. The wetted particules travel through the venturi tube to a cyclone spray collector. Efficiencies are very high, averaging 99.9 percent.[33] These high efficiencies are also evidenced in the small particle size ranges collected (<1 micron). This design is best suited to applications involving removal of 0.5 to 5 micron sizes. The construction is similar to a venturi meter with 25^{o} converging and 7^{o} diverging sections. This results in a 4:1 area reduction between the inlet and throat.

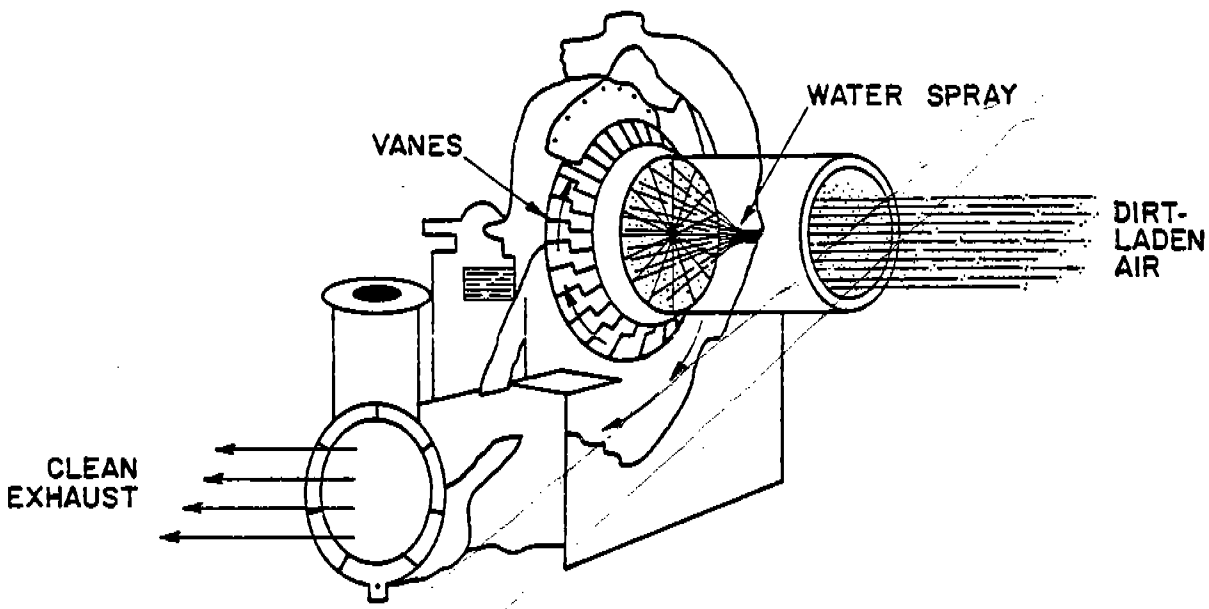

Figure 3.11 Mechanical - centrifugal scrubber.