2.12 FERTILIZER MIXING/BLENDING PLANTS

2.12.1 Process Description

The fertilizer mixing industry is divided into three categories according to the production technique employed: ammoniation-granulation, bulk blend and liquid mix plants. Within Ohio, there are 13 ammoniation-granulator facilities, 102 liquid mix plants and 260 bulk blending plants.[1] Since bulk blending plants have the greatest potential of fugitive particulate emissions, this process is addressed in this report.

Typical plant capacities range from 4 to 50 tons per hour, with an average of 20 tons per hour. Actual production is much lower. Plants produce an average of 1 ton per hour. Annual production ranges from 500 to 3500 tons per year, with an average plant production of 1270 tons per year. The greatest production (75%) occurs between January and June.[2]

Mixed fertilizers contain two or three of the nutrients nitrogen (N), phosphorus (P), and potassium (K). These mixtures are expressed as N-P-K grades. N represents the percentage of available nitrogen, P represents the percentage of available phosphorus pentoxide (P_2O_5) and K represents the percentage of soluble potassium oxide (K_2O). Over 75 percent of the mixed fertilizers consumed in this country contain all three of these primary plant nutrients.[3]

The bulk blending process in which feed materials are mixed to produce a balanced fertilizer is illustrated in Figure 2.12-1. The feed materials are dry and granular, and contain one or all

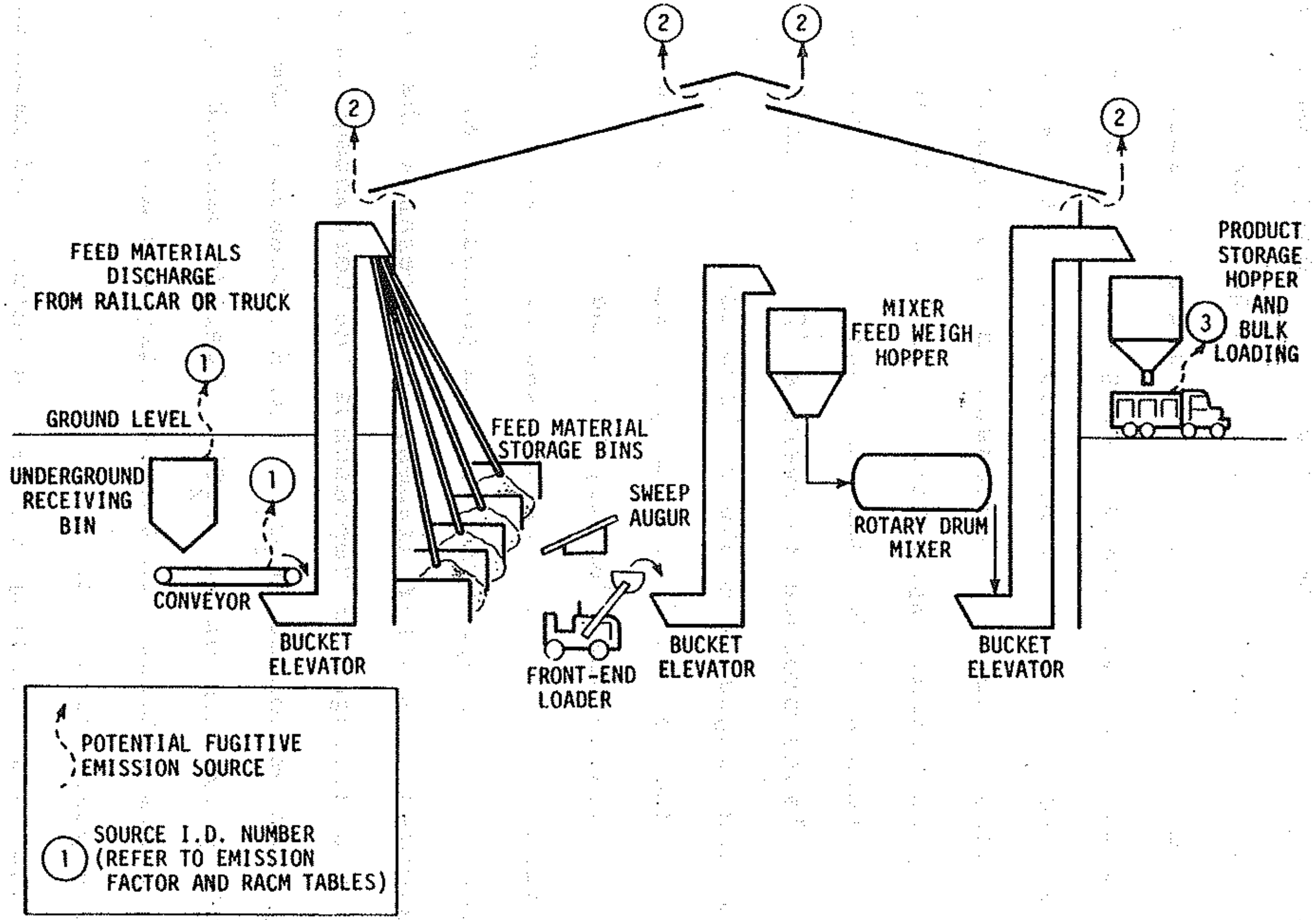

Figure 2.12-1. Typical flow diagram for fertilizer mixing/blending facilities and associated fugitive particulate emission sources.

of the primary plant nutrients. Normal and triple superphosphate, ammonium sulfate, urea and potash typify single nutrient feed materials. Mono or diammonium phosphate and potassium nitrate are typical multinutrient feed materials. In addition to these primary nutrients, micro-nutrients and organic herbicides are also frequently incorporated into fertilizers at the mixing and blending plant.

The feed materials are commonly received at the plant in hopper railcars which discharge into a receiving bin. The materials are transferred from the bin via belt conveyor to a bucket elevator for transfer by chute to specified storage areas or bins within the mixing building. As each feed material is needed, it is taken from bulk storage by a front-end loader or sweep auger and transferred to a bucket elevator. Material is then discharged into a weigh hopper for weighing, after which it is fed into a rotary-drum mixer. When the materials have been added for the desired mix formulation, the mixer drum is rotated until a uniform mixture is produced. The contents are then discharged and transferred by bucket elevator to storage hoppers from which the product can be either bulk loaded or bagged for shipping. Over half of the blending plants use a hopper-type loading station as shown in Figure 2.12-2. Bulk loading into open trucks can reportedly cause up to 75 percent of the emissions from bulk blending plants.[5]

The particulate emissions from bulk blending plants are fugitive in nature, and result from three sources:

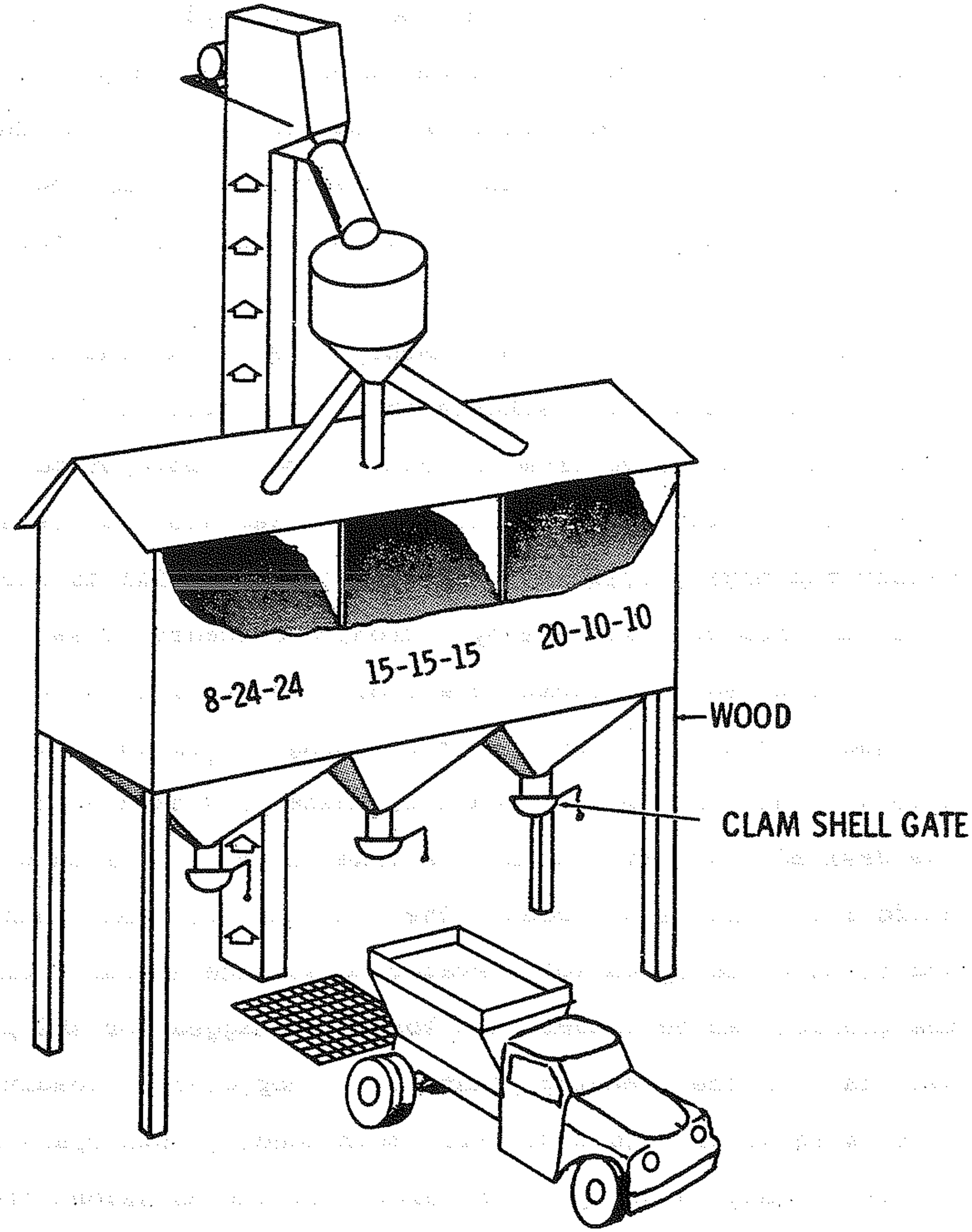

Figure 2.12-2. Bulk loading station with elevated storage used in fertilizer mixing/blending plants.[4]

1. rail car unloading and transfer to storage,

2. mixing building fugitive losses (caused by materials handling, mixing and bagging), and

3. loading operations (bulk loadout into open trucks).

A dust source that may also be found at fertilizer mixing and blending facilities is plant haul roads. This general emission category is addressed in Section 2.1.

2.12.2 Fugitive Dust Emission Factors

The particulate emission factors for fertilizer mixing and blending plant operations are presented in Table 2.12-1. The fugitive emission factors are based on particle size analyses (fraction smaller than 44 μm) of the raw materials used at bulk blending plants.[7] A worst-case estimate of emissions was then made. This estimate assumes that all material less than 44 μm is emitted to the atmosphere. No source test data are available.

2.12.3 Particle Characterization

Fugitive particulate emissions from fertilizer mixing and blending facilities are the same in composition as the feed materials (nutrients) input to the process. A composite threshold limit value (TLV) of 0.01 g/m^3 has been estimated for the nutrients used in bulk blending.[8] Herbicides also are used in fertilizer blending. The lowest TLV for commonly used herbicides is 0.0005 g/m^3.[9] However, since the emission factor for each herbicide never exceeds 0.001 percent of the total particulate emission factor, the concentrations are not expected to be at a level which would cause a health problem.[10]

TABLE 2.12-1. FUGITIVE DUST EMISSION FACTORS FOR FERTILIZER MIXING/BLENDING PLANTS

Source	Uncontrolled emission factor, lb/ton of product	Reference	Reliability rating[a]
(1) Rail car unloading and transfer to storage	0.2	6	E
(2) Mixing building[b] fugitive losses	0.2	6	E
(3) Loading operations[c]	0.2	6	E

[a] Emission factors are reportedly ± 100 percent.[6]

[b] Mixing building fugitive losses (through windows or doors) are generated by materials handling, mixing and bagging.

[c] Bulk loadout into open trucks.

2.12.4 Control Methods

A summary of the fugitive emission control alternatives is presented in Table 2.12-2. The majority of bulk blending facilities do not employ particulate control technology.[19] With the advent of more stringent regulations, however, control methods must be considered.

Skirts around railcars have been used at bulk blending plants to reduce emissions generated during unloading.[20] Telescopic chutes can be used to control emissions generated during transfer of raw materials to storage.[21] An alternative to telescopic chutes is a series of hoods ducted to a central fabric filter. Such a system also would include hoods and ducts to capture emissions from material handling, mixing, bagging and truck loadout. (Figure 2.12-3 illustrates this system as well as the design of skirts around railcars.)

A wet suppression system also can be used to control fugitive emissions. Water, liquid fertilizer or lightweight oils (including used motor oils) can be used to control dust when sprayed on the bulk fertilizer or raw materials during handling, mixing or bagging.[21] Additions of 1 percent liquid fertilizer or 1/2 to 1 percent lightweight oil have been shown to be effective in reducing emissions.[21] Oil should not be applied to any fertilizer mixture containing over 60 percent ammonium nitrate because of the potential explosion hazard.[21] (Figure 2.12-4 depicts a typical wet suppression system.)

Modifications can be made to high-speed bucket elevators (centrifugal discharge) to reduce emissions. This type of elevator does not discharge all of the material. Some falls to the

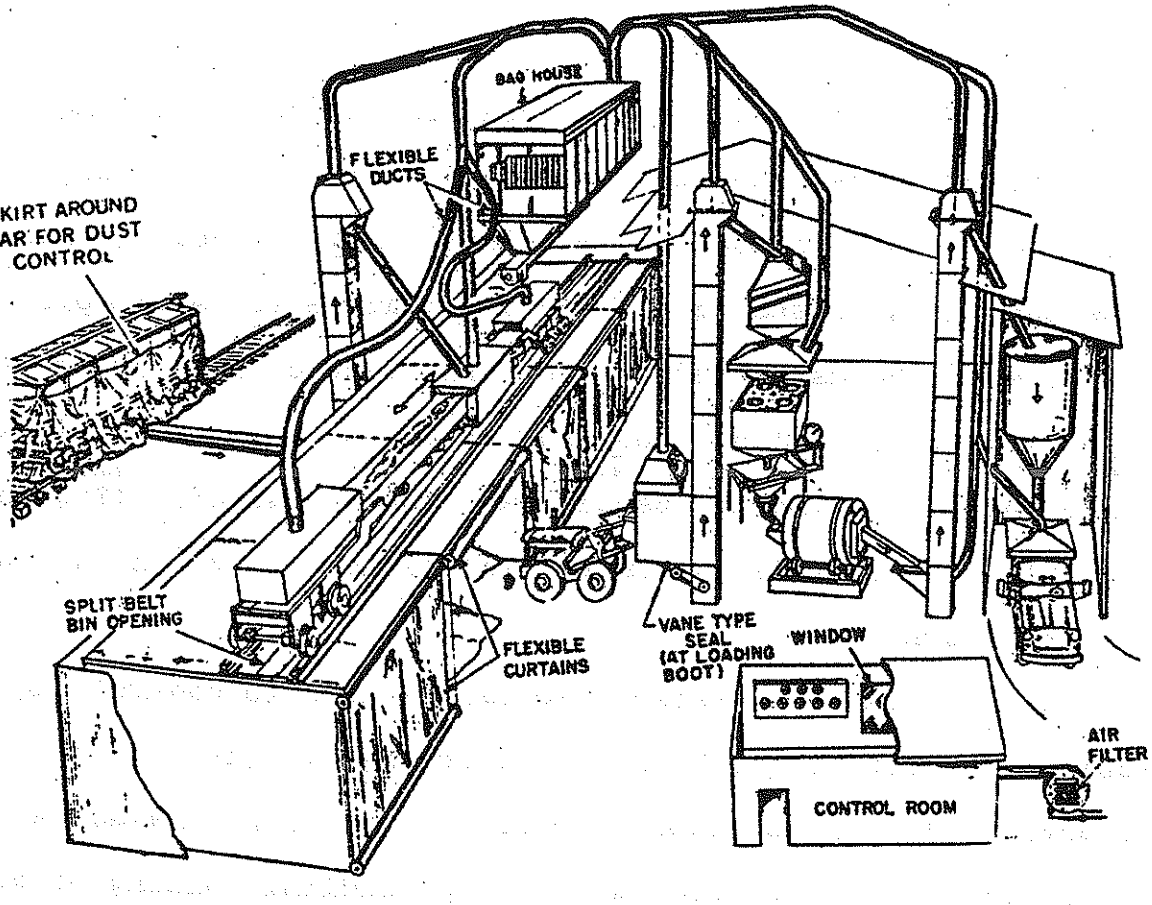

Figure 2.12-3. A bulk blending plant with fugitive dust emission controls consisting of skirts around railcar unloading and a series of hoods ducted to a fabric filter.[22]

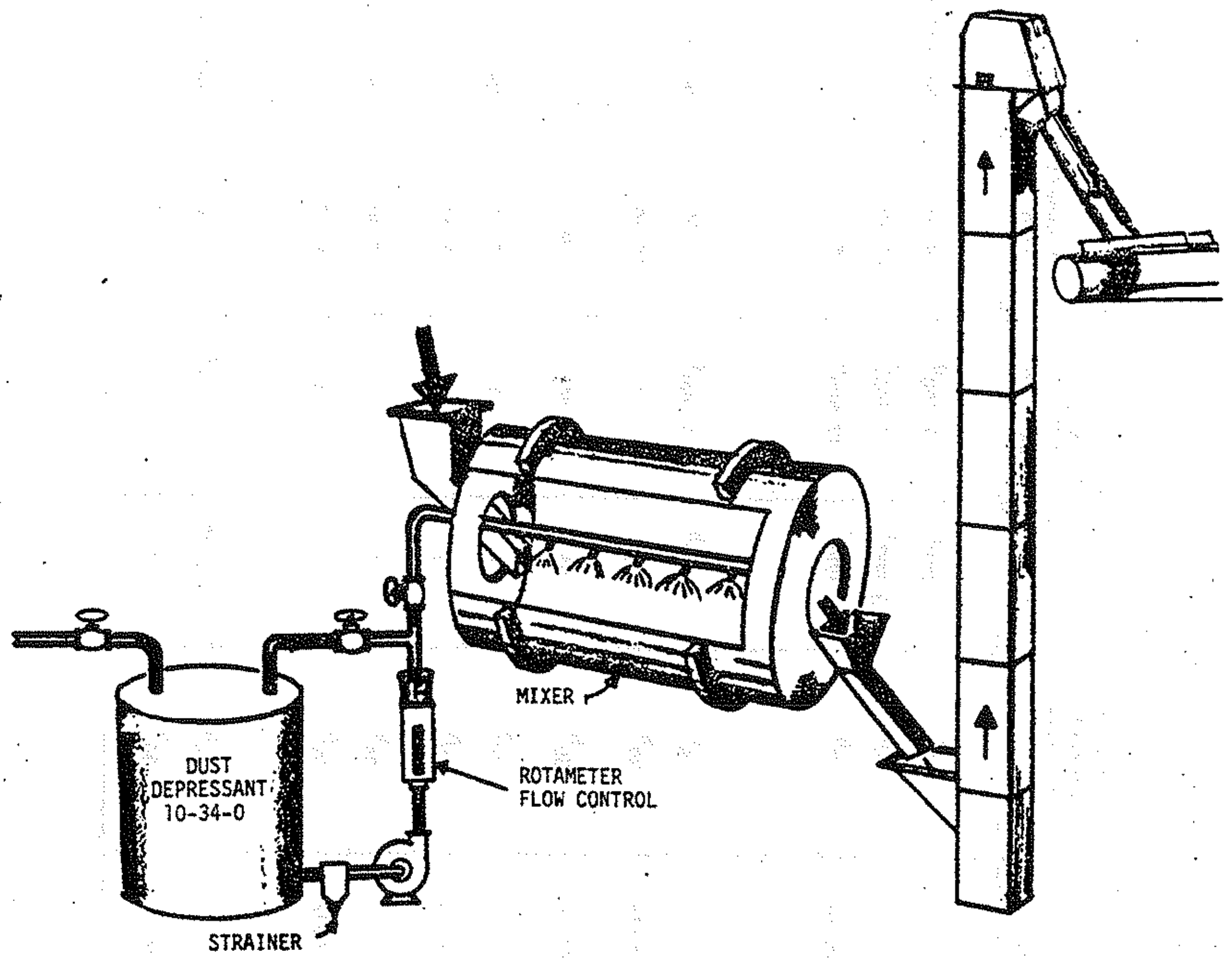

Figure 2.12-4. Dust suppressant application system.[23]

TABLE 2.12-2. A SUMMARY OF THE CONTROL ALTERNATIVES, EFFICIENCIES AND COSTS, AND THE RACM SELECTIONS FOR FUGITIVE DUST EMISSIONS FROM SOURCES AT FERTILIZER MIXING AND BLENDING PLANTS

Fugitive dust sources	Control alternatives	Control efficiency, %	Control costs $ (Jan. 1980) Capital	Annualized	Cost benefit,[a] $/lb	RACM selection
1 Material handling						
- railcar unloading	Skirts around railcars	50[b]	6,000[c]	1,200[d]	18.50	No control
- transfer to storage	Telescopic chutes	75[b]	13,500[e]	2,700[d]	27.70	No control
	Hooding, vent to fabric filter	99[b]	76,000[f]	17,000[g]	26.40	
2 Mixing building fugitive losses						
- material handling	Wet suppression	75[b]	5,000[h]	1,350[i]	6.90	No control
	Hooding, vent to fabric filter	99[b]	j	j	26.40	
	Bucket elevator modification	50[b]	NA	NA	NA	
- mixing	Wet suppression	50[k]	l	l	6.90	No control
	Hooding, vent to fabric filter	99[b]	j	j	26.40	
- bagging	Wet suppression	95[k]	l	l	6.90	No control
	Hooding, vent to fabric filter	99[b]	j	j	26.40	
3 Loading operations						
- truck loading (bulk)	Telescopic chutes	75[b]	4,500[m]	900[d]	4.60	Telescopic chutes
	Hooding, vent to fabric filter	99[b]	j	j	26.40	

(continued)

TABLE 2.12-2 (continued)

[a] Cost analysis based on a plant production of 1300 ton/yr.

[b] Engineering estimate.

[c] Based on 6,000 ft^2 of skirt at $1.00/$ft^2$. Reference 11.

[d] Estimated capital and maintenance charges at 20% of installed capital.

[e] Estimated costs for three telescopic chutes. Reference 12.

[f] Estimated cost for hooding, ductwork and 6000 acfm fabric filter. References 13 and 14. Includes control of materials handling, mixing, bagging and truck loading.

[g] Estimated based on capital charges at 17% and 3000 hr/yr operation. Reference 15.

[h] Estimate includes pump, tank, controls, piping, valves and indirect capital charges at 40%. Reference 16. Includes control of mixing and bagging.

[i] Estimated based on capital charges at 17% and operating/maintenance at 10%.

[j] Costs for this control technique are included under transfer to storage hooding and vent to fabric filter.

[k] Reference 17.

[l] Costs for this control technique are included under material handling wet suppression.

[m] Estimated cost for one telescopic chute. Reference 18.

NA = Not available.

boot of the elevator and escapes. A low-speed product discharge elevator uses idling sprockets to cause the buckets to round the head sprocket, giving an almost complete upturn. This allows all of the material to be emptied through the discharge chute. (Both of these types of bucket elevators are shown in Figure 2.12-5.)

During bulk fertilizer loadout into open trucks, telescopic chutes can be used to reduce emissions.

2.12.5 Recommended Reasonably Available Control Measures (RACM)

The recommended RACM for control of each fugitive emission source is listed in Table 2.12-2. The RACM's were selected on the basis of the degree of controls needed to meet state emission control regulations, practice in the industry, ease of application or installation, and economics.

Since bulk fertilizer blending plants typically are small (low annual production rates), the control alternatives are somewhat limited. The annual emissions are relatively low, causing a high cost benefit ratio. Therefore, requiring control of many of the emission sources would cause an economic hardship on this industry.

It is recommended that a telescopic chute, or other type loading spout which reduces free-fall distance, be used for bulk fertilizer load-out. This control is recommended because bulk loadout has been identified as potentially the largest single emission source at these plants and because it is the most cost-effective control. No controls would be required on the other sources for most plants. However, wet suppression may be reasonable for larger facilities or those which pose a nuisance or complaint problem.

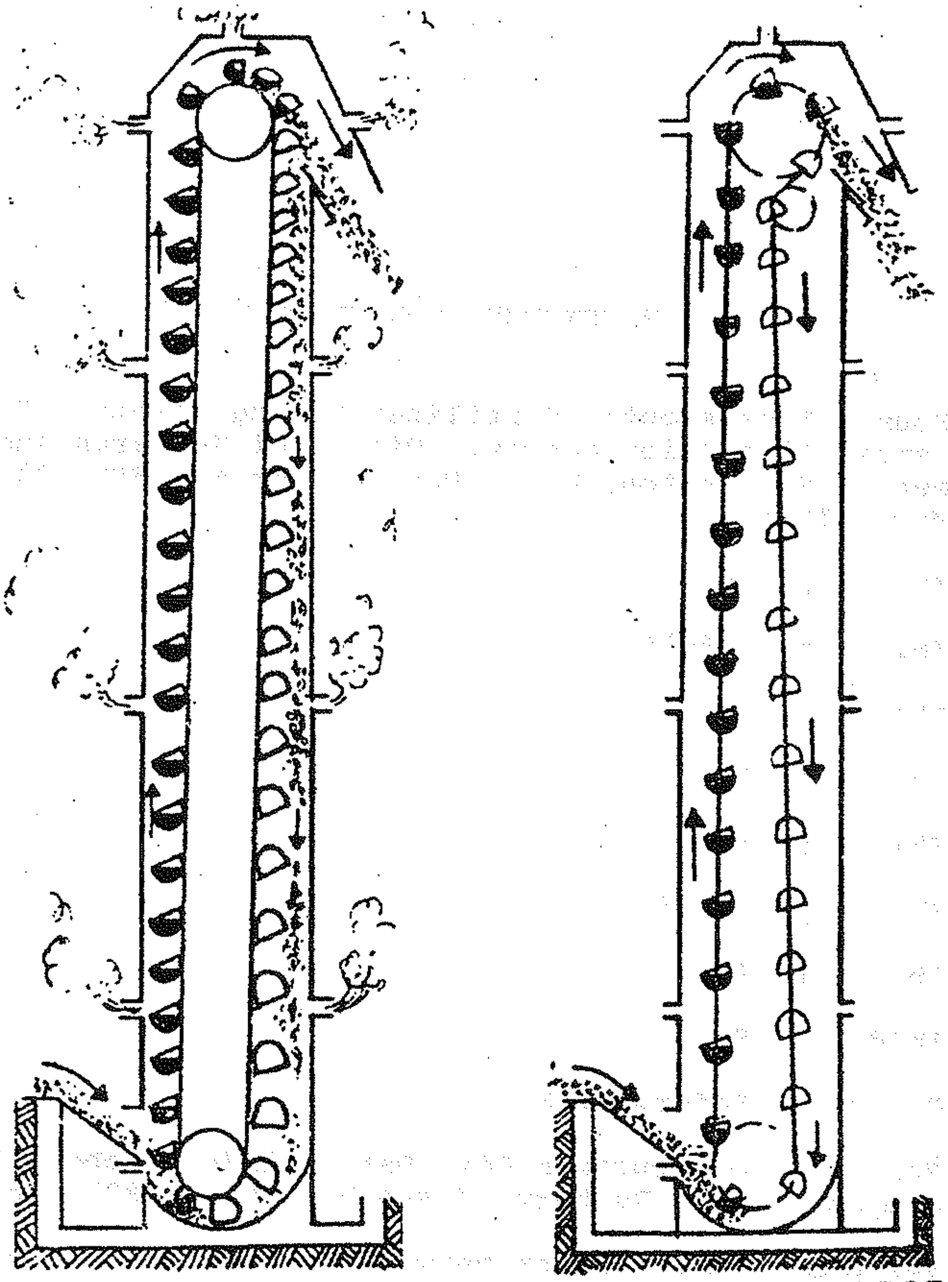

Figure 2.12-5. Bucket elevators used at bulk blending plants.[24]

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2. Ibid. p. 46.

3. Ibid. pp. 15-16.

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6. Ibid. p. 89.

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11. Building Construction Cost Data - 1978. Robert Snow Means Company, Inc. Duxbury, Massachusetts. 1977. p. 186.

12. Personal communication between Mr. Ron Pair, Ron Pair Enterprises, Inc. and Mr. John Zoller, PEDCo Environmental, Inc. October 26, 1976.

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15. Ibid. p. 3-5.

16. Op. cit. Reference 11. pp. 202 and 219.

17. Op. cit. Reference 1. p. 127.

18. Op. cit. Reference 12.

19. Op. cit. Reference 1. pp. 89 and 130.

20. Ibid. p. 130.

21. Op. cit. Reference 17.

22. Op. cit. Reference 1. p. 132.

23. Ibid. p. 129.

24. Ibid. p. 136.

APPENDIX FOR SECTION 2.12

(1) Material handling (Assume 1,300 tpy production)

Railcar unloading (Assume 1/2 of material handling emissions)
Emissions = (0.1 lb/ton)(1,300 tpy) = 130 lbs/yr

Skirts around railcars

$0.85/ft² (Means Bldg. Constr. Cost, 1978, p. 186)

$$\$0.85\ \frac{(249.6)}{(218.8)} = \$1.00/\text{ft}^2$$

Assume skirt: (30' x 10' x 10' x 2) = 6,000 ft²

Capital cost = ($1.00/ft²)(6,000 ft²) = $6,000

Annual cost (@ 17% for fixed costs and 3% for maintenance) = $6,000 (.2) = $1,200

$$C/B = \frac{\$1,200/\text{yr}}{.5\ (13)} = \$18.50/\text{lb}$$

Transfer to storage (Assume 1/2 of material handling emissions)

Telescopic chutes (Model D30-OT, 8 ft)

$$\text{Direct cost} = \$2,540\ \frac{(249.6)}{(198.1)} = \$3,200$$

Indirect cost (@ 40%) = $1,280
Capital cost = $4,480 x 3 chutes = $13,500
Annual cost (@ 17% fixed, 3% maintenance)

= 0.2 (13,500) = $2,700

$$C/B = \frac{\$2,700/\text{yr}}{.75\ (130)} = \$27.70$$

Hooding, vent to fabric filter

Source

- Transfer to storage (@1,000 acfm)
  (50 ft)($20/ft) = $1,000
  (3 elbows)($260/elbow) = $780

- Material handling hood (@ 1,000 acfm)
  Materials = $50
  Labor = $190
  Duct = (30 ft)($20/ft) = $600
  Elbow = (1 elbow)($260/elbow) = $260

- Mixing (@ 1,000 acfm)
  Hood = $240
  Duct = (50 ft)($20/ft) = $1,000
  Elbow = (2 elbows)($260/elbow) = $520

° Bagging (@ 1,000 acfm)
Hood = $240
Duct = (50 ft)($20/ft) = $1,000
Elbows = (2 elbows)($260/elbow) = $520

° Truck loading (@2,000 acfm)
Hood = $240
Duct = (60 ft)($20/ft) = $1,200
Elbows=(2 elbows)($260/elbow) = $520

Duct cost = $8,360 $\frac{(249.6)}{(192.1)}$ = $10,860

Installation (@ 75%) = $8,150
Direct cost (@ 40%) = $7,600

Total duct cost ≈ $27,000

Baghouse cost (@ 6,000 acfm), NMI, p. 3-3
= $40,000 $\frac{(249.6)}{(204.1)}$ = $49,000

Capital cost = $27,000 + $49,000 = $76,000

Annual cost:
Ductwork (@ 17% of capital) = $4,600
Baghouse = $10,000 $\frac{(249.6)}{(204.1)}$ = $12,200
(from NMI, p. 3-5, @ 3,000 hpy)

Total cost = $17,000

Emissions = 0.1 + 0.2 + 0.2 lb/ton = 0.5 lb/ton
(total emissions from transfer to storage, mixing bldg. and loading)

$$C/B = \frac{\$17,000/yr}{.5\ (1,300)(.99)} = \$26.40/lb$$

(2) Mixing building fugitive losses

Material handling
Emissions = (0.2 lb/ton)(1,300 tpy) = 260 lbs/yr
Assume an average control efficiency of (.75 + .50 + .95)/3 = 73% or ∿ 75%

Wet suppression (Means, p. 219)

Pump, check valve, tank, STD controls
116 PM @ 35 psig, 60 gallon tank = $1,275
Tank installation cost (@75%) = $950
Piping - copper 3/4" = $3.78/LF installed, p. 202
Assume 100' piping; cost = $378

3 valves @ $11.15 (installed) = $35
Nozzles, misc. = $100

Installed cost = $2,736 $\frac{(249.6)}{(192.1)}$ = $3,555

plus indirect charges (@ 40%) = $5,000

Capital cost = $5,000

Annual cost:
- Capital charges (@ 17%) = $850
- Dust suppressant
  - ° if liquid fertilizer is used
  - ° if liquid fertilizer (18-46-0) = $0.094/lb
  - ° if dry bulk = $0.12/lb

The expense of the liquid fertilizer will be recovered in the cost of the bulk fertilizer.

∴ additional cost of liquid fertilizer is negligible
O & M costs (@ 10%) = $500

Total annual costs = $1,350

$$C/B = \frac{\$1,350/yr}{(260)(.75)} = \$6.90/lb$$

Hood, vent to fabric filter
See ①

Bucket elevator modification
No data

Mixing

Wet suppression
See ② material handling
C/B = $6.90/lb

Hooding, vent to fabric filter
See ①
C/B = $26.40/lb

Bagging

Wet suppression
See ② material handling
C/B = $6.90/lb

Hooding, vent to fabric filter
See ①
C/B = $26.40/lb

(3) Loading operations

<u>Truck loading (bulk)</u>
Emissions = (0.2 lbs/ton)(1,300 tpy) = 260 lbs/yr

<u>Telescopic chutes</u>

Capital cost = $4,500 See (1)
Annual cost (@ 20%) = $900

$$C/B = \frac{\$900/yr}{.75\ (260)} = \$4.60/lb$$

<u>Hooding, vent to fabric filter</u>
See (1)
C/B = $26.40/lb

2.13 CEMENT MANUFACTURING AND BLENDING PLANTS

2.13.1 Process Description

Portland cement is used for making concrete for construction of many kinds of structures such as buildings, bridges and highways and for products such as concrete masonry, concrete pipe and many precast components for construction. Five types of Portland cement are produced in the United States to specifications which are governed by the desired characteristics, such as general construction, moderate heat release in massive structures, sulfate resistance or high early strength.

Raw materials include limestone, clay or shale, iron-bearing materials and siliceous materials. Table 2.13-1 lists the raw materials used in the production of Portland cement in the U.S. Most of these are taken from quarries by drilling and blasting procedures, then transported to crushers and screening plants. The product of these operations is transported to the storage facilities for continuation of the manufacturing process, which transforms these raw materials into a product known as "Portland cement clinker".

Dry Process - The raw materials are proportioned and conveyed to a drying/grinding unit where they are dried and ground either separately or simultaneously. The product of grinding is usually air classified (separated by size using the principles of air drag and particle inertia) before storage, with the oversize material returned to the grinding circuit. The product is then blended and stored before subsequent calcination.

TABLE 2.13-1. RAW MATERIALS USED IN PRODUCING PORTLAND CEMENT IN THE UNITED STATES[a,b]

Raw materials	1973 raw materials usage, 1000 Mg	1000 tons
Calcareous:		
Limestone (include aragonite)	78,652	86,699
Cement rock (includes marl)	23,647	26,067
Oystershell	4,667	5,144
Argillaceous:		
Clay	7,195	7,931
Shale	3,719	4,099
Other (includes staurolite, bauxite, aluminum dross, pumice and volcanic material)	218	240
Siliceous:		
Sand	1,862	2,053
Sandstone and quartz	679	748
Ferrous:		
Iron ore, pyrites, millscale and other iron-bearing material	878	968
Other:		
Gypsum and anhydrite	3,858	4,253
Blast furnace slag	619	682
Fly ash	271	299
Other	4	5
Total	126,269	139,188

[a] Includes Puerto Rico.

[b] Reference 1.

Wet Process - The raw materials are similar to the dry process, but generally include a naturally occurring wet marl or clay. Following the quarrying operation, they may be slurried in a wash mill and then ground to a high fineness with other raw materials, such as limestone, to produce a slurry with water. This slurry is blended through quality control procedures and fed to the rotary kiln, where the water is driven off and the raw mixture is calcined to form Portland cement clinker.

Calcination - The blended material (from either the wet or dry process) is fed directly to a long, inclined, rotating kiln or to a preheated system and then into the rotating kiln. The hot product of the calcination process, cement clinker, is discharged from the kiln and immediately cooled in the clinker cooler. After cooling, the clinker is combined with gypsum (about 5% by weight) and ground in rotary ball mills illustrated in Figure 2.13-1. The milled cement is air classified, and the oversized material returned to the mill. The cement is then stored to await packaging or bulk shipment by rail, barge or truck.

A process flow diagram for cement production is shown in Figure 2.13-2. Each potential process fugitive emission source is identified in the Figure. A dust source common to all cement producing facilities, but not specifically included in the figure, is plant roads. Proper evaluation of this emission category is explained in Section 2.1. In addition, limestone quarries, which are often an integral part of the cement facility,

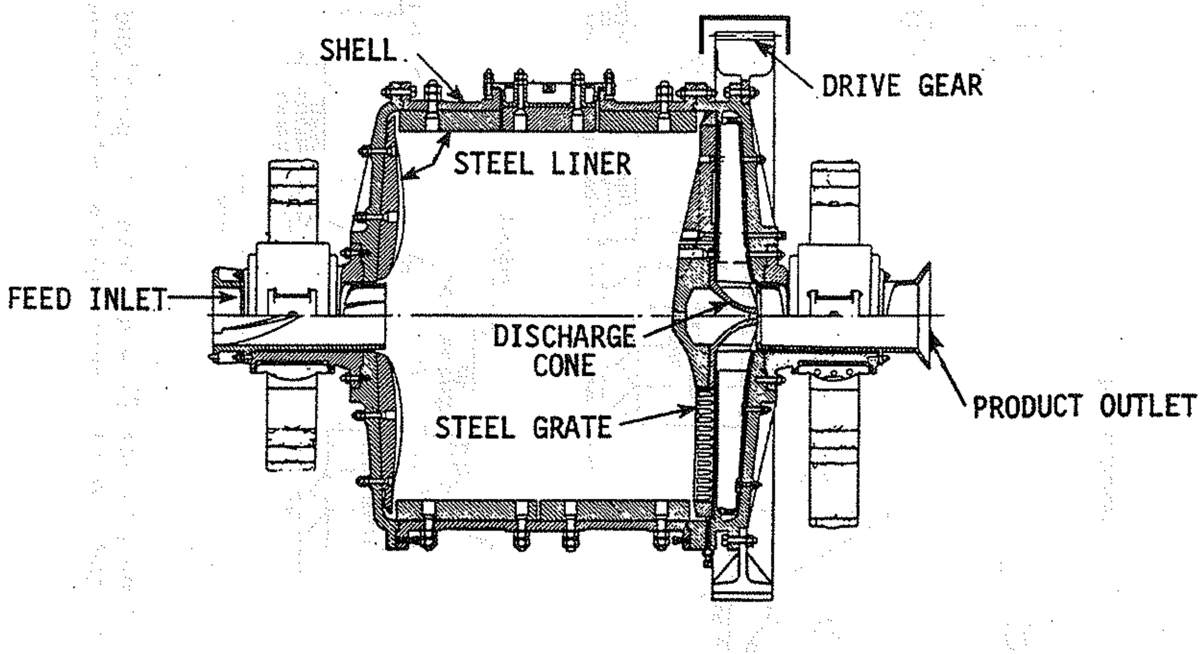

Figure 2.13-1. Typical rotary ball mill configuration.

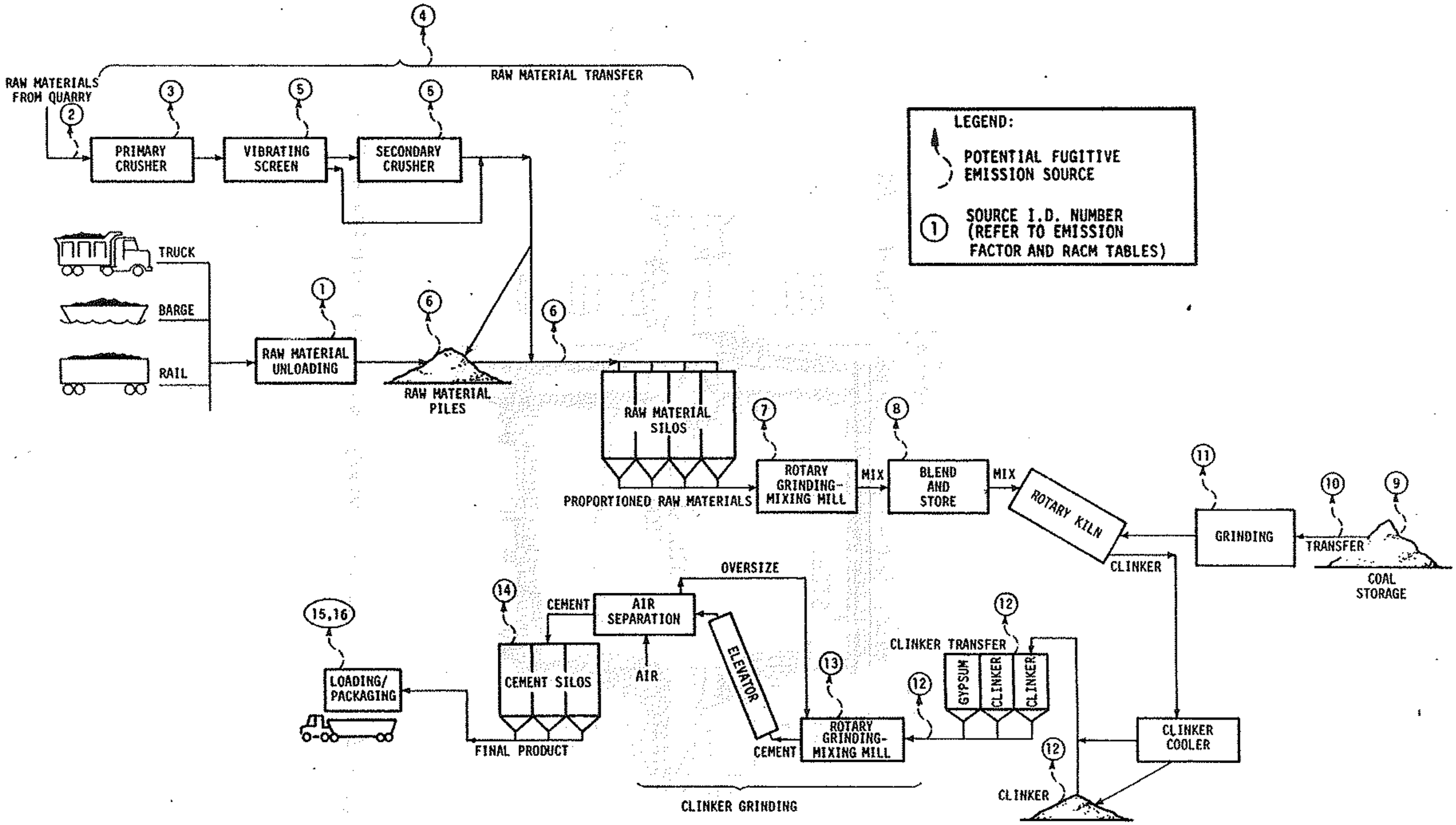

Figure 2.13-2. Simplified process flow diagram for portland cement production and associated fugitive particulate emission sources.

are not specifically included in this section. They are discussed separately, in detail, in Section 2.1.4.

2.13.2 Fugitive Dust Emission Factors

The estimated emission factors for cement production fugitive particulate emissions are presented in Table 2.13-2. All of these factors are based on either engineering judgment or visual observations as indicated by the references cited. No details are given on the methodology of development. The reliability of these types of estimates would be poor.

2.13.3 Particle Characterization

Fugitive particulate emissions from Portland cement production are composed of the same materials as handled in the various operations, but little information is available regarding the size range characteristics. The typical oxide composition ranges of clinker dust and cement dust are as follows.[6]

Compound	Fugitive emission oxide composition, percent by weight	
	Clinker dust	Cement dust
Silica	19-24	18-23
Al_2O_3	3-8	3-8
Fe_2O_3	1-5	1-5
CaO	62-69	61-66
MgO	0-5	0-5
SO_3	0-1	2-4
Free lime	0-2	0-2
Minor components	0-1	0-1

TABLE 2.13-2 FUGITIVE DUST EMISSION FACTORS FOR CEMENT PRODUCTION

Source	Emission factor	Reliability Rating	Reference
(1) Raw material unloading-gypsum, iron ore, clay, limestone, sand and coal	0.4 lb/ton coal unloaded 0.03 to 0.4 lb/ton other materials unloaded	E E	2 2
(2) Raw material charging to primary crusher	0.0003 to 0.04 lb/ton charged	D	3
(3) Primary crusher	0.5 lb /ton crushed	C	2,4
(4) Transfer and conveying	0.2 to 0.4 lb/ton handled	E	2
(5) Vibrating screen, secondary crusher	1.5 lb/ton screened, crushed	C	2,4
(6) Unloading outfall to storage	3.0 to 5.0 lb/ton unloaded	E	2
(7) Raw material grinding mill and feed/discharge exhaust systems	0.1 lb /ton milled	E	2
(8) Raw material blending and storage	0.05 lb /ton blended	E	2
(9) Coal storage	(See Table 2.2.1-1)	D	
(10) Coal transfer to grinding	0.2 lb /ton transferred	D	2
(11) Leakage from grinding	Negligible	E	2
(12) Clinker/gypsum outfall-unloading, storage, loadout	5.0 to 10.0 lbs/ton	E	2
(13) Finish grinding with mill leaks and feed discharge exhaust	0.1 lb /ton cement	E	2
(14) Cement silo vents	Negligible	E	2
(15) Cement loading	0.236 lb /ton loaded	E	5
(16) Cement packaging	0.01 lb /ton packaged	E	2

The American Conference of Governmental Industrial Hygienists has established levels for which airborne chemical compounds could be tolerated without adverse effect on humans.[7] Of the above compounds, aluminum oxide, iron oxide, magnesium oxide and free lime are considered nuisance substances which can be tolerated in large quantities. Silica may be hazardous depending upon the amount of quartz contained in the silica. Calcium oxide can be tolerated at levels up to 5 mg/m^3, and sulfur dioxide can be tolerated up to 13 mg/m^3.

2.13.4 Control Methods

Control techniques for raw material crushing and screening operations at cement plants are essentially the same as those described in Section 2.1. These operations are typically enclosed and often located subsurface, which further diminishes the potential for the escape of fugitive emissions. Water suppression via water sprays at the feed points of both primary and secondary crushing and screening operations are common. Hooding at bins, discharge points, and conveyor transfer points, which exhaust to primary fabric filters, are employed at some plants. Although coal dust can be collected by a fabric filter, the danger of an explosion must be noted.

Raw material and clinker handling results in fugitive emissions which are often controlled by the application of covers over transfer belts, or enclosing and/or hooding transfer points with exhaust to fabric filters. Properly designed hoods, used with 1000-4000 cfm fans, effectively control emissions.[8] Some plants use telescoping or ladder chutes for stockpiling of material, which confine the material and reduce its free fall distance.[9] Wet suppression methods are also practiced, but may be limited for clinker and gypsum due to the impairment of material quality and handling properties which may result.

One plant has experimented with foam to control clinker handling emissions; however, the resulting increase of entrained air in the cement product has severely limited employment of this control technique thus far.[10] The abrasive nature of clinker also may cause maintenance/attrition problems with pneumatic transfer and exhaust system equipment (ductwork, fans, etc.). Lowering of duct velocities is a solution, but its use is limited since the collection efficiency is simultaneously impaired.

Conveying and transfer of the powdery cement product by belt conveyor and/or pneumatic conveying is most often well confined and controlled for both prevention of product loss and air pollution control. Control techniques are similar to those for clinker conveying as described above. Pneumatic transport system air is typically controlled by fabric filters.

Clinker storage is one of the major potential sources of fugitive dust at a cement plant. Most facilities have some type of structure for protecting the clinker from the weather; however, for the most part, these partial enclosures are not sufficiently confining to prevent fugitive emissions from windage and loading/unloading activities. Some plants employ open-ended structures with partial sidewalls for storage of clinker and other materials. Such structures can become virtual wind tunnels during strong winds. The most effective control measure is complete enclosure of the storage area with ventilation to fabric filters.[9] One plant has a partially enclosed facility which employs a mobile clinker ladder exhausted to a fabric filter to practically eliminate emissions from unloading the clinker to storage.[10]

Emissions which escape from the hoods designed to capture emissions from raw material grinding and cement grinding mills, and their associated air separators and elevators, are significant at some plants because of the poor capture efficiency of the primary control system. These operations can be improved by increasing the blower head and vent rate of the primary control system and by redesigning the hooding.

Leaks in the ball mills, for example from worn-out rubber seals between the nuts and bolts which fasten steel plates to the inner walls of the mills, can be another significant emission source. A conscientious maintenance program is the best means for controlling these types of emissions.[11] These grinding mills are often located in an enclosed structure, which helps to prevent the escape of these emissions.

Cement storage silo vents (for the discharge of displacement air as cement is fed to the silos) are either uncontrolled, covered by fabric "socks", or exhausted to fabric filters which are part of the pneumatic conveying systems. The control trend is toward aspiration to fabric filters.

Cement loading operations for bulk truck, rail and ship/barge transport are typically gravity-feed systems which are partially enclosed (for truck and rail loading) or unconfined (for ship/barge loading). Cement packaging is often located in a building or partial enclosure. Some plants exhaust the cement dust, which is emitted with the displaced air during loading and packaging, to fabric filters; while others have no control system at all. A loading or packaging aspiration system which consists of a filling spout with an outer concentric aspiration duct to a fabric filter is being employed at an increasing number of plants. Section 2.1 provides further discussion on the general aspects of loading and associated control systems.

Most of the material collected by fabric filters at a cement plant is returned in a closed loop to its related process operation; however, when this collected material cannot be reused, disposing of it to waste storage areas by discharge and transport in open trucks, can be an intermittent yet severe problem. Wet suppression and enclosure of the unloading operation and covering of the truck can reduce these emissions. Control of waste disposal area emissions has been discussed in Section 2.1.

A conscientious housekeeping program involving the routine clean-up of spills from conveyor pick-up and transfer points, accumulation of leaks from grinding mills and similar sources exposed to wind erosion is a very important part of the cement facility's overall fugitive emissions control program.

Table 2.13-3 summarizes available control alternatives, their effectiveness, estimated costs, and RACM selections.

2.13.5 Recommended Reasonably Available Control Measures (RACM)

The RACM selections for control of fugitive particulate emissions from cement manufacturing and blending plants are presented in Table 2.13-3. Recommended control for raw material storage and handling (primary and secondary crushing/screening, grinding, conveying, etc.) is through use of a wet dust suppression system with a chemical wetting agent. This system provides good control effectiveness (approximately 90-95%) and reduces visible emissions significantly. Further justification for this measure, besides the economical aspect, is that it is already commonly used within Portland cement plants.

Recommended control for handling/storage of clinker and gypsum as well as the cement product is the construction of an enclosure with air (and dust) displacement to a fabric filter baghouse system. This is advantageous not only for its high degree of particulate control but also for the added benefit of product recovery. Wet suppression is not feasible due to the impairment of material quality and handling properties which can result. Greater product yield, which can stem from the employment of a fabric filter system, should aid to offset the high cost for such control.

TABLE 2.13-3. A SUMMARY OF THE CONTROL ALTERNATIVES; EFFICIENCIES AND COSTS, AND THE RACM SELECTIONS FOR FUGITIVE DUST EMISSIONS FROM SOURCES AT CEMENT MANUFACTURING AND BLENDING PLANTS

Fugitive dust sources	Control alternatives	Control efficiency, %	Control costs, Jan. 1980, $		Cost benefit, $/lb	RACM selection
			Capital	Annualized		
(1) Raw material unloading of gypsum, iron ore, clay, limestone, sand and coal	Enclosure, vent to fabric filters	99[a,b]	87,400[c]	21,000[d]	0.29	Wet suppression (chemical)
	Enclosure	50[e]	15,000[f]	2,600[g]	0.07	
	Wet suppression (chemical)	95[h,i]	64,000[j]	15,700[k]	0.004	
(2) Raw material charging to primary crusher	Enclosure, vent to fabric filter	95[l]	130,000[m]	33,000[n]	0.008	Wet suppression (chemical)
	Wet suppression (chemical)	90[o]	p	p	0.004	
(3) Primary crusher	Enclosure, vent to fabric filter	95[l]	q	q	0.008	Wet suppression (chemical)
	Wet suppression (chemical)	90[o]	p	p	0.004	
(4) Transfer and conveying (raw material)	Enclosure, vent to fabric filter	99[a]	q	q	0.008	Wet suppression (chemical)
	Wet suppression (chemical)	95[h]	p	p	0.004	
(5) Vibrating screen, secondary crushing	Wet suppression (chemical)	90[o]	p	p	0.004	Wet suppression (chemical)
	Enclosure, vent to fabric filter	95[l]	q	q	0.008	
(6) Unloading outfall to storage (raw material)	Enclosure, vent to fabric filter	99[a]	q	q	0.008	Wet suppression (chemical)
	Adjustable chutes	75[r]	(See Section 2.1)		NA	
	Wet suppression (chemical)	95[h]	p	p	0.004	
(7) Raw material grinding and feed/discharge exhaust systems	Wet suppression (chemical)	90[o]	p	p	0.004	Wet suppression (chemical) (dry process)
	Enclosure, vent to fabric filter	95[l]	q	q	0.008	No control (wet process)
(8) Raw material blending and storage	Wet suppression (chemical)	95[h]	p	p	0.004	Wet suppression (chemical) (dry process)
	Enclosure, vent to fabric filter	95[a]	q	q	0.008	No control (wet process)
(9) Coal storage Loading onto pile	Enclosure	70-99[r]	(See Section 2.1)		NA	Wet suppression (chemical)
	Wet suppression (chemical)	80-90[r]	(See Section 2.1)		NA	
	Adjustable chutes	75[r]	(See Section 2.1)		NA	

(continued)

TABLE 2.13-3 (continued)

Fugitive dust sources	Control alternatives	Control efficiency, %	Control costs, Jan. 1980, $ Capital	Annualized	Cost benefit, $/lb	RACM selection
Wind erosion	Enclosure	95-99[r]	(See Section 2.1)		NA	Wet suppression (chemical)
	Wet suppression (chemical)	90[r]	(See Section 2.1)		NA	
	Watering	50[r]	(See Section 2.1)		NA	
	Wind screens	Very low	(See Section 2.1)		NA	
(10) Coal transfer to grinding	Wet suppression (chemical)	80-90[r]	(See Section 2.1)		NA	Wet suppression (chemical)
	Watering	50[r]	(See Section 2.1)		NA	
	Gravity feed onto conveyor	80[r]	s	s	NA	
(11) Leakage from grinding (coal)	Improved operation and maintenance program	Unknown	s	s	NA	Improved operation and maintenance program
(12) Clinker/gypsum outfall-unloading, storage, loadout	Adjustable chutes	75[r]	(See Section 2.1)		NA	Enclosure, vent to fabric filter
	Enclosure, vent to fabric filter	95-99[t]	130,000[m]	33,000[m]	0.01	
(13) Finish grinding with leaks from milling and feed/discharge exhaust systems	Enclosure, vent to fabric filter plus good operating program	95[l]	u	u	0.01	Enclosure, vent to fabric filter plus good operating program
	Pneumatic conveying	99[v]	99,000[w]	21,200[w]	0.48	
(14) Cement silo vents	Vent filter ("fabric socks")	99[x]	s	s	NA	Vent to fabric filter
	Vent to fabric filter	99[y]	u	u	0.01	
(15) Cement loading	Adjustable chutes	75[r]	(See Section 2.1)		NA	Vent to fabric filter
	Vent to fabric filter	99[y]	u	u	0.01	
(16) Cement packaging	Vent to fabric filter	99[a]	u	u	0.01	Vent to fabric filter
	Choked feed	75[r]	(See Section 2.1)		NA	

(continued)

TABLE 2.13-3 (continued)

[a] Reference 10.

[b] No visible emissions after control-Reference 11.

[c] Based upon 20' x 20' x 15' enclosure and a jet pulse baghouse treating 10,000 acfm @ 70° with a 6.5 to 1 air/cloth ratio.

[d] Reference 12. Based on 3000 h/yr operation.

[e] Estimate based on engineering judgment.

[f] Reference 13. Based on 20' x 20' x 30' enclosure.

[g] Includes capitalization charges only.

[h] Reference 14.

[i] Visible emissions reduced to 0% (5% opacity observed on rare occasions). Reference 15.

[j] Reference 16. Based on 75 ton/h throughput capacity. Includes application at unloading, primary crusher inlet and outlet, secondary crusher inlet and outlet, stockpile loadout and transfer points.

[k] Reference 17. Based on 3000 h/yr operation.

[l] Reference 18. Estimated dust control for crushing operations.

[m] Reference 19. Based on 20,000 acfm.

[n] Reference 20. Based on 3000 h/yr operation.

[o] Reference 21.

[p] Costs included within those for Source 1 - wet suppression. One system to control emissions from raw material processing, handling and storage.

[q] Costs included with those for Source 2 - enclosure/fabric filter. One system to control emissions from raw material processing, handling and storage.

[r] Reference 22.

[s] Costs not available.

[t] Assumed same as for raw material handling.

[u] Costs included within those for Source 12 - enclosure/fabric filter. One system to control losses from clinker/cement product storage and handling.

[v] Assumed with control of conveying air by fabric filter.

[w] Costs assumed same as for conveying of lime product (refer to Table 2.3-2-Source 6).

[x] Engineering judgment.

[y] Control efficiency assumed to be same as for raw materials storage and handling.

NA = Not available.

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17. Op. cit. Reference 12. p. 3-39.

18. Op. cit. Reference 11. p. 4-8.

19. Ibid. p. 4-11.

20. Op. cit. Reference 1. p. 2-245.

21. Op. cit. Reference 11. p. 3-3.

22. Ibid. p. 3-6.

23. Op. cit. Reference 12. p. 3-15.

24. Op. cit. Reference 1. p. 2-38 and 2-39.

APPENDIX FOR SECTION 2.13

Average plant capacity = 444,525 tpy

(1) Raw material unloading

Emissions (coal unloading) = (0.4 lb/ton)(87,197 tpy) = 34,880 lbs/yr

Emissions (other material unloading) = $\left(\frac{.03 + .4}{2}\ \text{lb/ton}\right)$ (177,576 tpy) = 38,180 lbs/yr

Total emissions = 73,060 lbs/yr

Enclosure, vent to fabric filter

Capital cost = $87,400
Annual cost = $21,000

$$C/B = \frac{\$21,000/yr}{.99\ (73,060)} = \$0.29/lb$$

Enclosure

Capital cost = $15,000
Annual cost = $2,600

$$C/B = \frac{\$2,600/yr}{.5\ (73,060)} =$$

Wet suppression (chemical)

See (8)
C/B = $0.004/lb

(2) Raw material charging to primary crusher

$$\text{Emissions} = \left(\frac{0.003 + 0.04}{2}\ \text{lb/ton}\right)(651,345\ \text{tpy}) = 13,125\ \text{lbs/yr}$$

Enclosure, vent to fabric filter

Capital cost = $130,000
Annual cost = $33,000

$$C/B = \frac{\$33,000/yr}{.95\ (13,125)} = \$0.008/lb$$

Wet suppression (chemical)

See (8)
C/B = $0.004/lb

(3) Primary crusher
Emissions = (0.5 lb/ton)(651,338 tpy) = 325,670 lbs/yr

Enclosure, vent to fabric filter

See (8)
C/B = $0.008/lb

Wet suppression (chemical)

See (8)
C/B = $0.004/lb

(4) Transfer and conveying (raw material)
Emissions = (0.3 lb/ton)(651,338 tpy) = 195,400 lbs/yr

Enclosure, vent to fabric filter

See (8)
C/B = $0.008/lb

Wet suppression (chemical)

See (8)
C/B = $0.004/lb

(5) Vibrating screen, secondary crushing
Emissions = (1.5 lb/ton)(651,175 tpy) = 976,760 lbs/yr

Enclosure, vent to fabric filter

See (8)
C/B = $0.008/lb

Wet suppression (chemical)

See (8)
C/B = $0.004/lb

(6) Unloading outfall to storage (raw material)
Emissions = (4 lb/ton)(650,687 tpy) = 2,602,750 lbs/yr

Enclosure, vent to fabric filter

See (8)
C/B = $0.008/lb

Adjustable chutes

NA (See Section 2.1)

Wet suppression (chemical)

See (8)
C/B = $0.004/lb

(7) Raw material grinding and feed / discharge exhaust systems
Emissions = (0.1 lb/ton)(649,387 tpy) = 64,940 lbs/yr

Wet suppression (chemical)

See (8)
C/B = $0.004/lb

Enclosure, vent to fabric filter

See (8)
C/B = $0.008/lb

(8) Raw material blending and storage
Emissions = (0.05 lb/ton)(649,355 tpy) = 32,470 lbs/yr

Wet suppression (chemical) (for sources (1) thru (8))

Capital cost = $64,000
Annual cost = $15,700

$$C/B = \frac{\$15{,}700/\text{yr}}{.95\ (73{,}060) + .9\ (13{,}125) + .9\ (325{,}670) + .95\ (195{,}400) + .9\ (976{,}760) + .95\ (2{,}602{,}750) + .9\ (64{,}940) + .95\ (32{,}470)}$$

$$= \$0.004/\text{lb}$$

Enclosure, vent to fabric filter (for sources (2) thru (8))

Capital cost = $130,000
Annual cost = $33,000

$$C/B = \frac{\$33{,}000/\text{yr}}{.95\ (13{,}125) + .95\ (325{,}670) + .99\ (195{,}400) + .95\ (976{,}760) + .99\ (2{,}602{,}750) + .95\ (64{,}940) + .95\ (32{,}470)}$$

$$= \$0.008/\text{lb}$$

(9) Coal storage

Loading onto pile

See Section 2.1

Wind erosion

See Section 2.1

(10) Coal transfer to grinding

See Section 2.1

(11) Leakage from grinding (coal)

Improved operation and maintenance program
No data

(12) Clinker / gypsum outfall - unloading, storage, loadout

$$\text{Emissions} = \left(\frac{5 + 10}{2}\ \text{lb/ton}\right)(446{,}059\ \text{tpy})$$

$$= 3{,}345{,}440\ \text{lbs/yr}$$

Enclosure, vent to fabric filter

See (16)
C/B = $0.01/lb

Adjustable chutes

See Section 2.1

(13) Finish grinding with leaks from milling and feed / discharge exhaust systems

Emissions = (0.1 lb/ton)(444,525 tpy) = 44,450 lbs/yr

Enclosure, vent to fabric filter plus good operating program

See (16)
C/B = $0.01/lb

Pneumatic conveying

Capital cost = $99,000
Annual cost = $21,200

$$C/B = \frac{\$21{,}200/\text{yr}}{.99\ (44{,}450)} = \$0.48/\text{lb}$$

(14) Cement silo vents
Emissions =(000.1 lb/ton)(444,500 tpy) = 44 lbs/yr

Vent filter ("fabric socks")

No data

Vent to fabric filter

See (16)
C/B = $0.01/lb

(15) Cement loading
Emissions = (0.236 lb/ton)(413,485 tpy) = 97,580 lbs/yr

Adjustable chutes

See Section 2.1

Vent to fabric filter

See (16)
C/B = $0.01/lb

(16) Cement packaging
Emissions = (0.01 lb/ton)(30,980 tpy) = 310 lbs/yr

Vent to fabric filter (for sources (12) thru (16))

Capital cost = $130,000
Annual cost = $33,000

$$C/B = \frac{\$33,000/yr}{.97\ (3,345,440) + .95\ (44,450) + .99\ (44) + .99\ (97,580) + .99\ (310)}$$

C/B = $0.01/lb

Choke feed

See Section 2.1

2.14 FERROALLOY PRODUCTION

2.14.1 Process Description

Ferroalloy is a generic term for alloys containing iron and one or more other metals. Ferroalloys are used in steel production to introduce the nonferrous metals into the melt as alloying elements or deoxidants. The three basic types of ferroalloys are silicon-based including ferrosilicon and calciumsilicon, manganese-based including ferromanganese and silicomanganese, and chromium-based including ferrochromium and ferrosilicochrome. Other ferroalloys produced include ferrotitanium, ferrocolumbium, ferrotungsten and ferrovanadium.

While several processes are available to produce ferroalloys, electric smelting furnaces are used to produce over 75 percent of the total.[1] Thus, it is the process which will be described herein and is outlined in Figure 2.14-1. Other processes such as the electrolyte process and the vacuum process do not result in significant emissions of particulate matter.

As shown by the Figure, feed materials such as chrome ore, limestone, quartz (silica), coal, wood and scrap iron are typically unloaded from hopper cars and conveyed to outside storage piles. As needed, the materials are conveyed to a crusher, then screened and dried before being fed by conveyor and bucket elevator to feed storage bins. The materials are gravity discharged from the bins to a weigh feeder programmed for a specific blend of the feed materials. The weighed materials blend is

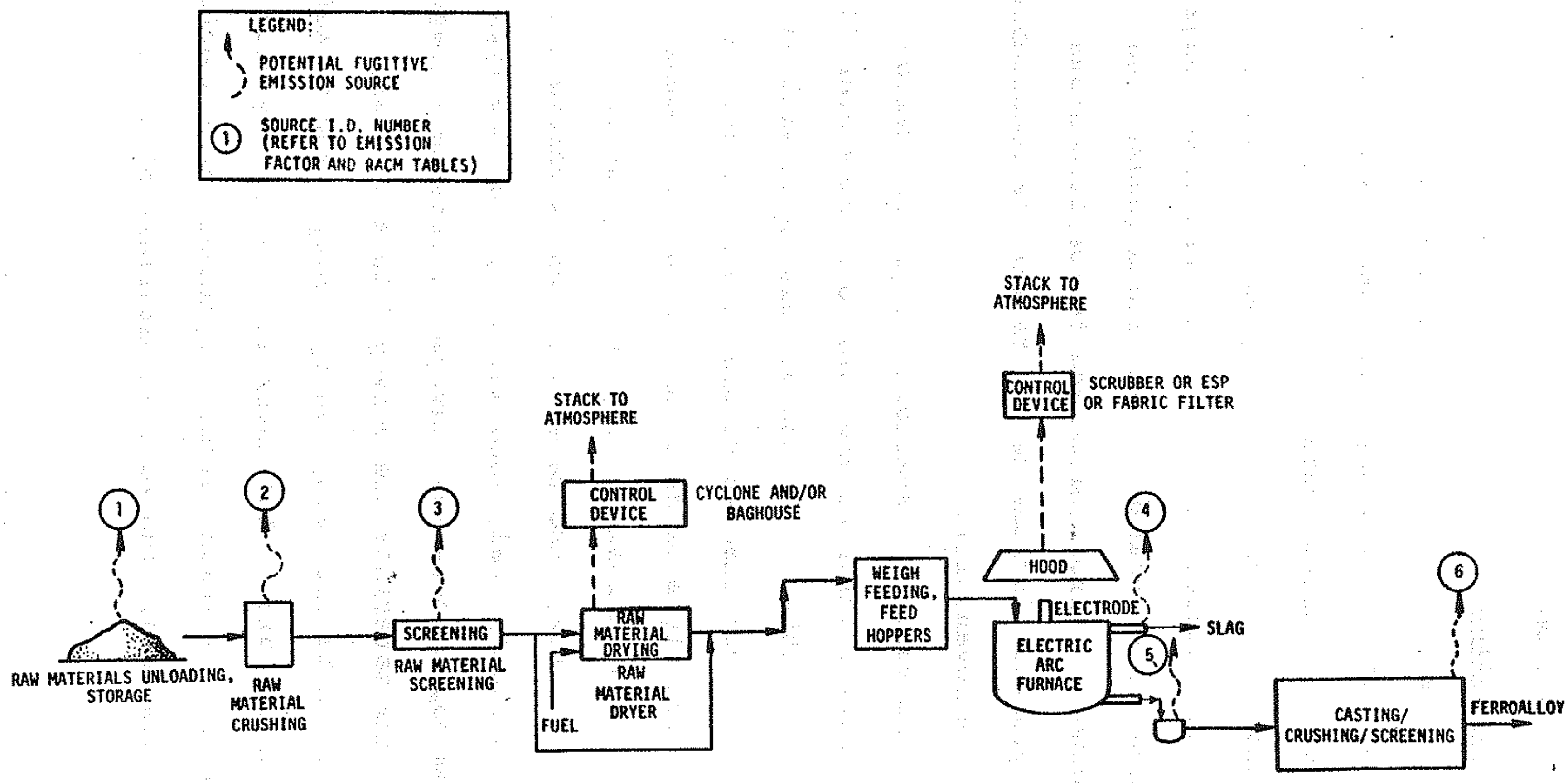

Figure 2.14-1. Simplified process flow diagram for ferroalloy production and associated fugitive particulate emission sources.

taken by bucket elevator and belt conveyor to charge hoppers from which it discharges by gravity into the smelting furnace.

In the electric submerged arc smelting furnace, carbon electrodes extend from the top of the furnace to near the bottom. A sketch of a typical furnace is shown in Figure 2.14-2.[2] Heat is generated by arcing of the electrodes to obtain temperatures of 4000 to 5000°F around the electrodes.[3] Such a temperature permits carbon reduction of the metallic oxides present and melts the feed materials charged to the furnace. Various impurities are trapped in the slag which floats on the molten ferroalloy collecting at the bottom of the furnace. The average smelting furnace production capacity is about 120 tons per day or 40,000 tons per year of ferroalloys.[4]

The molten product is tapped from the bottom of the furnace into a receiving ladle and is taken to the cast house where it is poured into molds, cooled to a solid form, crushed, screened to desired sizes, and stored. Product is taken from storage for packaging and shipment.

Several sources of fugitive particulate emissions exist at a ferroalloy manufacturing plant. As shown in Figure 2.14-1, these sources include the following:

1. feed materials unloading and storage,
2. feed materials crushing,
3. feed materials screening,
4. charging and smelting in an electric arc furnace,

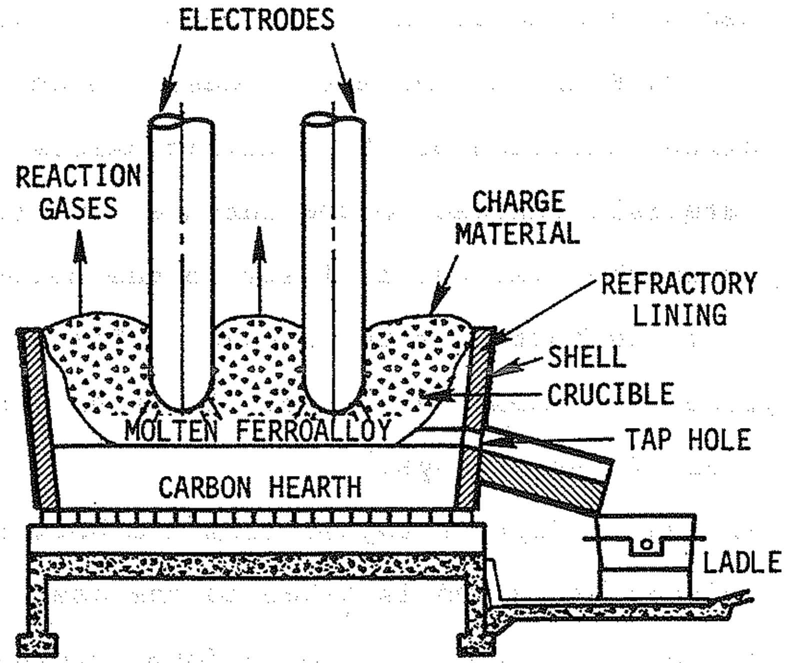

Figure 2.14-2. Submerged-arc furnace for ferroalloy production.[2]

5. furnace tapping, and

6. casting, crushing and screening.

Of these listed sources, the greatest source of fugitive particulate by far is the electric smelting furnace.

2.14.2 Fugitive Dust Emission Factors

The fugitive particulate emission factors for the various production steps are set forth in Table 2.14-1. The factors are based upon a study[5] of the ferroalloy industry and are considered of fair reliability.

As can be noted from the table, the fugitive emissions factor for electric arc furnace operation and tapping are larger than for the other sources. The values cited are median values for a semi-enclosed type furnace at which leakage occurs around the electrodes. The factor for ferrosilicon production is higher than for ferromanganese alloy because of the higher furnace temperatures required for its production.

The factor cited for the cast house is comprised of emissions from the casting operation and the product crushing and screening operations. No data were available to obtain separate emission factors for these sources.

2.14.3 Particle Characterization

The properties of particulates emitted into the atmosphere from raw material handling are similar to those of the feed materials. Dusts generated range in particle size from 3 to 100

TABLE 2.14-1. FUGITIVE DUST EMISSION FACTORS FOR FERROALLOY PRODUCTION

Source	Emission factor	Reliability rating	Reference
(1) Raw materials unloading and storage	2.8 lb/ton stored	D	5
(2) Raw material crushing	4.0 lb/ton crushed	D	5
(3) Raw material screening	4.5 lb/ton screened	D	5
(4) Furnace charging and melting	5.0[a] to 15.5[b] lb/ton melted	C	5
(5) Furnace tapping	12.0 lb/ton tapped	D	5
(6) Casting, crushing and screening			
6a. Casting	2.4 lb/ton cast	D	5
6b. Crushing/grinding product	7.2 lb/ton crushed or ground	D	5

[a] Use for FeMn alloy (semienclosed furnace).

[b] Use for FeSi (50%) alloy (semienclosed furnace).

microns[6] and have a bulk density of 35 to 100 pounds[6] per cubic foot.

Particulates emanating from the electric arc smelting, tapping and casting operations tend to be very small in size and are reported[7] to range in size from 0.1 to 1 micron in diameter. The particulate bulk density is low, 4 to 30 pounds[7] per cubic foot. The chemical composition varies depending upon the particular alloy being produced. Silicon alloys produce a gray fume containing a high percentage of silicon dioxide. Ferrochrome silicon alloys generate silicon dioxide and chromium oxide emissions. Ferromanganese alloy production produces a brown fume consisting of silicon dioxide and manganese oxides. An additional component of the particulate in all cases is carbon which comes from the carbonaceous reducing agents in the feed materials. Other alloys would also result in metallic oxide emissions (i.e., vanadium oxides, titanium oxides, etc.).

The crushing and screening of the product alloy emits metallic particulates that range in size from 3 to 100 microns.[8] The chemical composition of the dust is the same as that of the ferroalloy being produced.

The literature surveyed did not reveal any data concerning the toxicity of the particulate emitted. The gases evolved from a semi-enclosed arc furnace contain a large proportion of carbon monoxide.

2.14.4 Control Methods

The alternatives considered for the control of the various emission sources are presented in Table 2.14-2.

For the customary outside storage of feed materials, the use of wet dust suppression and wind breaks on the windward side of the piles is proposed.

For feed materials crushing and screening, emissions can be controlled by venting them through hoods to either mechanical collectors or fabric filters.

Fugitive emissions from a semi-enclosed smelting furnace can be controlled either by maintenance of the feed seal around the electrodes or by use of a back-up hood vented to a fabric filter or a combination of the two. These measures control only the fugitive emissions from around the electrodes. The point source gaseous effluent is routed to a control device such as a high pressure venturi scrubber or fabric filter which would exhaust via a stack to the atmosphere.

Emissions from tapping of the ferroalloy melt can be controlled by venting them via a hood installed above the tap and ductwork connected either to a separate fabric filter or to the existing main furnace effluent control device. However, in cases where a blowing tap occurs, control is infeasible due to the force with which the tap emissions are expelled.

The cast house fugitive emissions come from both ferroalloy casting operations and from product crushing and screening. Control of these emissions can be achieved either by the hooding

TABLE 2.14-2. A SUMMARY OF THE CONTROL ALTERNATIVES, EFFICIENCIES AND COSTS, AND THE RACM SELECTIONS FOR FUGITIVE DUST EMISSIONS FROM SOURCES AT FERROALLOY PRODUCTION PLANTS

Fugitive dust source	Control alternative	Control efficiency, %	Control costs, $ (Jan. 1980) Capital	Control costs, $ (Jan. 1980) Annual Operating	Cost benefit, $/lb	RACM selection
(1) Raw materials unloading and storage	Wet suppression	50[a]	11,000[b]	7,000[c]	0.13	Wet suppression and wind breaks
	Wind breaks	40[d]	35,000[e]	7,000[f]	0.16	
(2) Raw materials crushing	Hood and vent to fabric filter	90[g]	61,000[h]	18,000[i]	0.13	Hood and vent to fabric filter
	Hood and vent to mechanical collectors	80[j]	30,000[k]	6,000[k]	0.05	
(3) Raw materials screening	Hood and vent to fabric filter	90[g]	61,000[h]	18,000[i]	0.11	Hood and vent to fabric filters
	Hood and vent to mechanical collectors	80[j]	30,000[k]	6,000[k]	0.04	
(4) Furnace charging (semi-enclosed type)	Feed seal maintenance	80[l]	Unknown	Unknown	Unknown	Back-up hoods with a fabric filter and feed seal maintenance
	Back-up hoods with a fabric filter	90[g]	61,000[h]	18,000[i]	0.03	
(5) Furnace tapping	Hoods and venting to new fabric filter	90[g]	600,000[m]	200,000[m]	0.46	Hood and duct into existing control device
	Hood and duct into existing control device	90[g]	Unknown	Unknown	Unknown	
(6) Casting, crushing and screening	Hood and duct crushing operations to a fabric filter	50[n]	130,000[o]	47,000[p]	0.18	Hood and duct crushing and screening operations to a fabric filter (no control for casting)
	Building ventilation to fabric filter	90[q]	390,000[r]	130,000[s]	0.38	

(continued)

TABLE 2.14-2 (continued)

[a] Estimated per reference 9.

[b] Estimated per reference 10 for one site of water spray application.

[c] Estimated per reference 11 for one site of water spray application.

[d] Estimated per reference 12.

[e] Estimated per reference 13 for concrete block walls on windward side of storage piles.

[f] Estimated for maintenance of wall and amortization of capital investment.

[g] Combined efficiency of hood capture of 90% and fabric filter retention of 99.9%.

[h] Per reference 14 for a fabric filter with an air flow of 10,000 scfm.

[i] Per reference 15 for a fabric filter with 10,000 scfm air flow and 8400 hours per year operation. Air flow rate is considered typical for this application.

[j] Efficiency estimated as combined efficiency of 90% for mechanical collector per reference 16 and of 90% for hood capture.

[k] Estimate based upon data of reference 17 adjusted for ambient temperature operations.

[l] Estimated efficiency.

[m] Per reference 18.

[n] Estimated efficiency of particulate collection compared to total emission generation in the cast house.

[o] Per reference 14 for 20,000 scfm exhaust air rate.

[p] Per reference 15 for 20,000 scfm exhaust air rate.

[q] Estimated capture efficiency for total building ventilation.

[r] Per reference 14 for 100,000 scfm estimated air flow rate.

[s] Per reference 15 for 100,000 scfm estimated air flow rate.

and venting of the specific sites of emission to fabric filters or by exhaust of the building air to a single large capacity fabric filter installation.

2.14.5 Recommended Reasonably Available Control Measures (RACM)

The recommended RACM for each of the listed emission sources is shown in Table 2.14-2. Selection was based on considerations of ease of installation, the meeting of state regulations and industrial practice.

For raw materials unloading and storage on outside piles, wet dust suppression in combination with wind breaks is recommended since it is easily accomplished and is readily available. Refer to Section 2.1 which deals with the control of dusting from plant roads and storage piles.

The use of fabric filters for emissions control from feed materials crushing and screening is recommended on the basis of industrial practice.[19] Such a control system can meet state emissions regulations concerning opacity and grain loading (0.030 gr/dscf). If it is practical at a given plant site, emissions from crushing and screening can be vented to a common dust collector to save the cost of two separate installations. The collected dust is easily recycled to the process stream, thus preventing loss of feed materials.

As noted in Table 2.14-2, the costs of maintaining the feed seals around the electrodes of a furnace are unknown. If it is assumed, however, that the incurred costs are nominal, then such practice,in combination with the use of hoods and a fabric filter, is the preferred method of control.

Venting of emissions to the existing furnace control device the recommended RACM for melt tapping. The costs are unknown is since they would be highly variable from one installation to another. Also, this option may not be possible at some plants because of capacity limitations of the furnace control device or equipment configuration problems. In these cases, a new control device is recommended due to the significance of tapping emissions.

The collection and capture of emissions from specific points of generation (i.e., crushers, grinders, screens) is the recommended RACM for the cast house operations. The method is advocated because it maintains a cleaner environment within the building and avoids retrofit difficulties associated with installation of a very large fabric filter. No control is recommended for casting. The only viable control option for casting emissions is building evacuation to a fabric filter. However, this measure does not appear to be cost effective due to the large air exhaust volumes and the size of the fabric filter required. Furthermore, casting at a typical Ohio ferroalloy production plant is generally performed at a number of locations and buildings. Since the cost-benefit value presented for building evacuation to a fabric filter represents control for one building only, control of additional buildings where casting is performed would not be cost effective.

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4. Ibid, p. 4-5.

5. Op. cit. Reference 2, pp. VI-29, -31, -39, -41, -42.

6. Op. cit. Reference 2, p. VI-3.

7. Op. cit. Reference 2, p. VI-5.

8. Op. cit. Reference 2, p. VI-8.

9. Technical Guidance for Control of Industrial Process Fugitive Particulate Emissions. EPA-450/3-77-10, March 1977. p. 2-39.

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11. Ibid, p. 4-12.

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15. Op. cit. Reference 10, p. 3-5.

16. Particulate Control Costs for Intermediate Sized Boilers, Industrial Gas Cleaning Institute for U.S. EPA under Contract No. 68-02-1473, Task No. 18, February 1977. p. 2-3.

17. Ibid, pp. 3-2 and 3-10.

18. Op. cit. Reference 2, p. IX-40.

19. Private communications with Mr. T.E. Casto, Ohio Ferroalloy Corporation, Canton, Ohio, by PEDCo Environmental, Inc., September 25, 1979.

APPENDIX FOR SECTION 2.14

Assume average throughput = 40,000 tpy

(1) Raw materials unloading and storage

Emissions = (2.8 lbs/ton)(40,000 tpy) = 112,000 lbs/yr

<u>Wet suppression</u>

Capital cost = \$11,000
Annual cost = \$7,000

$$C/B = \frac{\$7,000/yr}{.5\ (112,000)} = \$0.13/lb$$

<u>Wind breaks</u>

Capital cost = \$35,000
Annual cost = \$7,000

$$C/B = \frac{\$7,000/yr}{.4\ (112,000)} = \$0.16/lb$$

(2) Raw materials crushing

Emissions = (4.0 lbs/ton)(40,000 tpy) = 160,000 lbs/yr

<u>Hood and vent to fabric filter</u>

Capital cost = \$61,000
Annual cost = \$18,000

$$C/B = \frac{\$18,000/yr}{.9\ (160,000)} = \$0.13/lb$$

<u>Hood and vent to mechanical collectors</u>

Capital cost = \$30,000
Annual cost = \$6,000

$$C/B = \frac{\$6,000/yr}{.8\ (160,000)} = \$0.05/lb$$

(3) Raw materials screening

Emissions = (4.5 lb/ton)(40,000 tpy) = 180,000 lbs/yr

<u>Hood and vent to fabric filter</u>

Capital cost = \$61,000
Annual cost = \$18,000

$$C/B = \frac{\$18,000/yr}{.9\ (180,000)} = \$0.11/lb$$

Hood and vent to mechanical collectors

Capital cost = $30,000
Annual cost = $6,000

$$C/B = \frac{\$6,000/yr}{.8\ (180,000)} = \$0.04/lb$$

4 Furnace charging and melting (semi-enclosed type)
Emissions = (15.5 lbs/ton)(40,000 tpy) = 620,000 lbs/yr

Feed seal maintenance
No cost data

Back-up hoods with a fabric filter

Capital cost = $61,000
Annual cost = $18,000

$$C/B = \frac{\$18,000/yr}{.9\ (620,000)} = \$0.03/lb$$

5 Furnace tapping
Emissions = (12 lbs/ton)(40,000 tpy) = 480,000 lbs/yr

Hoods and venting to new fabric filter

Capital cost = $600,000
Annual cost = $200,000

$$C/B = \frac{\$200,000/yr}{.9\ (480,000)} = \$0.46/lb$$

Hood and duct into existing control device
No cost data

6 Casting, crushing and screening
Emissions (casting) = (2.4 lbs/ton)(40,000 tpy) = 96,000 lbs/yr
Emissions (crushing & screening) = (7.2 lbs/ton)(40,000 tpy)
= 288,000 lbs/yr

Hood and duct crushing operations to a fabric filter

Capital cost = $130,000
Annual cost = $47,000

$$C/B = \frac{\$47,000/yr}{.9\ (288,000)} = \$0.18/lb$$

Building ventilation to control device

Capital cost = $390,000
Annual cost = $130,000

$$C/B = \frac{\$130,000}{.9\ (288,000 + 96,000)} = \$0.38/lb$$

2.15 METAL SALVAGE OPERATIONS

2.15.1 Process Description

Automobile shredding comprises the majority of metal salvage operations. Figure 2.15-1 illustrates the fundamental unit steps of this process and the potential sources of fugitive particulate emissions. Cars are first compacted, though not necessarily on site, to allow them to be fed into the shredder/hammermill. Additional engines, fuel tanks and other items are often enclosed in the auto prior to compacting to increase the metal weight for sale.[1] Compacted cars are then fed (often by crane) into the shredder. Combustible fluids (oils) are usually drained prior to compaction and shredding. Shredding without draining these fluids can result in fires or explosions when ignition occurs due to the friction and heat generated. Some shredders are equipped with water sprays that reduce both fugitive particulate emissions and heat.

Another source of fugitive emissions at metal salvage operations is the torching station where combustibles often are accidentally ignited during the removal of various auto parts with acetylene torches. These stations can result in significant emissions of smoke.

After shredding, the materials are transported, usually by belt conveyor, through vibrator (shaker) and magnetic separation equipment to remove ferrous material from nonferrous scrap. Ferrous material is transferred by stacker conveyor to open storage and may be loaded by front-end loader or by belt conveyor

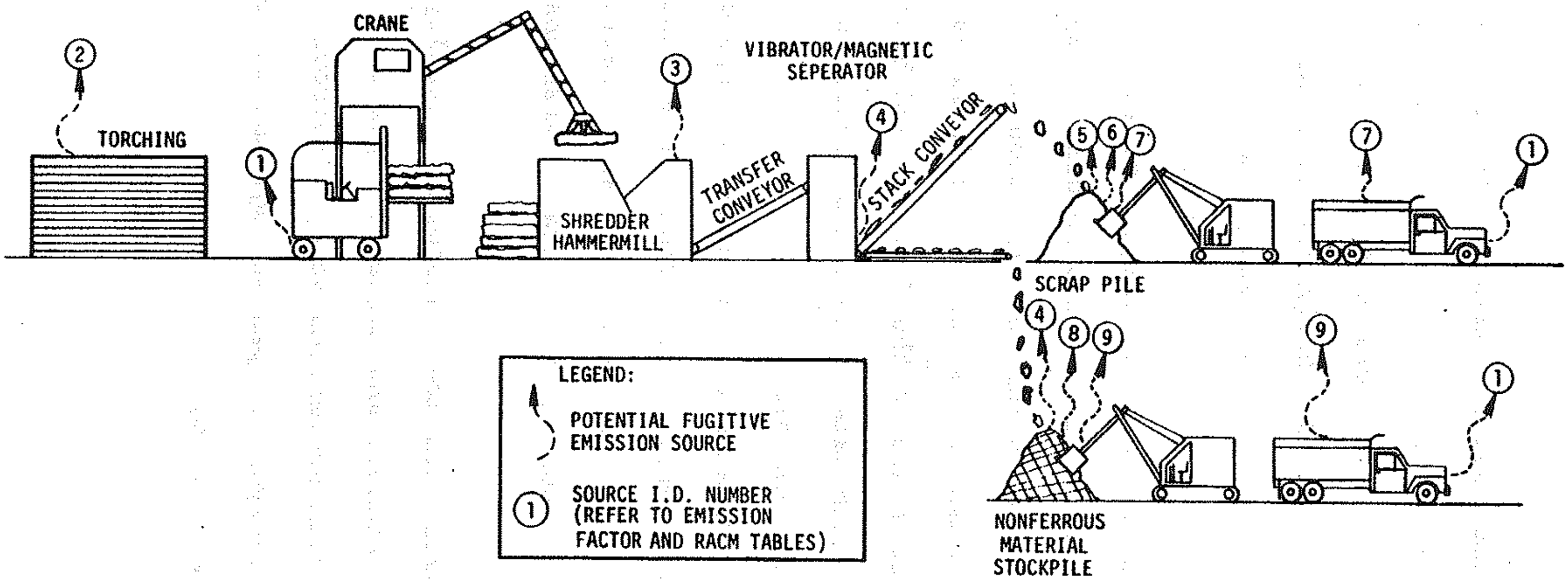

Figure 2.15-1. Process schematic for metal salvage/auto shredding illustrating potential fugitive particulate emission points.

onto truck, railcar or barge. Nonferrous scrap is stockpiled for eventual shipment to recycling or disposal.

2.15.2 Fugitive Dust Emission Factors

A survey of the literature revealed that there has been no effort to quantify the emissions from metal salvage operations. No specific emission factors were discovered that could even be considered as analogous operations. The development of reliable emission factors for metal salvaging operations would require a thorough testing program on several such operations. Given the dearth of emission data, no attempt was made to estimate fugitive emissions from metal salvaging operations.

2.15.3 Particle Characterization

Particle size and density data are not available for metal salvaging fugitive emission sources. While handling and storage of ferrous material contribute to fugitive dust emissions, handling and storage of nonferrous material and smoke from combustion in the shredding operation are the primary fugitive emission sources. Nonferrous particles consist predominately of fibrous material from seat cushion/upholstery (about 80 percent), rust (about 15 percent), and dirt or mud (about 5 percent).[2] Smoke due to combustion within the shredding operations has been observed to reach opacity levels of 80 to 90 percent as often as once or twice daily.[2]

2.15.4 Control Methods

Alternative control methods for the fugitive emission sources are presented in Table 2.15-1 along with their estimated

TABLE 2.15-1. A SUMMARY OF THE CONTROL ALTERNATIVES, EFFICIENCIES AND COSTS, AND THE RACM SELECTIONS FOR FUGITIVE DUST EMISSIONS FROM SOURCES AT METAL SALVAGE OPERATIONS

Fugitive dust sources	Control alternatives	Control efficiency, %	Control costs $ (Jan. 1980) Capital	Control costs $ (Jan. 1980) Annualized	Cost benefit, $/lb	RACM selection
(1) Hauling over unpaved surfaces	(See 2.1.1)	(See 2.1.1)	(See 2.1.1)	(See 2.1.1)	(See 2.1.1)	Oiling or paving
(2) Torching	Use of fire extinguishers	100	a	a	b	Use of fire extinquishers
(3) Shredder	Venting to wet scrubber	90[c] to 99+[c]	100,000[c]	36,000[c]	b	
	Draining/removal of combustible fluids-wet scrubber	75[d] to 90[d]	-	120,000[e]	b	Drainage/removal of combustible fluids plus wet shredding and vent to wet scrubber
	Wet suppression/cooling	50[f] to 75[f]	50,000[f]	11,000[f]		
(4) Magnetic separation/conveying of nonferrous material onto open storage pile	Withdraw lighter material by cyclone(s)/wet scrubber system; convey heavy fraction to storage pile	90 to 95[g]	300,000[g]	92,000[g]	b	Withdraw lighter material by cyclone(s)/scrubber system; convey heavy fraction to storage pile
	Enclosure (conveyor with telescopic chute)	(See 2.1.3)	(See 2.1.3)	(See 2.1.3)	(See 2.1.3)	
(5) Conveying of ferrous material onto open storage pile	Adjustable conveyor plus wet suppression	50[h] to 85[h]	1,200[h]	3,000[h]	b	Adjustable conveyor plus wet suppression
	Enclosure (conveyor with telescopic chute)	(See 2.1.3)	(See 2.1.3)	(See 2.1.3)	(See 2.1.3)	
(6) Ferrous scrap stockpile	Wet suppression	50[h]	1,200[h]	3,000[h]	b	Wet suppression
	Wind screens	Very low	a	a	b	
	Enclosures	95 to 99[i]	300,000,000[j]	a	b	
(7) Ferrous material handling and loadout	Operational control procedures and wet suppression	50[h] to 85[h]	1,200[h]	3,000[h]	b	Operational control procedures and wet suppression
	Enclosure (conveyor with telescopic chute)	(See 2.1.3)	(See 2.1.3)	(See 2.1.3)	(See 2.1.3)	
(8) Nonferrous material stockpile (if stored on-site)	Wet suppression	50[h]	1,200[h]	3,000[h]	b	Wet suppression
	Wind screens	Very low	a	a	b	
	Enclosures	95[i] to 99[i]	300,000[j]	a	b	
(9) Nonferrous material handling and loadout	Operational control procedures and wet suppression	50[h] to 85[h]	1,200[h]	3,000[h]	b	Operational control procedures and wet suppression
	Enclosure (conveyor with telescopic chutes)	(See 2.1.3)	(See 2.1.3)	(See 2.1.3)	(See 2.1.3)	

(continued)

TABLE 2.15-1 (continued)

[a] No costs available.

[b] Cost benefit not calculated due to lack of emission factor.

[c] Reference 3 and 4. Capital expenditure includes 1/8 inch thick carbon steel Venturi scrubber, elbow, separator, pumps, and controls (flange-to-flange). Operating costs based on approximately 50,000 acfm and 20 inch (ΔP) pressure drop.

[d] Estimated efficiencies based on process observation and engineering judgment. Smoke produced from friction created during shredding and resulting ignition of the fibrous upholstery material.

[e] Reference 1. Based on approximately 60,000 tons of scrap produced annually and an estimated prehandling cost of the compacted autos of $2 per ton.

[f] Reference 5. Estimated dust control efficiency (75 percent) by manufacturer for adapting water spray system within dry shredding mill. Installed capital cost averaged from estimated $25,000 to $75,000 by manufacturer. System operation would be automatic. Labor required (on a daily basis) would be that needed to start and stop the system. Labor determined at $13 per man-hour. Annual operating costs include direct and fixed charges.

[g] References 4, 6, and 7. Control system efficiency based on engineering judgment. System capital turnkey costs are for (2) cyclones with 3/16 inch thick carbon steel, 4 inch thick refractory lining, and intake velocity of approximately 50,000 acfm plus (1) wet scrubber (as addressed earlier - footnote c). Cyclone(s) direct installation cost was based on 130 percent of initial equipment price. Annual operating costs include direct and fixed charges. Direct operating costs were determined at 11 percent of the cyclone installed capital cost.

[h] References 4 and 8. Capital cost based on estimates for installation of required water piping and a hose station. Annual operating costs include direct and fixed charges.

[i] Estimates based on engineering judgment.

[j] References 1, 8, and 9. Storage enclosure volume would need to be at least 500,000 ft^3 based on a maximum pile size of 200 ft x 100 ft x 25 ft. Capital expenditure averaged from $3.95 to $9.38 per ft^3.

control effectiveness and costs. The more significant problems associated with auto shredding operations involve curbing the emissions generated from the trucking of autos, from the shredder itself and in handling of the nonferrous material. Vehicular movement of front-end loaders and trucks over unpaved surfaces also may cause a major fugitive dust problem. A variety of methods are available for control of fugitive dust from materials handling operations and unpaved road dust. These methods are discussed in detail in Sections 2.1.1 and 2.1.3.

For accidental fires at torching stations, fire extinguishers may be used to put out fires and, thereby, eliminate smoke generation. Proper torching practices should also be employed to prevent such fires.

The use of venturi scrubbers is common to metal salvage facilities. Pneumatic pick-up of and venting the dust (including fibrous "fluff" material) to the scrubber aids in controlling shredder fugitive losses. Also, wet shredding can serve to suppress much of the particulate problem.[5] Internal sprays can be adapted to "dry" shredder systems resulting in improved dust control.[5] Friction created in operating either system (wet or dry) can ignite combustible materials contained within the vehicles. Removal of motors and transmissions containing combustible fluids can help to eliminate explosions and decrease the high opacity problem from blue smoke. Motors and transmissions can be fed separately into the shredder, after they have been drained of their combustible fluids. Precautionary measures of this type can result in fewer shutdowns from explosions and fire, resulting in greater productivity.

Magnetic separation and conveyor (belt) transfer points also generate fugitive dust emissions. Auto shredding facilities control these sources through the use of low-energy cyclone/wet scrubber systems. These systems also aid in the separation/removal of lighter nonferrous scrap material. The material collected (by the cyclone) is stored prior to disposal and the heavier nonferrous material fraction is conveyed to storage prior to byproduct recovery. Enclosure is an efficient alternative to the cyclone/scrubber system for controlling these emissions, but is not common in the industry due to its initial high cost.

In the handling of ferrous and nonferrous materials both to and from storage, enclosure techniques show the greatest potential as a fugitive dust control measure. In addition, conveyors can be adjusted to decrease the material free-fall distance and minimize the dust generation. Wet suppression measures can also be used to control product and nonferrous material loss.

Windblown losses from scrap material storage piles can be controlled via numerous techniques. These include enclosure, wind screens, and wetting. These techniques have been addressed in Section 2.1.2.

2.15.5 Recommended Reasonably Available Control Measures (RACM)

The recommended RACM are designated in Table 2.15-1 for control of fugitive emission sources from metal salvaging operations.

It is recommended that accidental fires at torching operations be prevented by the use of good operating practices. Also, the use of fire extinguishers to promptly put out fires is recommended.

The recommended control technique for shredding operations is again implementation of the program to remove all combustible fluids coupled with the use of wet shredding and venting the shredder to a wet scrubber. These techniques have been used in the industry and are very effective in reducing fugitive particulate emissions.

The recommended control technique for magnetic separation and conveying operations is the use of a cyclone/wet scrubber system on the basis that it is an effective technique already in use in the industry.

Handling both the ferrous and nonferrous materials to and from storage can be effectively controlled using adjustable conveyors to reduce free-fall distance coupled with wet suppression prior to loading/loadout to reduce windage losses. Wet suppression is also recommended as the control technique for reducing windage losses from the storage piles.

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2.16 PULP AND PAPER MILLS

2.16.1 Process Description

The basic process for production of paper involves the destruction of lignin that binds the cellulose fibers of wood together. The cellulose fibers (or pulp) are the raw materials from which paper and cardboard products are produced.

Several different chemical processes are used to dissolve the lignin. The major processes are sulfate (Kraft) pulping, sulfite pulping and neutral sulfite semichemical (NSSC) pulping. The processes differ somewhat in the steps used in the pulp process, but all start out with wood chips as basic raw material.

Wood chips may be purchased from an outside source or may be produced on site. The logs are first debarked using mechanical means. The debarked logs are then cut at a 45 degree angle to the grain in a high-speed chipper, producing chips of a size of about 1 inch by 1 inch by 3/16 inch. The chips are then screened for proper sizing and stored for subsequent use. The prepulping steps are illustrated in Figure 2.16-1 with the potential fugitive dust sources indicated.

As the first step in the pulping process, the chips are conveyed to a digester where they are "cooked" with the lignin-dissolving chemicals. It is at this point that the pulping processes vary, since several different chemicals may be used to dissolve the lignin. From a fugitive dust standpoint, the remaining process steps, in any of the pulping processes, are all "wet" operations; and, therefore, are not fugitive sources.

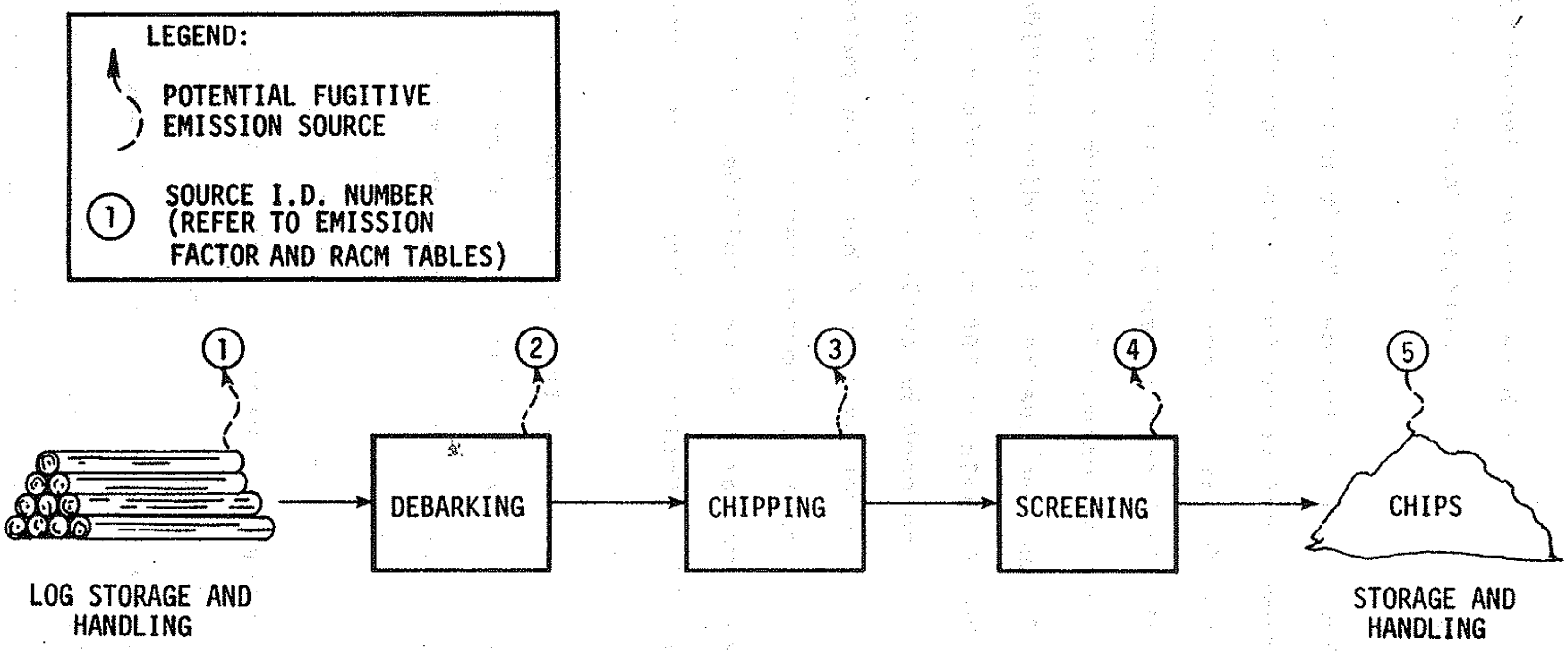

Figure 2.16-1. Simplified process flow diagram for raw material preparation for wood pulping processes at pulp and paper mills, and associated fugitive particulate emission sources.

However, for informational purposes, a brief process description of the major pulping process in the U.S., sulfate (Kraft) pulping, is provided.[1]

Figure 2.16-2 is a flow sheet of typical Kraft pulp mill operations showing the recovery and recycling of the valuable sodium salts. Wood chips are fed into a continuous digester countercurrent to a fresh chemical stream (called white liquor) containing about 21 percent active chemicals, of which three quarters is sodium hydroxide and one quarter is sodium sulfide in water solution. The digester is held at 100 to 135 psig and 338° to 347°F.[2] Time required for the cooking cycle is from 1 hour for unbleached brown pulp to as much as 5 or 6 hours for pulps that are to be bleached.[2] The cooking process causes formation of malodorous sulfide gases, such as hydrogen sulfide, methyl mercaptan and dimethyl sulfide. Venting of these gases gives a kraft mill its typical sour odor.

The contents of the digester exit through a "blow tank," where steam and noncondensibles are flashed-off, and cooked chips are sent to a filter that separates the pulp from the spent cooking liquor, now called "black liquor". The pulp passes on for further refining and possibly bleaching before it is pressed, dried and sold as pulp or made into paper or other products.

Satisfactory economics for the Kraft process require efficient recovery of sodium and sulfur values from the black liquor, as depicted on the flow sheet. The organic sulfides, also called "reduced sulfur" or "mercaptans", are often oxidized as an air

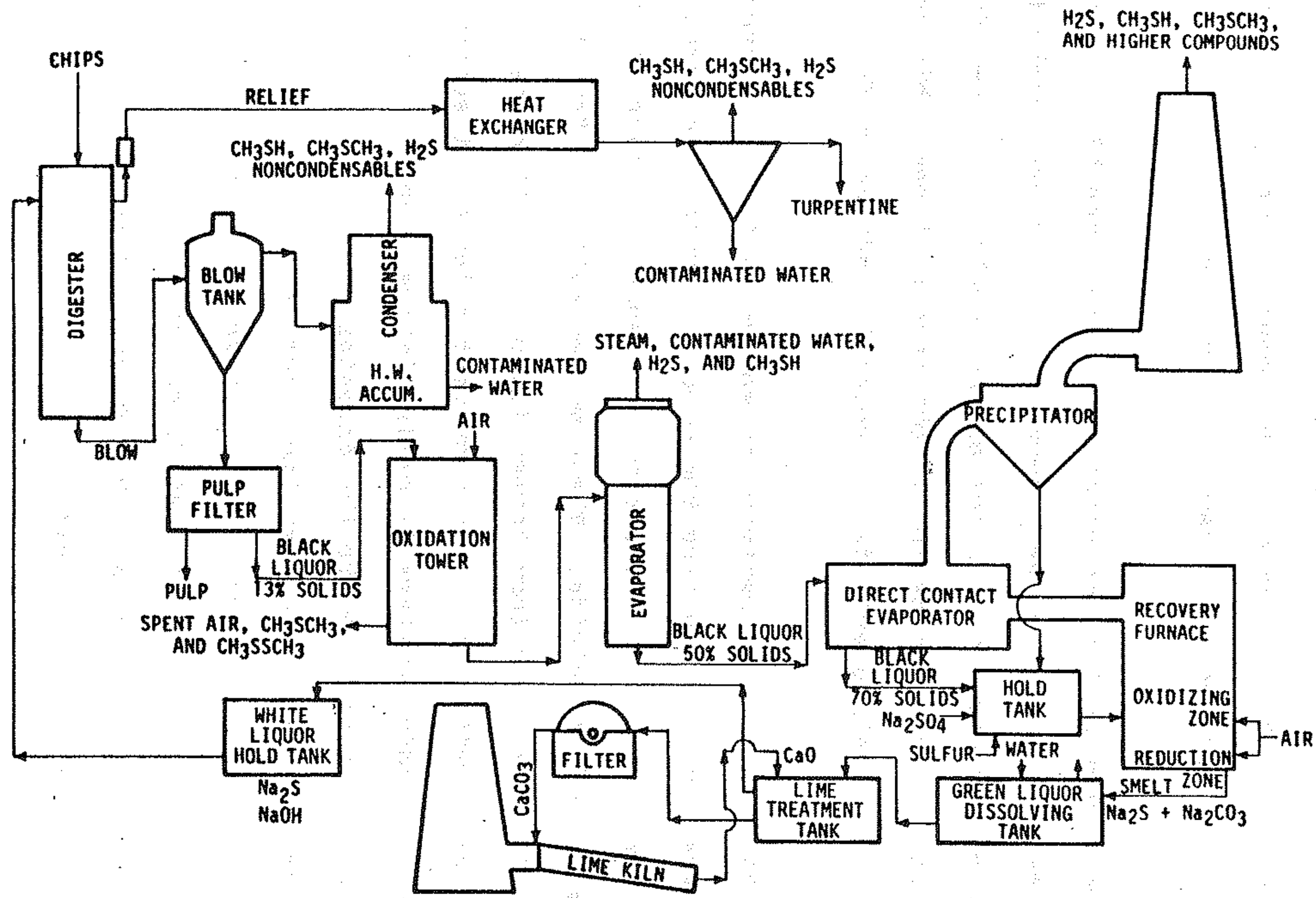

Figure 2.16-2. Typical kraft sulfate pulping and recovery process.

pollution control measure to render them less volatile and, thus, diminish loss when a direct contact evaporator is used in subsequent steps. The black liquor is then concentrated to 50 percent solids in a multiple-effect evaporator and pumped to the recovery furnace.

Where direct contact evaporation is used, the black liquor is concentrated in the recovery furnace to 70 percent combustible solids by countercurrent flow against hot combustion gases from the furnace. If good oxidation is obtained upstream, this unit will emit only small quantities of volatile reduced sulfur compounds.

The black liquor concentrate is sprayed into the recovery furnace, where the carbon from the wood is burned, the remaining water is evaporated and the sodium is changed to molten sodium carbonate or sodium sulfide. These molten salts, or "smelt", are redissolved in water to form "green liquor", and then are clarified and causticized with lime. The resultant solution of sodium hydroxide and sodium sulfate is called "white liquor". The "white liquor" is recycled to the digester.

The calcium carbonate resulting from causticizing is filtered from the "white liquor" and is passed on to an oil- or gas-fired kiln. Entering the kiln at 35 percent moisture, the calcium carbonate is dried and then decomposed at about 2370°F to calcium oxide and carbon dioxide.

2.16.2 Fugitive Dust Emission Factors

Little data exists on the quantity of fugitive emissions from debarking, chipping and handling operations at pulp mills. One source estimates that there are negligible emissions from log handling operations.[3] This would seem reasonable especially in cases where the logs are received in a wet state, a common occurrence at pulp mills. The emission factor for log debarking is estimated as 0.024 pounds per ton of logs debarked.[4] This estimate is cited as an order-of-magnitude number. If the log debarking operation is carried out on wet logs or a wet process is used (i.e., drum barkers, bag barkers or hydraulic barkers), the emissions would be insignificant. No emission factors could be located for the chipping, screening, handling or storage operations. However, due to the large size of the chips (1" x 1" x 3/16"), it is probable that these operations do not result in significant, airborne emissions.

Perhaps the most significant source of fugitive emissions at pulp and paper mills would be lime storage, handling and transfer operations. These operations are essentially the same as for lime plants and are described in Section 2.3. Another source of fugitive dust at pulp and paper mills is plant haul roads. Proper evaluation of this source is detailed in Section 2.1.

2.16.3 Particle Characterization

No data are available on the characteristics of fugitive particulate emissions from pulp and paper mills. The particles would consist of the wood being processed as well as dirt and dust adhering to the wood and bark from previous handling. The characteristics of the lime dust generated are described in Section 2.3.3.

2.16.4 Control Methods

No specific data are available on control methods for the wood debarking, chipping, screening, handling and storage operations - if, indeed, there is any necessity for control. The control techniques generally applicable to materials handling and storage operations are described in Sections 2.1.2 and 2.1.3. However, it should be emphasized that, if the logs are in a wet state, this in itself is a good control technique.

Control techniques for lime handling operations are described in Section 2.3.4.

2.16.5 Recommended Reasonably Available Control Measures (RACM)

Given the lack of data on fugitive emissions from pulp and paper mills, no specific control measures can be recommended for the potential fugitive sources. General control techniques applicable to the various operations are described in the sections on materials handling, materials storage and plant roadways. However, it is probable that the log handling and storage, debarking, chipping, screening and chip handling and storage operations are insignificant sources of fugitive particulates, and based upon this, no control is recommended for these operations.

RACM for the lime operations are given in Section 2.3.5.

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2.17 WOODWORKING OPERATIONS

2.17.1 Process Description

This category includes any woodworking operation that emits fugitive particulate matter, such as wood shavings, sanderdust and sawdust, during the processing of wood, bark, or any wood byproducts. Such woodworking operations may include debarking, sawing, planing, chipping, shaping, moulding, hogging, latheing, drilling, carving and sanding. These operations are found in the following industries: sawmills; plywood, particleboard, and hardboard plants; and furniture and miscellaneous wood product manufacturing plants.[1]

Because of the large number of industries using woodworking operations and the large number and variety of woodworking equipment employed, a complete process description of each is beyond the scope of this study. However, a brief process description of the lumber and furniture manufacturing industry, which employs a wide range of woodworking equipment, will be discussed as a representative example.

A furniture manufacturing plant may use either logs or cut lumber as a raw material. The choice usually depends on the volume and type of final product manufactured. In either case, a sawmill is used for the primary processing of cut wood.[2]

Cut wood is transferred from the forest to the sawmill by truck, or floated down a river or towed by tugs in the form of "log booms or rafts". It is stored at the sawmill by either stacking on the ground or by using a log pond.[3] For ease of handling, the larger logs are cut to smaller lengths in a process called bucking.

The logs are then debarked by using any one of the five following types of machines: drum barkers, ring barkers, bag barkers, hydraulic barkers and cutterhead barkers. The ring and cutterhead barkers are dry processes, whereas the other three are wet processes using water.

After the logs are cut to certain lengths, they are cut lengthwise into standard sizes.

After this cutting process, the lumber is dried in the ambient air or in a kiln, and then transferred to the furniture manufacturing plant.[4]

At the furniture manufacturing plant, additional air or kiln drying of the lumber may be provided. The kiln drying is necessary in order to prevent the warping or shrinking of furniture due to the high moisture content in natural wood. Natural wood contains approximately 60 to 70 percent moisture while kiln-dried wood contains about 5 to 8 percent moisture.[5]

At furniture manufacturing plants, there are five main processing areas. These are 1) rough milling, 2) finish milling, 3) sanding, 4) assembly and 5) finishing.[6]

In the rough milling area, the lumber is cut to the approximate, required dimensions, and natural defects are removed. The woodworking operations normally used here include sawing, planing and molding.

Finish milling, which further refines the lumber, may include such woodworking operations as sawing, shaping, lathe work, mortising, and routing.

Sanding is used to create a smooth wood finish. It is usually performed by sanding machines rather than by hand.

The assembly operation usually consists of gluing and stapling wood pieces together, assemblying the pieces and performing minor hand sanding if necessary.

The finish operation usually consists of applying surface coatings to the products and drying. In the final step, the finished furniture is inspected and then packaged and shipped to the customer.[7]

Woodworking operations, such as planing, sanding and sawing, at furniture manufacturing and other miscellaneous wood processing plants, are normally performed indoors and have pneumatic transfer systems for removing wood waste from the work area. Such systems are necessary in woodworking operations in order to remove the tremendous quantity of wood waste that would otherwise accumulate. They also are a convenient transport system to collect wood waste at a central collection point for ultimate disposal. These pneumatic transfer systems usually consist of hooding devices which have scooped openings that capture wood waste from woodworking equipment as it is thrown out. The hooding devices are ducted to either cyclones and/or fabric filters. An exhaust fan is employed to provide the necessary draft to pick up most of the wood waste. Bins are used to store the wood waste which is captured by the cyclone and/or fabric filter.

Large diameter cyclones are used more extensively than fabric filters. This is primarily because such devices are relatively inexpensive, require little maintenance and have moderate power requirements. Fabric filters are generally used in woodworking operation exhaust systems where a significant amount of fine dust such as wood flour or sanderdust is encountered, or where dust nuisances cannot be tolerated. Fabric filters are very efficient in capturing wood waste and are often used in conjunction with less efficient collectors such as cyclones or impingement traps which remove most of the larger wood particles.[8,9]

The design of a cyclone collector is based on the air volume and type of wood waste being handled. At woodworking operations where sanderdust waste predominates, high efficiency cyclones with diameters of less than 3 feet are used. For woodworking operations where larger wood waste predominates, cyclones with diameters up to 8 feet are effective. However, many operations employ a wood/bark hogging machine to reduce the particle size for ease of transport and/or for use in wood-fired boilers (see Figure 2.17-1). For woodworking operations generating varying sizes of wood wastes, cyclones with intermediate diameters are used.[10,11]

The wood waste which escapes the pneumatic transfer system is generally insignificant, as is that which escapes through building doors, windows and ventilation systems. Therefore, individual woodworking operations which are used at a furniture manufacturing plant and other wood processing plants have negligible fugitive emissions and are not considered in this study.[13] Furthermore, for any woodworking operation, which is performed indoors and which employs a pneumatic transfer system and cyclone for wood waste removal, the source of emissions is usually considered to be the cyclone rather than the individual woodworking operations. The cyclone is, therefore, considered as the "source operation" and is a point source.[14]

A process flow diagram for lumber and furniture manufacturing as well as plywood and particleboard manufacturing is illustrated in Figure 2.17-2. The figure identifies each potential source of fugitive dust. Those sources are as follows: for sawmills - log debarking, sawing and sawdust pile loading, unloading and storage; and for furniture, plywood or particleboard manufacturing, or any similar woodworking operation - log debarking (at veneer/plywood manufacturing plants), wood waste storage bin vents and wood waste storage bin loadouts. Another potential source of fugitive dust, which is not discussed here, is plant roads. This source is covered in Section 2.1.1.

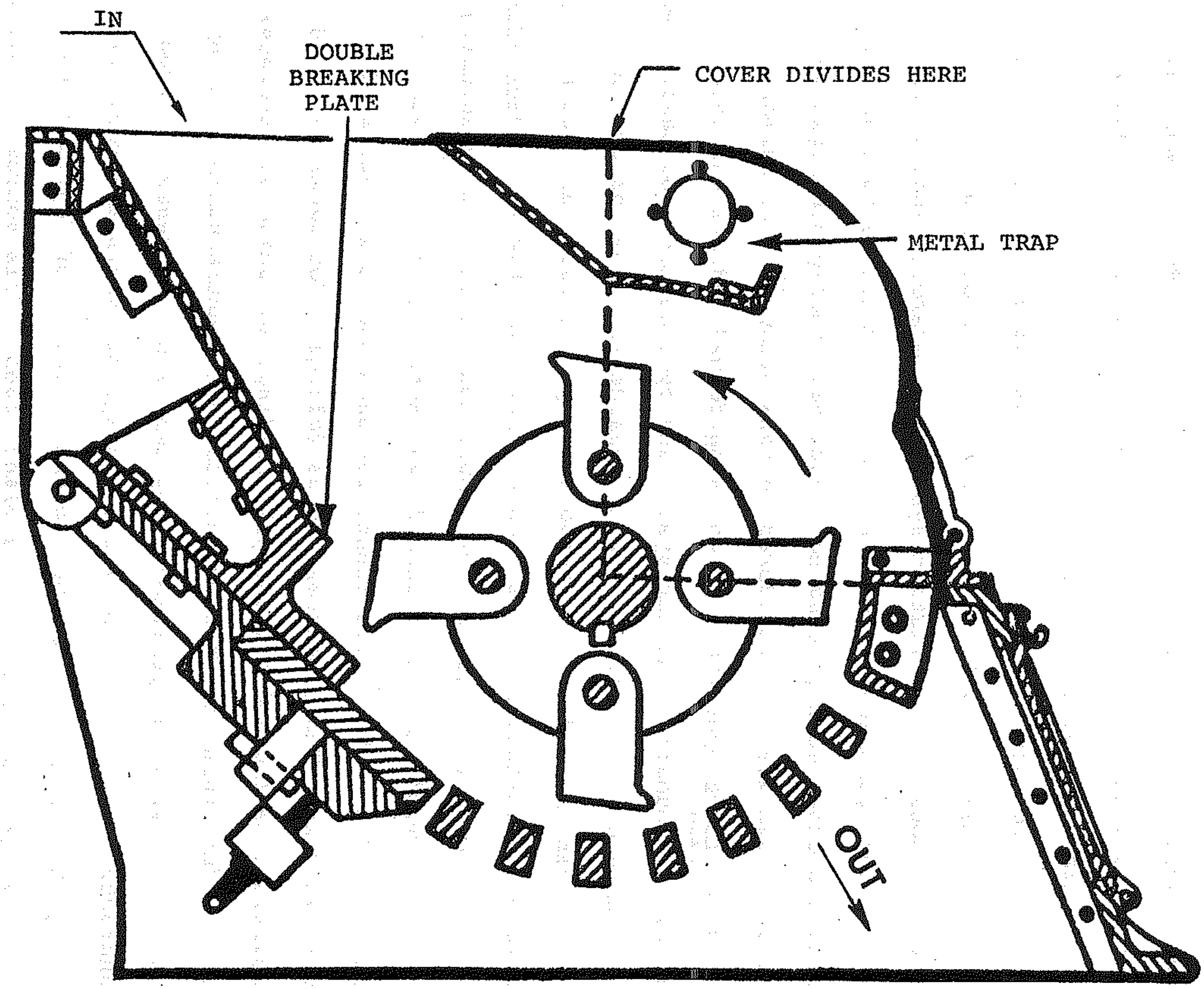

Figure 2.17-1. Cross-section of a typical wood hogging machine.[12]

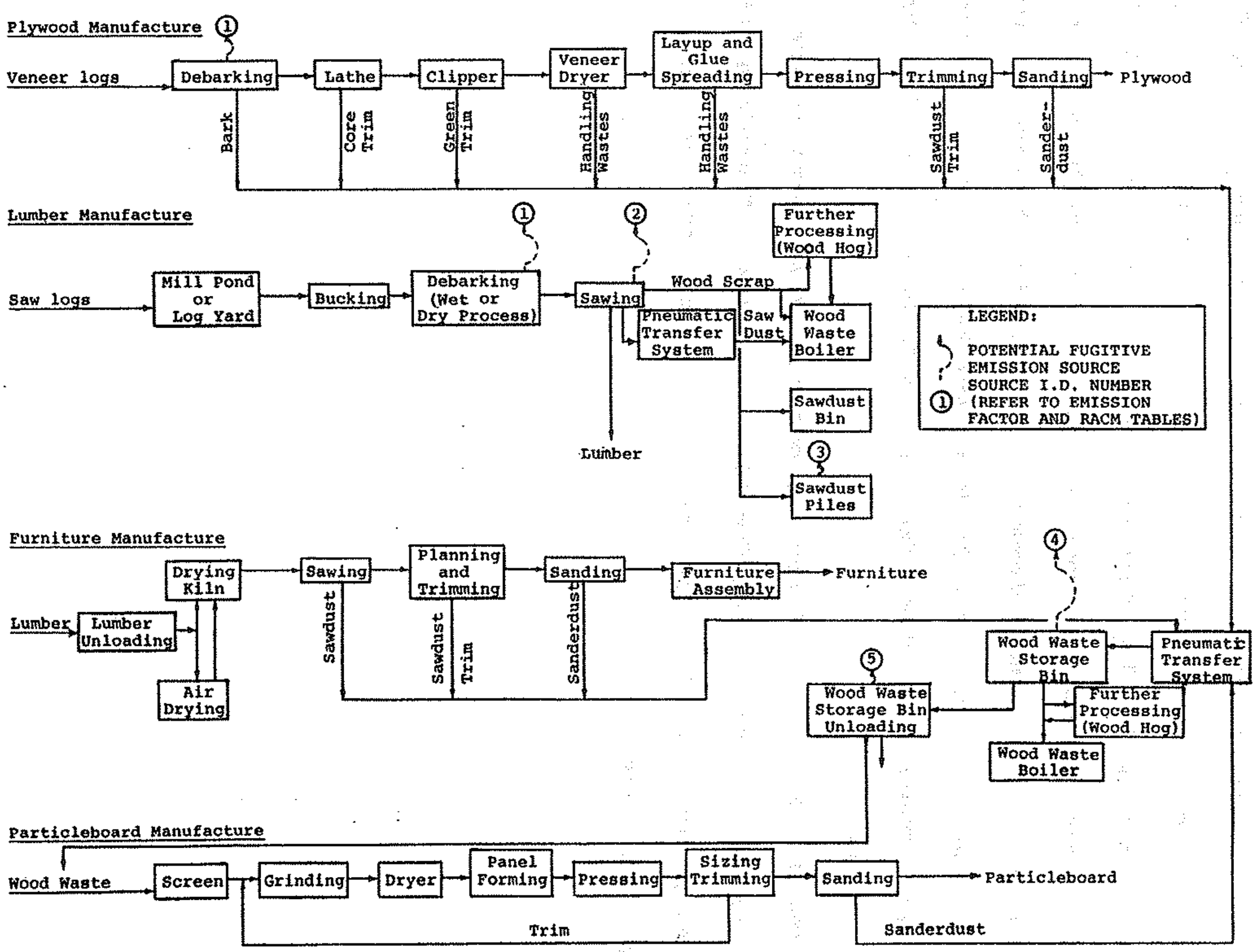

Figure 2.17-2. Simplified process flow diagram for woodworking operations at several wood product manufacturing plants and associated fugitive particulate emission sources.[15,16]

2.17.2 Fugitive Dust Emission Factors

The estimated emission factors for various woodworking fugitive particulate emission sources are summarized in Table 2.17.1. The emission factors for log debarking, sawing, and sawdust pile loading, unloading and storage are rough estimates that are based on material balance and engineering judgment. The emission factors for wood waste storage bin vents and loadouts are based on only engineering judgment. Therefore, these factors should be considered to have a poor reliability.

The log handling and bucking operations at sawmills are considered to be negligible sources of fugitive emissions. Therefore, these operations are not identified as fugitive dust sources, and no emission factors are presented.

TABLE 2.17-1 FUGITIVE DUST EMISSION FACTORS FOR WOODWORKING OPERATIONS

	Source	Emission factor	Reliability rating	Reference
(1)	Log debarking (sawmills)	0.024 lb/ton logs debarked	E	17
(2)	Sawing (sawmills)	0.35 lb/ton logs sawed	E	17
(3)	Sawdust pile loading, unloading and storage (sawmills)	1.0 lb/ton wood waste stored	E	17
(4)	Wood waste storage bin vent	1.0 lb/ton wood waste stored	E	17
(5)	Wood waste storage bin loadout	2.0 lb/ton wood waste loaded out	E	17

2.17.3 Particle Characterization

The fugitive particulate emissions from sawmills consist primarily of broken bark particles and sawdust from sawing operations. In addition, fugitive particulate emissions occur from dirt and dust which are embedded in the bark of logs and become airborne during unloading, dragging, debarking and storage operations.[18]

There is very limited data available on the particle size of fugitive emissions from sawmill operations. One study reported that approximately 91 percent of the particulate matter generated from sawmill operations at lumber yards is larger than 991 microns in diameter and that few of these sawdust particulates would be less than 30 microns in diameter. Thus, it is highly probable that few of these particulates would remain suspended in the ambient air for a significant amount of time.[19]

There is also very little published data available on the particle size of fugitive emissions from furniture manufacturing or other plants. One study was found regarding a western red cedar furniture manufacturing plant which was equipped with a pneumatic exhaust system on the majority of woodworking operations. It was found that most of the suspended particles in the plant environment had a particle size diameter of less than 2 microns.[20]

The particle size of the wood waste generated by woodworking operations varies and can be less than 1 micron in diameter or up to several inches long. The particle size of wood waste from such woodworking operations is dependent on a number of factors such as the type of operation, the type of wood processed and the sharpness of the cutting tools used.[21]

The type of operation significantly affects the particle size of wood waste generated. For example, a hammermill-type wood hog will emit particles of all sizes, while a sander will generate only fine particles. Wood waste particles from other types of machines are generally larger in size, have greater uniformity than the above equipment and have a particle size that is seldom less than 10 microns in diameter.[22]

The type of wood processed also affects the particle size of the wood waste generated. For instance, hardwoods usually will tend to splinter and break into smaller particles than softwoods, which tend to tear and shred.[23]

The sharpness of the cutting tools used affects the wood waste particle size, since dull cutting tools tend to increase the tearing and shredding of the wood thereby resulting in larger particle sizes.[24]

For a comparison of the relative particle sizes of wood waste, Table 2.17-2 gives approximate size ranges for the typical components of wood residue used as fuel in boilers.

TABLE 2.17-2. APPROXIMATE SIZE RANGE OF TYPICAL COMPONENTS OF WOOD FUEL

Component	Size range, inches
Bark	1/32 - 4
Coarse wood residues	1/32 - 4
Planer shavings	1/32 - 4
Sawdust	1/32 - 3/8
Sanderdust	2 μ^a - 1/32
Reject "mat finish"	10 μ^a - 1/4

[a] Small end of the range is measured in microns.

Fugitive particulate emissions from woodworking operations are generally considered to be non-hazardous with respect to health, property and welfare; however, such emissions can create nuisance problems under certain conditions. In any case, the proper collection and disposal of wood waste from woodworking operations employing lumber that has been treated with a toxic preservative such as pentachlorophenol should always be practiced. Pentachlorophenol is a hazardous chemical and is a known carcinogen.[26]

2.17.4 Control Methods

This section will describe all known control methods for the fugitive dust sources identified in this study. The control methods described will include those which are typical in the industry, those which are in use but not typical in the industry and those which are technically feasible but not in use by the industry.

Log debarking operations at sawmills using wet process debarking, such as drum barkers, bag barkers and hydraulic barkers, usually do not require any additional control methods for fugitive emissions. If further fugitive emission control is required, the logs could be kept in wet storage prior to debarking. For sawmills which already employ log ponds, the logs may simply be kept in such ponds until they are required at the debarking operation. For those sawmills which require addtional control and do not employ log ponds, a wet storage pond could be installed. Log debarking operations which use dry processes, such as ring and cutterhead barkers, can be controlled by wet storage of the logs prior to debarking. For dry and wet process debarking operations which require additional control, or if wet storage is not possible, the debarking operation may be totally enclosed or fixed hoods may be installed with aspiration to either a cyclone or fabric filter. However, the use of a cyclone or fabric filter to control log debarking operations is not in use by the industry, although it is a technically feasible control technique. In summary, for both wet and dry process debarking, there is no typical control technique currently used by the industry for control of fugitive emissions. In fact, the majority of such operations employ no control technique whatsoever.[27]

For fugitive emissions from sawing operations at sawmills, the typical control technique used by the industry is hooding with aspiration to a cyclone. Also, the use of a fabric filter in place of a cyclone is a technically feasible control alternative, although it is not generally used in the industry. Lastly, the use of thinner saw blades will help reduce the amount of fugitive emissions generated and will result in an economic benefit through the more efficient use of lumber.[28]

Fugitive emissions from sawdust pile loading, unloading and storage may be controlled by the use of wet suppression techniques, although this is not a typical control technique used by the industry. Generally, the most typical control technique used by the industry is to remove the sawdust as soon as possible, and thus, minimize the size of the sawdust storage pile. For facilities which have wood-fired boilers or a manufacturing process which uses wood waste (i.e., particleboard facility), sawdust pile loading, unloading and storage may be partially or totally eliminated by directly blowing the sawdust from the pneumatic transfer system to such boiler or process. For those sawmill operations which do not have such boilers or processes or are not able to directly blow sawdust into a boiler or process, the early removal of sawdust from the site should be practiced.[29]

In recent years, sawmills, as well as other generators of wood waste, have found it easier to dispose of the wood waste generated by the manufacturing operations. Traditionally, wood waste from operations employing kiln-dried wood has had high sales value, while "green" wood waste has been essentially worthless. At the present time, "green" wood waste is increasingly being used for fuel in wood-fired boilers as well as for certain manufacturing operations (e.g., the production of pressed-wood pallets).

Early removal of sawdust can be made possible by notifying potential users of its availability. As an example of the potential market for such waste, one source cites the following productive uses:

1. plastic bulking agent for products such as plastic wood, masonite, etc.;
2. pressed woods such as firewood, fiberboard, Firtex, and others;
3. soil additives;
4. smokehouse fuel (hardwood sawdust is burned to produce smoke in the processing of bacon, ham, pastrami, etc.);
5. floor sweep (sawdust with and without oil is spread on floors before they are swept to help hold dust particles);
6. woodfiller (sawdust can be mixed with water resins and other liquids and used as wood filler);
7. floor cover in butcher shops, restaurants, etc.; and
8. waste heat boilers (heat can be recovered from incinerator flue gases to generate steam, hot water, etc.).[30]

Finally, the control techniques and precautions presented in Section 2.1.2 may be adaptable to sawdust storage.

As was stated earlier in this report, the sawing, planing, sanding and other miscellaneous woodworking operations are usually performed indoors without any fugitive emissions escaping and are controlled by pneumatic transfer systems.

Fugitive emissions from wood waste storage bin vents are often partially controlled by screens. Greater emission reduction may be achieved if this screen is replaced with a simple unaspirated fabric filter (cloth tube filter). Figure 2.17-3 illustrates such a system as installed and used on a cement silo.[31]

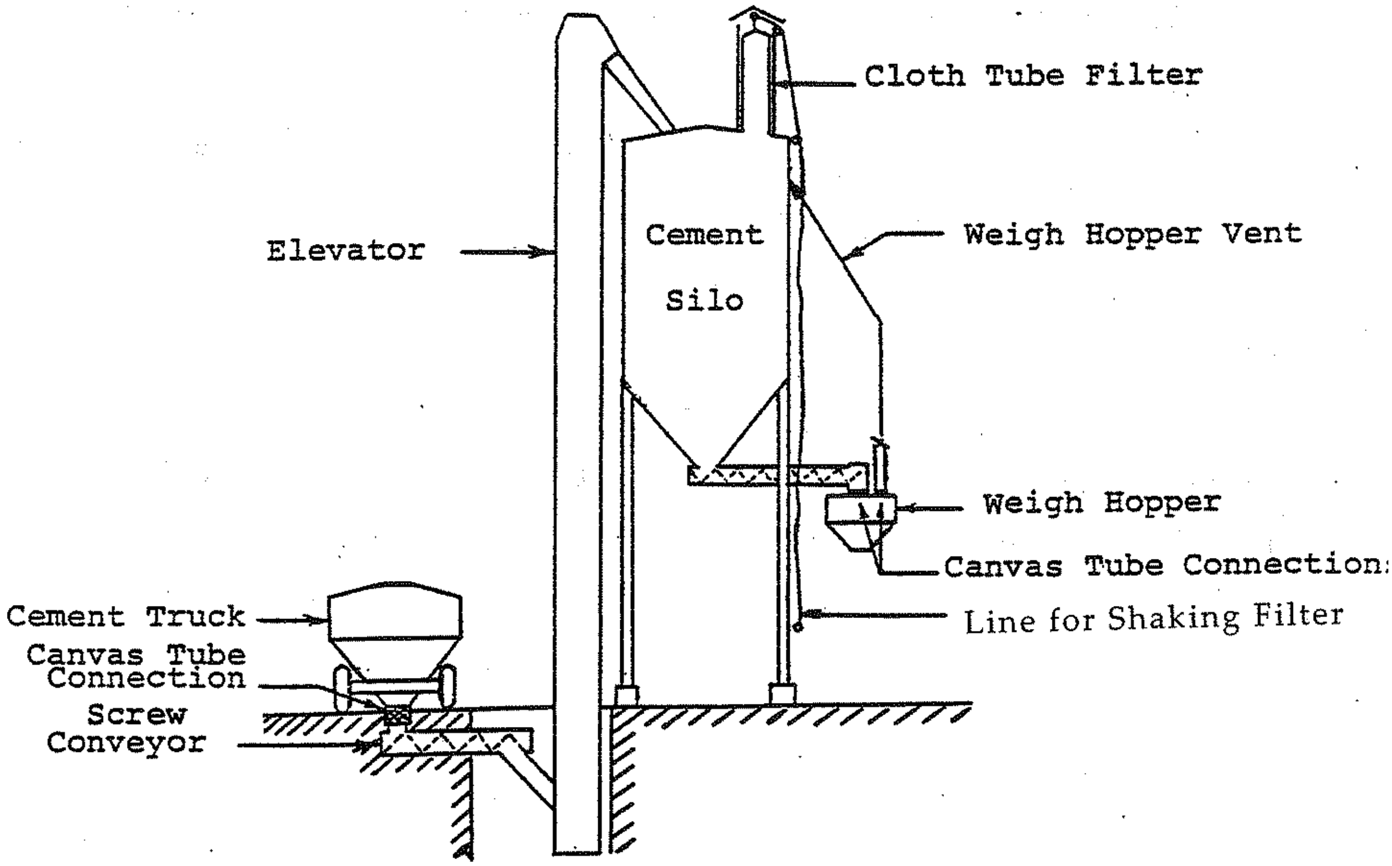

Figure 2.17-3. Cement-receiving and storage system.[31]

For fugitive emissions from wood waste storage bin loadouts, emission reduction may be achieved by the use of telescopic tubes during loadout from the storage bins to trucks. Telescopic tubes reduce the freefall distance and thereby reduce fugitive emissions.

Telescopic tubes used in conjunction with a canvas-covered truck and side curtains will provide additional control. Greater fugitive emission control may be obtained by enclosing the loadout area as much as possible or by using such an enclosure with ventilation to a cyclone or fabric filter. Generally, some type of chute is used by the industry for such operations. However, it is usually not as adjustable as a telescoping chute, and does allow a greater quantity of fugitive emissions.[32]

The control techniques, efficiencies and estimated costs, and RACM selections are summarized in Table 2.17-3.

2.17-5 Recommended Reasonably Available Control Measures (RACM)

The RACM selections for woodworking operation fugitive emission sources are presented in Table 2.17-3.

No control measure is recommended for log debarking. The cost benefit of all of the control alternatives is unreasonable due primarily to the relatively small amount of fugitive emissions generated from such operations.

For those sawing operations at sawmills which emit fugitive particulates into the ambient air, the selected control technique is hooding with ventilation to a cyclone. Although the cost benefit ($2.40/lb) of this control option is high, economies of scale often can be attained by ducting other woodworking operations to this system without decreasing efficiency to any significant degree. Furthermore, many sawmills currently employ such a system.

The selected control technique for sawdust pile loading, unloading and storage at sawmills is the use of telescopic tubes to reduce the free fall distance of the wood waste. Several precautionary control measures, as identified in Section 2.1.2, are also recommended for this source. For example, the use of wind breaks also helps to reduce the potential for fugitive emissions.

TABLE 2.17-3. A SUMMARY OF THE CONTROL ALTERNATIVES, EFFICIENCIES AND COSTS, AND THE RACM SELECTIONS FOR FUGITIVE DUST EMISSIONS FROM SOURCES IN WOODWORKING OPERATIONS

Fugitive dust sources	Control alternatives	Control efficiency, %	Control costs, Jan. 1980 $		Cost benefit, $/lb	RACM selection
			Capital	Annualized		
(1) Log debarking (sawmills)	Wet storage of logs prior to debarking	95[a]	173,000[b]	21,500[c]	51.0	No control
	Enclosure	100	15,000[d]	2,600[d]	5.83	
	Hooding, vent to cyclone	80[a]	166,000[e]	26,000[f]	92.0	
	Hooding, vent to fabric filter	99[g]	306,000[h]	126,600[i]	287.0	
(2) Sawing (sawmills)	Hooding, vent to cyclone	80[a]	59,500[e]	10,900[j]	2.37	Hooding, vent to cyclone
	Hooding, vent to fabric filter	99[g]	122,000[h]	42,000[i]	7.43	
(3) Sawdust pile loading, unloading and storage (sawmills)	Wet suppression	50[a]	24,500[k]	7,300[l]	5.86	Telescopic tubes
	Enclosure (silo)	100	260,600[m]	34,900[n]	14.00	
	Telescopic tubes	75[o]	8,560[o]	1,150[p]	0.61	
(4) Wood waste storage bin vent	Screens	Unknown	-	-	NA	Fabric filter (non-aspirated)
	Fabric filter (non-aspirated)	99[g]	5,000[g]	670[n]	0.45	

(continued)

TABLE 2.17-3 (continued)

Fugitive dust sources	Control alternatives	Control efficiency, %	Control costs, Jan. 1980 $		Cost benefit, $/lb	RACM selection
			Capital	Annualized		
(5) Wood waste storage bin loadout	Telescopic tubes	75[o]	8,560[o]	1,150[p]	0.61	Telescopic tubes
	Enclosure (3-sided)	60[r]	27,700[r]	6,100[r]	3.39	
	Enclosure, vent to cyclone	80[e]	87,200[s]	17,000[s]	7.08	
	Enclosure, vent to fabric filter	99[g]	149,700[t]	48,100[t]	16.20	

(continued)

TABLE 2.17-3 (continued)

[a] Estimate based on engineering judgment.

[b] Reference 33. Capital cost for wet storage (log pond) is based on the cost for a 100,000 sq.ft. primary clarification system.

[c] Annual operating and maintenance costs were assumed to be negligible. Annualized capital charges were estimated on the basis of a 30-yr. life and a 12 percent annual cost of capital.

[d] Reference 34. Based on 20' x 20' x 30' enclosure.

[e] Reference 35.

[f] Reference 35. Annual maintenance costs were estimated at $0.065/acfm, operating costs at $1.70/hr at 2000 hrs/yr. and capital charges were determined assuming a 20-yr. life and 12 percent cost of capital.

[g] Reference 36.

[h] Reference 37.

[i] Reference 38. Annual capital charges were based on a 20-yr. life and 12% cost of capital.

[j] Reference 35. Annual maintenance costs were estimated at $0.065/acfm, operating costs at $0.42/hr at 2,000 hrs/yr. and capital charges were determined assuming a 20-yr. life and 12 percent cost of capital.

[k] Reference 39. Estimated from Figure 4-5 at 12.5 tons/hr.

[l] Reference 40. Estimated from Figure 4-5 at 12.5 tons/hr. and 2,000 hours/yr of operation.

[m] Reference 41. Capital cost based on an average of $6.27/ft^3$ of enclosed storage.

[n] Includes capital charges only at 20-yr. life and 12 percent cost of capital.

[o] Reference 42.

[p] Includes capital charges only at 20-yr. life and 12 percent cost of capital.

[q] Reference 43. Estimate based on 50 to 60 ft^2 fabric filter.

[r] Obtained from Section 2.6, Table 2.6-3, for truck unloading.

[s] Based on capital and annual costs for 3-sided enclosure and comparable cyclone system as used for sawing at sawmills.

[t] Based on capital and annual costs for 3-sided enclosure and comparable fabric filter system as used for sawing at sawmills.

For the control of fugitive emissions from wood waste storage bin vents, a non-aspirated, fabric filter is recommended. This system is cost effective and is capable of achieving no visible emissions.

The selected control technique for wood waste storage bin loadouts is the use of telescopic tubes. This control alternative was selected due to its low cost effectiveness.

1. Compilation of Air Pollutant Emission Factors. U.S. Environmental Protection Agency, Office of Air and Waste Management, Office of Air Quality Planning and Standards. Publication No. AP-42. Research Triangle Park, North Carolina. April 1976. p. 10.4-1.

2. Technical Guidance for Control of Industrial Process Fugitive Particulate Emissions. EPA-450/3-77-010, March 1977. p. 2-332.

3. Jones, H.R. Fine Dust and Particulates Removal. Noyes Data Corporation. Park Ridge, New Jersey. 1972. p. 112.

4. Op. cit. Reference 2. p. 2-332.

5. Ibid.

6. Ibid.

7. Ibid. pp. 2-332 to 2-333.

8. Op. cit. Reference 1. p. 10.4-1.

9. Air Pollution Engineering Manual, Second Edition. Danielson, J.A. (ed.). U.S. Environmental Protection Agency. Research Triangle Park, North Carolina. May 1973. pp. 372-374.

10. Op. cit. Reference 1. p. 10.4-1.

11. Op. cit. Reference 9. pp. 373-374.

12. Control of Particulate Emissions from Wood-Fired Boilers. EPA-340/ 1-77-026. p. 2-4.

13. Op. cit. Reference 2. pp. 2-333, 2-336.

14. Op. cit. Reference 1. p. 10.4-1.

15. Op. cit. Reference 2. p. 2-334.

16. Op. cit. Reference 3. p. 112.

17. Op. cit. Reference 2. p. 2-335.

18. Op. cit. Reference 2. p. 2-336.

19. Ibid. pp. 2-336 to 2-337.

20. Ibid. p. 2-337.

21. Op. cit. Reference 9. p. 373.

22. Ibid.

23. Ibid.

24. Ibid.

25. Op. cit. Reference 12. p. 2-3.

26. Federal Register, Volume 43, No. 21 - Tuesday, January 31, 1978. p. 4109.

27. Op. cit. Reference 2. pp. 2-337, 2-338.

28. Ibid.

29. Ibid. p. 2-339.

30. Op. cit. Reference 9. pp. 374-375.

31. Ibid. p. 336.

32. Op. cit. Reference 2. p. 2-339.

33. Process Design Techniques for Industrial Waste Treatment. Associated Water & Air Resources Engineers, Inc. AWARE, Inc. Adams, C.E. and Eckenfelder, W.W. (eds.). Enviro Press, Inc. Nashville. 1974. p. 256.

34. PEDCo Environmental, Inc. Control Techniques for the Crushed and Broken Stone Industry, EPA Contract Nos. 68-01-4147 and 68-02-2603, Cincinnati, Ohio. July, 1974. p. 3-38.

35. GARD, Inc. Capital and Operating Costs of Selected Air Pollution Control Systems. EPA-450/3-76-014. May, 1976. pp. 3-1 to 4-89.

36. Op. cit. Reference 9. p. 373.

37. Nonmetallic Minerals Industries Control Equipment Costs. Industrial Gas Cleaning Institute for U.S. EPA under Contract No. 68-02-143. Task No. 19. February 1977. p. 3-3.

38. Ibid. p. 3-5.

39. Op. cit. Reference 37. p. 4-9.

40. Ibid. p. 4-12.

41. Op. cit. Reference 2. p. 2-40.

42. Fugitive Emissions from Integrated Iron and Steel Plants. EPA-600/2-78-050. March, 1978. p. 6-6.

43. Personal communication between Paul Norris, Kramer-Norris Equipment Company and James A. Cummings, Ohio EPA. January 22, 1980.

APPENDIX FOR SECTION 2.17

A typical sawmill and furniture manufacturing plant has the following production data:

Sawmill

Logs debarked: 3,400,000 bd-ft/yr or 18,587 tons/yr

Logs sawed: 16,320 tons/yr

Sawdust handled: 2,493 tons/yr

Furniture Plant (Supplied by the above sawmill)

Lumber usage: 3,000,000 bd-ft/yr or 4,500 tons/yr
Wood waste stored: 1,500 tons/yr
Wood waste storage bin loadout: 1,500 tons/yr

(1) Log debarking (sawmills)

a. Wet storage of logs prior to debarking:

$$\text{Capital cost} = \$100{,}000\ \frac{(249.6)}{(144.1)} = \$173{,}213 \text{ or } \approx \$173{,}000$$

Annual capital charges:

$$PV = R \cdot PVF$$
$$i = 12\%,\ n = 30 \text{ yrs.}$$

$$173{,}000 = R\ (8.055)$$
$$R = \$21{,}477 \text{ or } \approx \$21{,}500$$

$$C/B = \frac{\$21{,}477/\text{yr}}{\left(0.024\ \frac{\text{lb}}{\text{ton}}\right)\left(18{,}587\ \frac{\text{tons}}{\text{yr.}}\right)(.95)} = \$50.68 \text{ or } \approx \$51.00$$

b. Enclosure:

$$C/B = \frac{\$2.600/\text{yr}}{\left(0.024\ \frac{\text{lb}}{\text{ton}}\right)\left(18{,}587\ \frac{\text{tons}}{\text{yr}}\right)(1.0)} = \$5.83$$

c. Hooding, vent to cyclone: 20' x 10' rectangular canopy

acfm required = 1.4 PDV (Tech. Guidance..p. 3-16)
= 1.4 (60')(5')(200'/min)
= 84,000 acfm

Cost of control device (cyclone) and auxilaries:

Canopy

Plate area req'd (Fig. 4-17, Gard) = 500 sq.ft.
Assume 10 gage carbon steel, 1/4 in. plate
20% for structural supports
(500 sq.ft.)(5.625 lb/sq.ft.)(1.2) = 3,375 lbs.

Material cost = LG + $0.194/lb
= (20')($8/ft) + (0.194/lb)(3,375 lbs.)
= 160 + 654.75
= $814.75

Ducts (Assume 100' req'd)

The duct diameter necessary to keep a 4000 fpm exhaust velocity is:
(Air Pollution Engr. Manual, p. 373)

$$A = (84,000 \text{ cfm})(4,000 \text{ ft/min}) = 21 \text{ sq.ft.}$$

$$d = \sqrt{4A/\pi} = \sqrt{(4)(21)/\pi} = 5.2 \text{ ft.}$$

Duct cost (Fig. 4-21) = $92/ft.
($92/ft)(100 ft) = $9,200

Elbow duct

(Fig. 4-24) $1,830

Expansion joint

(Fig. 4-26) $3,200

Mechanical collectors (2)

(4" ΔP, @ 40,000 cfm, Fig. 4-53)
2 x ($5,400) = 10,800

Supports

(Fig. 4-37)
2 x ($2,900) = $5,800

Dust hoppers

(Fig. 4-38)
2 x ($900) = $1,800

Scrolls

(Fig. 4-39)
2 x $1,600 = $3,200

Fans

(60", Class 2, backwardly curved, 4" ΔP, Fig. 4-40)
2 x ($5,800) = $11,600

Motors

(Fig. 4-41) 600 rpm
2 x ($4,000) = $8,000

Starters
(Fig. 4-41)
2 x ($600) = $1,200

Total cost = $57,445

Capital cost:

(1) Equipment costs (control device & auxilaries) = $57,445

(2) Tax and freight @ 7% of (1) = $4,021

(3) Installation cost & hooding labor = $43,984
(Table 4-12, Fig. 4-19)

(4)	Subtotal	= $105,450
(5)	Engineering @ 10% of (4)	= 10,545
(6)	Subtotal (4) + (5)	= 115,995
(7)	Contingencies @ 10% of (6)	= 11,599
(8)	Total capital costs (6) + (7)	= 127,594
	$127,594 (294.6/192.1) ≈$166,000	= 165,786

Annual cost
Maintenance: ($0.065/cfm)(84,000 cfm)
x (249.6/204.1) = $6,677
Operating cost: (Fig. 4-60)
($1.70/hr)(2,000 hrs/yr) x
(249.6/204.1) = $4,418
Capital charges:
PV = R·PVF
i = 12%, n = 20 yrs.
166,000 = R·(7.469)
R = $22,225

Total annual cost = $6,677 + 4,418
+ 22,225 = $33,320 or
≈ $33,000

$$C/B = \frac{\$33,000/yr}{\left(0.024 \frac{lb}{ton}\right)\left(18,587 \frac{tons}{yr}\right)(.8)}$$
= $92.47 or ≈$92.00

d. Hooding, vent to fabric filter:

Capital cost = $250,000 (Nonmetallic Minerals, p. 3-3)
$250,000 (249.6/204.1) = $305,732 or
≈ $306,000

Annual cost

Operating cost: $70,000 (249.6/204.1)
= $85,605 or ≈$85,600

Capital charges:

$$PV = R \cdot PVF$$

$$n = 20,\ i = 12\%$$

$$\$306{,}000 = R(7.469)$$

$$R = \$40{,}969 \text{ or } \approx \$41{,}000$$

Total annual cost = $126,600

$$C/B = \frac{\$126{,}600/\text{yr}}{\left(0.024\ \frac{\text{lb}}{\text{ton}}\right)\left(18{,}587\ \frac{\text{tons}}{\text{yr}}\right)(.99)} = \$286.67$$

or ≈$287.

(2) Sawing (sawmills)

a. Hooding, vent to cyclone

Assume slot hood (Fig. 3-1, Tech. Guidance)
L = 6', W = 2'

$$Q = 3.7\ LVX$$
$$= 3.7\ (200'/\text{min})(6')(5')$$
$$= 22{,}000 \text{ cfm}$$

Slot hood

Plate req'd (Fig. 4-17, Gard) = 30 sq.ft.
(30 sq.ft.)(5.625 lb/sq.ft.)(1.2) = 202.5 lbs.
Material cost = LG + $0.194/lb
= 6' ($6/ft) + (0.194)(202.5)
= 36 + 39.3
= $75.30

Duct

Duct diameter necessary to keep a 4,000 fpm exhaust velocity (Air Pollution Engr. Manual, p. 373)

$$A = (22{,}000 \text{ cfm})(4{,}000 \text{ ft/min})$$
$$= 5.55 \text{ sq.ft.}$$
$$d = \sqrt{4 \cdot A/\pi}$$
$$= \sqrt{4 \cdot 5.55/\pi}$$
$$= 2.66 \text{ ft.}$$

(Fig. 4-21) $50/ft (100') = $5,000

Elbow duct
(Fig. 4-24) $670

Expansion joint
(Fig. 4-26) $2,100

Mechanical collector
Collector inlet area = 8.3 sq.ft.
Collector price (Fig. 4-35) = $4,000

Supports
(Fig. 4-37) $2,570

Dust hoppers
(Fig. 4-38) $694

Scroll
(Fig. 4-39) $1,645

Fans
(40", Class 2, 4" ΔP, Fig. 4-40)
$2,900

Motor
(Fig. 4-41) 800 rpm $850

Starter
(Fig. 4-41) $200

Total cost = $20,704

Capital cost:

(1)	Equipment costs (control device & auxilaires	= $20,704
(2)	Tax and Freight @ 7% of (1)	= 1,449
(3)	Installation cost & hooding labor (Table 4-12, Fig.4-19)	= 15,678
(4)	Subtotal	= $37,831
(5)	Engineering @ 10% of (4)	= 3,783
(6)	Subtotal (4) + (5)	= $41,614
(7)	Contingencies @ 10% of (6)	= 4,161
(8)	Total capital costs	= $45,775
	45,775 (249.6/192.1)	= $59,477

Annual cost

Maintenance: ($0.065/cfm)(22,200 cfm)
x (249.6/204.1) = $1,765

Operating cost: ($0.42/hr)(2,000 hr/yr)
x (249.6/192.1) = $1,091

Capital charges:
PV = R·PVF
n = 20 yrs, i = 12%
$59,477 = R· (7.469)
R = $7,963

Total annual charges = $1,765 + 1,091
+ 7,963 = $10,819

$$C/B = \frac{\$10,819/yr}{\left(0.35\ \frac{lb}{ton}\right)\left(16,320\ \frac{tons}{yr}\right)(0.8)}$$

≈ $2.37

b. Hooding, vent to fabric filter

Capital cost = $100,000 (249.6/204.1)
= $122,292

Annual cost:

Operating cost: $21,000 (249.6/204.1) = $25,682

Capital charges:
PV = R·PVF
n = 20 yrs, i = 12%
$122,292 = R (7.469)
R = $16,373
Total annual cost ≈ $42,000

$$C/B = \frac{\$42,000}{\left(0.35\ \frac{lb}{ton}\right)\left(16,320\ \frac{tons}{yr}\right)(0.99)} = \$7.43$$

(3) Sawdust pile loading, unloading and storage (sawmills)

a. Wet suppression

$$\left(2,493\ \frac{tons}{yr}\right)\left(\frac{yr}{2,000\ hrs}\right) = 1.25\ tons/hr$$

1.25 [(100 lb/cu.ft. stone)/(10 lb/cu.ft. sawdust)]
= 12.5 tons/hr

Capital cost (p. 4-9 NMI)
($20,000)(249.6/204.1) = $24,459
≈ $24,500

Annual cost (p. 4-12 NMI)

($6,000)(249.6/204.1) = $7,338
or ≈ $7,300

$$C/B = \frac{\$7,300/yr}{(1\ \frac{lb}{ton})(2,493\ \frac{tons}{yr})(0.5)} = \$5.86$$

b. Enclosure

[Based on average cost of $5.13/cu.ft. x (249.6/204.1) = $6.27/cu.ft.]

$$\text{Storage needed} = (2,493\ \frac{tons}{yr})(\frac{yr}{12\ mo.}) = 207.8\ tons/mo.$$

Assume 1 month storage capacity needed

Capital cost

Storage capacity needed =
(207.8 tons)(2,000 lbs/ton)(cu.ft./10 lbs)
= 41,560 cu.ft.
(41,560 cu.ft.)($6.27/cu.ft.) = $260,581

Annual cost

PV = R·PVF
n = 20 yrs, i = 12%
$260,581 = R· (7.469)
R = $34,888

$$C/B = \frac{\$34,888/yr}{(1\ \frac{lb}{ton})(2,493\ \frac{tons}{yr})(1)} = \$13.99$$

c. Telescopic tubes (Fug. Emissions from Integrated Iron & Steel, p. 6-6)

Capital cost

$7,000 (249.6/204.1) = $8,561

Annual cost

Capital charges only
PV = R·PVF
n = 20 yrs, i = 12%
8,561 = R (7.469)
R = $1,146

$$C/B = \frac{\$1,146/yr}{(1\ \frac{lb}{ton})(2,493\ \frac{tons}{yr})(0.75)} = \$0.61$$

(4) Wood waste storage bin vent

a. Fabric filter (non-aspirated)

Capital cost

$5,000

Annual cost

Capital charges only

PV = R·PVF

n = 20 yrs, i = 12%

5,000 = R (7.469)

= $670

$$C/B = \frac{\$670/yr}{\left(1 \frac{lb}{ton}\right)\left(1{,}500 \frac{tons}{yr}\right)(0.99)} = \$0.45$$

(5) Wood waste storage bin loadout

a. Telescopic chutes (same as 3)

b. Enclosure (3-sided)

$$C/B = \frac{\$6{,}100/yr}{\left(2 \frac{lb}{ton}\right)\left(1{,}500 \frac{tons}{yr}\right)(0.6)} = \$3.39$$

c. Enclosure, vent to cyclone

Assume a comparable system to hooding, vent to cyclone for sawing at sawmills is adaptable to this area.

Capital cost

$59,500 + 27,700 (for 3-sided enclosure)

= $87,200

Annual cost

$10,900 + 6,100 = $17,000

$$C/B = \frac{\$17{,}000}{\left(2 \frac{lb}{ton}\right)\left(1{,}500 \frac{tons}{yr}\right)(0.8)} = \$7.08$$

d. Enclosure, vent to fabric filter

Assume a comparable system to hooding, vent to fabric filter for sawing at sawmills is adaptable to this area.

Capital cost

$122,000 + 27,700

= $149,700

Annual cost

$42,000 + 6,100

= $48,100

$$C/B = \frac{\$48{,}100}{\left(2 \frac{lb}{ton}\right)\left(1{,}500 \frac{tons}{yr}\right)(0.99)} = \$16.20$$

2.18 AGGREGATE PROCESSING PLANTS

2.18.1 Process Description

This category presents a study of the fugitive dust emissions from sources at aggregate processing plants.

Aggregate processing plants produce a product consisting of rock or slag particles which are usually graded into specific size ranges. Aggregate may be obtained from gravel or carbonate rock deposits, or slag. It is used extensively as a base material for roadways and as an ingredient for the manufacture of portland cement concrete, and asphaltic concrete. It is also used in agriculture, glass manufacturing, metal refining, fireproofing and waste treatment.[1]

Ohio basically has three major sources of aggregate. These are 1) sand and gravel, 2) crushed stone, and 3) blast-furnace and steel furnace slag.[1]

Sand and gravel deposits are found extensively throughout the State with some production of the materials occurring in at least 68 counties. They basically occur in unconsolidated natural sedimentary deposits consisting of various sizes of stone particles. Sand is defined as any aggregate which will pass through a No. 4 sieve, while gravel is any rock particles or pebbles which are retained on a No. 4 sieve. The sand and gravel production in Ohio in 1977 was approximately 40 million tons with 22 million tons of that figure being gravel production.[1,2]

Crushed stone products in Ohio consist of limestone and dolomite. These minerals are essentially hard rocks that occur in beds or strata, and which generally require drilling and blasting in order to shatter the deposit into fragments small enough to be processed.[1] The crushed stone production in Ohio in 1977 was approximately 44 million tons.[3]

Slag is a nonmetallic byproduct of metallurigal operations, consisting of silicates and aluminosilicates of lime and other bases. It is produced simultaneously with iron in a blast furnace. It is also produced simultaneously with steel in open hearth, basic oxygen or electric arc furnaces. Slag is used as a substitute for aggregate produced from natural deposits.[1]

This study is concerned only with the fugitive dust emission sources at aggregate processing plants and not the mining or quarrying operations. For information on fugitive dust emission from mineral extraction operations, the reader is referred to Section 2.1.4. of this document.

As used in this study, an aggregate processing plant is a production facility where aggregate is crushed, pulverized, screened and classified into a variety of products. The specific processes employed by an aggregate processing plant depend on the type of aggregate and the customer's specifications on size and the amount of impurities. Process flow diagrams for sand and gravel, crushed stone and slag processing plants are illustrated in Figures 2.18-1 thru 2.18-3, respectively. The following narrative discusses each process in detail.

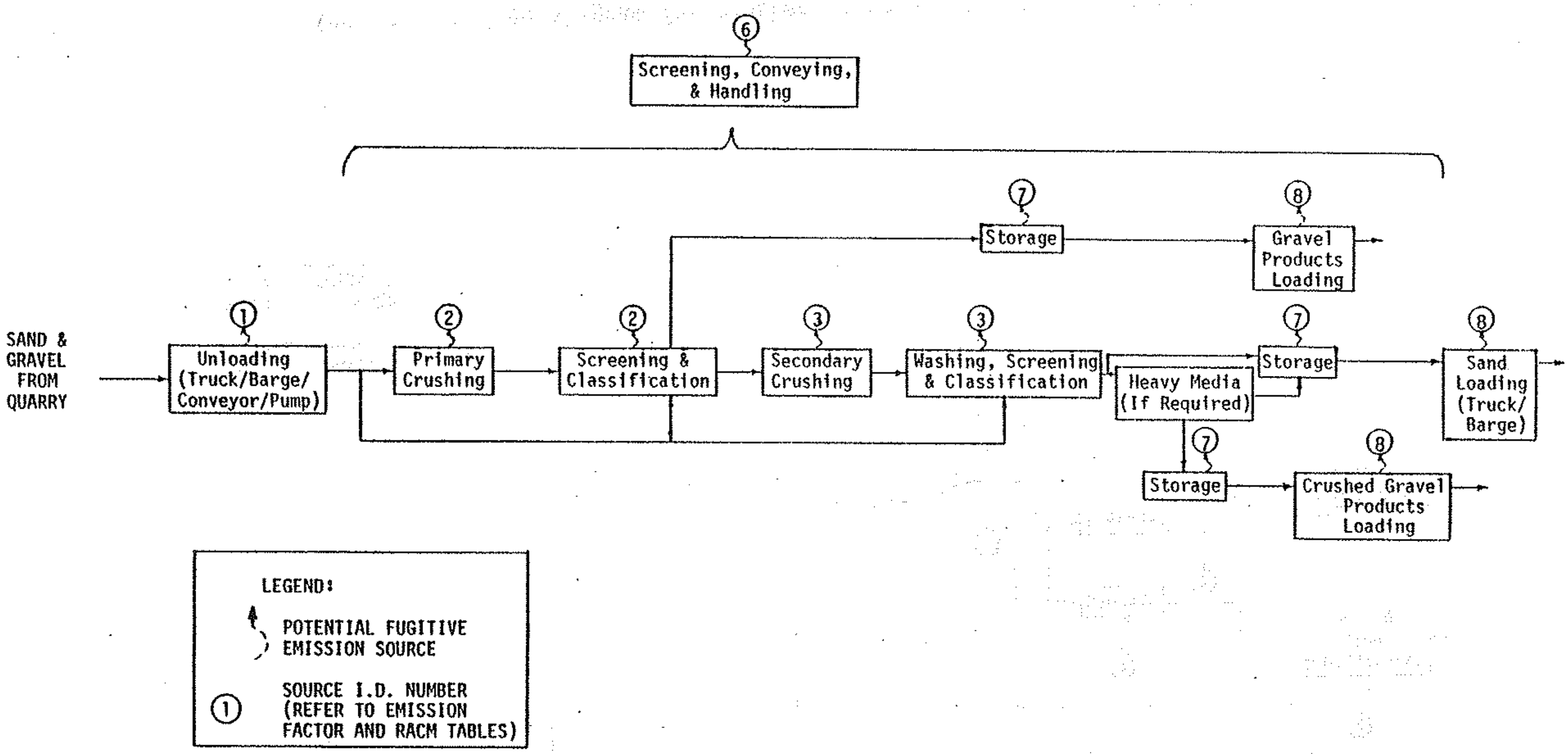

Figure 2.18-1. Simplified process flow diagram for sand and gravel processing plants and associated fugitive particulate emission sources.

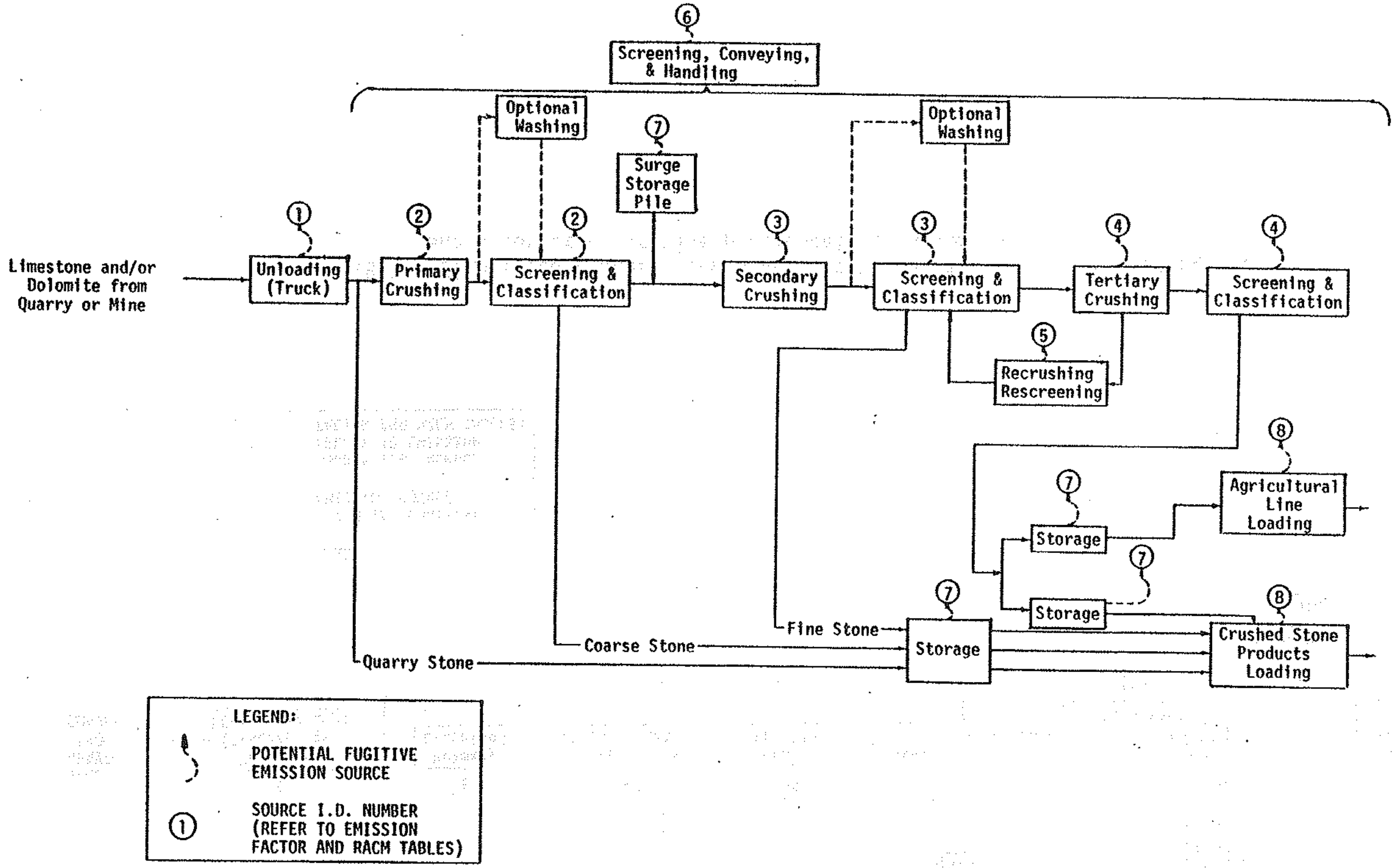

Figure 2.18-2. Simplified process flow diagram for crushed stone processing and associated fugitive particulate emission sources.

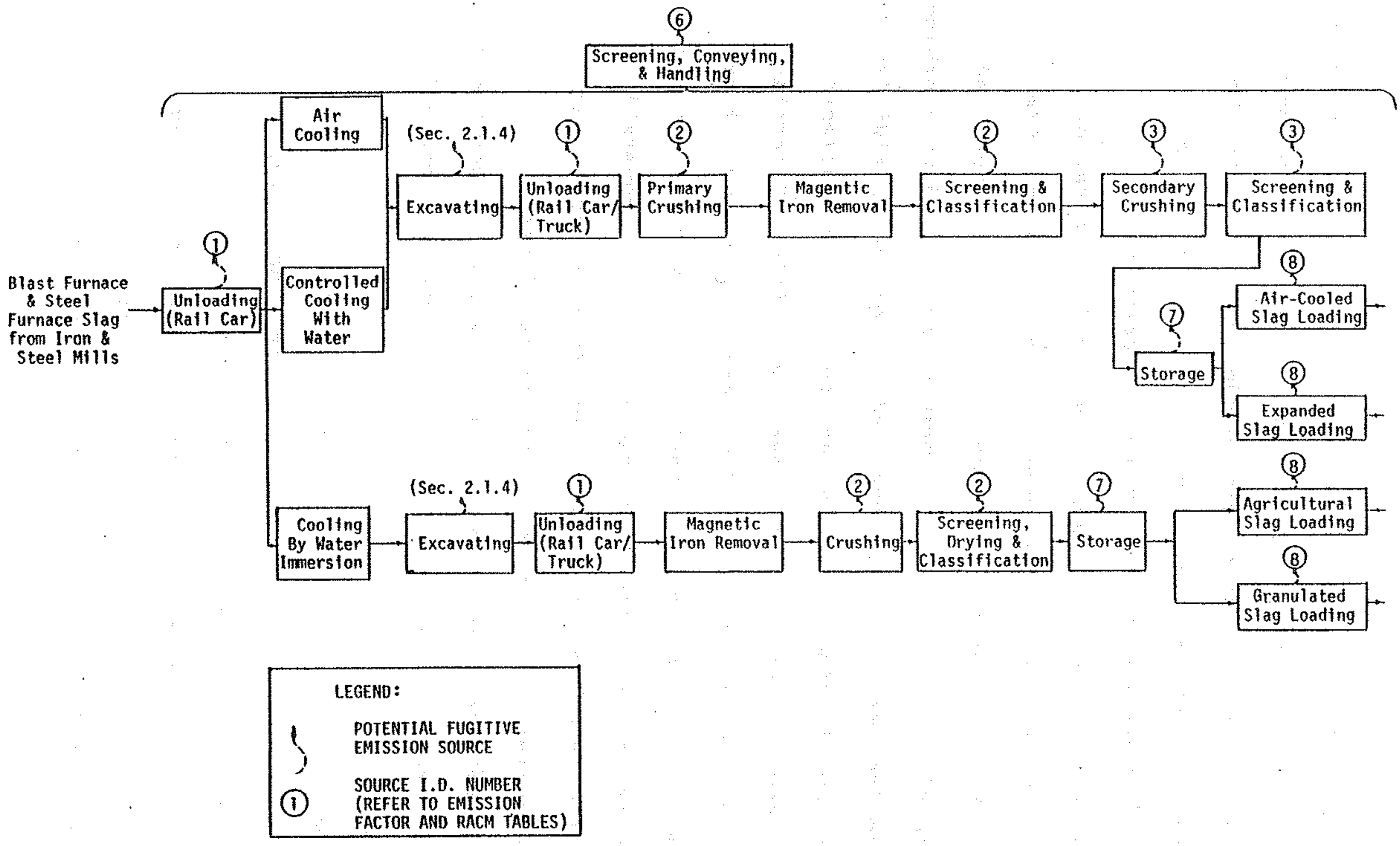

Figure 2.18-3. Simplified process flow diagramfor slag processing and associated fugitive particulate emission sources.

Sand and gravel deposits are either dredged or quarried depending on the location of the deposit. The material is extracted by power shovels, draglines, cableways or suction dredge pumps. It is then usually transferred to the processing plant through the use of suction pumps, earth movers, barges, trucks or conveyors.[4]

At the processing plant, the material may undergo a variety of process operations depending on the purpose of the plant and the type of material being processed. The operations at a typical sand and gravel processing plant may include primary and secondary crushing, screening, conveying, washing, and heavy media cleaning in addition to the unloading and loading activities and the open and enclosed storage of processed and partially processed materials. Generally, sand and gravel operations tend to differ significantly from other types of mineral processing plants in that less processing equipment is used and the raw material and processed material are generally wet. Consequently these operations emit less fugitive dust than from comparable crushed stone and slag processing plants.

Sand and gravel operations typically produce a wide spectrum of products ranging from various sizes of sand and gravel to crushed gravel products.

Typical operations at a crushed stone processing plant may include primary, secondary, and tertiary crushing, screening, conveying washing, unloading and loading activities, and open and enclosed storage of processed and partially processed aggregates. These operations produce a variety of crushed stone products ranging in size from quarry stone to the pulverized stone used for agricultural lime.

Lastly, typical operations at slag processing plants begin with the unloading of hot slag into slag pits from railroad cars. The slag is then either air-cooled or cooled with water sprays or by immersion in water. After cooling, the slag is excavated and hauled to an unloading area. Subsequent processing operations may include primary and secondary crushing, screening, conveying, iron removal, loading, and open and enclosed storage of processed and partially processed material. Drying of slag may also be performed; however, such processing is rarely performed.

These operations may also produce a variety of slag products as shown in Figure 2.18-3. The air-cooled slag product is produced from molten slag that has been allowed to solidify under atmospheric conditions. Expanded slag product is produced from molten slag which has been treated with controlled quantities of water in order to speed solidification and increase the cellular structure. This type of slag is consequently a light-weight product. Granulated slag is produced from molten slag which has been quickly quenched in water so as to produce a glassy, granular, sand-size product. Agricultural slag is simply granulated slag which has been finely pulverized for use as a soil neutralizer.[1]

Although there is a variety of operations at aggregate processing plants, each differing in equipment and process employed, a general process description can be given which covers all three types of plants. The process description begins with unloading.

Generally, unloading operations consist of truck dumping into a hoppered feeder which subsequently feeds into a primary crusher. The crushed material and the grizzly troughs are then transported via belt conveyor to either a surge pile or silo for temporary storage.[5]

The crushed material in the surge pile is usually removed by use of a series of vibrating feeders under the surge pile. These feeders distribute the material onto a belt conveyor which moves the material to a scalping screen. At the scalping screen, the material is segregated into three fractions: oversize, undersize and troughs. The oversize material is fed into a secondary crusher in order to obtain further size reduction. The undersize material is discharged to storage since it needs no further processing. The troughs (unwanted fines and screenings) are removed from the process and are stockpiled as crusher-run material (total unscreened product of a stone crusher).[1,6]

The discharge from the secondary crushers (usually 1 inch or less in size) is conveyed to a secondary screen for sizing. The oversize material from this screen is conveyed or discharged directly to a tertiary crusher (if required). (The crushed material from the tertiary crusher is usually routed back to the secondary screen for sizing.) The undersize material from the secondary screens goes directly to the finish screens. The trough material from the secondary screens is also conveyed to the finish screens. The subsequent products are gravity fed to finish-product storage bins or are stockpiled in open storage piles by using conveyors or trucks.[7]

Some product specifications, such as for concrete aggregate, require washing of the material. This is generally performed after the aggregate has been initially crushed in the primary crusher. Washing is performed by dropping the material onto fine mesh screens, onto which a heavy water spray is directed.

The finished product at an aggregate processing plant is stored either in open piles or in storage bins. Loading from open storage piles is generally accomplished through the use of front-end loaders. Loading from elevated silos is performed by gravity dumping into open-bed trucks.

As previously mentioned, there is considerable variety in the type of equipment used in aggregate processing. With respect to crushing equipment, there are four types of crushers used in the industry: jaw, gyratory, roll and impact crushers.[8]

Jaw crushers are generally used by the industry for primary crushing. The most commonly used jaw crusher is the Blake or double-toggle type which is illustrated in Figure 2.18-4. The lesser-used single-toggle jaw crusher is shown in Figure 2.18-5. The aggregate in these crushers is subjected to crushing by compression against a fixed jaw.[10]

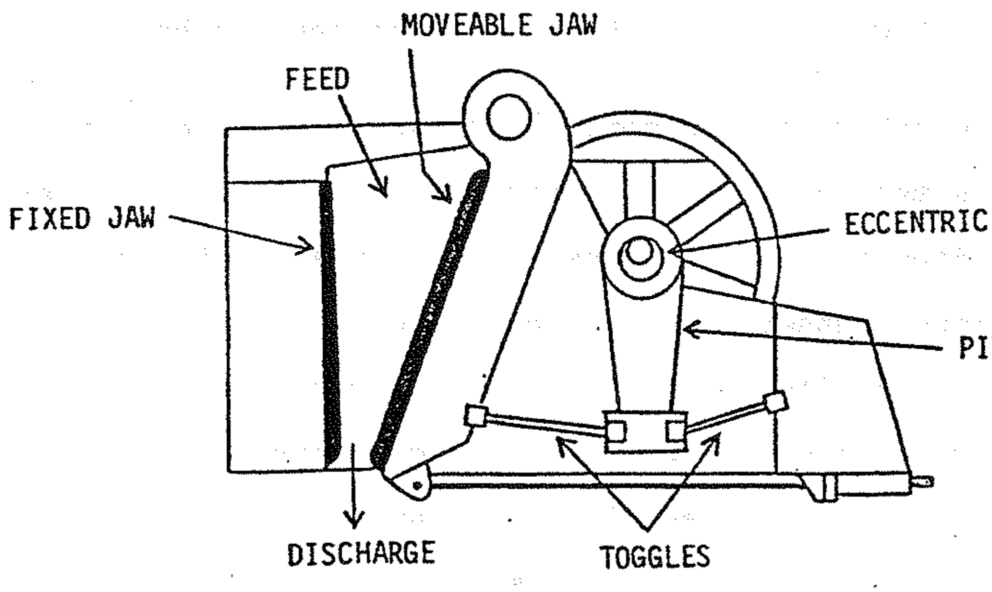

Figure 2.18-4. Double-toggle jaw crusher.[9]

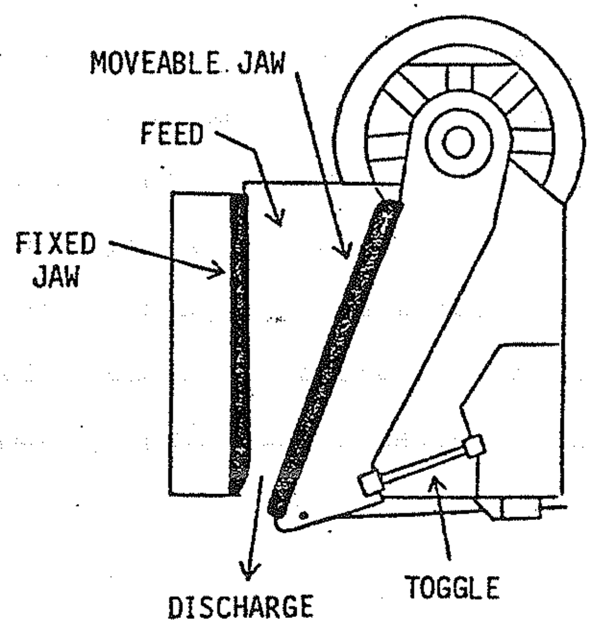

Figure 2.18-5 Single-toggle jaw crusher.[9]

Gyratory crushers are commonly employed for secondary and tertiary crushing. This type of crusher is similar to a jaw crusher, except that circular jaws are used to crush the material. The three basic types of gyratory crushers are pivoted-spindle, fixed-spindle and cone. The fixed-spindle and pivoted-spindle crushers are used for primary and secondary crushing, while the cone crushers are the most commonly used crushers for secondary and tertiary crushing. The pivoted-spindle and cone gyratory crushers are illustrated in Figures 2.18-6 and 2.18-7, respectively.[11]

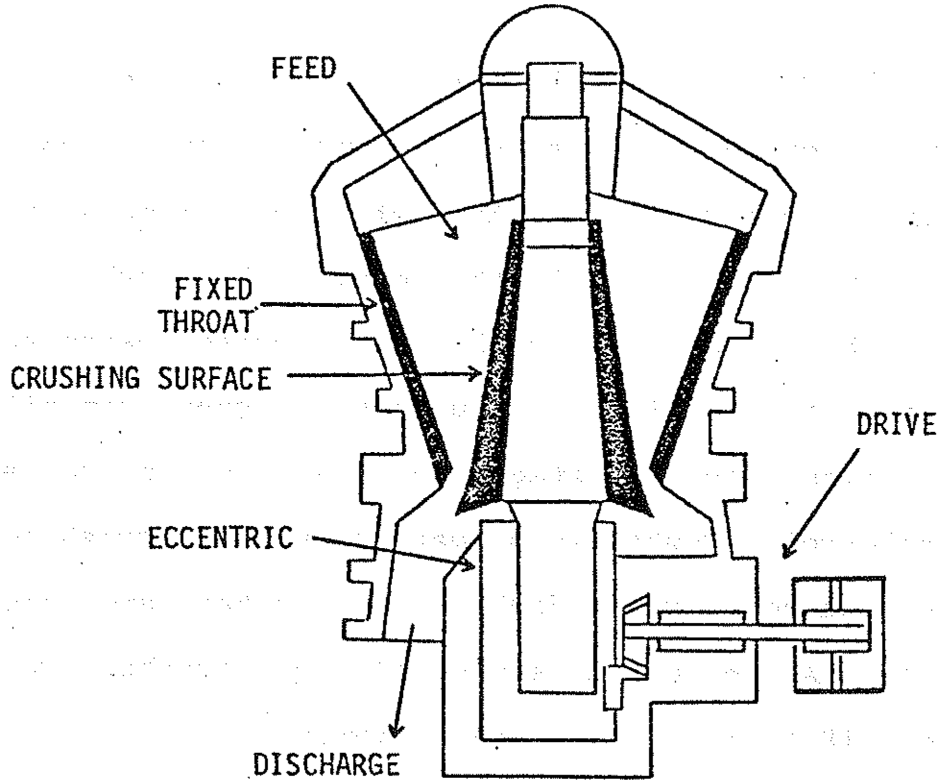

Figure 2.18-6. Pivoted-spindle gyratory crusher.[12]

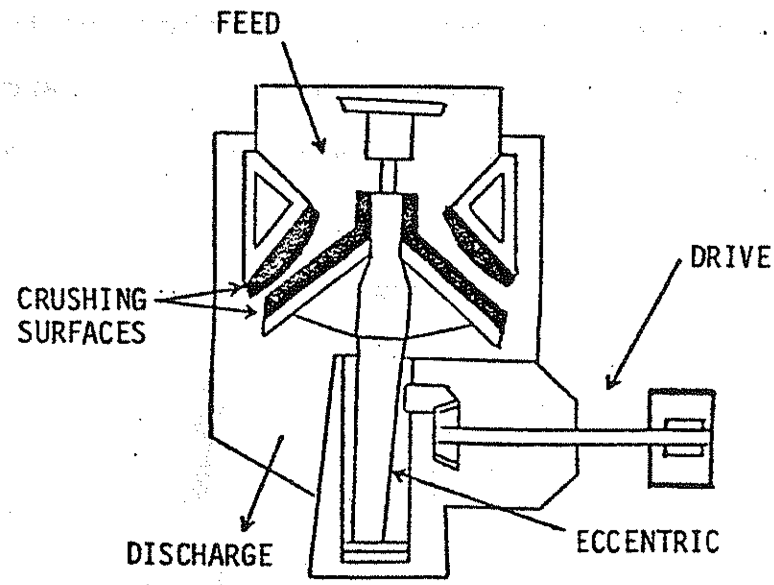

Figure 2.18-7. Cone gyratory crusher.[12]

Single-roll and double-roll crushers consist of one or two rotating rolls which crush the material by compression. Crushing is accomplished in a single-roll crusher by the action of a single rotating roll upon a fixed crushing plate. In the double-roll crusher, crushing is performed by two parallel rolls which rotate toward each other. Single-roll and double-roll crushers are used primarily at intermediate or final size reduction stages and frequently at portable plants. The single-roll crusher is primarily used for crushing soft materials such as limestone, while double-roll crushers are used for hard materials. A single-roll and double-roll crusher are illustrated in Figures 2.18-8 and 2.18-9, respectively.[13]

Other crushing equipment commonly used in aggregate processing are impact crushers. These crushers include hammermills and impactors (Figures 2.18-10 and 2.18-11). An impact crusher uses fast, rotating impellers or hammers to shatter the falling aggregate. Due to the high size reduction capabilities of those units, they are primarily used where it is desirable to have a wider range of particle sizes and a larger proportion of fines, such as for agricultural aggregate.[15]

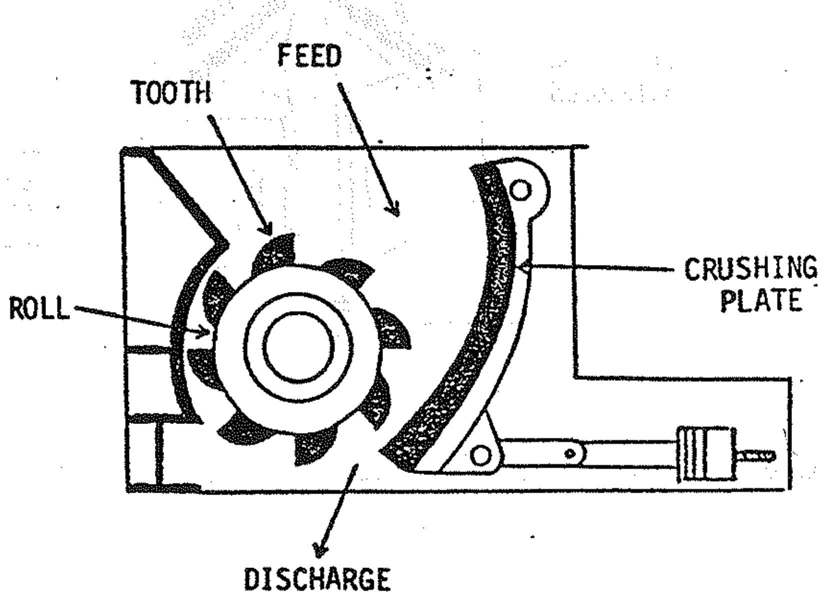

Figure 2.18-8. Single-roll crusher.[14]

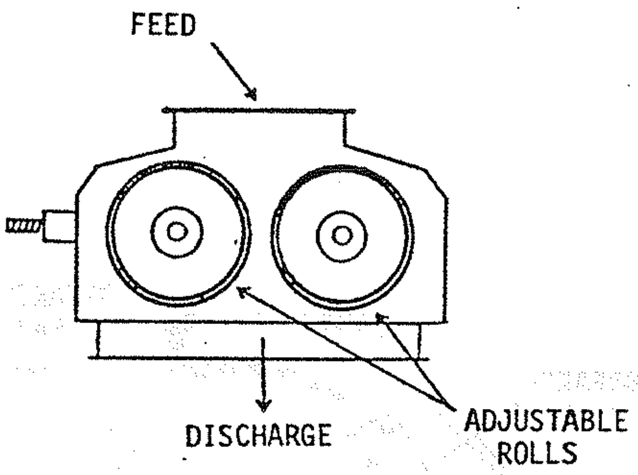

Figure 2.18-9. Double-roll crusher.[14]

Because impact crushers generate a large quantity of fine particles and impart high velocities to the particles as a result of the whirling hammers, fugitive dust emissions are usually much greater from the impact crushers than other types of crushers.[17]

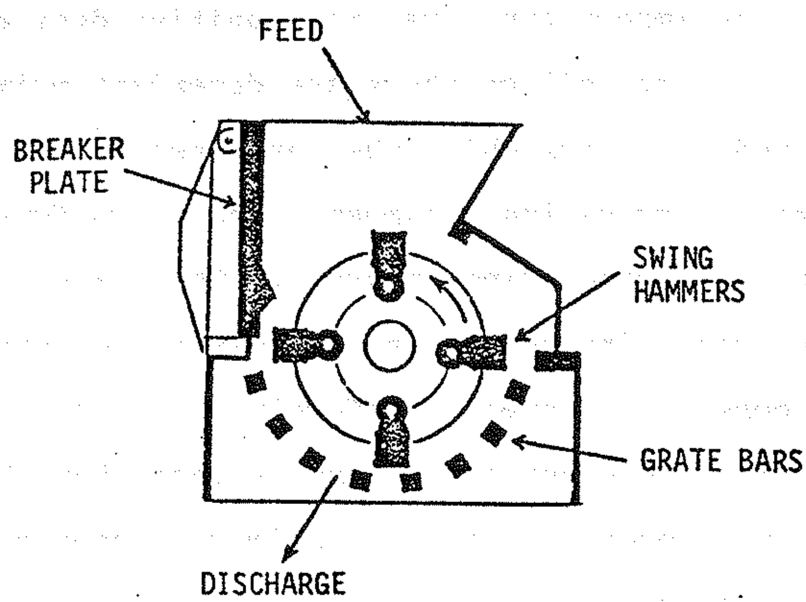

Figure 2.18-10. Hammermill crusher.[16]

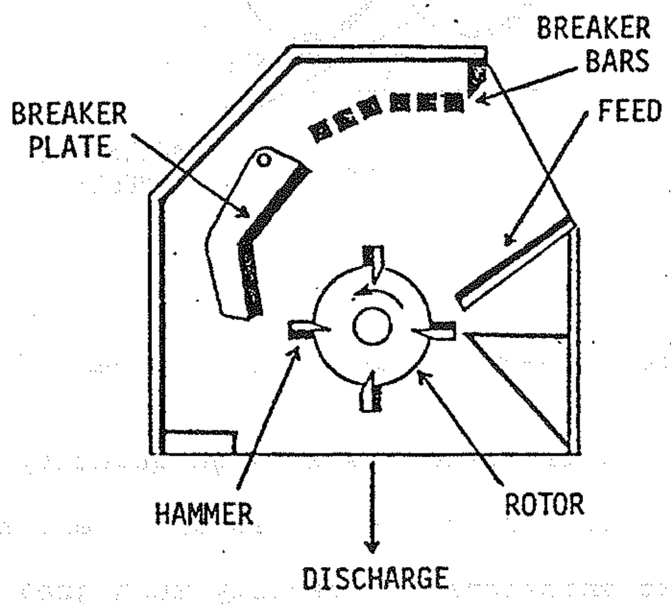

Figure 2.18-11. Impact crusher.[16]

In contract to impact crushers, the fugitive dust emissions from jaw, gyratory, cone and roll crushers are dependent primarily on the degree of size reduction for which they are used.[17]

With respect to screening equipment, there are four basic types used in the aggregate processing industry. These are grizzlies, shaking screens, vibrating screens and revolving screens.[18]

Grizzlies consist of several uniformly spaced horizontal or inclined bars which are wider on the top surface than the bottom surface to prevent clogging. They are primarily used to remove fines before primary crushing. There are three types of grizzlies which are used by the industry. These are stationary, cantilevered (one end fixed and the discharge end vibrated), and mechanically vibrating types. A vibrating grizzly is illustrated in Figure 2.18-12.[18]

Shaking screens consist of a rectangular frame with perforated plate or wire cloth as a screening medium. These screens are mechanically shaken to assist separation. They are primarily used for screening coarse material (1/2 inch or larger).[19]

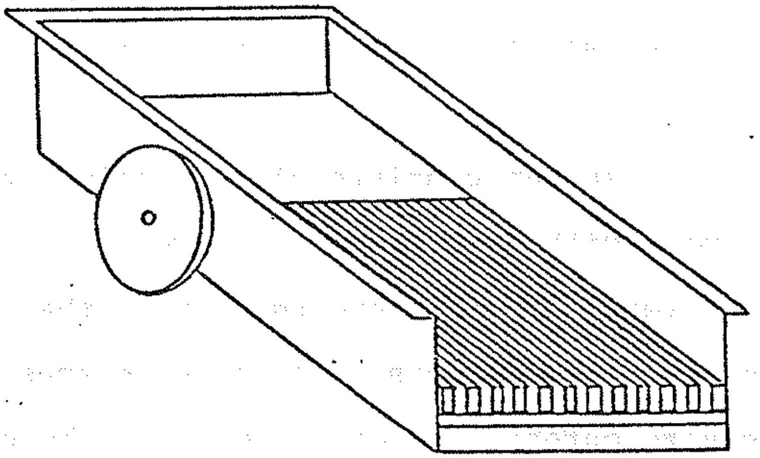

Figure 2.18-12. Vibrating grizzly.[20]

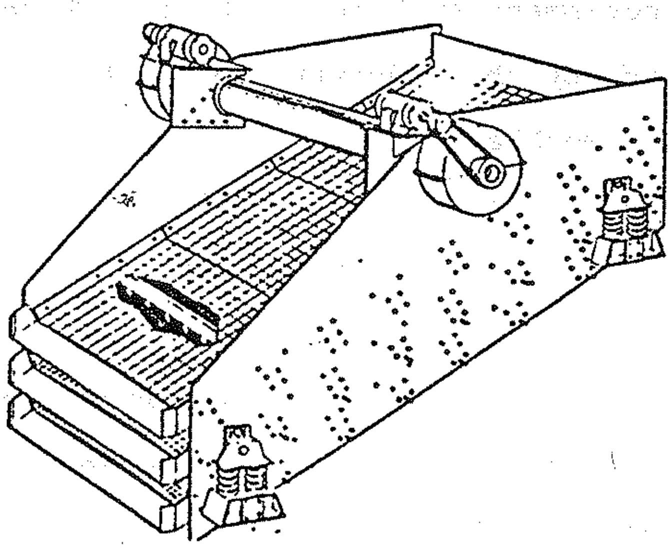

Figure 2.18-13. Vibrating screen.[20]

The most commonly used type of screen in the aggregate processing industry is the vibrating screen. It consists of an inclined, flat or slightly convex screening surface which is rapidly vibrated in a plane normal to the screening surface. This type of screen may have from one to three screening decks. A vibrating screen is shown in Figure 2.18-13.[21]

A revolving screen consists of an inclined cylindrical frame which is wrapped with a screening surface of wire cloth or perforated plate. The material is fed into the top of the frame as the screen is being rotated. The undersize material passes through the screen, and the oversize material is discharged out the other end.[22]

An aggregate processing plant also employs a number of material handling devices. The most commonly used devices include feeders, belt conveyors, bucket elevators and screw conveyors.[23]

Feeders are used to discharge material at a uniform rate into processing equipment such as crushers. There are five basic types which are used by the industry: apron, belt, reciprocating-plate, vibrating and wobbler.[23]

Apron feeders consist of overlapping metal pans or aprons which are hinged together by chains to form a conveyor that is supported by rollers.[23]

Belt feeders are simply short conveyor belts with roller supports, where the material feed rate is controlled by adjustable gates.[23]

Reciprocating-plate feeders consist of a horizontal plate which is driven in a oscillating motion that causes the material to move forward. The material feed rate is controlled by adjusting the frequency and length of the oscillating motion.[24]

Vibrating feeders are similar to reciprocating-plate feeders, except that the feed rate is controlled by the slope of the feeder bed and the amplitude of the vibration.[24]

Wobbler feeders consist of a series of closely spaced elliptical bars that are mechanically rotated, thereby causing the oversize material to tumble to the discharge end of the feeders and the undersize material to pass through the bed spaces. The material feed rate in this type of unit is controlled by the bar spacing and the speed of the rotating bars.[24]

The most commonly used method of material handling is the belt conveyor. A belt conveyor consists of an endless belt that is supported by a series of idlers which are angled such that the belt forms a trough. The belt is stretched over a drive pulley at one end and a tail pulley at the other. A belt conveyer system which is used to transport material to another conveyor is illustrated in Figure 2.18-14.[25]

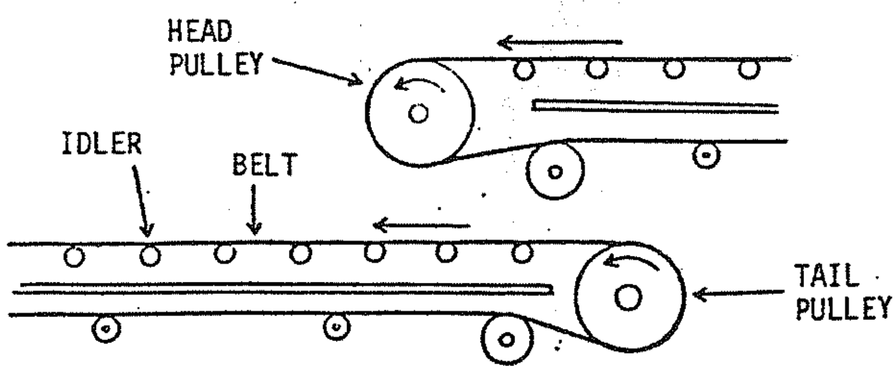

Figure 2.18-14. Belt conveyor transfer point.[26]

Another means of elevating material is through the use of bucket elevators. These elevators consist of buckets attached to a single-or double-strand chain or belt which is driven by a head-and-foot assembly. The three most common types of bucket elevators are high-speed centrifugal-discharge, slow-speed positive- or perfect-discharge and continuous discharge. These are depicted in Figure 2.18-15.[27]

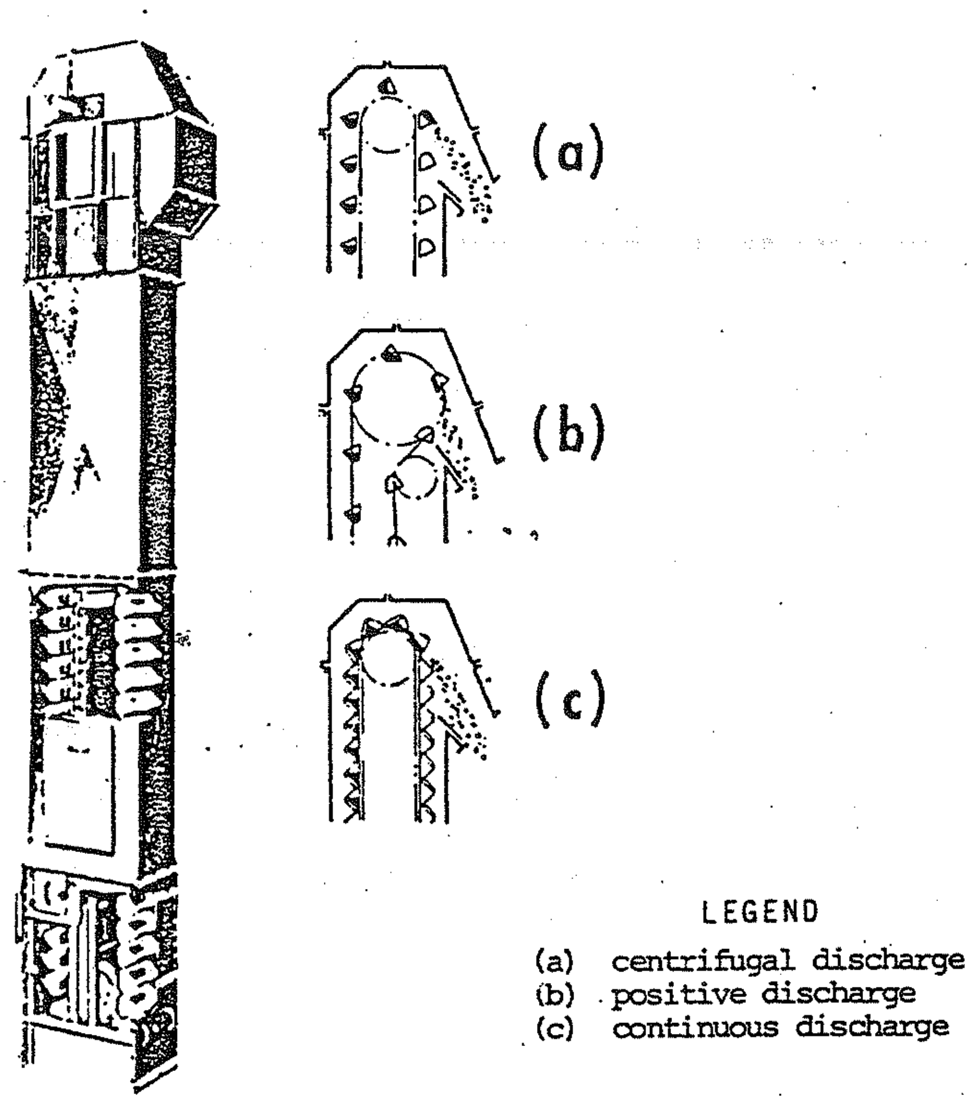

Figure 2.18-15. Types of bucket elevators.[28]

The centrifugal discharge elevator consists of evenly spaced buckets on a single-strand chain or belt. As the buckets round the tail pulley, they scoop material and elevate it to the discharge point at the head pulley. The material is discharged from the bucket by the centrifugal force of the bucket rounding the head pulley.[27]

The positive-discharge elevator is similar to the centrifugal-discharge elevator, except that it has a double-strand chain and a sprocket set below the head pulley. These added devices bend the strands causing the buckets to be totally inverted and resulting in a positive discharge.[29]

The continuous-discharge elevator uses closely spaced buckets attached to either a single- or double-strand belt or chain. The buckets are loaded directly during ascent and are discharged by gravity free fall. The back of each preceding bucket is used as a discharge chute.[29]

Lastly, screw conveyors are also used for material handling and elevating. They consist of a steel shaft with a helical fin that pushes material along the trough when the shaft is rotated.[29]

Heavy media cleaning equipment is infrequently used at aggregate processing plants. Generally only a few sand and gravel plants employ heavy media cleaning equipment. For a description of this type of equipment, see Section 2.19.1.

Figures 2.18-1 through 2.18-3 also identify the sources of fugitive dust emissions. Those sources are 1) raw material unloading, 2) primary, 3) secondary and 4) tertiary crushing and screening, 5) recrushing and screening, 6) screening, conveying, and handling, 7) open storage and 8) finished product loading. Inplant haul roads and vehicle movement around open storage piles are also significant sources of fugitive dust emissions. These sources are discussed in detail in Section 2.1.1 and, consequently, will not be discussed in this section. Also, for further information with respect to aggregate storage piles, material handling and mineral extraction at aggregate processing plants, the reader may want to refer to Sections 2.1.2 through 2.1.4.

2.18.2 Fugitive Dust Emission Factors

The estimated emission factors for aggregate processing plant fugitive dust sources, as identified in Section 2.18.1, are summarized in Table 2.18-1. The emission factor reliability ratings indicate that these engineering estimates are applicable only to a group of such sources and are of questionable accuracy for site-specific estimates.

The quantification of fugitive dust emissions from aggregate processing plants is extremely difficult due to the variety of factors that may affect the emissions. Such factors include the moisture content of the raw material, the type of raw material processed, the type of equipment used and the operating practices employed.[30]

The moisture content of the raw material may vary from zero to several percent depending upon the geographic and climatic conditions. The degree of wetness in the raw material will have a significant affect on the initial processing operations. The surface wetness will cause fine particles to adhere to the larger pieces of aggregate, thereby reducing the potential for fugitive dust emissions. Thus, surface wetness is an important factor in minimizing the fugitive dust emissions from primary crushing and the operations preceding primary crushing. In subsequent operations, such as secondary crushing, attrition and moisture evaporation result in more surface area being exposed. Thus, the previous dust suppression effects resulting from surface moisture diminish and may become insignificant.[31]

TABLE 2.18-1. FUGITIVE DUST EMISSION FACTORS FOR AGGREGATE PROCESSING PLANTS

Source	Emission factor	Reliability rating	Reference
(1) Unloading (truck)			
Sand & gravel	0.02 lb/ton unloaded	E	33
Crushed stone	0.04 lb/ton unloaded	E	33
Slag	0.02 lb/ton unloaded	E	33
(2) Primary crushing & screening			
Sand & gravel	0.1 lb/ton crushed[a]	NA	34
Crushed stone	0.5 lb/ton crushed[b]	C	35
Slag	0.5 lb/ton crushed[b]	E	35
(3) Secondary crushing & screening			
Sand & gravel	0.1 lb/ton crushed[a]	NA	34
Crushed stone	1.5 lbs/ton crushed[b]	C	35
Slag	1.5 lbs/ton crushed[b]	E	35
(4) Tertiary crushing & screening			
Crushed stone	6.0 lbs/ton crushed[b]	C	35
(5) Recrushing & rescreening			
Crushed stone	1.0 lbs/ton crushed[b]	C	35
(6) Screening, conveying, & handling			
Sand & gravel	0.3 lb/ton handled	E	36
Crushed stone	2.0 lbs/ton stored[d]	C	35
Slag	2.0 lbs/ton stored[d]	E	35
(7) Storage piles[e]			
Loading onto piles			
Sand & gravel	0.0012 lb/ton loaded	E	37
Crushed stone	0.0014 lb/ton loaded	E	37
Slag	0.0058 lb/ton loaded	E	37
Loading out			
Sand & Gravel	0.0023 lb/ton loaded	E	37
Crushed stone	0.0029 lb/ton loaded	E	37
Slag	0.012 lb/ton loaded	E	37
Wind erosion			
Sand & gravel	0.47 lb/ton stored	E	37
Crushed stone	0.093 lb/ton stored	E	37
Slag	0.074 lb/ton stored	E	37
Vehicular traffic			
Sand & gravel	0.064 lb/ton stored	E	37
Crushed stone	0.032 lb/ton stored	E	37
Slag	0.13 lb/ton stored	E	37

Continued

TABLE 2.18-1. FUGITIVE DUST EMISSION FACTORS FOR AGGREGATE PROCESSING PLANTS

Source	Emission factor	Reliability rating	Reference
(8) Loading (truck)			
Sand & gravel	0.02 lb/ton loaded	E	33
Crushed stone	0.04 lb/ton loaded	E	33
Slag	0.02 lb/ton loaded	E	33

NA = Not available.

[a] Emission factor represents total emissions from primary and secondary crushing and screening.

[b] Based on raw material entering primary crusher.

[c] Based on an assumption of 20 percent of the primary crusher throughput undergoing recrushing and rescreening.

[d] Based on units of stored product.

[e] Assuming $S_{cs} = S_s = 2$, $S_{sg} = 10$, $M_{cs} = 2$, $M_{sg} = 5$, $M_s = 1$, $D_{cs} = D_{sg} = 76$, $D_s = 60$, $d_{cs} = d_{sg} = d_s = 225$, $K_{cs} = 0.25$, $K_{sg} = K_s = 1.0$, $Y_{cs} = Y_{sg} = Y_s = 3$, $U = 10$, $f = 26$, and substituting these values into the equations presented in Section 2.1.2.

The type of raw material processed is also a significant factor in the degree of fugitive dust emissions from aggregate processing sources. The extent of dust emissions appears to be related to the softness or hardness of the raw material itself. Soft aggregates produce a larger amount of screenings than do hard aggregates due to their greater friability. As a result, the processing of softer aggregates tend to produce more fugitive dust emissions. For example, the major rock types and their degree of hardness in order of increasing hardness is as follows: limestone and dolomite, sandstone, granite, trap rock, quartzite and quartz. Thus, one would expect more fugitive dust emissions from the processing of limestone than quartz.[32]

The type of equipment and operating practices used are also significant factors which affect the extent of fugitive dust emissions. The type of equipment used is generally dependent a number of factors including the type of quarry, the material processed and the final product desired. The extent of fugitive dust emissions from processing equipment is generally dependent on the size distribution of the processed material and the velocity imparted to the material.[32]

Since the above-mentioned factors may significantly affect the uncontrolled fugitive dust emissions, they also therefore, may directly affect the reliability of the selected emission factors presented in Table 2.18-1.

The emission factors for unloading operations (truck dumping) were taken from the published USEPA emission factor (0.04 lb/ton) for truck dumping of aggregate. However, for sand and gravel and slag unloading operations, a value of half the above factor was used due to the larger size of the broken slag being dumped and also due to the higher moisture content of the sand and gravel and the water quenched slag. This 50 percent reduction in the emission factor was based on the estimated control efficiency for watering, which was assumed to be comparable to the effects of higher moisture content and larger aggregate size. As a result of these estimations, the reliability of these emission factors is considered poor.[33]

The emission factors for primary, secondary and tertiary crushing and screening, and recrushing and rescreening were taken from published USEPA emission factors for sand and gravel processing,[34] and stone quarrying and processing.[35] Since comparable processes and equipment are found at crushed stone and slag processing plants, and because there is a similarity in visible emissions, the emission factors for stone processing were also used for slag processing operations. The reliability of the emission factor for sand and gravel processing is not known. An average reliability was reported for the emission factors for the above operations at stone processing plants. Since the emission factors for slag processing were based on only engineering judgment and visual observations, those factors should be considered of poor reliability.

For screening, conveying, and handling of aggregate, the emission factor for sand and gravel operations was based on a reported value for transfer and conveying of sand. The reported reliability of this emission factor was poor.[36] The emission factor for crushed stone was taken from published USEPA data. This factor was rated as an average reliability.[35] The emission factor for crushed stone was used for slag operations due to the similarity of the materials and equipment used. Because of this assumption, the reliability rating for the slag operations was listed as poor.

The emission factors for open storage pile activities are divided into four sources of fugitive dust: loading onto piles (continuous load-in), loading out, wind erosion, and vehicular traffic. These factors were obtained by using the empirical equations presented in Table 2.1.2-5 of this study and the assumed input variables presented in footnote (e) of Table 2.18-1. Since the assumed input variables are estimates based on engineering judgment, and the deriviation, accuracy, and limitations of the equations were not available, the emission factors presented should be considered of poor reliability.[37]

The emission factors presented for the loading activities are those identified for truck unloading. This is a very conservative estimate of the uncontrolled fugitive dust emission generated by loading, since the material loaded is generally drier and finer that which is unloaded. No emission factors were found in the literature for truck loading per se. Again, these factors should be considered as of a poor reliability.

Emission factors for haul roads are not presented in this section. The reader should refer to Section 2.1.1.

2.18.3 Particle Characteristics

There is limited data on general particle characteristics of fugitive dust emissions from aggregate processing plants.

One source does report that fugitive dust emissions from limestone storage, handling and transfer typically have a mean particle diameter of 3 to 6 μm, 45 to 70 percent of which are less than 5 μm.[38]

Other sources have reported information on particle size distribution from stack emissions from hammermills, screening operations and a bagging house. This data should give an indication of the particle size distribution from similar fugitive dust sources at aggregate processing plants. The data is as follows:[39,40]

Operation	Particle size distribution
Hammermill (crusher)	30% < 3 μm, 47% < 5 μm, 60% < 10 μm 74% < 20 μm, 86% < 40 μm
Screening	46% < 3 μm, 72% < 5 μm, 85% < 10 μm 95.5% < 20 μm, 98.8% < 40 μm
Bagging house	71% < 5 μm, 87.3% < 10 μm 96% < 20 μm, 98.8% < 40 μm

No other data is available concerning particle characteristics from the fugitive dust sources at aggregate processing plants.

The American Conference of Governmental Industrial Hygientists has identified limestone particles as nontoxic nuisance particulates if other toxic impurities are not present.[41] However, data on other toxic materials that may be associated with limestone were not available.

Exposure to fugitive dust emissions from sand and gravel operations may be harmful to human health depending on the amount of silica (SiO_2) present in the dust and the length of exposure. Inhalation of silica dust over extended periods of time has been known to cause a respiratory ailment known as silicosis. Silicosis is a chronic lung disease characterized by diffuse fibrosis.

More frequently, fugitive dust emissions from aggregate processing plants result in the creation of nuisance conditions, rather than causing any significant health problems.

2.18.4 Control Methods

A summary of the control methods available for sources of fugitive dust emissions from aggregate processing plants is presented in Table 2.18-2, along with their control efficiencies and costs. This section will discuss each of these control methods.

In general, there are two basic, operationally proven methods of controlling dust emissions from process equipment at aggregate processing plants. These include the use of wet sprays, preferably containing a surface active ingredient or wetting agent that reduces water surface tension, and the use of hoods, ductwork, and fabric filters. Many existing operations use a combination of these two techniques, where wet suppression is used in the early process stages (larger-sized aggregate) and a dry captive system is used in the latter process stages (smaller-sized aggergate).[42]

A wet suppression system may be used to control fugitive dust emissions from all of the sources identified in this study. The application of water, with or without chemical wetting agents, is accomplished by use of spray bars and nozzles which are located at the critical dust producing points such as transfer points and screening areas. Generally, the addition of a chemical wetting agent to the water is necessary, especially in the intermediate and final processing stages, because the addition of water alone can result in excessive moisture being added to the aggregate. This excessive moisture may cause the blinding of screening equipment and/or the inability to achieve product specifications. The addition of a chemical wetting agent drastically reduces the water needed (about 4 to 1) for effective dust suppression. It has been reported that 75 to 85 percent of all crushed stone plants could use a wet suppression system. The other plants, because of stone type and product size, cannot solely use wet suppression and must rely on either dry collection systems or a combination system of dry collection and wet suppression.[43] Recent technological innovations, however, have produced an electrostatic spray system and a foaming agent spray system which may be used in lieu of certain dry collection systems.

The type, number, and location of application points, as well as the amount of water and wetting agent used are dependent on a number of factors which include aggregate size, production rate and equipment accessibility. Generally, the amount of water/wetting agent applied by a complete wet suppression system is about 1.5 gallons per ton of aggregate production. Without the use of chemical agents, the necessary water application rate could well be three or four times higher.[44]

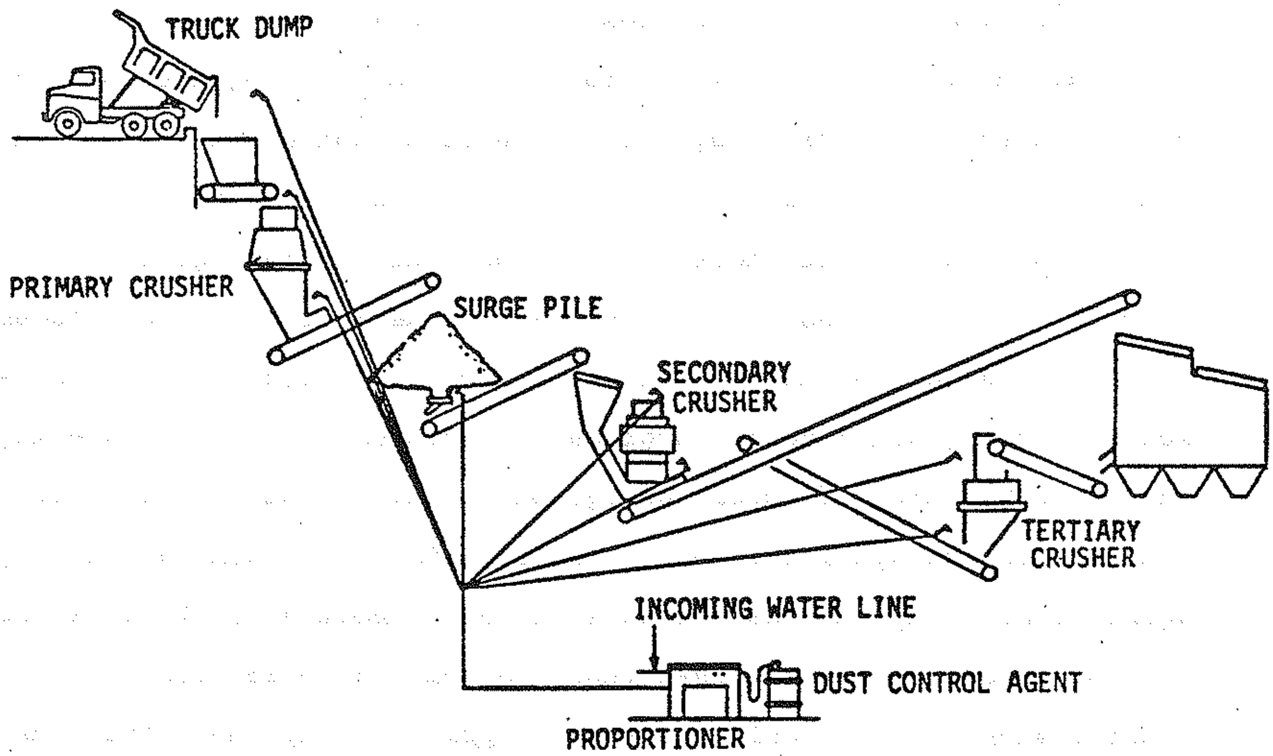

Figure 2.18-16. Wet dust-suppression system.[45]

At a typical aggregate processing plant, water/wetting agent spray application points are usually applied at truck unloading, at the entrance and exits of the crushers, at material transfer points such as belt conveyor transfer points (Figure 2.18-14), at the underfeed from surge piles to belt conveyors, and at the belt conveyor loadouts to open storage piles. Figure 2.18-16 illustrates the design of a typical wet suppression system at a crushed stone plant. Figure 2.18-17 depicts a typical spray system applied at the discharge point from a crusher to a belt conveyor.

A wet suppression system reduces the emission of fugitive dust particles by 1) causing the smaller particles to agglomerate, 2) causing the smaller particles to adhere to large pieces of aggregate and 3) increasing the density of particles. The use of a wetting agent (surfactant) aids this dust suppression effect by reducing the surface tension of water, and, thereby, allowing more particle surface area to become wet.

It has also been reported that wet suppression systems using foams instead of wetting agents have been effective in controlling fugitive dust emissions at several mining and processing operations. However, little experimental data across a range of aggregate processing industries is available. Therefore, the effectiveness of this technique is not fully known.[47]

The fugitive dust emissions generated at crushers, screens, conveyor transfer points, and bins may also be controlled by capturing and venting such emissions to a collection device such as a fabric filter (most commonly used device). Wet scrubbers may also be used; however, they are seldom employed at aggregate processing plants. The above sources may be controlled by using one centrally located fabric filter or by several strategically located fabric filters.

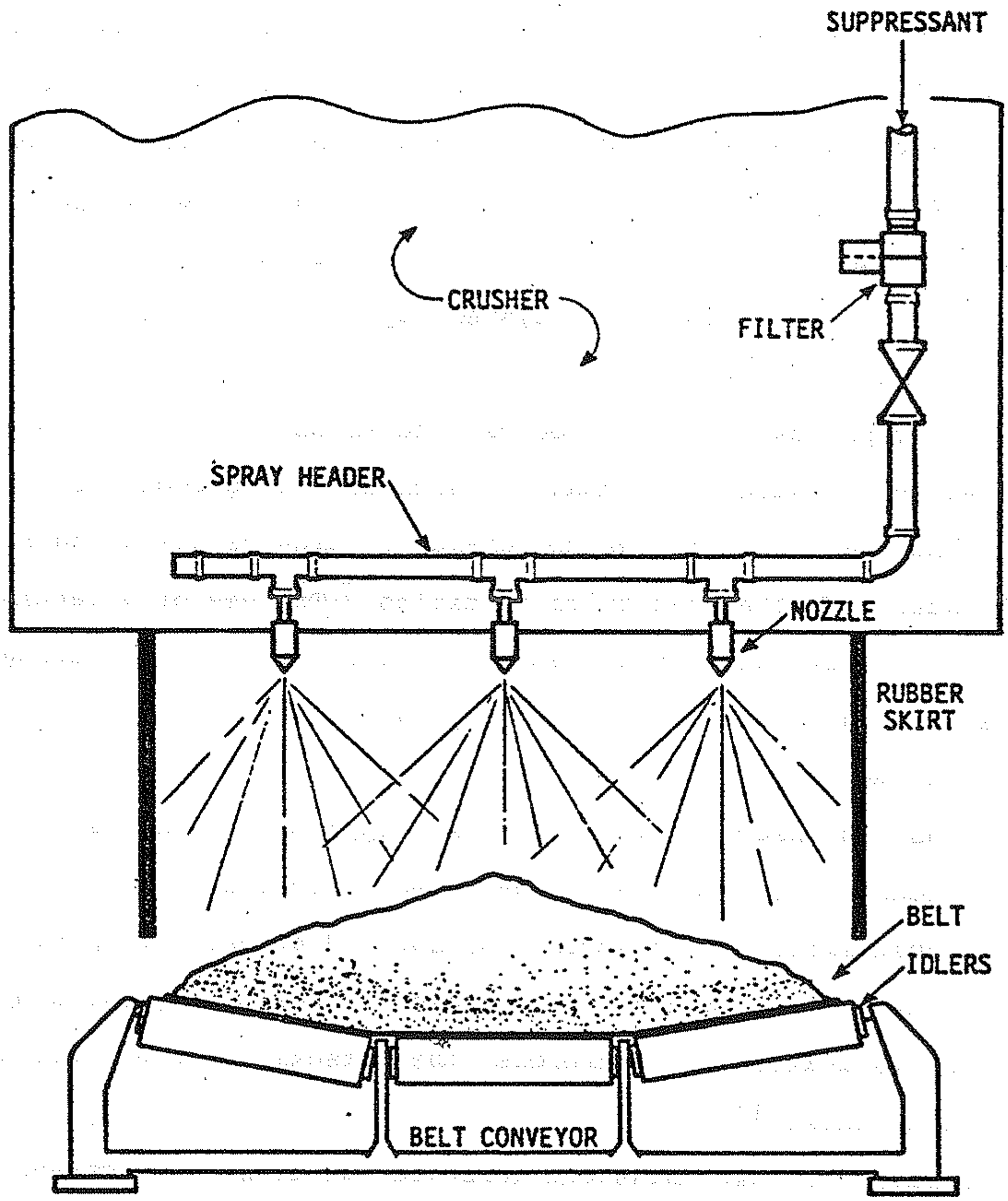

Figure 2.18-17. Wet dust-suppression application at a crusher discharge point.[46]

In order for effective control by fabric filters, an adequate capture system must be designed for each of the above dust sources. For example, the design of a hood enclosure for a material transfer point is dependent on the free-fall distance involved. Figure 2.18-18 and Figure 2.18-19 show an effective hood configuration for free-fall distances of less than or greater than 3 feet.

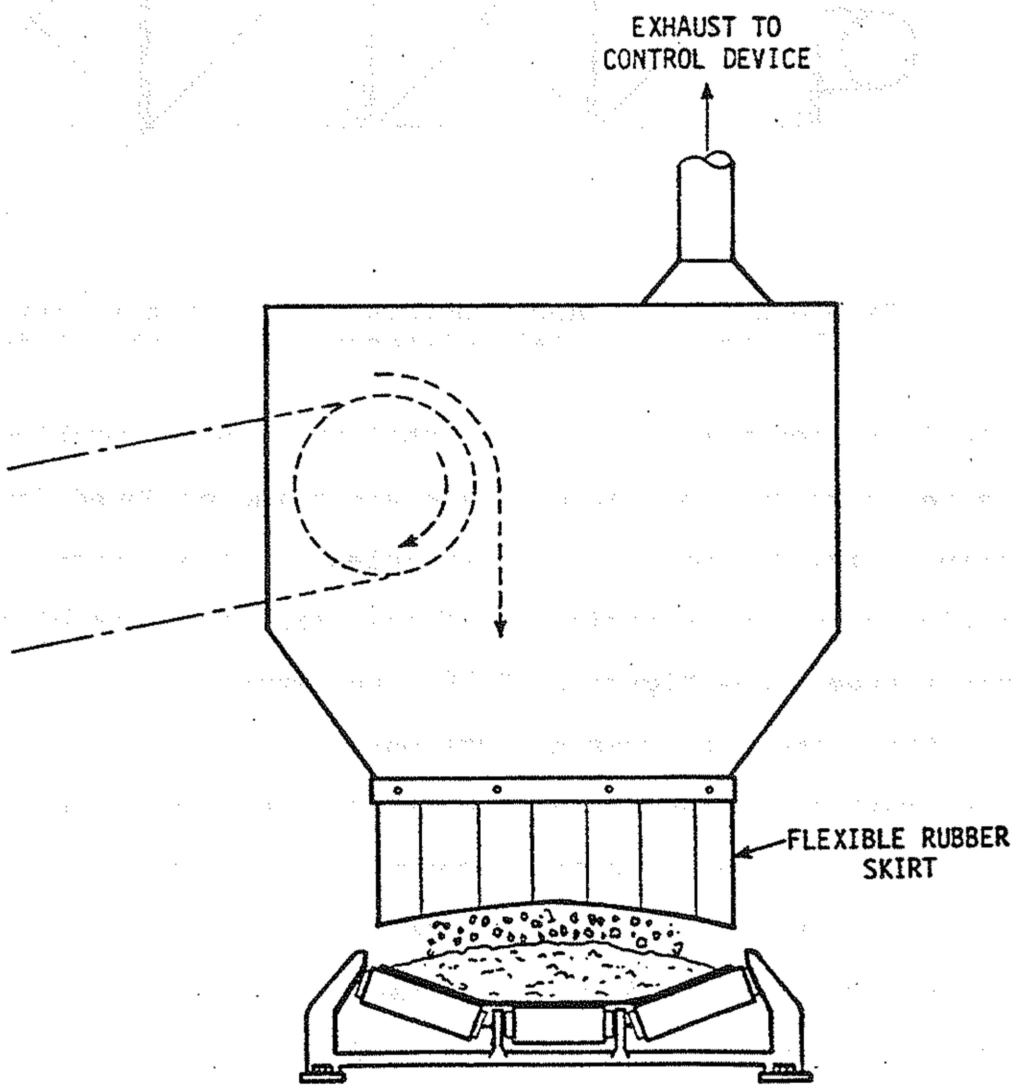

Figure 2.18-18. Hood configuration for a transfer point having a free-fall distance less than 3 feet.[48]

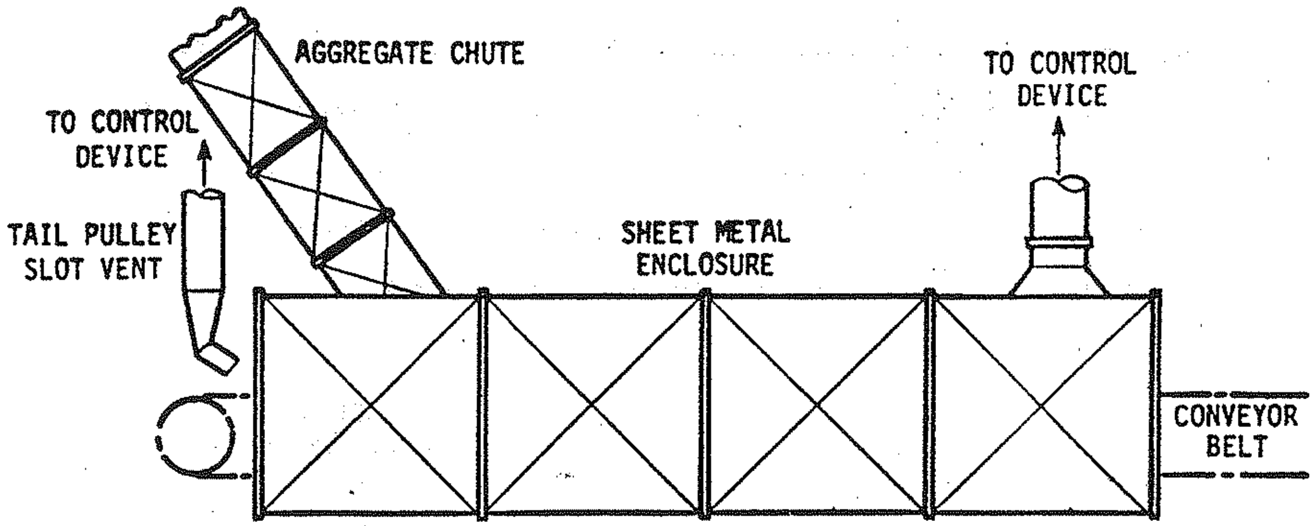

Figure 2.18-19. Hood configuration for a transfer point having a free-fall distance greater than 3 feet.[49]

In instances where water availability is not a problem and where fine-sized products that aggomerlate are being produced (crushing and screeningoperations on 1/4 inch particles) a combination system consisting of wet suppression and fabric filtration is often used. In such systems (see Figure 2.18-20), wet suppression is generally used at the primary processing portions of the process, i.e., the primary crushing and screening operations, reclaim feeders and conveyor transfer points. The processing operations following these activities, such as secondary and tertiary crushers, screens and recirculating conveyors, are controlled by a baghouse collector. The combination systems generally have higher annualized costs than a full wet suppression system, but less than a complete dry system assuming water is readily available. If water must be transported into a plant via truck, the added cost of hauling must be considered. In a combination system, since the wet suppression system is only used at a portion of the plant, the water use will be only about 40 percent of the use for a total wet suppression system.[50]

Therefore, the combination system represents a practical alternative to a fully dry collection system due to 1) less capital cost, 2) less water usage, and 3) the elimination of screen clogging when finer material is being processed.[50]

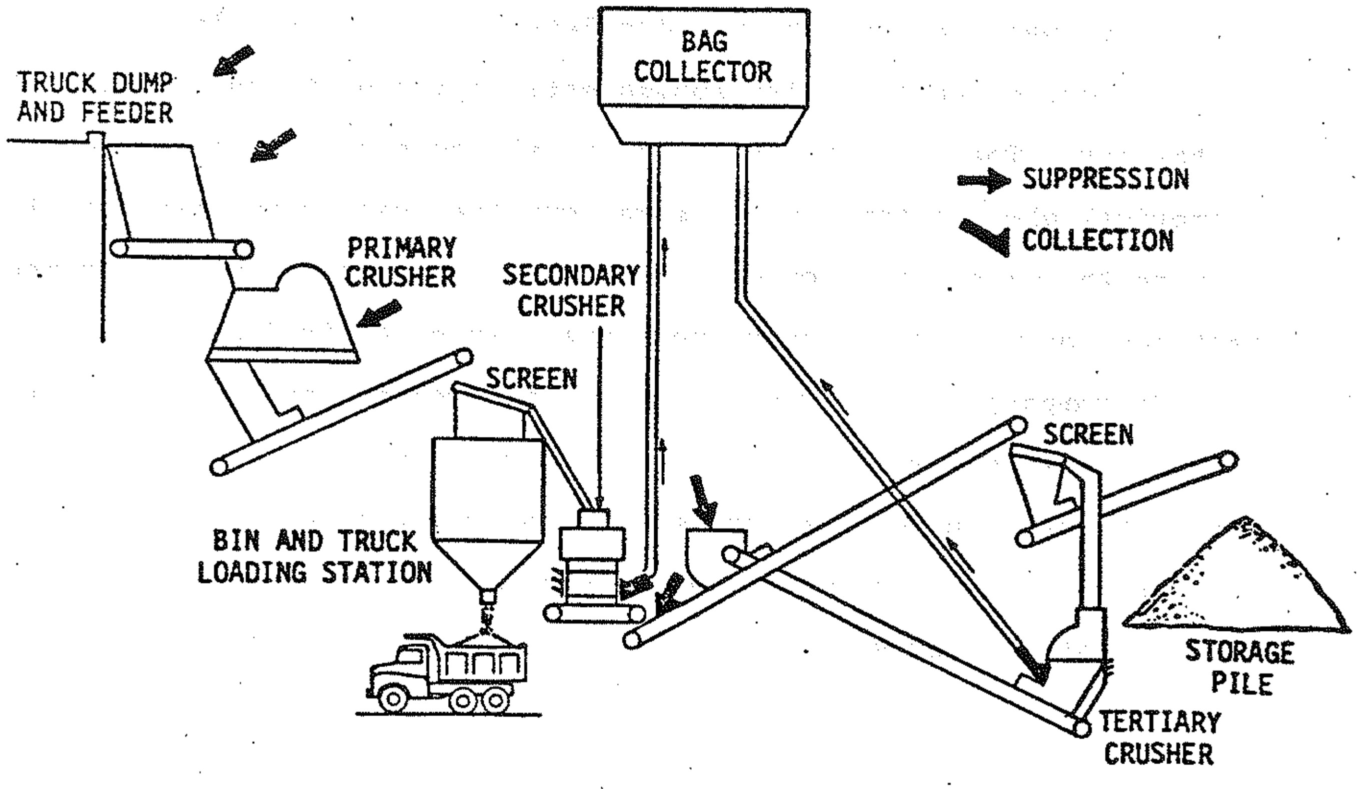

Figure 2.18-20. A combination control system consisting of wet suppression and dry collection.

Another dust control technique for aggregate processing activities which has been recently developed is electrostatic spray systems. Very little data is available on their actual performance. In fact, one source indicated that there is no known electrostatic spray system that has been demonstrated to be effective in an outside environment at an aggregate processing plant. The most promising feature of this control measure is that it shows promise for use in applications where very fine dusts are emitted and where use of water, as in wet dust suppression systems, is technically infeasible. According to the limited knowledge of the principles behind this new technique, in general, particles below 8 microns in diameter tend to be negatively charged while larger particles tend to have positive charges or to be uncharged. This technique uses an appropriately charged water fog to attract the oppositely charged particulates. Contact is made between the fog droplets and the particulates.

The wetted particulates subsequently agglomerate and settle out of the air. The equipment used may merely consist of a modified commerical electrostatic paint spray gun that uses compressed air to atomize the water into fog droplets. The fog droplets may be formed uncharged or with positive or negative charges as is desired.[51]

In comparison to a comparable wet suppression system using 450 gallons of water per hour for a plant production rate of 300 tons per hour, the water usage rate for an electrostatic spray system is 9.5 gallons/hr. Thus, the water usage is drastically reduced with an electrostatic spray system.[52]

Therefore, electrostatic spray systems should be considered for further experimentation on small (< 10 microns) dust particles generated, for example, by tertiary crushing where wet suppression techniques cannot be used due to product specifications or moisture content. Also, it could be used in advance of a control device such as a wet scrubber in order to improve efficiency and reduce energy requirements.[52]

Fugitive dust emissions may be significant from conveyor and transfer points. The control alternatives for conveyor emissions include wet suppression and enclosure of the conveyor.

Fugitive dust emissions from aggregate storage piles originate from four sources: 1) loading onto pile, 2) loading out, 3) wind erosion and 4) vehicular traffic.

For fugitive dust emissions from loading onto storage piles from belt conveyors, wet suppression and minimizing the free-fall distance are effective methods of control. For loading onto finished product storage piles, the use of wet suppression sprays at the conveyor drop points may not be necessary if sufficient dust suppressant has been applied in the previous stages of processing. However, if excessive visible emissions are noted during loading onto storage piles, the source may be controlled by either increasing the application rate of dust suppressant at the prior application points, or by installing a separate spray system at the conveyor drop point.

Minimizing free-fall distances from loading onto piles may be accomplished through the use of stone ladders, telescopic chutes and hinged-boom stacker conveyors.

Loading out from storage piles also may create fugitive dust emissions. Generally, loading out at aggregate processing plants is performed by the use of a front-end loader or by an under pile, gravity-feed conveyor system (usually for surge storage piles only). Control methods for this fugitive dust source may consist of wet suppression, which keeps the stored material wet, and the use of an under pile, gravity-feed conveyor system (in place of loading with a front-end loader).

For control of fugitive dust emissions due to wind erosion of storage piles, wet suppression, watering, and enclosure of the pile are the generally available control options. For very inactive storage piles, surface crusting agents may be sprayed over the entire surface of the pile. Also, the location of storage piles behind natural or manufactured windbreaks, and maintaining the working area on the leeward side of the storage piles can help to further reduce fugitive dust emissions.[53]

The control methods for fugitive emissions due to vehicular traffic around storage piles are presented in Section 2.1.1.

Fugitive dust emissions from product loading by front-end loaders into trucks may be controlled by keeping the stored material as moist as possible so that emissions are minimized. Furthermore, the use of operating precautions, such as emptying the loaded bucket as close to the bed of the truck as possible, will help minimize emissions.[54]

For produce loading by gravity free fall from storage bins into open bed trucks, the loading area may be partially enclosed or partially enclosed and exhausted to a fabric filter. The use of telescopic chutes at the loadout is also an effective control method.

2.18.5 Recommended Reasonably Available Control Measures (RACM)

The RACM selections for aggregate processing plant, fugitive dust emission sources are presented in Table 2.18-2.

For the unloading of raw material (usually by truck), the selected RACM is the use of a wet suppression system (spray application at the transfer point where the material falls off the truck). This system, when used for control on other sources at an aggregate processing plant, provides effective control at a relatively low annual cost. Of course, for operations such as the unloading of wet sand and gravel, no control is acceptable if visible emissions during unloading are negligible.

Similarly, wet suppression is selected as the RACM for all crushing, screening, conveying and handling operations. This selection is based on the low cost to benefit ratio for wet suppression as compared to the more costly alternative of enclosure with ventilation to a fabric filter. For those facilities which are not able to totally employ a wet suppression system for these operations because of problems with screen clogging, inability to achieve product specifications due to excessive fines in the material, and/or infeasibility (e.g., no water can be used in processing of agricultural lime due to the fine particle sizes), then a combination system should be used. The combination system may consist of wet suppression with either 1) enclosure with ventilation to a fabric filter, 2) electrostatic spray systems or 3) foaming agent spray systems.

Wet suppression was also selected as RACM for loading, loading out and wind erosion from storage piles. If an adequate dust suppressant has been applied in prior processing stages, separate spray application points at the storage pile may not be necessary.

TABLE 2.18-2. A SUMMARY OF THE CONTROL ALTERNATIVES, EFFICIENCIES AND COSTS, AND THE RACM SELECTIONS FOR FUGITIVE DUST EMISSIONS FROM AGGREGATE PROCESSING PLANTS

Fugitive dust sources	Control alternatives	Control efficiency, %	Control costs, Jan. 1980 $		Cost benefit, $/lb			RACM selection
			Capital	Annualized	Stone	Sand	Slag	
(1) Raw material unloading (trucks)	Enclosure, vent to fabric filter	99[a]	87,400[b]	13,500[c]	0.85	2.27	2.13	Wet suppression (chemical)
	Enclosure	70[d]	11,000[e]	1,900[f]	0.17	0.45	0.42	
	Wet suppression (chemical)	90[g]	72,000[h]	26,000[h]	0.008	0.18	0.04	
	Water sprays	50[i]	NA	NA	-	-	-	
(2) Primary crushing and screening	Enclosure, vent to fabric filter	99[a]	154,000[j]	53,000[j]	0.01	0.45	0.07	Wet suppression (chemical)
	Wet suppression (chemical)	90[g]	h	h	0.008	0.18	0.04	
	Water sprays	70[a]	NA	NA	-	-	-	
(3) Secondary crushing and screening	Enclosure, vent to fabric filter	99[a]	j	j	0.01	0.45	0.07	Wet suppression (chemical)
	Wet suppression (chemical)	90[g]	h	h	0.008	0.18	0.04	
(4) Tertiary crushing and screening	Enclosure, vent to fabric filter	99[a]	j	j	0.01	-	-	Wet suppression (chemical)
	Wet suppression (chemical)	90[g]	h	h	0.008	-	-	
(5) Recrushing and rescreening	Enclosure, vent to fabric filter	99[a]	j	j	0.01	-	-	Wet suppression (chemical)
	Wet suppression (chemical)	90[g]	h	h	0.008	-	-	
(6) Screening, conveying and handling	Enclosure, vent to fabric filter	99[a]	j	j	0.01	0.45	0.07	Wet suppression (chemical)
	Wet suppression (chemical)	90[g]	h	h	0.008	0.18	0.04	

(continued)

TABLE 2.18-2 (continued)

Fugitive dust sources	Control alternatives	Control efficiency, %	Control costs, Jan. 1980 $		Cost benefit, $/lb			RACM selection
			Capital	Annualized	Stone	Sand	Slag	
(7) Storage piles								
Wind erosion	Enclosure	100[k]	3,890,000[k](s) 4,550,000(sg) 6,090,000(cs)	661,000[f](s) 747,000(sg) 1,035,000(cs)	134	27	169	Wet suppression (chemical)
	Wet suppression (chemical)	90[g]	h	h	0.008	0.18	0.04	
	Watering	80[k]	13,500[k]	2,700[l]	0.44	0.59	0.68	
	Windbreaks	30[m]	NA	NA	-	-	-	
Loading onto piles	Enclosure (stone ladders)	80[m]	24,500[m]	4,200[f]	9.38	14.58	2.83	Wet suppression (chemical)
	Wet suppression (chemical)	90[g]	h	h	0.008	0.18	0.04	
	Telescopic chutes	75[m]	8,600[h]	1,500[f]	3.57	5.55	1.08	
	Stacker conveyors	25[m]	122,000[m]	21,000[f]	150	233	45.30	
Loading out	Wet suppression (chemical)	90[g]	h	h	0.008	0.18	0.04	Wet suppression (chemical)
	Under pile conveyor	80[n]	NA	NA	-	-	-	
(8) Product loading (truck)								
Front-end loaders	Watering material prior to loading	70[a]	NA	NA	-	-	-	Wet suppression (chemical) and precautions
(coarse aggregate)	Wind breaks	50[m]	NA	NA	-	-	-	
	Precautions (minimize free-fall distance, etc.)	NA	NA	NA	-	-	-	
	Wet suppression (chemical)	90[g]	h	h	0.008	-	-	

(continued)

TABLE 2.18-2 (continued)

Fugitive dust sources	Control alternatives	Control efficiency, %	Control costs, Jan. 1980 $		Cost benefit, $/lb			RACM selection
			Capital	Annualized	Stone	Sand	Slag	
Loading from storage bins (fine aggregate)	Telescopic chutes	75[m]	8,600[m]	1,500[f]	0.13	0.33	0.31	Wet suppression (chemical) and telescopic chutes
	Enclosure of loading area	70[d]	11,000[e]	1,900[f]	0.17	0.45	0.42	
	Enclosure, vent to fabric filter	99[a]	87,400[b]	13,500[c]	0.85	2.27	2.13	
	Wind breaks	50[m]	NA	NA	-	-	-	
	Water sprays	50[i]	NA	NA	-	-	-	
	Wet suppression (chemical)	90[g]	h	h	0.008	-	-	

[a] Engineering estimate.

[b] Based on a 20' x 20' x 15' enclosure and a jet pulse baghouse treating 10,000 acfm @ 70°F with a 6.5 to 1 air/cloth ratio.

[c] Reference 55. Based on 1,000 hrs/yr operation.

[d] Reference 56.

[e] See Section 2.3 for truck unloading.

[f] Includes capital charges only at 17% of capital.

[g] Reference 57.

[h] Reference 58. Based on a 300 tph plant. Includes application at unloading, primary, secondary and tertiary crusher inlets and outlets, conveyor transfer points, storage pile sources, and loading out.

[i] Reference 59.

[j] Reference 60. Based on a 300 tph plant. Includes control of primary, secondary, and tertiary crushers, conveying and transfer.

[k] Reference 61. Based on a wind-activated sprinkler system.

[l] Includes capital charges and maintenance at 20% of capital.

[m] Reference 61.

[n] Reference 62.

Fugitive dust emissions from product loading via front-end loader should be controlled by the use of wet suppression in preceding operations and by precautions such as minimizing the drop distance from the loader bucket to the material surface in the truck. Wet suppression may also be used directly on the material during loading, if necessary, with minimal detriment to product quality (due to agglomeration of fines), since the aggregate that is loaded via front-end loader is coarse material.

For product loading from storage bins, RACM consists of the use of telescopic loading chutes and wet suppression as applied in preceding operations. Generally, the application of a dust suppressant in the previous process operations and the use of telescopic chutes are sufficient to reduce fugitive dust emissions from fine product loading.

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APPENDIX FOR SECTION 2.18

Assume a typical plant for each aggregate type:

	tph	tpy	hrs/yr	tons stored
Crushed stone	300	400,000	1,300	83,000
Sand & gravel	300	300,000	1,000	62,000
Slag	300	320,000	1,100	53,000

Wet Suppression System for Control of all Sources:

Capital cost (1977 \$) = \$58,643 p. 33, JACA

$$\$58,643 \; \frac{(249.6)}{(204.1)} \approx \$72,000$$

Annualized cost (1977 \$) = \$21,493

$$\$21,493 \; \frac{(249.6)}{(204.1)} \approx \$26,000$$

$$C/B_{cs} = \frac{\$26,000/yr}{(.9)(400,000\ tpy)(0.04 + 0.5 + 1.5 + 6.0 + 1.0 + 0.0014 + 0.0029 + 0.04) + (.9)(83,000)(2.0 + 0.093)}$$

$$C/B_{cs} = \$0.008 \text{ or } \sim \$0.01/\text{lb TSP removed}$$

$$C/B_{sg} = \frac{\$26,000/yr}{(.9)(300,000\ tpy)(0.02 + 0.1 + 0.3 + 0.0012 + 0.0023 + 0.02) + (.9)(62,000)(0.47)}$$

$$= \$0.18/\text{lb TSP removed}$$

$$C/B_{s} = \frac{\$26,000/yr}{(.9)(320,000\ tpy)(0.02 + 0.5 + 1.5 + 0.0058 + 0.012 + 0.02) + (.9)(53,000)(2.0 + 0.074)}$$

$$= \$0.0376 \approx \$0.04/\text{lb TSP removed}$$

Fabric Filter System for Control of Sources ②, ③, ④, ⑤, and ⑥:

Capital cost (1977 \$) = \$125,922 p. 45, JACA

$$\$125,922 \; \frac{(249.6)}{(204.1)} = \$154,000$$

Annualized cost (1977 \$) = \$43,412

$$\$43,412 \; \frac{(249.6)}{(204.1)} = \$53,000$$

$$C/B_{cs} = \frac{\$53,000/yr}{(0.99)(400,000\ tpy)(0.5 + 1.5 + 6.0 + 1.0) + (.099)(83,000)(2.0)}$$

$$= \$0.01/lb\ TSP\ removed$$

$$C/B_{sg} = \frac{\$53,000/yr}{(0.99)(300,000\ tpy)(0.1 + 0.3)}$$

$$= \$0.45/lb\ TSP\ removed$$

$$C/B_{s} = \frac{\$53,000/yr}{(.99)(320,000\ tpy)(0.5 + 1.5) + (.99)(53,000)(2.0)}$$

$$= \$0.07/lb\ TSP\ removed$$

Raw Material Unloading Via Truck:

A. Enclosure, vent to fabric filter

Capital cost = $87,400 (See Section 2.3, Lime)

Annual cost (1977 $) = $11,000 NMI, p. 3-5, @ 1,000 h/y

$$\$11,000 \quad \frac{(249.6)}{(240.1)} \simeq \$13,500$$

$$C/B_{cs} = \frac{\$13,500/yr}{(0.99)(400,000\ tpy)(0.04)}$$

$$= \$0.85/lb\ TSP\ removed$$

$$C/B_{sg} = \frac{\$13,500/yr}{(0.99)(300,000\ tpy)(0.02)}$$

$$= \$2.27/lb\ TSP\ removed$$

$$C/B_{s} = \frac{\$13,500/yr}{(0.99)(320,000\ tpy)(0.02)}$$

$$= \$2.13/lb\ TSP\ removed$$

B. Enclosure

Capital cost = $11,000 (See Section 2.19, Truck Unloading)

Annual cost = $1,900

Control efficiency = 70%

$$C/B_{cs} = \frac{\$1{,}900/yr}{(0.70)(400{,}000\ tpy)(0.04)}$$

$$= \$0.17/lb\ TSP\ removed$$

$$C/B_{sg} = \frac{\$1{,}900/yr}{(0.70)(300{,}000\ tpy)(0.02)}$$

$$= \$0.45/lb\ TSP\ removed$$

$$C/B_{s} = \frac{\$1{,}900/yr}{(0.70)(320{,}000\ tpy)(0.02)}$$

$$= \$0.42/lb\ TSP\ removed$$

Storage Piles:

A. Wind erosion

1. Enclosure

Control efficiency = 100% MRI, p. 6-6

Capital cost (1977 $) =

($60/ton stored) (53,000 tons) = $3,180,000
" (62,000 tons) = 3,720,000
" (83,000 tons) = 4,980,000

$$\$3{,}180{,}000\ \left(\frac{249.6}{204.1}\right) = \$3{,}890{,}000$$
$$3{,}720{,}000\ (\ "\ ) = 4{,}550{,}000$$
$$4{,}980{,}000\ (\ "\ ) = 6{,}090{,}000$$

Annualized cost (@17%)

$3,890,000 (.17) = $661,000
4,550,000 (.17) = 774,000
6,090,000 (.17) = 1,035,000

$$C/B_{cs} = \frac{\$1{,}035{,}000/yr}{(.093)(83{,}000\ tons)}$$

$$= \$134/lb\ TSP\ removed$$

$$C/B_{sg} = \frac{\$774{,}000/yr}{(.47)(62{,}000\ tons)}$$

$$= \$27/lb\ TSP\ removed$$

$$C/B_{s} = \frac{\$661{,}000}{(.074)(53{,}000\ tons)}$$

$$= \$169/lb\ TSP\ removed$$

2. Watering (wind activated sprinkler system)

Control efficiency = 80%

Capital cost (1977 $) = $11,000

$$\$11{,}000 \ \frac{(249.6)}{(204.1)} = \$13{,}500$$

Annual cost (@ 20%)

$13,500 (.2) = $2,700

$$C/B_{cs} = \frac{\$2{,}700/yr}{(.8)(.093)(83{,}000)}$$

= $0.44/lb TSP removed

$$C/B_{sg} = \frac{\$2{,}700/yr}{(.8)(.093)(62{,}000)}$$

= $0.59/lb TSP removed

$$C/B_{s} = \frac{\$2{,}700/yr}{(0.8)(0.093)(53{,}000)}$$

= $0.68/lb TSP removed

B. Loading onto piles

1. Enclosure (stone ladder)

Control efficiency = 80% MRI, p. 6-6

Capital cost (1977 $) = $20,000

$$\$20{,}000 \ \frac{(249.6)}{(204.1)} = \$24{,}500$$

Annual cost (@ 17%)

$24,500 (0.17) = $4,200

$$C/B_{cs} = \frac{\$4{,}200/yr}{(0.8)(0.0014)(400{,}000 \text{ tpy})}$$

= $9.38

$$C/B_{sg} = \frac{\$4{,}200/yr}{(0.8)(0.0012)(300{,}000 \text{ tpy})}$$

= $14.58

$$C/B_{s} = \frac{\$4{,}200/yr}{(0.8)(0.0058)(320{,}000 \text{ tpy})}$$

= $2.83

2. Telescopic chutes

Control efficiency = 75%   MRI, p. 6-6

Capital cost (1977 \$) = \$7,000

$$\$7,000\ \frac{(249.6)}{(204.1)} = \$8,600$$

Annual cost (@ 17%)

\$8,600 (.17) = \$1,500

$$C/B_{cs} = \frac{\$1,500/yr}{(.75)(.0014)(400,000\ tpy)}$$

= \$3.57/lb TSP removed

$$C/B_{sg} = \frac{\$1,500/yr}{(.75)(.0012)(300,000\ tpy)}$$

= \$5.55/lb TSP removed

$$C/B_{s} = \frac{\$1,500/yr}{(.75)(.0058)(320,000\ tpy)}$$

= \$1.08/lb TSP removed

3. Stacker conveyor (stationary stacker)

Control efficiency = 25%   MRI, p. 6-6

Capital cost (1977 \$) = \$100,000

$$\$100,000\ \frac{(249.6)}{(204.1)} = \$122,000$$

Annual cost (@ 17%)

\$122,000 (.17) = \$21,000

$$C/B_{cs} = \frac{\$21,000/yr}{(.25)(.0014)(400,000\ tpy)}$$

= \$150/lb TSP removed

$$C/B_{sg} = \frac{\$21,000/yr}{(.25)(.0012)(300,000\ tpy)}$$

= \$233/lb TSP removed

$$C/B_{s} = \frac{\$21,000/yr}{(.25)(.0058)(320,000\ tpy)}$$

= \$45.30/lb TSP removed

Product Loading:

A. Loading from storage bins

1. Telescopic chutes

Control efficiency = 75% MRI, p. 6-6

Capital cost = $8,600

Annual cost = $1,500

$$C/B_{cs} = \frac{\$1,500/yr}{(.75)(.04)(400,000)}$$

$$= \$0.13/lb\ TSP\ removed$$

$$C/B_{sg} = \frac{\$1,500/yr}{(.75)(.02)(300,000)}$$

$$= \$0.33/lb\ TSP\ removed$$

$$C/B_{s} = \frac{\$1,500/yr}{(.75)(.02)(320,000)}$$

$$= \$0.31/lb\ TSP\ removed$$

2. Enclosure of loading area

Assume same as truck unloading

3. Enclosure, vent to fabric filter

Assume same as truck unloading

2.19 COAL PROCESSING PLANTS

2.19.1 Process Description

This section presents a study of the fugitive dust emissions from sources at coal processing plants. For purposes of this study, the term "coal processing plants" includes all coal preparation plants and coal handling facilities.

Coal preparation plants include any facility (excluding underground mining operations) which prepares coal by one or more of the following processes: breaking, crushing, screening, wet or dry cleaning, and thermal drying. Generally, coal preparation plants can be classified into three types:

(1) those performing complete preparation, i.e., cleaning of both coarse and fine coal;

(2) those performing partial preparation, i.e., cleaning only coarse coal; and

(3) those performing only crushing of coal to a specific size.[1]

Coal handling facilities include any facility (excluding those associated with mining) which processes coal solely by use of one or more of the following operations: transferring, conveying, loading, unloading, or storing.

The subject of fugitive dust emissions from coal mining operations is not discussed in this section. For information on this subject, the reader should refer to Section 2.1.4 where an analysis of fugitive dust emissions from 1) overburden removal, 2) drilling and blasting, 3) off-highway truck loading, 4) waste disposal, and 5) reclamation is provided.

Generally, all coal mining operations have either a preparation or handling facility for the processing of the mined coal (commonly known as run-of-mine or ROM coal). These facilities are usually located at permanent sites near the mining operation in order to minimize transportation costs; however, some processing plants (generally small operations) have portable equipment and move with the mining location.

Coal processing plants can vary in size, complexity and purpose. For example, the type of coal processing plant can range from a simple coal loading station (tipple) which handles only a few tons of coal per hour to a complex coal washing plant processing over 1,000 tons of coal per hour. The type of coal processing performed depends on the requirements of the end user. Figure 2.19-1 illustrates the various types of coal processing plants that can be encountered.

As shown in Figure 2.19-1, this study of fugitive dust emissions from coal processing plants begins at the point where ROM coal is brought to the processing plant via some mode of transportation (truck, rail car, conveyor) and is unloaded. The study concludes at the point where the processed coal is loaded into transportation equipment (truck, rail car, conveyor, barge) for shipment to the end user.

At most surface coal mines in Ohio, ROM coal is usually loaded into off-highway trucks and/or rail cars and then transported to a central processing plant or transfer area. At underground coal mines in Ohio, if the processing plant is located near the mine mouth, the ROM coal is usually delivered directly from the mine to the processing plant or transfer area via rail cars or belt conveyors. If the processing plant is located a great distance from the underground coal mine mouth, the ROM coal is usually delivered by overland conveyors or by rail cars.

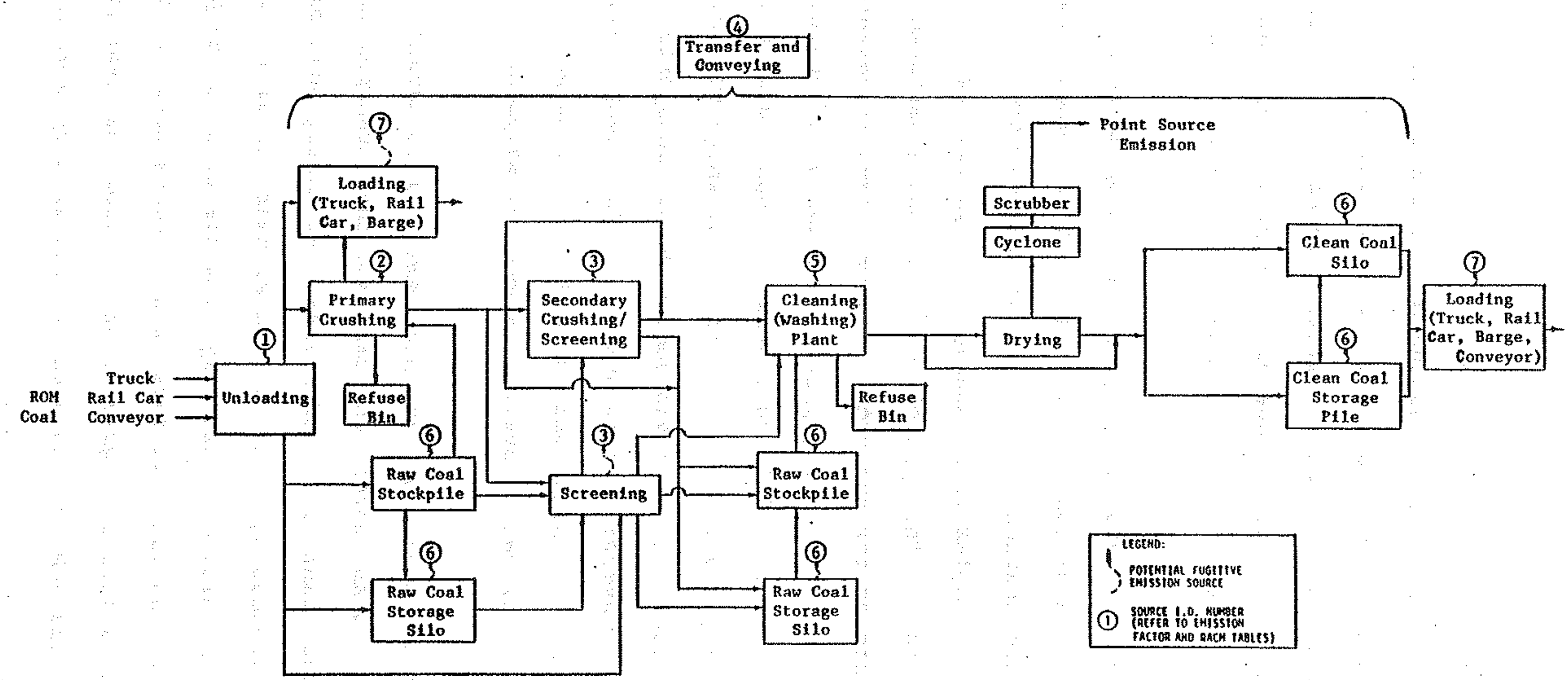

Figure 2.19-1 Simplified process flow diagram for coal processing plants and associated fugitive particulate emission sources.

At the processing plant, the ROM coal is unloaded from trucks or rail cars by dumping into a receiving hopper which discharges to a primary crusher, a tipple or to a feeder. A feeder subsequently empties onto a conveyor for transfer to an open storage pile or enclosed silo. ROM coal that is carried directly to the processing plant by conveyors is unloaded by dropping onto open storage piles or into enclosed silos.

Coal is normally stored in either open storage piles or silos to allow for optimum scheduling of processing and transportation equipment. The coal is transferred from open storage piles to either crushing, screening or loading operations by either front-end loaders or self-feeding tunnel conveyors. The coal which is stored in silos is transferred to processing equipment through the use of belt conveyors or is loaded into trucks or railroad cars by gravity.

Belt conveyors which have large carrying capacities are the most common method of transporting material at a coal processing plant. This is due to the large amount of material which must be transported. Therefore, screw, vibrating or continuous-flow conveyors are seldom used.[2]

ROM coal at any preparation plant undergoes at least a crushing operation. At many smaller plants, the coal that is processed by crusher is loaded directly into either a truck, rail car or barge for shipment to the user. Most of the larger mining operations will also provide secondary crushing, screening, wet or dry cleaning, and drying of the crushed coal. The remainder of this process description will discuss such processing at a typical coal preparation plant.

The cleaning or beneficiation of coal at preparation plants is performed for a number of reasons. One such reason is to improve the coal quality.

The quality of coal is improved through cleaning by the removal of undesirable impurities. This increases the heating value of the coal and provides a better fuel for the user. In fact, coal cleaning is often necessary in order to market ROM coal, since mined coal may contain up to 60 percent of reject material.[3]

Another reason for the cleaning of coal is that air pollution control requirements on the user often dictate the partial removal of pyrites with the ash in order to reduce the sulfur content of the coal. Also, ash content must often be monitored and reduced to levels stipulated in sales contracts. However, a minimum ash content must be maintained in order to ensure optimum combustion characteristics.[4]

Lastly, substantial savings in freight costs for shipping coal may be achieved by the removal of impurities before loading. Also, it is much easier to dispose of the impurities at the mining site rather than at the burning site because the burning site is generally located in a populated urban area.[4]

Whatever the reason for coal cleaning, a significant amount of coal mined in Ohio is washed. In 1977, approximately 37 percent (17.4 million tons) of all coal mined in Ohio was washed at a preparation plant. About 87 percent of this coal originated from underground mining operations, while the remainder came from surface mines.[5]

At coal preparation plants, the initial process operations consist of "tramp iron" removal and size reduction.[6] These removal and size reduction operations, which precede coal cleaning, are shown in Figure 2.19-2, where a typical coal preparation plant is illustrated.[7]

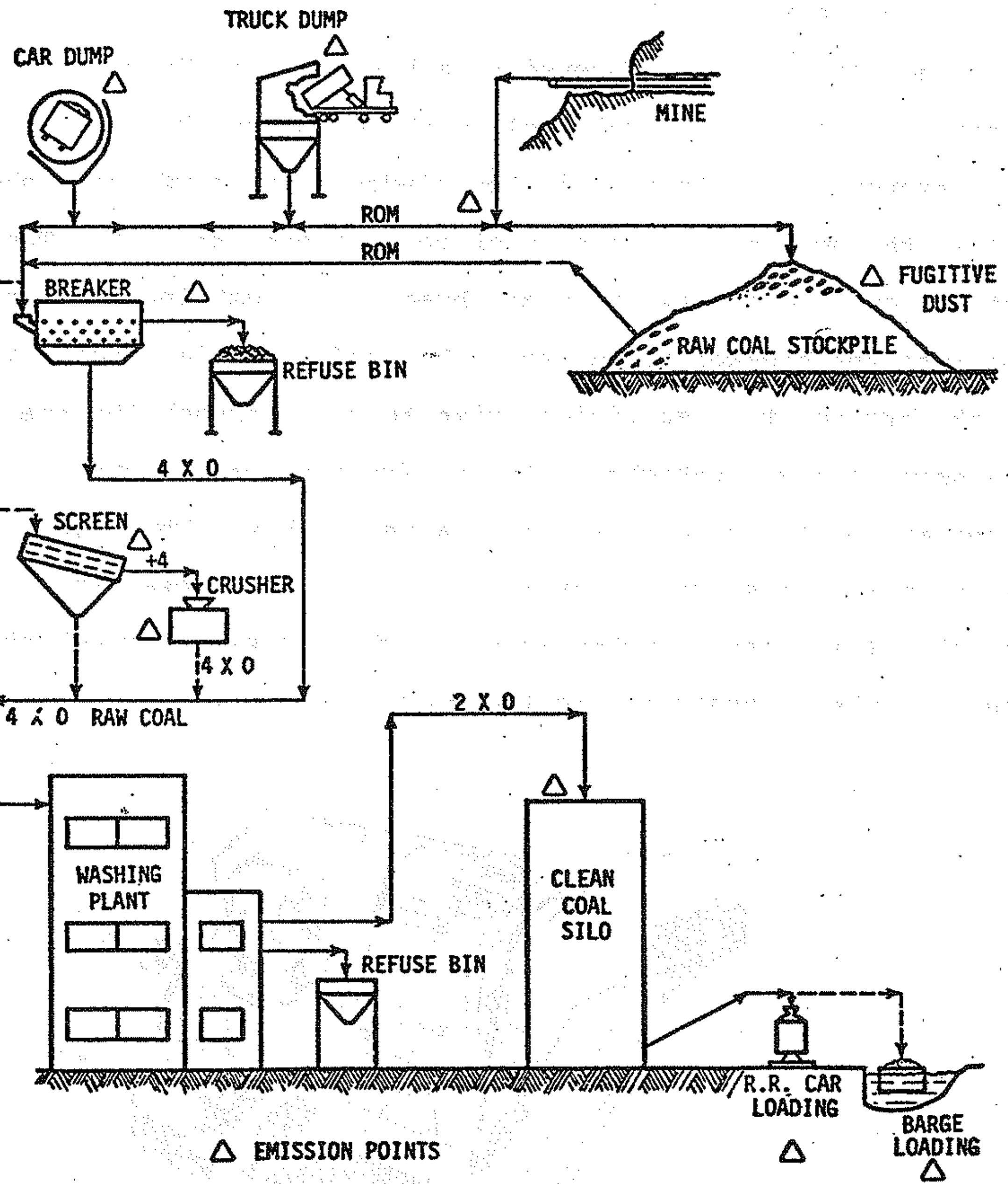

Figure 2.19-2. A coal sizing circuit at a coal preparation plant.[7]

The ROM coal is first exposed to a high-intensity magnet, which is usually suspended over the incoming belt conveyor, and the iron impurities are extracted from the coal. This high-intensity magnet may also be located after the breaker, but it is always located prior to the screen and crusher.

The coal is next conveyed to a breaker (see Figure 2.19-3) which consists of a cyclindrical shell with perforated holes (2 to 8 inches in diameter) and interior lifting blades. The perforated shell allows the smaller size ranges of coal to pass through. The breaker rotates on a horizontal axis and breaks the tumbling coal which is fed into the breaker at one end. The soft material (coal) is broken in the breaker to a sufficient size to pass through the shell, while the hard, larger, unbroken material (reject) passes out through the other end of the breaker and into a refuse bin. The reject material is eventually disposed by hauling to a waste disposal area. The coal (usually less than 4 inches in size) which passes through the breaker shell is then transferred to the cleaning plant.[6]

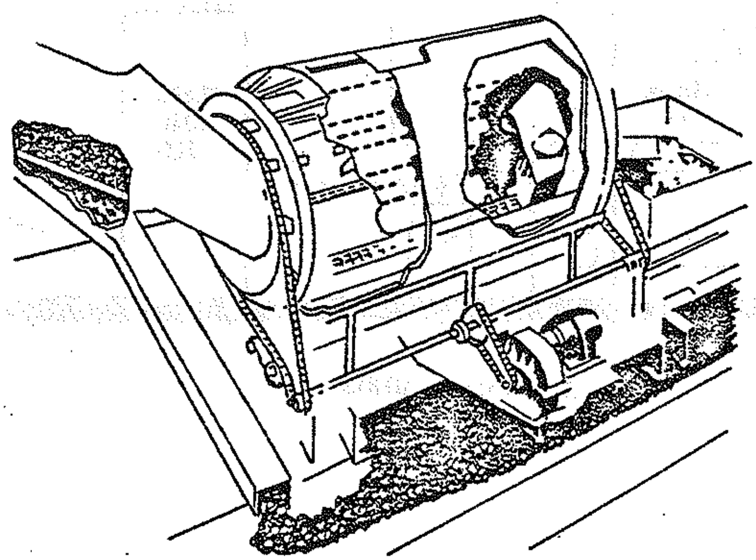

Figure 2.19-3. Rotary breaker.[8]

Instead of entering the breaker, some ROM coal is diverted to a scalping screen. From the scalping screen, the oversized material (> 4 inches) falls into a crusher and is reduced in size to less than 4 inches. This material is then combined with the screenings from the scalping screen and is transferred to the cleaning plant. This alternative flow is used more often than the breaker circuit despite the disadvantage of exposing the crusher to large pieces of material. A heavy-duty single roll crusher with tramp iron protection is most often used for this process.[9]

There are a number of crushers which may be used for crushing at a coal preparation plant. The most common types used are the hammermill, and the single, double-roll and ring crushers. The type to be used is dependent on the size of coal desired. These crushers are illustrated in Figures 2.19-4 through 2.19-7.[10]

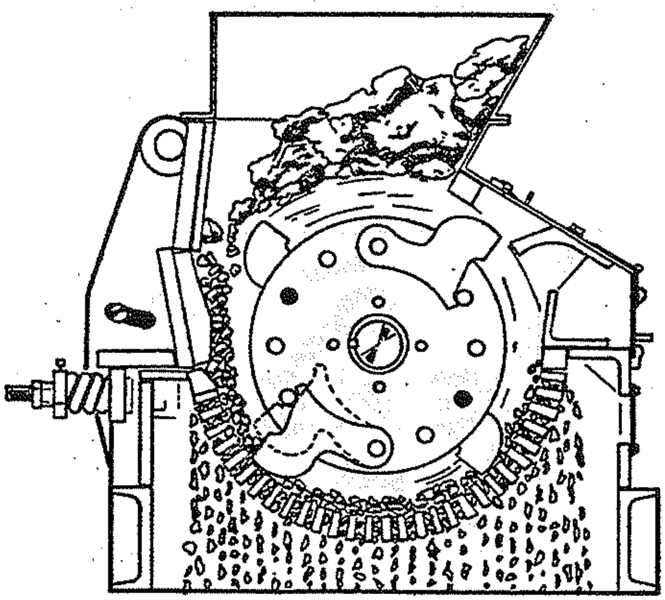

Figure 2.19-4. Hammermill.[8]

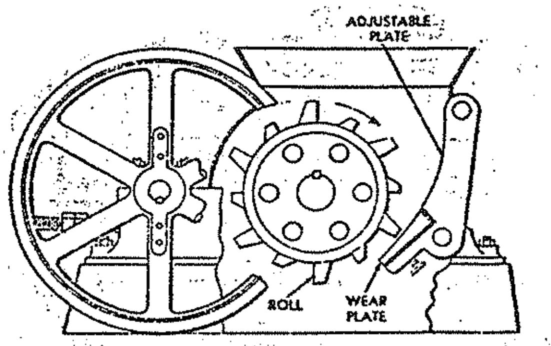

Figure 2.19-5. Single-roll coal crusher.[11]

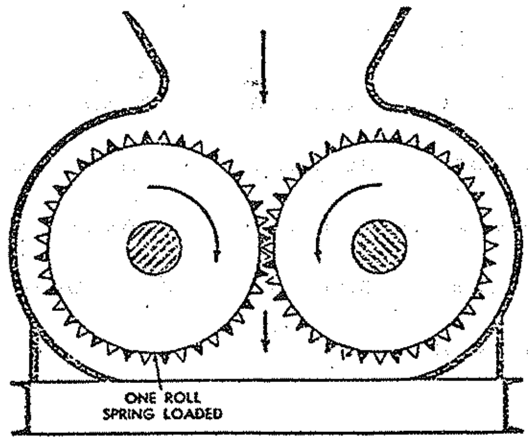

Figure 2.19-6. Double-roll coal crusher.[11]

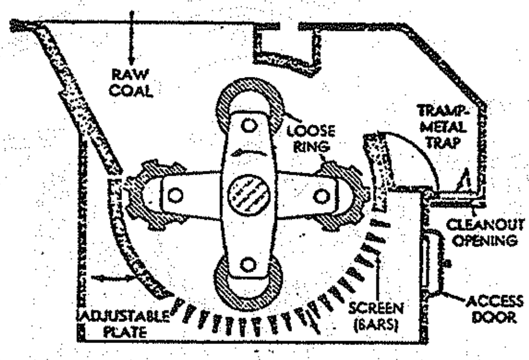

Figure 2.19-7. Ring coal crusher.[12]

As in the case of crushing equipment, coal preparation plants also use a variety of screening equipment for coal sizing. The types generally used are the grizzly, shaker and vibrating screens.

Grizzly screens, which size coal by gravity only, are usually used on ROM coal preceding a crusher or belt conveyor loading operation.[13]

Shaker screens are used infrequently and rarely provide a separation less than 2 inches.[14]

Vibrating screens are the most common type of separating device. They are used in both dry and wet processing plants.[14]

After crushing and screening, the raw coal at a preparation plant is usually stored in an open pile or in a silo prior to washing to allow for the smooth, efficient operation of the cleaning plant.[9]

At the cleaning plant, the type of mechanical cleaning equipment used is dependent on the size range of the coal entering the plant and the desired coal size. For example, coal that is larger than 8 inches is usually crushed; however, if lump coal is desired, the large fraction above 8 inches is cleaned by slate pickers. Table 2.19-1 lists the nominal size ranges and the corresponding cleaning equipment generally used. This cleaning equipment is discussed in the following sections.[21]

Table 2.19-1. COAL SIZE RANGES FOR CLEANING EQUIPMENT[15]

+8 inches	Picking tables
8" x 1/4"	Heavy media bath or drums Jigs
1/4" x 48 mesh	Diester tables Heavy media cyclones Air tables
48 mesh x 0	Froth flotation

Coal of a size range less than 3/8 inches is often cleaned by using pneumatic cleaning devices or air tables. These devices have a perforated bottom plate over which a layer of coal passes. A current of air is passed upward through the bed which removes the finer particles. The fines are eventually removed from the air stream by cyclones and fabric filters. By the time the coal reaches the ends of the air tables, it is separated into layers. The bottom layer contains heavy (high-ash content) material, the center layer is medium-weight coal and bone (high-ash content), and the top layer is coal (low-ash content). The center layer is removed, added to the refuse from the bottom layer and rewashed or included with the coal from the top layer and discharged to storage. Figure 2.19-8 shows a typical pneumatic cleaning circuit; and in Figure 2.19-9, an air table is illustrated.[16]

Generally, air tables are not very efficiency with respect to their ability to remove ash from coal. One source reports that their efficiency of ash removal is limited to 2 to 3 percent.[16]

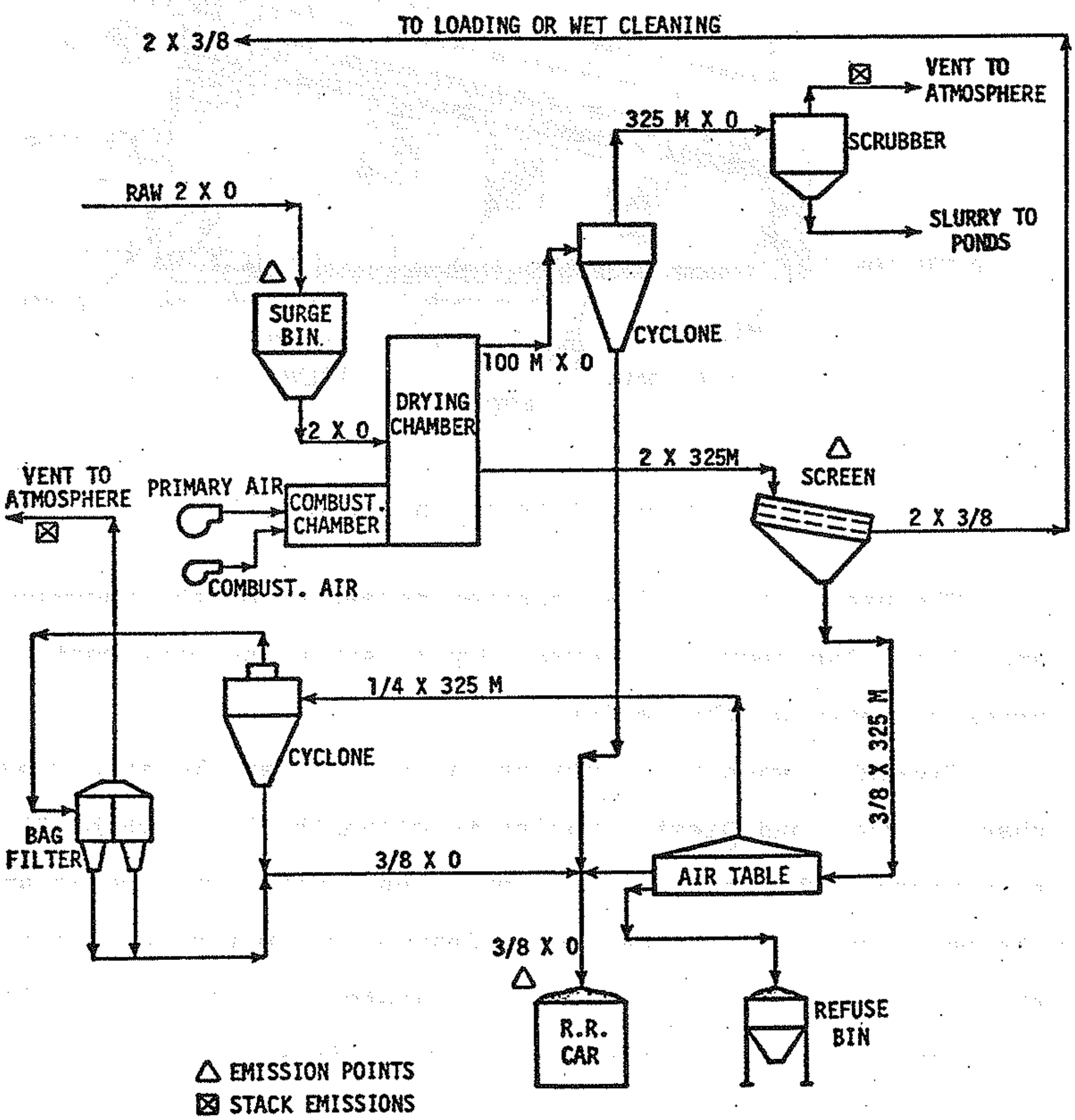

Figure 2.19-8. Pneumatic cleaning circuit.[17]

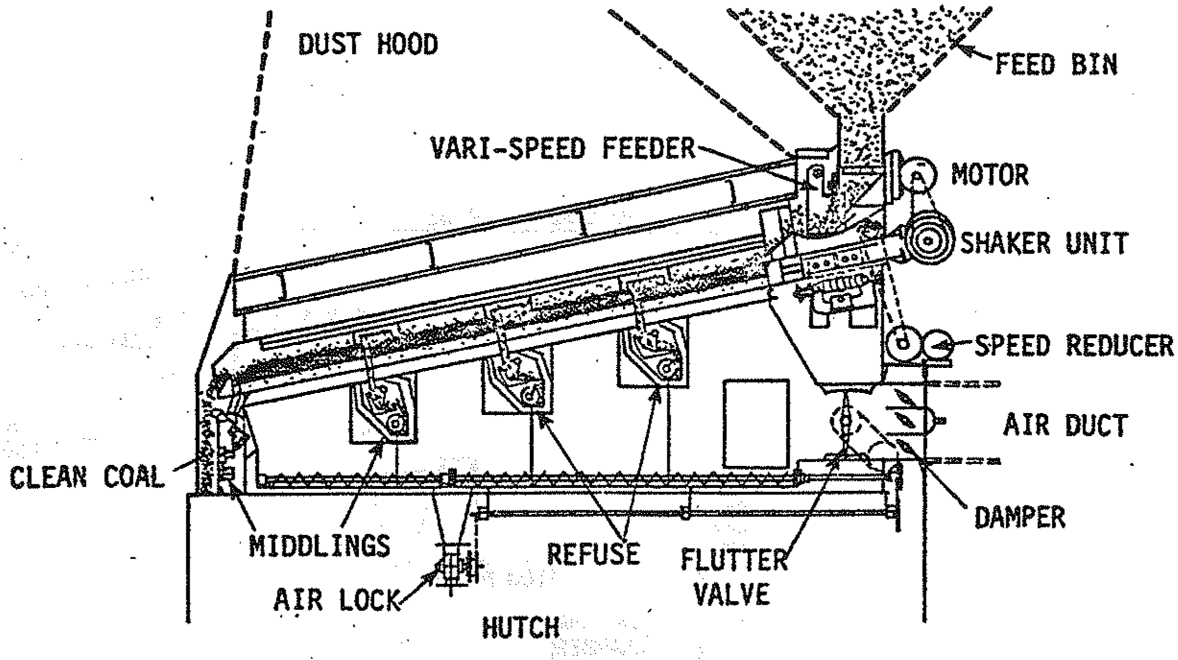

Figure 2.19-9. Air table.[18]

The use of air tables requires screening of the incoming coal, and often also requires thermal drying since the coal must be dry prior to entry on the tables.[16]

Jig-table washing plants use jigs to clean the size range greater than 1/4 inch and Diester tables to clean the 1/4 inch by 28 mesh size range. This equipment is often used with Froth cells and/or thermal dryers. A typical coal cleaning circuit using a jig-table is shown in Figure 2.19-10. The air-pulsated type of jig is illustrated in Figure 2.19-11, and the Diester table is shown in Figure 2.19-12.[19]

In a jig-table wash plant, the raw coal (< 8 mesh) is first separated on a wet screen (usually 1/4 inch mesh). The larger sized coal enters the jig, while the remaining coal is transferred to another separate cleaning circuit. The coal exiting the jig is dewatered on screens and in centrifuges, crushed, and loaded or stored.

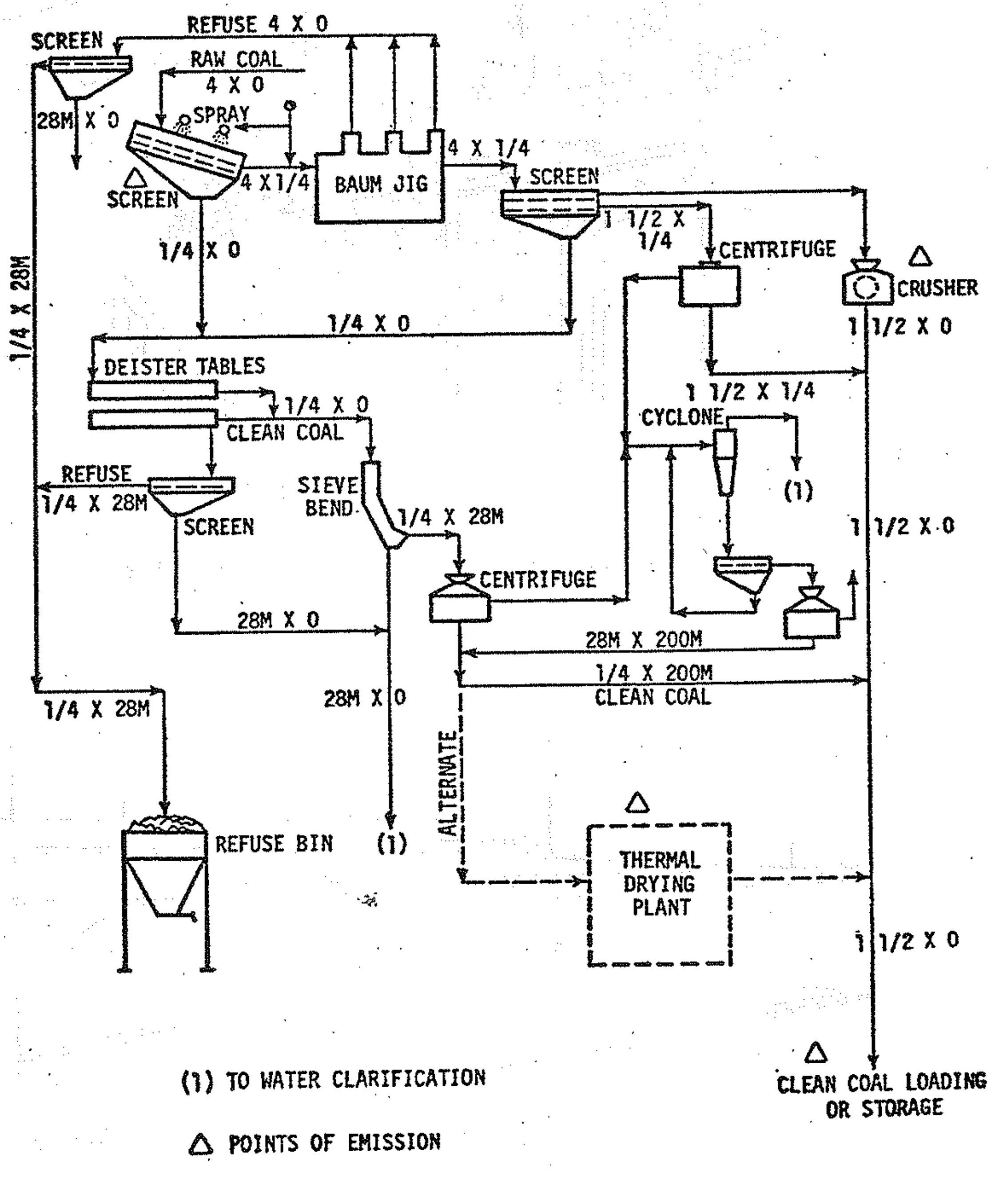

Figure 2.19-10. Jig-table cleaning circuit.[20]

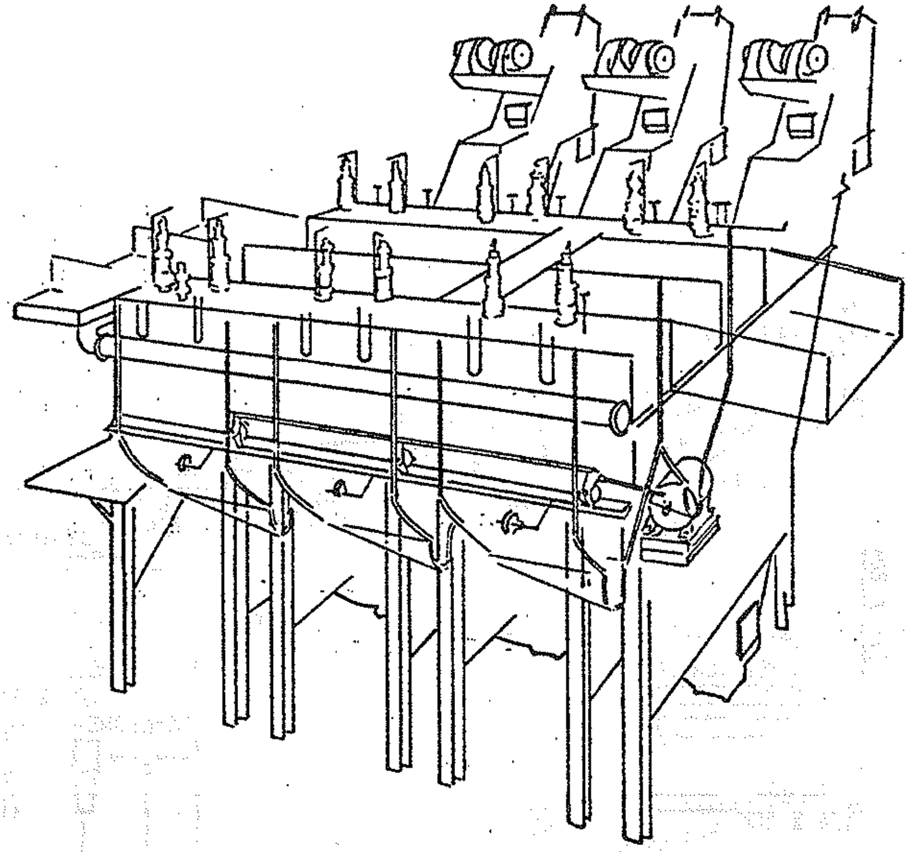

Figure 2.19-11. Air-pulsated jig.[21]

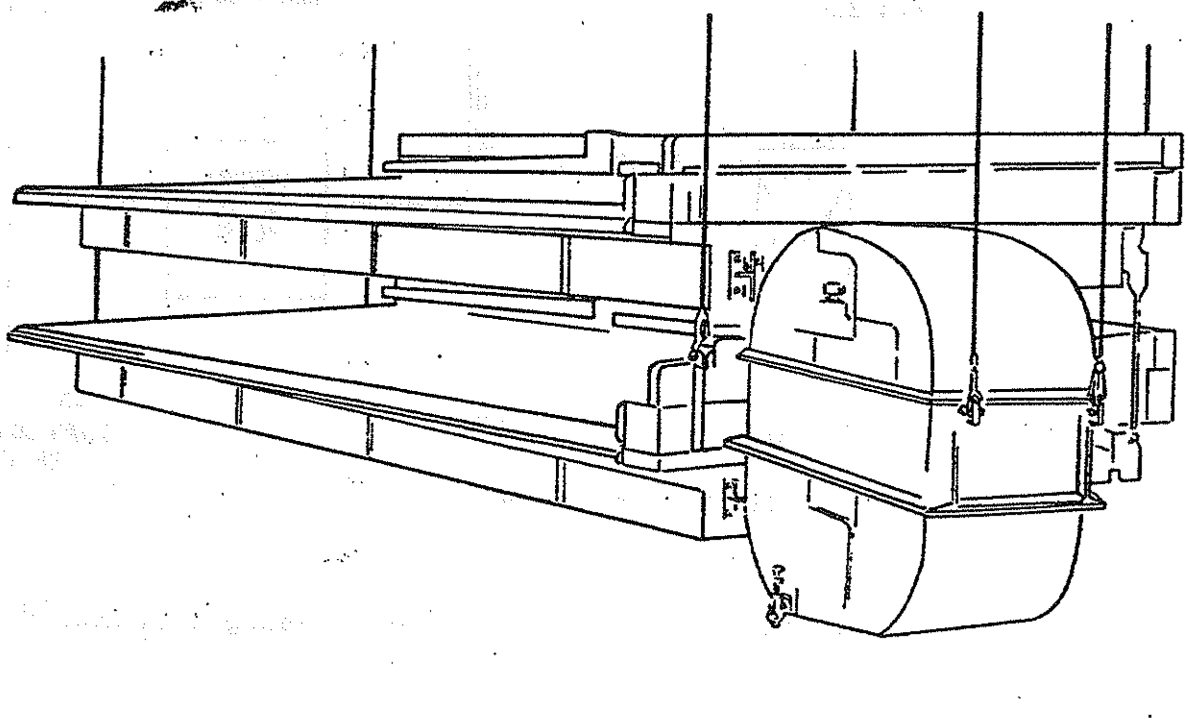

Figure 2.19-12. Deister table.[21]

The jig operates on the principles of setting in rising and falling water currents. The finer coal (< 1/4 inch) is mixed with water and then poured into the tables, where the refuse is separated from the coal. Water is removed from the refuse by screening and the refuse is deposited into a bin for storage until it may be hauled to a disposal area. The washed coal is then dewatered by using a stationary gravity screen or "sieve bend", where the fines are removed and sent to a centrifuge for dewatering and extraction of the fines. Finally, the washed coal is loaded or conveyed to a thermal dryer.[19]

A Diester table has a flat, riffled surface (about 12 square feet in area) which oscillates perpendicularly to the riffles toward the flow of coal. The heavy reject material falls off one end of the table, while the light coal is discharged off the opposite end. The remaining material is distributed in between.[19,20]

A heavy-media wash plant performs the cleaning of coal by flotation in a medium with a selected specific gravity, in which a dispersion of finely ground magnetite (Fe_3O_4) is maintained. Figure 2.19-13 depicts a typical heavy-media cleaning circuit.[22]

In this type of plant, the raw coal is first separated at 1/4 inch on an inclined screen. The oversize fraction is transferred to a flat, wet screen, where the finer particles are sprayed off the > 1/4 inch coal. The oversize material from this wet screen is then discharged into a heavy-media bath, where the refuse is separated from the coal. The refuse is then dewatered by discharging to a screen. The medium which is removed from the bath is divided into two parts, one returning to circulation via the heavy-medium sump and the other being pumped to the magnetite recovery system. The refuse is discharged from the screen for disposal. The coal is next removed from the washer to a rinse screen, where the coal is dewatered and

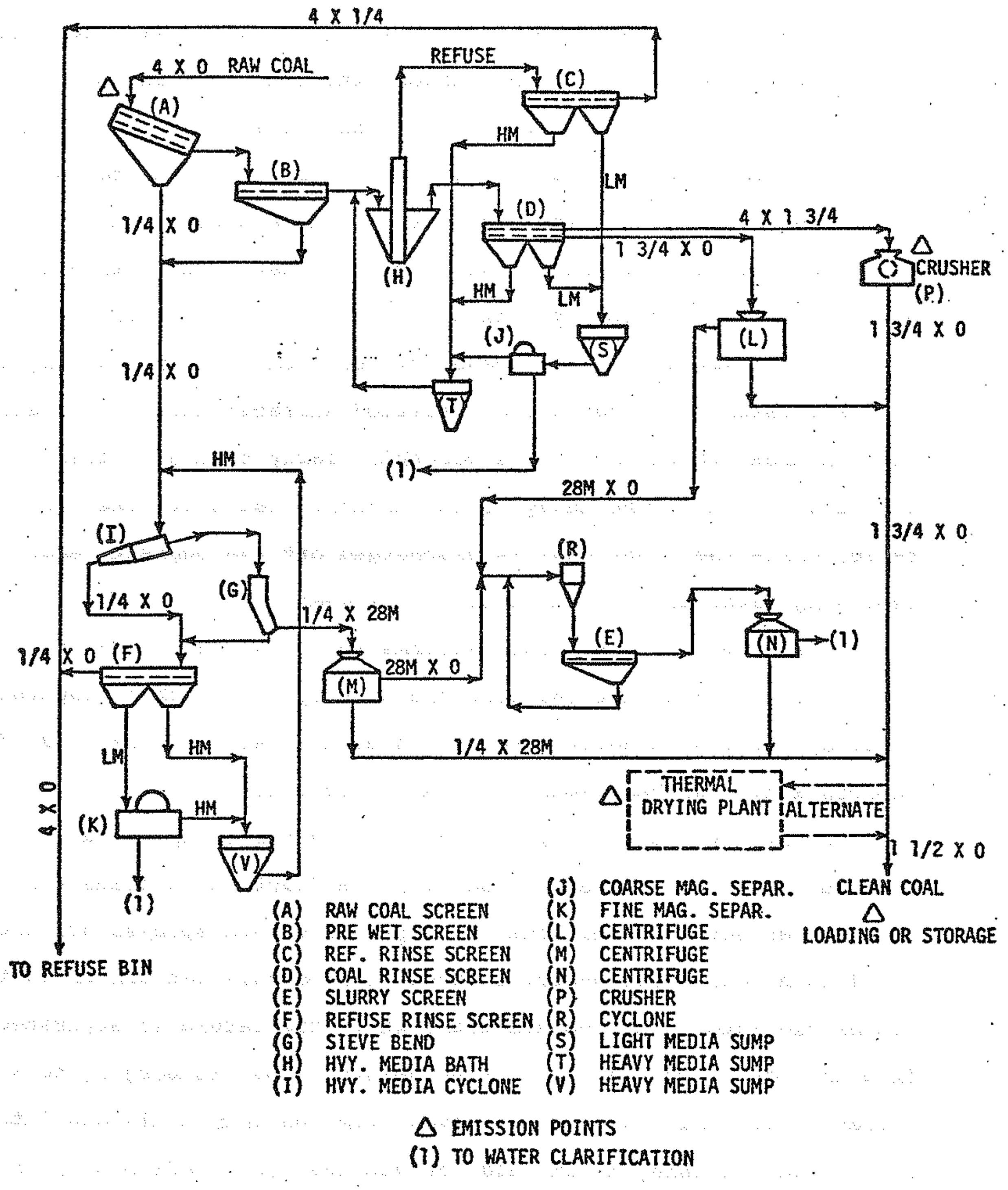

Figure 2.19-13. Heavy-media cleaning circuit.[23]

the resulting medium is treated similarly to that from the refuse screen. The washed coal is then centrifuged, crushed, and stored or loaded. The fine coal (< 1/4 inch) from the raw coal screens is combined with magnetite and water and pumped to a heavy-media cyclone as shown in Figure 2.19-14, where the coal is separated from the refuse by cyclonic action. The heavy-medium used in the cyclone is generally finer than that used in the heavy-media bath. The refuse from the heavy-media cyclone is then dewatered and the medium is recovered in a manner similar to that in the previous processes. Finally, this coal is then discharged over a sieve bend, centrifuged and transferred to a thermal dryer or to storage or loading.[24]

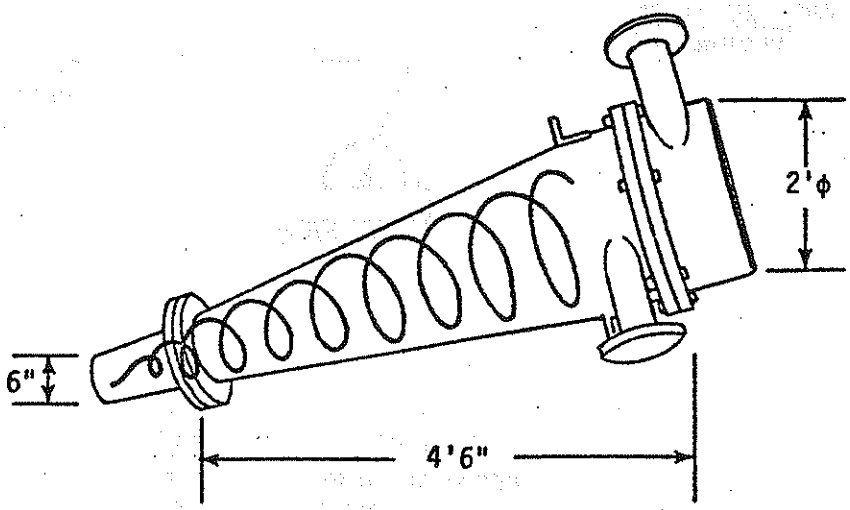

Figure 2.19-14. Heavy-media cyclone.[25]

The diluted magnetite is recovered via magnetic separators which consist of a shaft-mounted steel drum containing an interior fixed magnet. This cylinder rotates within a vessel containing coal slurry and magnetite, thereby retrieving the solid magnetite from the slurry via a magnetic field within the drum. Generally, each bath and cyclone have their own separate magnetic separator.[26]

The centrifuge effluents contain < 28 mesh coal which was broken from larger pieces of clean coal. These effluents are thickened in a cyclone, deslimed on a screen, and centrifuged before storage or loading.[27]

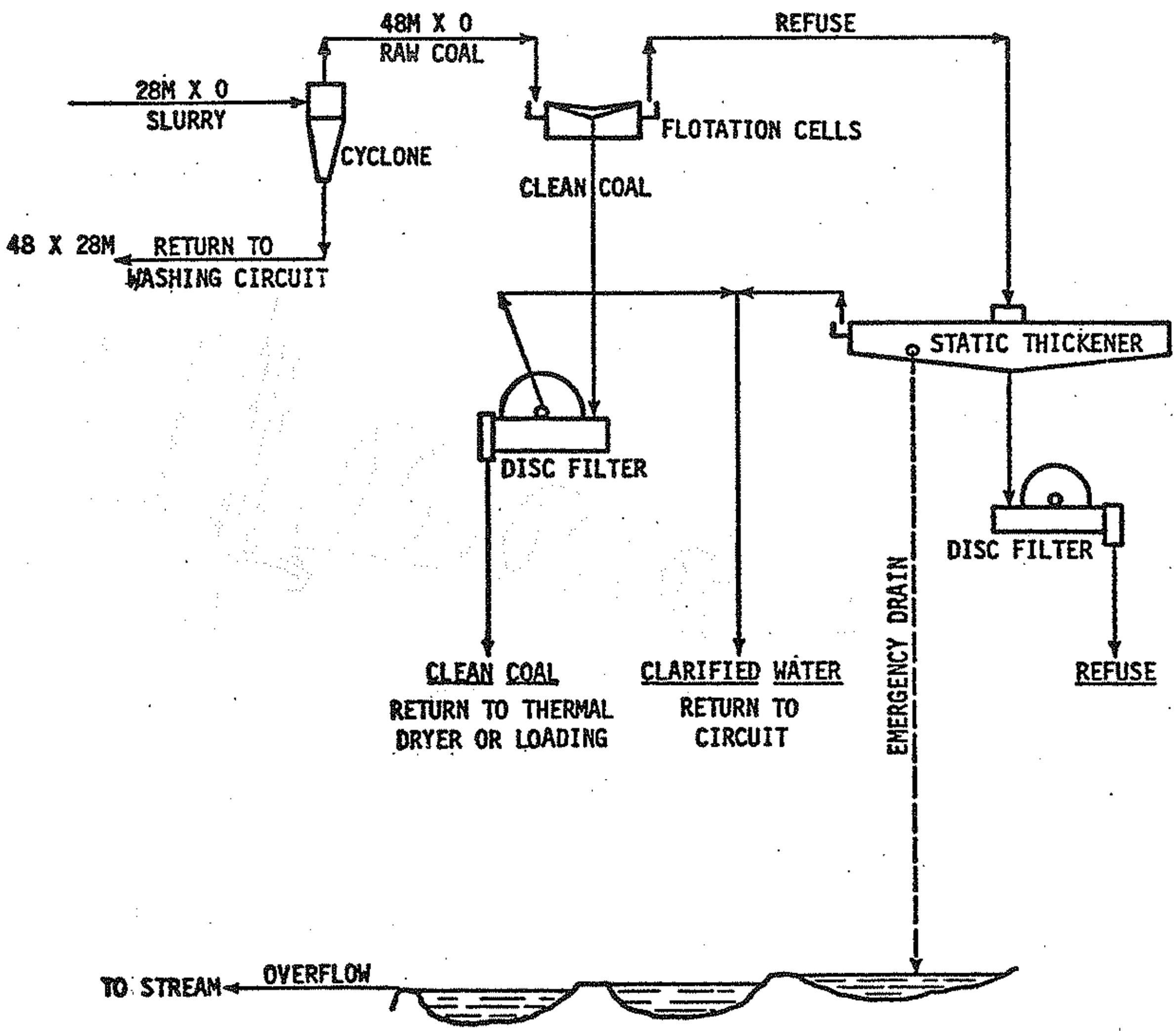

Figure 2.19-15. Water clarification circuit.[28]

A water clarification plant is also an integral part of a coal wash plant. It receives all of the slurry from the washing plant, separates the 48 mesh by 0 fraction for cleaning, and recycles water back to the plant. A typical clarification plant is shown in Figure 2.19-15. The 48 mesh by 0 fraction is discharged to froth flotation cells, where it is mixed with a light oil. The coal becomes coated with the oil and floats off the top of the cells to a disc filter, where the excess water is vacuumed off through a filter. The water is then recycled by pump back to the wash plant, and the coal fines are transported to a thermal dryer, storage or loading. A froth flotation unit is shown in Figure 2.19-16.[27]

The refuse, which does not accept the oil coating, sinks to the bottom of the flotation cells and is removed along with the incoming water to a static thickener. A static thickener is a large setting tank which allows enough retention time for the refuse to sink to the bottom. The clarified water is drawn off the top of the thickener by skimming troughs located around the perimeter of the tank, and is sent back to the wash plant.[27]

The static thickener contains a rotating rake which rakes the refuse at the bottom of the tank to the center where it is collected by a pump and transferred to a disc filter. The disc filter returns some of the water back to the wash plant and discharges the solids as refuse.[30]

The thermal drying of coal is used at coal processing facilities employing washing equipment. Generally, coal is dryed via a thermal dryer for one or more of the following reasons:

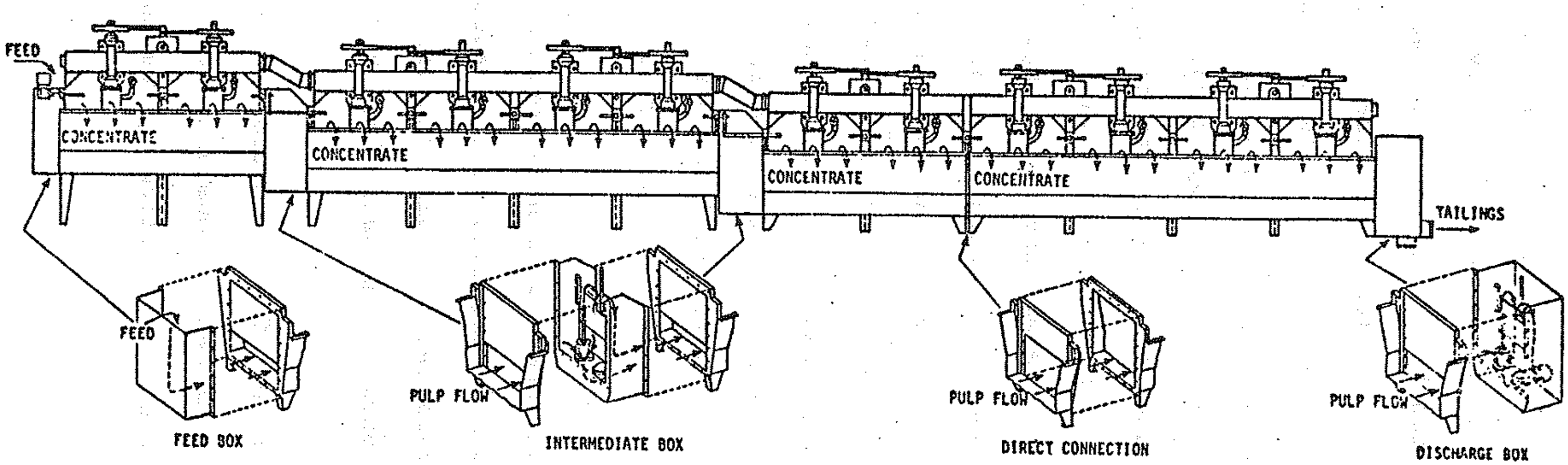

Figure 2.19-16. Froth flotation unit.[29]

1. to avoid freezing difficulties and to facilitate handling during shipment, storage, and transfer;
2. to maintain high pulverizer capacity;
3. to improve the quality of coal used for coking; and
4. to decrease transportation costs.[31]

Thermal dryers are generally used to dry the 1/4 by 0 inch fraction. However, sometimes the plus 1/4 inch portion is dried for ease of screening.[15]

Thermal dryers are simply contacting devices where hot exhaust gases from the combustion process in the dryer are used to heat the wet coal and to evaporate the surface moisture. There are seven basis types of thermal dryers which are presently used: rotary, screen, cascade, continuous carrier, flash or suspension, multilouver, and fluidized bed. However, the most prevalent types of thermal dryers are the flash and fluidized bed dryers.[32]

A rotary dryer consists of a rotating cylindrical drum (8 to 10 feet in diameter, 65 to 80 feet long) in which the wet coal flows countercurrently to the flow of hot gases. The dryer contains lifting vanes which help drop the coal through the hot gases.[32,33]

A screen dryer performs the drying function by transporting the wet coal over reciprocating screens while hot gases are passed through the bed. This dryer is usually used for coal in a size range from 1/2 mm to 2 inches. Figure 2.19-17 illustrates a typical screen dryer.[32,33]

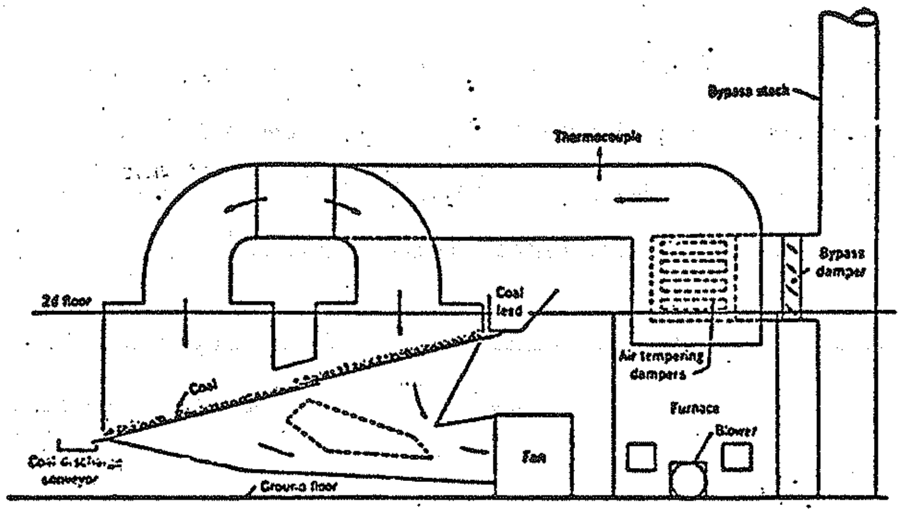

Figure 2.19-17. Screen-type thermal coal dryer.[32]

In a cascade dryer, wet coal is first fed to the dryer via a rotary feeder. The wet coal cascades through wedge-wire shelves which vibrate. Simultaneously, hot gases are drawn upward through and between the wedge-wire shelves. The dried coal is then collected at the bottom of the dryer and removed. This type of dryer is most commonly used for drying fine coal (3/8 x 0 inch). A cascade dryer is shown in Figure 2.19-18.

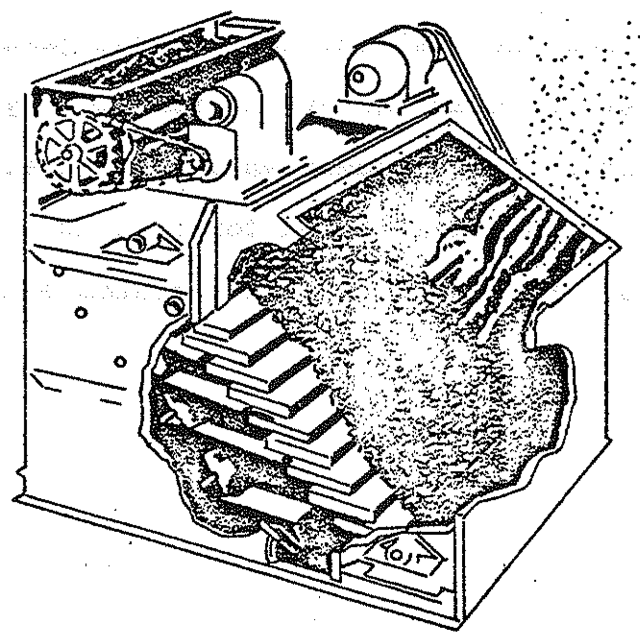

Figure 2.19-18. Cascade thermal coal dryer.[35]

A continuous carrier thermal coal dryer is a very uncommon type of dryer. A literature survey provided no description or illustration of this type of dryer.

A flash or suspension dryer is the second most used type of dryer. In this dryer, the hot gases generated in the combustion furnace of the dryer transport the wet coal up a riser. The turbulence created in the riser provides an excellent drying environment. This type of dryer is used for extremely fine coal with the top size not exceeding 3/8 inch. A flash or suspension dryer is shown in Figure 2.19-19.[32,36]

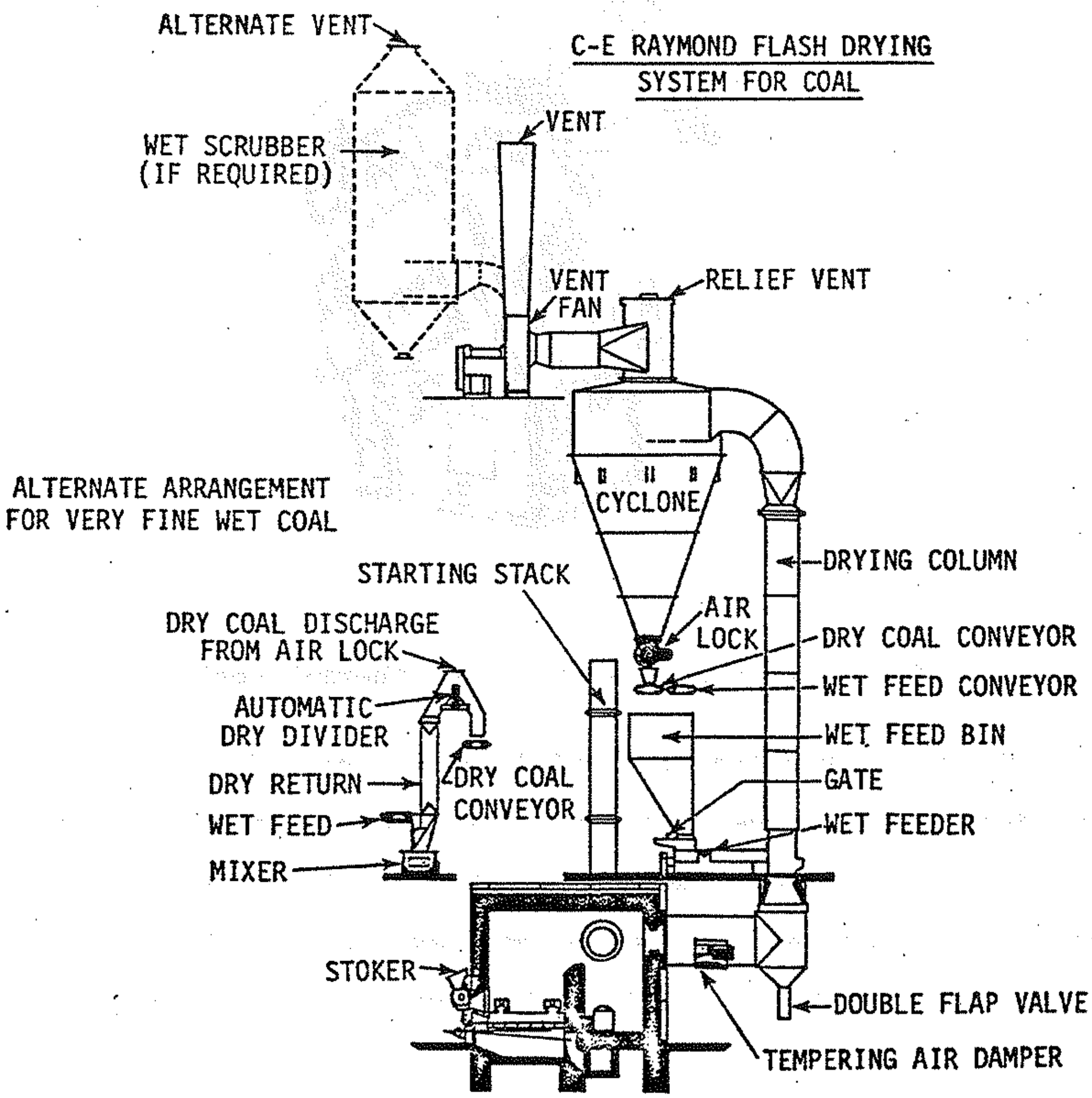

Figure 2.19-19. Flash or suspension thermal coal dryer.[37]

A multilouver dryer, shown in Figure 2.19-20, is used primarily for drying large volumes of coal and for drying coal which requires rapid drying. In this type of dryer, wet coal is transported up in flights and then flows downward in a shallow bed over the ascending flights. The coal gradually moves across the dryer during each pass from the feed entrance to the discharge area.[38]

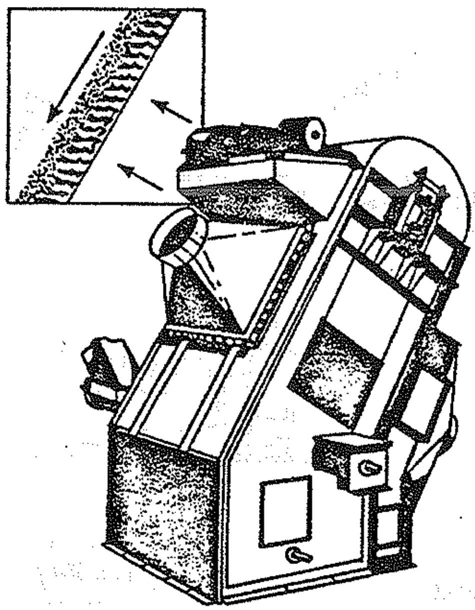

Figure 2.19-20. Multilouver thermal coal dryer.[35]

The most prevalent type of dryer in use today is the fluidized bed dryer. This dryer contains a perforated plate in a negative pressure fluidizing chamber above which coal is suspended by a rising column of hot gases. The dried coal exists from the dryer at an overflow weir. Figure 2.19-21 illustrates a typical fluidized bed dryer.[32,39]

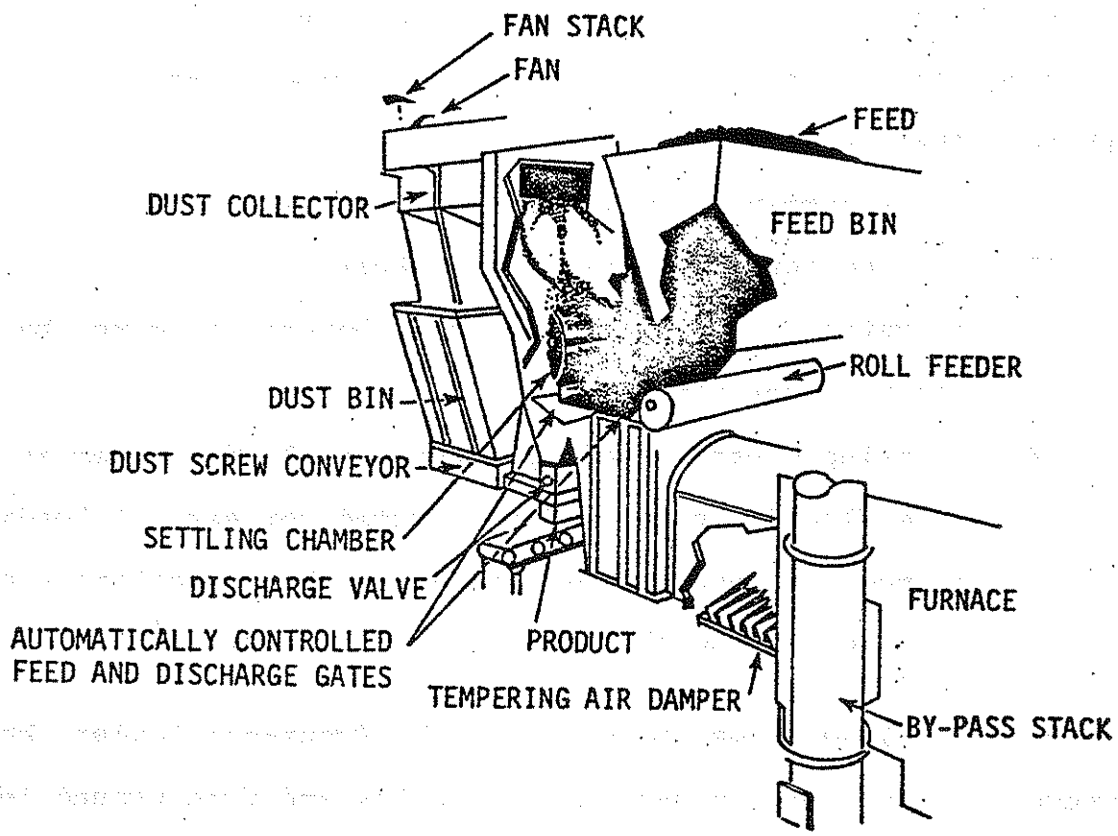

Figure 2.19-21. Fluidized bed thermal coal dryer.[40]

After washing and drying, mines using unit train shipment, usually store enough clean coal to fill a train. Silos are often used for this purpose. Furthermore, silo storage prevents accumulation of moisture and exposure to wind. Some mines employ open storage, using conveyors for loading. Lastly, at some mines, railroad cars or barges are loaded directly as the coal is processed.

In general, the method of loading coal is dependent on the size of the processing plant, the available transportation mediums, and the location of the end users. The transportation mediums most often used are barge, rail, truck, and overland conveyor.

Barge loading of coal is usually performed by any one of five methods. These are:

(1) truck dumping directly into the barge,

(2) loading through a stationary chute,

(3) elevating - boom loading, where barges are moved back and forth in the river beneath,

(4) floating - barge loading, where the loading boom is mounted on a floating barge and is pivoted for ease of loading, and

(5) tripper - conveyor loading, where the barges are stationary and the loading chute moves back and forth.[41]

Rail car loading may be performed by front-end loader, belt conveyor, booms from overhead storage silos and from ground level storage piles with underground loading. Silo loading into rail cars is used frequently at large coal processing plants where unit trains are flood-loaded through telescopic chutes. Such silos commonly have a capacity ranging from 10,000 to 15,000 tons.[42]

Truck loading is performed through the use of front-end loaders, belt conveyors and overhead storage silos.

With overland conveyors the coal is transported directly to the end user (usually a power plant).

In Ohio, the majority of all coal is loaded into either trucks or railroad cars. In 1977, of the approximately 47 million tons of coal produced, the disposition of the coal was as follows:[43]

Truck	23.54	million
Rail	13.17	"
Conveyor	6.48	"
Barge	3.28	"
Storage	0.33	"
Other	0.14	"

The potential sources of fugitive dust emissions from coal processing plants are the unloading of ROM coal, primary crushing, secondary crushing/screening, transfer and conveying, cleaning, storage of processed coal, and the loading of coal. These sources are indicated in Figure 2.19-1.

The fugitive dust emissions created by vehicle traffic over roadways at the processing plant is addressed in Section 2.1.1. The fugitive dust emissions created by vehicular movement around storage piles is also addressed in Section 2.1.1.

For additional information with respect to fugitive dust emissions from coal storage piles and coal handling, the reader is referred to Section 2.1.2 and 2.1.3, where a detailed discussion is presented.

2.19.2 Fugitive Dust Emission Factors

The estimated emission factors for coal processing plant fugitive dust sources as identified in Section 2.19.1 are summarized in Table 2.19-2. As noted in Table 2.19-2, the reliability of all of the emission factors is poor since they were based on engineering estimates.

TABLE 2.19-2. FUGITIVE DUST EMISSION FACTORS FOR COAL PROCESSING PLANTS

Source	Emission factor	Reliability rating	Reference
(1) Unloading			
Truck	0.02 lb/ton unloaded	E	44
Rail car	0.40 lb/ton unloaded[a]	E	45, 46
(2) Primary crushing	0.02 lb/ton crushed	E	47
(3) Secondary crushing/ screening	0.16 lb/ton crushed/ screened	E	47
(4) Transfer and conveying	0.20 lb/ton transferred or conveyed	E	48
(5) Cleaning	Negligible		49
(6) Storage			
Loading onto pile	0.08 lb/ton loaded	D	50
Vehicular traffic	0.16 lb/ton stored	D	50
Loading out	0.10 lb/ton loaded	D	50
Wind erosion	0.09 lb/ton stored	D	50
(7) Loading			
Truck	0.02 lb/ton loaded	E	44
Rail car	0.40 lb/ton loaded	E	45, 46
Barge	0.40 lb/ton loaded	E	45, 46

[a] For bottom dumping only. Emission factors for railroad car unloading by side and rotary dumping were unavailable.

Since there were a number of published emission factors for many of the fugitive dust sources, the factors selected for this study were those most widely referenced in the literature and those which would be more applicable to a "typical" fugitive dust source rather than to a site-specific source.

The emission factor for truck unloading was developed by PEDCo by taking half of the published EPA emission factor for truck dumping. The rationale for this derivation was that coal dumping would be expected to generate less fugitive dust emissions than comparable dumping of aggregate. This is because of the larger size of the coal being handled and its higher moisture content. The 50 percent reduction was based on the estimated control efficiency of watering which PEDCo believes is comparable to the effects of higher moisture content and larger material size.[44]

The emission factor for rail car unloading was taken from Section 2.4 for rail car unloading at coal-fired power plants.[45] This factor is also cited by another source for all modes of transport.[46]

The estimated emission factors for primary crushing and secondary crushing and screening were based on estimates by PEDCo from limited test data and engineering judgment.[47]

The estimated emission factor for transfer and conveying was derived from emission estimates made by ERT for combined processing sources at coal mines in northwestern Colorado. The emission factor of 0.20 pound per ton was developed by subtracting the emission estimates for crushing (0.18 lb/ton) and storage (0.054 lb/ton) from the estimated emission factor (0.44 lb/ton) for the processing sources which were identified as transfer and conveying, crushing, and storage. One study points out that the resulting emission factor for transfer and conveying does seem high when compared to estimated emissions from conveying other material. This may be an indication that other sources may have been included in the ERT emission factor for the processing sources.[48]

Our reference in this study indicated that fugitive dust emissions from coal cleaning operations were negligible.[49] No published fugitive dust emission factors for coal cleaning were found in the literature.

The emission factors for storage were based upon limited test data and engineering judgment. Their reliability is, however, considered below average.[50]

The emission factors for loading were assumed to be the same as for unloading. This assumption was made by one source with respect to unloading and loading operations in general.[46]

2.19.3 Particle Characteristics

No data were located on the particle size distributions for fugitive dust emissions from coal processing plant sources.

For coal dust emissions, one source reports that at a concentration of 2 mg/m^3 detrimental health effects may occur if the respirable dust fraction contains less than 5 percent quartz.[51] Furthermore, another source indicates that the potential health hazards of coal dust are dependent on the amount of silica (SiO_2) present in the dust.[52] Exposure to silica by breathing over extended periods of time has resulted in a respiratory problem known as silicosis. Silicosis is a chronic lung disease characterized by diffuse fibrosis.

Coal dust emissions from fugitive dust sources at coal processing plants often result in the creation of nuisance conditions if the plant is located near a densely populated area. Coal dust may cause significant property damage through the soiling of the exterior of vehicles and homes, since such dust is difficult to remove without an extensive cleaning effort.

2.19.4 Control Methods

This section presents the fugitive dust control methods which are or may be used by the coal processing industry for those sources identified in this study.

The fugitive dust emissions from truck or rail car may be controlled by 1) total enclosure with ventilation to a fabric filter, 2) a partial enclosure, 3) a water spray system, and 4) a wet suppression system using water and chemical wetting agents, or foams.

For primary and secondary crushing and screening operations, control methods consist of enclosures with ventilation to a fabric filter and wet suppression systems utilizing a chemical wetting agent or foams.

For fugitive dust emissions from conveying operations, the control methods generally used are partial (top) enclosure, total enclosure, or wet suppression. Also, fugitive dust emissions created by the droppings from the return belt conveyors may be controlled through the use of dribble pans.

Fugitive dust emissions from transfer points may be controlled through the use of total enclosure, enclosure with ventilation to a fabric filter, or wet suppression systems using chemical wetting agents.

Cleaning activities are usually performed inside an enclosed building and may undergo wet processing operations. Therefore, cleaning activities are insignificant sources of fugitive dust emissions, and no control is generally required.

The fugitive dust emissions from storage piles consist of four sources: load-in, wind disturbance, vehicular traffic and load-out. The control methods available for those sources vary with the type of source.

For load-in at storage piles, control methods include 1) enclosure through the use of stone ladders, 2) wind guards, 3) telescopic chutes, 4) wet suppression and, of course, operating precautions.

Fugitive dust emissions from wind disturbances at storage piles may be controlled through the use of wet suppression and the application of surface crusting agents. Also, operating precautions such as orienting the storage piles perpendicular to prevailing winds to reduce the exposed surface is helpful in reducing wind erosion.

For vehicular traffic at coal storage piles, the control methods are listed in Section 2.1.1.

For loading out from coal storage piles, control measures consist of the installation of under-pile conveyor systems, bucket wheel reclaimer systems, and wet suppression.

For coal storage in silos or bins, fugitive dust emissions are normally controlled by covering conveyors which transport and dump the coal into the silos or bins. Also, the fugitive dust in the displaced air from silos and bins may be controlled by the addition of either bin vent filters or exhausted fabric filters; however, these emissions are not considered significant.

Control methods for loading operations consist of telescopic chutes and wet suppression. For operations which use wet suppression in subsequent processes, generally only telescopic chutes are required for dust control if an adequate treatment of wetting agent has been previously applied to the coal.

2.19-5 Recommended Reasonably Available Control Measures (RACM)

The RACM selections for coal processing fugitive dust emission sources are presented in Table 2.19-3.

The selected control technique for unloading of coal by both rail car and truck is a wet suppression system utilizing a chemical wetting or foaming agent for more efficient control of fugitive dust. This measure is less costly than the more efficient application of a fabric filter, and is more efficient than the other less reliable methods of control.

Primary and secondary crushing and screening activities may be effectively controlled by using a wet suppression system which is also used for the unloading and transfer and conveying operations. This system is less costly than the alternate of installing an enclosure with ventilation to a fabric filter.

Wet suppression is the selected RACM for transfer and conveying because it is less costly than the alternative of enclosure with or without a fabric filter.

Since cleaning operations are generally performed inside enclosed buildings and/or include wet processing, no control is required.

Coal storage pile load-in activities can be controlled to a high degree by the use of telescopic chutes supplemented by wet suppression systems. For wind erosion and loading activities, wet suppression has also been selected as RACM due to its high efficiency and relatively low cost.

For loading activities, RACM is the use of wet suppression systems and/or telescopic chutes. If an adequate treatment of wetting agent has been applied in subsequent operations, only telescopic chutes need be used. For loading activities which do not use wetting agent applications in subsequent operations, both telescopic chutes and wet suppression systems are recommended.

TABLE 2.19-3. A SUMMARY OF THE CONTROL ALTERNATIVES, EFFICIENCIES AND COSTS, AND THE RACM SELECTIONS FOR FUGITIVE DUST EMISSIONS FROM COAL PROCESSING PLANTS

Fugitive dust sources	Control alternatives	Control efficiency, %	Control costs, Jan., 1980 $		Cost benefit, $/lb	RACM selection
			Capital	Annualized		
(1) Unloading ROM coal						
Rail car	Enclosure, vent to fabric filter	99[a]	120,000[a]	39,000[b]	0.03	Wet suppression (chemical)
	Enclosure	70[c]	33,000[d]	5,600[e]	0.005	
	Wet suppression (chemical)	80[f]	98,000[g]	37,000[h]	0.01	
	Watering	50[i]	NA	NA	NA	
Truck	Enclosure, vent to fabric filter	99[a]	87,400[j]	23,000[k]	0.31	Wet suppression (chemical)
	Enclosure	70[c]	11,000[l]	1,900[e]	0.03	
	Wet suppression (chemical)	80[f]	98,000[g]	37,000[h]	0.03	
	Watering	50[i]	NA	NA	NA	
(2) Primary crushing	Enclosure, vent to fabric filter	99[m]	129,000[n]	38,000[b]	0.06	Wet suppression (chemical)
	Wet suppression (chemical)	90[m]	o	o	0.01	
(3) Secondary crushing/ screening	Enclosure, vent to fabric filter	99[m]	p	p	0.06	Wet suppression (chemical)
	Wet suppression (chemical)	90[m]	o	o	0.01	

(continued)

TABLE 2.19-3 (continued)

Fugitive dust sources	Control alternatives	Control efficiency, %	Control costs, Jan., 1980 $		Cost benefit, $/lb	RACM selection
			Capital	Annualized		
(4) Transfer and conveying	Enclosure of conveyors and transfer points, vent to fabric filter	99[a]	100,000[q]	30,000[r]	0.04	Wet suppression (chemical)
	Enclosure of conveyors and transfer points	70[a]	28,000[s]	8,400[r]	0.02	
	Wet suppression (chemical)	90[m]	o	o	0.01	
(5) Cleaning	Enclosure	100[m]	NA	NA	NA	No control
(6) Storage						
Loading onto piles	Enclosure (stone ladder)	80[t]	24,000[t]	4,000[e]	0.02	Wet suppression (chemical), telescopic chutes
	Telescopic chutes	75[t]	8,600[t]	1,500[e]	0.01	
	Wet suppression (chemical)	75[t]	73,000[t]	36,000[h]	0.20	
	Wind guards	50[t]	61,000[t]	12,000[u]	0.10	
Wind erosion	Enclosures	100[t]	15,000,000[t]	2,550,000[e]	9.44	Wet suppression (chemical)
	Wet suppression (chemical)	99[t]	13,400[t]	6,400[v]	0.02	
Loading out	Under pile conveyor	80[w]	14,520,000[x]	2,900,000[u]	12.08	Wet suppression (chemical)
	Wet suppression (chemical)	95[t]	73,000[t]	36,000[h]	0.13	
	Bucket wheel reclaimer	80[t]	6,480,000[t]	1,300,000[u]	5.42	

(continued)

TABLE 2.19-3 (continued)

Fugitive dust sources	Control alternatives	Control efficiency, %	Control costs, Jan., 1980 $		Cost benefit, $/lb	RACM selection
			Capital	Annualized		
(7) Loading						
Rail car/barge	Wet suppression (chemical)	80[t]	73,000[t]	36,000[h]	0.04	Wet suppression (chemical), telescopic chutes
	Telescopic chutes	75[t]	8,600[t]	1,500[e]	0.01	
Truck	Wet suppression (chemical)	80[t]	73,000[t]	36,000[h]	0.75	Wet suppression (chemical), telescopic chutes
	Telescopic chutes	75[t]	8,600[t]	1,500[e]	0.03	

NA = Not available.

[a] Reference 53.

[b] Reference 54. Based on a 750 tph rock crushing plant and an operating rate of 5,000 hrs/yr.

[c] Reference 55. Partial enclosure without exhausting to a fabric filter.

[d] Reference 56. Based on (50' x 30' x 21') 10 Ga steel enclosure of rail car dump.

[e] Includes capital charges at 17% of capital costs.

[f] Reference 53.

[g] Reference 57. Based on a 750 tph rock crushing plant. Includes spray application at unloading, primary crushing, secondary crushing/screening, transfer and conveying.

[h] Reference 58. Based on 5,000 hr/yr operation.

[i] Reference 59.

[j] See Section 2.3, p. 2-163. Based upon 20' x 20' x 15' enclosure and a jet pulse baghouse treating 10,000 acfm @ 70°F with a 6.5 to 1 air/cloth ratio for a limestone truck unloading operation.

[k] Reference 54. Based on a 750 tph rock crushing plant and an operating rate of 5,000 hrs/yr. Annual cost includes enclosure cost.

(continued)

TABLE 2.19-3 (continued)

[l] Reference 56. Based on (20' x 20' x 15') 10 Ga steel enclosure of rail car dump.

[m] Engineering estimate.

[n] Reference 60. Based on 20,000 acfm fabric filter.

[o] Costs included above, see footnote g. Assumes rail car unloading.

[p] Costs for secondary crushing/screening included in cost for primary crushing.

[q] Reference 53. Based on 400 ft of conveyor and three transfer points. Capital costs based on $70/ft for conveyors and $18,000/transfer point.

[r] Annualized cost based on 30% of capital cost.

[s] Reference 53. Based on 400 ft of conveyor and three transfer points. Capital costs based on $35/ft for conveyors and $3,000/transfer point.

[t] Reference 61.

[u] Includes capital charges and maintenance at 20% of capital.

[v] Reference 61. Based on $.052/ft^2 storage area, 250,000 ton storage and 1 month storage.

[w] Reference 62.

[x] Reference 62. Based on $47.5/ton of storage.

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14. Ibid. p. 6-8.

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19. Ibid. p. 4-12.

20. Ibid. p. 4-13.

21. Ibid. p. 4-14.

22. Ibid. p. 4-15.

23. Ibid. p. 4-16.

24. Ibid. pp. 4-15, 4-18.

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62. Op. cit. Refererence 65. p. 2-39.

APPENDIX FOR SECTION 2.19

Data Used in Calculations:

Hourly rate of ROM coal entering plant = 750 tph
Hourly production rate of clean coal = 600 tph
Annual production rate of clean coal = 3,000,000 tpy
Input to preparation plant (assuming 20% reject) = 3,750,000 tpy

(1) Unloading ROM coal:

A. Railroad car

1. Enclosure, vent to fabric filter

Control efficiency = 99% MRI, p. 6-3
Capital cost (1977 \$) = \$100,000

$$\$100,000 \ \frac{(249.6)}{(204.1)} \approx \$120,000$$

Annualized cost (1977 \$) = \$32,000 NMI, p. 3-5

$$\$32,000 \ \frac{(249.6)}{(204.1)} \approx \$39,000$$

$$C/B = \frac{\$39,000}{(0.4\ \text{lb/ton})(3,750,000\ \text{tpy})(.99)}$$

= \$0.03/lb TSP removed

2. Enclosure

Control Efficiency = 70% MRI, p. 6-2
Assume an enclosure of 50' x 21' x 30'
Total area of 10 Ga plate (skirts)

= (21' x 50') + 2(30' x 50') + 2(30' x 21')
= 1,050 + 3,000 + 1,260
= 5,310 ft^2

mass = 5,310 ft^2 x 5.625 lb/ft^2 x 1.2
= 35,800 lbs.

Cost (labor & materials) =
(.208/lb + 0.30/lb)(35,800 lbs) = \$18,200

Turnkey = 1.4 (18,200) = \$25,500

$$\$25,500 \ \frac{(249.6)}{(192.1)} \approx \$33,000$$

Annualized cost (No O & M)
Fixed = .17(33,000) = $5,600

$$C/B = \frac{\$5,600/yr}{(0.4\ lb/ton)(3,750,000\ tpy)(.7)}$$
= $0.005/lb TSP removed

3. Wet suppression (chemical) for sources ①, ②, ③, ④

Control efficiency = 80% for 1 (MRI, p. 6-3)
= 90% for ②, ③, ④

Capital cost (1977 $) = $80,000 NMI, p. 4-9

$$\$80,000\ \frac{(249.6)}{(204.1)} = \$98,000$$

Annualized cost (1977 $) = $30,000 NMI, p. 4-12
@ 5,000 hpy

$$\$30,000\ \frac{(249.6)}{(204.1)} = \$37,000$$

$$C/B = \frac{\$37,000/yr}{(3,750,000\ tpy)[(.8)(.4)+(.9)(0.2 + .16 + .20)]}$$
= $0.01/lb TSP removed

4. Watering for sources ① and ② only

Control efficiency = 50% TG, p. 2-245
No costs available

B. Truck

1. Enclosure, vent to fabric filter

Control efficiency = 99%
Capital cost = $87,400 (Section 2.3, p. 2-163 for limestone unloading)

Annualized cost (1977 $) = $17,000 (NMI, p. 3-5)

$$\$17,000\ \frac{(249.6)}{(204.1)} = \$21,000$$

plus $2,400 fixed enclosure cost
= $23,000

$$C/B = \frac{\$23,000/yr}{(0.02\ lb/ton)(3,750,000\ tpy)(.99)}$$
= $0.31/lb TSP removed

2. Enclosure

Control efficiency = 70% MRI, p. 6-2.
Assume an enclosure of 20' x 20' x 15'

Total area of 10 Ga plate (skirts)
= (15' x 20') + 2(20'x15') + 2(20'x20')
= 1,700 ft^2

mass = 1,700 ft^2 x 5.625 lb/ft^2 x 1.2
= 11,475 lbs.

Cost (labor & materials) =
(.208/lb + 0.30/lb)(11,475 lbs.) = $5,829

Turnkey = 1.4 (5,829) = $8,160

$$\$8,160 \frac{(249.6)}{(192.1)} \approx \$11,000$$

Annualized cost (No O & M)
Fixed = .17 (11,000) ≈ $1,900

$$C/B = \frac{\$1,900/yr}{(0.02\ lb/ton)(3,750,000\ tpy)(.99)}$$
= $0.03/lb TSP removed

3. Wet suppression (chemical) for sources ①, ②, ③, ④

Control efficiency = 80% for 1 (NMI, p. 6-3)
= 90% for ②, ③, ④

Capital cost (1980 $) = $98,000

Annualized cost (1980 $) = $37,000

$$C/B = \frac{\$37,000/yr}{(3,750,000\ tpy)[(.8)(.02)+(.9)(.02 + .16 + .20)]}$$
= $0.03/lb TSP removed

4. Watering for sources ① and ② only

Control efficiency = 50% TG, p. 2-245
No costs available

② Primary crushing

1. Enclosure, vent to fabric filter for sources ②, ③

Control efficiency = 99%
Capital cost (1977 $) = $105,412 NMI, p. 3-4
@ 20,000 acfm

$$\$105,412 \frac{(249.6)}{(204.1)} = \$129,000$$

Annualized cost (1977 \$) = \$31,000

$$\$31,000\ \frac{(249.6)}{(204.1)} = \$38,000$$

$$C/B = \frac{\$38,000}{(3,750,000\ \text{tpy})(.99)(.02 + .16\ \text{lb/ton})}$$

C/B = \$0.06/lb TSP removed

2. Wet suppression (chemical) for sources ①, ②, ③, ④

Same as for truck & RR car unloading
Capital cost = \$98,000 for RR car unloading
Annualized cost = \$37,000 for RR car unloading
C/B = \$0.01/lb for RR car unloading

Capital cost = \$98,000 for truck unloading
Annualized cost = \$37,000 for truck unloading
C/B = \$0.03/lb for truck unloading

③ Secondary crushing/screening

1. Enclosure, vent to fabric filter for sources ②,③
Same as for primary crushing

2. Wet suppression (chemical) for sources ①, ②, ③, ④
Same as for primary crushing

④ Transfer and conveying

1. Enclosure of conveyors and transfer points, vent to fabric filter

Control efficiency = 99% MRI, p. 6-3
Assume 400 ft of conveyor and three transfer points.

Capital cost (1977 \$): (MRI, p. 6-3)
(\$70/ft)(400 ft) = \$28,000 for conveyors
(\$18,000/TP)(3 TP) = \$54,000 for transfer pts.

Total cost = \$82,000

$$\$82,000\ \frac{(249.6)}{(204.1)} \approx \$100,000$$

Annualized cost (@ 30% of capital cost)
= \$30,000

$$C/B = \frac{\$30,000/\text{yr}}{(3,750,000\ \text{tpy})(.99)(.2\ \text{lb/ton})}$$

= \$0.04/lb TSP removed

2. Enclosure of conveyors and transfer points with no control device

Control efficiency = 70% MRI, p. 6-3
Assume 400 ft of conveyor and three transfer points

Capital cost (1977 $): (MRI, p. 6-3)
($35/ft)(400 ft) = $14,000 for conveyors
($3,000/TP)(3 TP) = $9,000 for transfer pts.

Total cost = $23,000

$$\$23{,}000\ \frac{(249.6)}{(204.1)} \approx \$28{,}000$$

Annualized cost (@ 30% of capital cost)
($28,000)(.3) = $8,400

$$C/B = \frac{\$8{,}400/yr}{(3{,}750{,}000\ tpy)(.70)(.2\ lb/ton)}$$
= $0.02/lb TSP removed

3. Wet suppression (chemical) for sources ①, ②, ③, ④
Same as for primary crushing

⑤ Cleaning

No control required -generally a wet process operation and performed in a building

⑥ Storage

A. Loading onto piles

1. Enclosure (stone ladder)

Control efficiency = 80% MRI, p. 6-6
Capital cost (1977 $) = 20,000

$$\$20{,}000\ \frac{(249.6)}{(204.1)} \approx \$24{,}000$$

Annualized cost (@ 17% of capital cost)
$24,00 (0.17) = $4,000

$$C/B = \frac{\$4{,}000/yr}{(0.08\ lb/ton)(3{,}000{,}000\ tpy)(.80)}$$
= $0.02/lb TSP removed

2. Telescopic chutes

Control efficiency = 75% MRI, p. 6-6
Capital cost (1977 $) = 7,000

$$\$7,000 \frac{(249.6)}{(204.1)} = \$8,600$$

Annualized cost (@ 17% of capital cost)
$8,600 (.17) = $1,500

$$C/B = \frac{\$1,500/yr}{(.75)(3,000,000\ tpy)(.08\ lb/ton)}$$
= $0.01/lb TSP removed

3. Wet suppression (chemical)

Control efficiency = 75% MRI, p. 6-6
Capital cost (1977 $) = $60,000

$$\$60,000 \frac{(249.6)}{(204.1)} = \$73,000$$

Annualized cost = $29,400

$$\$29,400 \frac{(249.6)}{(204.1)} = \$36,000$$ NMI, p. 4-11

$$C/B = \frac{\$36,000/yr}{(3,000,000\ tpy)(.75)(.08\ lb/ton)}$$
= $0.20/lb TSP removed

4. Wind guards

Control efficiency = 50% MRI, p. 6-6
Capital cost (1977 $) = $50,000

$$\$50,000 \frac{(249.6)}{(204.1)} = \$61,100$$

Annualized cost (@ 20% of capital costs for maintenance and capital charges)

(.2)(61,000) = $12,000

$$C/B = \frac{\$12,000/yr}{(3,000,000\ tpy)(.5)(.08\ lb/ton)}$$
= $0.10/lb TSP removed

B. Wind erosion

1. Enclosures

Control efficiency = 100% MRI, p. 6-6
Capital cost
($60/ton stored)(3,000,000 tpy)/12 months/yr
= $15,000,000

Annualized costs ($ 17%) =
($15,000,000)(.17) = $2,550,000

$$C/B = \frac{\$2,550,000/yr}{(3,000,000\ tpy)(.09\ lb/ton)}$$

= $9.44/lb TSP removed

2. Wet suppression (chemical)

Control efficiency = 99% MRI, p. 6-6
Capital cost (1977 $) = $11,000

$$\$11,000\ \frac{(249.6)}{(204.1)} = \$13,450$$

Annualized cost: (250,000 tons storage)
250,000 tons (40 ft^3/ton)(100 ft height)
= 100,000 ft^2

$$[\$\left(\frac{.004 + .1}{2}\right)/ft^2](100,000\ ft^2) = \$5,200$$

$$\$5,200\ \frac{(249.6)}{(204.1)} = \$6,400$$

$$C/B = \frac{\$6,400/yr}{(0.09\ lb/ton)(3,000,000\ tpy)(.99)}$$

= $0.02/lb TSP removed

C. Loading out

1. Under pile conveyor

Control efficiency = 80% TG, p. 2-39
Capital cost (1977 $)

($47.5/ton)(250,000 tons) = $11,875,000

$$\$11,875,000 \frac{(249.6)}{(204.1)} = \$14,520,000$$

Annualized cost (@ 20%)
(0.2)(14,520,000) = $2,900,000

$$C/B = \frac{\$2,900,000/yr}{(.8)(.1\ lb/ton)(3,000,000\ tpy)}$$

= $12.08/lb TSP removed

2. Wet suppression (chemical)

Control efficiency = 95% MRI, p. 6-6
Capital cost (1977 $) = $60,000

$$\$60,000 \frac{(249.6)}{(204.1)} = \$73,400$$

Annualized cost = $29,400 NMI, p. 4-11

$$\$29,400 \frac{(249.6)}{(204.1)} = \$36,000$$

$$C/B = \frac{\$36,000/yr}{(3,000,000\ tpy)(.95)(.1\ lb/ton)}$$

= $0.13/lb TSP removed

3. Bucket wheel reclaimer

Control efficiency = 80% MRI, p. 6-6
Capital cost (1977 $) = $5,300,000

$$\$5,300,000 \frac{(249.6)}{(204.1)} = \$6,480,000$$

Annualized cost (@ 20% of capital cost)
(.2)(6,480,000) = $1,300,000

$$C/B = \frac{\$1,300,000/yr}{(3,000,000\ tpy)(.8)(.1\ lb/ton)}$$

= $5.42

(7) Loading

A. Truck loading

1. Wet suppression (chemical)

Control efficiency = 80% MRI, p. 6-6
Capital cost = $73,000

Annualized cost = $36,000

$$C/B = \frac{\$36,000/yr}{(3,000,000\ tpy)(.80)(.02\ lb/ton)}$$

= $0.75/lb TSP removed

2. Telescopic chutes

Control efficiency = 75% MRI, p. 6-6
Capital cost = $8,600

Annualized cost = $1,500

$$C/B = \frac{\$1,500/yr}{(3,000,000\ tpy)(.75)(.02\ lb/ton)}$$

= $0.03/lb TSP removed

B. Rail car or barge loading

1. Wet suppression (chemical)

Control efficiency = 80% MRI, p. 6-6
Capital cost = $73,000

Annualized cost = $36,000

$$C/B = \frac{\$36,000/yr}{(3,000,000\ tpy)(.8)(.4\ lb/ton)}$$

= $0.04/lb TSP removed

2. Telescopic chutes

Control efficiency = 75% MRI, p. 6-6
Capital cost = $8,600

Annualized cost = $1,500

$$C/B = \frac{\$1,500/yr}{(3,000,000\ tpy)(.75)(.4\ lb/ton)}$$

= <$0.01/lb TSP removed