PREFACE

Rule 3745-17-08 of the Ohio Administrative Code gives examples of reasonably available control measures (RACM) which should be employed for various types of fugitive dust sources. The rule covers a large number of diverse types of sources and, of necessity, is written in general terms.

The burden of developing an acceptable control program, which will meet the requirements of this rule and result in the use of reasonably available control technology (RACT) for one or more fugitive dust sources, lies with the owner/operator of the source(s). The type of control measures which are presently used by industry throughout the nation and which would constitute RACT for specific sources can, in general, be easily discerned by researching available environmental control publications and literature.

The Office of Air Pollution Control (OAPC) realizes that Ohio industry will need assistance in developing acceptable control programs and that the Agency's field office personnel will need assistance or guidance in reviewing those programs. This document has been prepared to specifically address those needs.

The OAPC would like to emphasize that the definitions of RACT in this document for the various types of fugitive dust sources are not "cast in concrete". Deviations from the general definitions or recommendations will be permitted based upon source-specific considerations; however, as stated earlier, the burden will be upon the owner/operator of an affected facility to demonstrate that the proposed, overall control program constitutes RACT and meets the requirements of rule 3745-17-08.

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1.0 INTRODUCTION

In general, all the early State Implementation Plans (SIP's) required by the Federal Clean Air Act (CAA) explicitly and specifically addressed point source control and relied on point source reduction measures as the means of attaining the National Ambient Air Quality Standards (NAAQS) for Total Suspended Particulate (TSP). Control of fugitive dust emissions was only cursorily addressed in these plans--generally in the form of a modified "nuisance" regulation, and was often patterned after the form presented in the Federal Register.

Widespread failure to attain the National Ambient Air Quality Standards for particulate matter in many urban areas has resulted in reexamination of the nature of the urban particulate problem. Basically, the particulate control strategy developed as part of the original SIP's included an analysis of the contribution of conventional point and area sources without much consideration of other "less conventional" sources of particulate such as industrial process fugitive emissions, material handling operations, storage piles, unpaved roads and parking lots, etc.

In light of the significant potential impact of fugitive dust emissions on the levels of suspended particulates in the ambient air, the Ohio Environmental Protection Agency (OEPA) has undertaken a program to prepare guidelines for selection of reasonably available control measures (RACM) for major manufacturing categories.

2.0 REASONABLY AVAILABLE CONTROL MEASURES (RACM)

The purpose of this report is to provide agency personnel with information on industry categories relating to potential fugitive dust problems, and available means to alleviate the problems. In accomplishing this purpose, the guideline presents detailed data on 30 industry categories. The information supplied includes a general process description of the industry; identification of fugitive dust sources; a listing of available fugitive dust emission factors; available data on particle characteristics and potential adverse impacts; data on available control techniques, their effectiveness, and costs; and selection of RACM for each emission source.

The process description is a general explanation of the process operations in which each potential fugitive emission source is identified. Available emission factors for these sources are listed along with a reliability rating for each. The reliability ratings are indicative of the supportive data used to develop the factor. The following rating system is employed:

A - Excellent - Supportable by a large number of tests, process data, and engineering analysis work.

B - Above average - Supportable by multiple tests, moderate process data, and engineering analysis work.

C - Average - Supportable by multiple tests.

D - Below average - Supportable by limited test data and engineering judgment.

E - Poor - Supportable by best engineering judgment (visual observation, emission tests for similar sources, etc.).

Available data on composition, size range, and potential environmental and/or health effects of the fugitive particles are presented to provide insight into the potential impacts of the fugitive emissions.

For each of the fugitive dust sources identified, available control measures are described. Data on the effectiveness and costs are also included. Costs in the document have been adjusted to reflect 1980 dollars as described in Appendix A. The costs are presented as an order-of-magnitude guide and should not be considered as accurate for a site-specific application.

Of the available control techniques, one is selected that exemplifies RACM. The selection is based upon technological feasibility, economic feasibility, and cost-effectiveness. The selection process was judgmental; and it should be emphasized that for retrofit applications, control characteristics are highly plant-specific and could dictate another control technique as RACM. This document provides guidelines to selecting RACM for various processes and is not meant to preclude consideration of other control measures in site-specific analyses.

2.1 GENERAL FUGITIVE DUST EMISSION SOURCES

The general fugitive dust category presents a description of those dust sources which would be common to a number of industries. These sources include fugitive dust from 1) plant roadways and parking areas, 2) aggregate storage piles, 3) material handling, and 4) mineral extraction. These four fugitive dust sources have been grouped together and treated as a separate section in order to avoid redundancy within the remainder of the text.

The location or placement of a given fugitive dust source will vary greatly within a specific industry. An example of this variability is illustrated by a conveying operation. The conveyor may be located at a number of points within the industrial process: unloading of raw material, transport from a storage facility, and movement of material within the industrial process itself. Because of the great variation in placement, it is not possible to devise a typical flow diagram for these sources. However, to give the reader of this document a feel for the possible order and location of each general fugitive dust source, two hypothetical industrial settings are provided. Figure 2.1-1 presents a hypothetical flow diagram for an unspecified industry with fugitive dust sources from 1) plant roadways and parking areas, 2) aggregate storage piles, and 3) material handling operations. Figure 2.1-2 presents another hypothetical flow diagram depicting a mineral mining operation. The fugitive dust sources illustrated in this figure are common to mineral extraction operations.

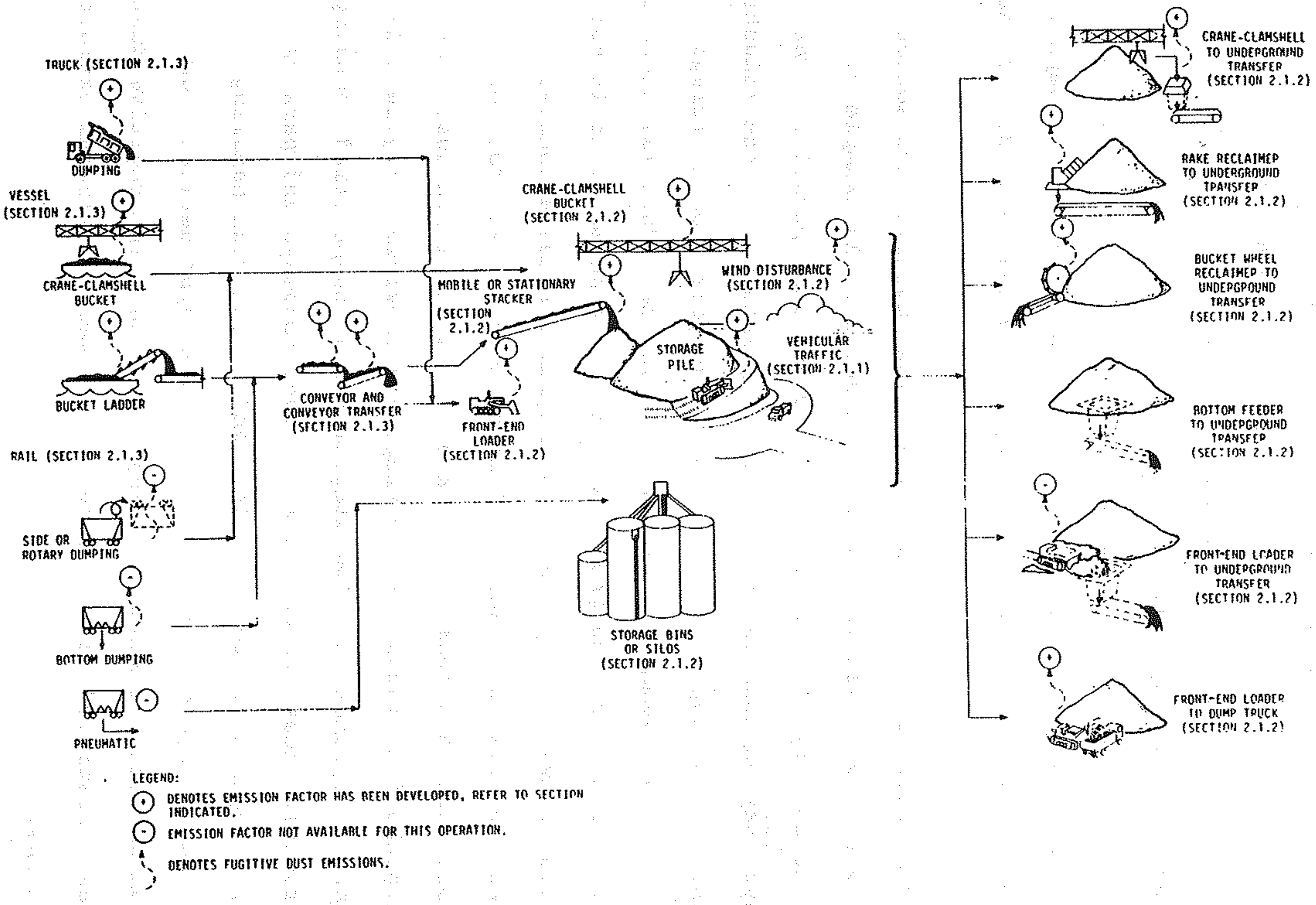

Figure 2.1-1. Order and location of general fugitive dust sources in a hypothetical industrial setting.

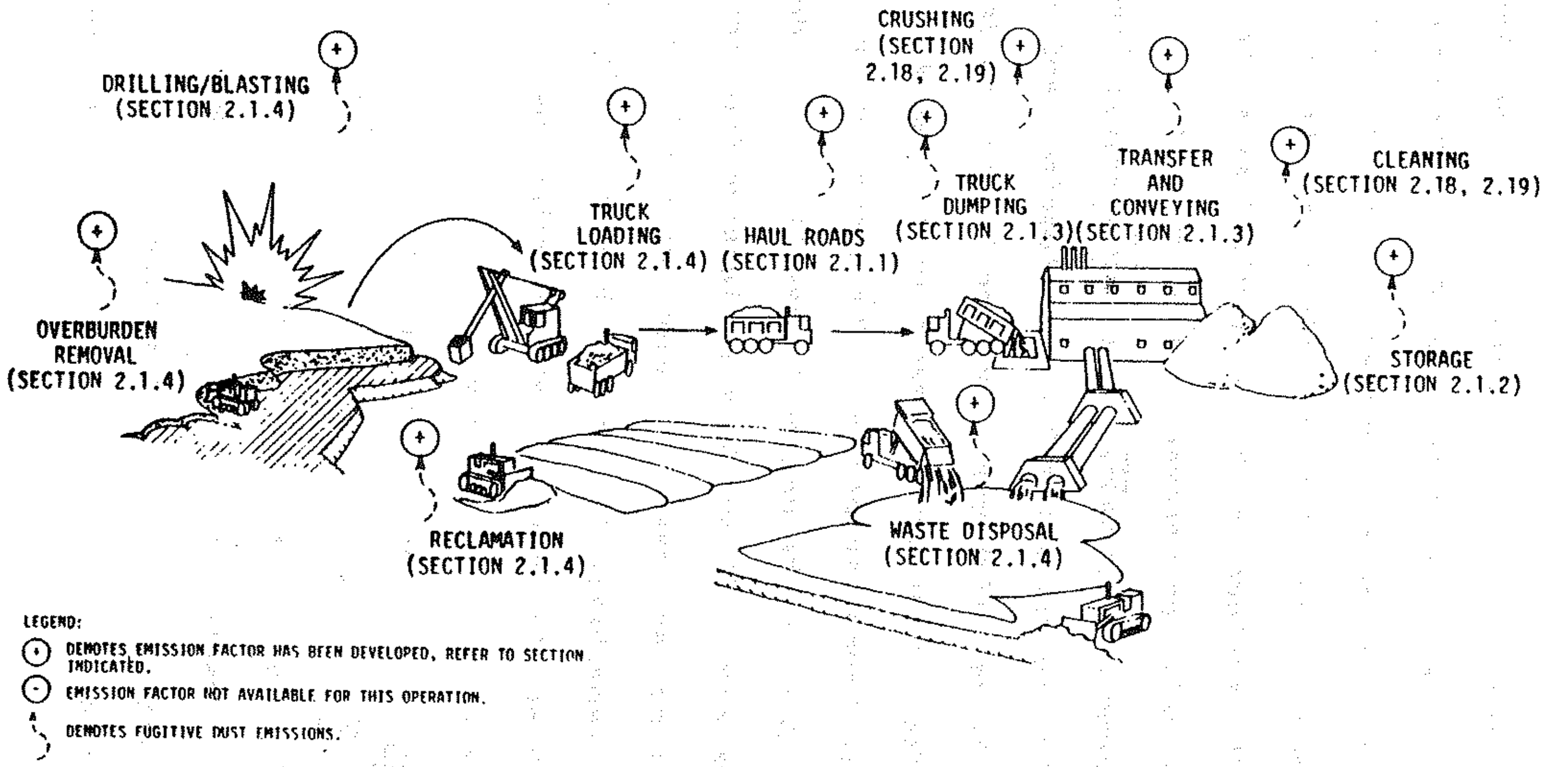

Figure 2.1-2. Order and location of general fugitive dust sources in hypothetical mineral mining operation.

2.1.1 Plant Roadways and Parking Areas

2.1.1.1 Source Description--

The roadways and parking areas located on plant property can be significant sources of fugitive dust. The potential that a given road or parking area surface has for generating fugitive dust is dependent upon traffic volume and the nature of its surface. The surface can be categorized as either paved (concrete or asphalt) or unpaved (gravel or dirt).

Dust generated from paved surfaces results from vehicle activity that agitates the "surface loading" and causes that loading to become airborne. Surface loading is defined as the amount of foreign material present on a paved surface having the potential to become suspended. The amount of surface loading on a paved surface is the composite result of: 1) deposition of mud and dirt carryout, 2) spillage or leakage from moving vehicles, 3) pavement surface wear, 4) runoff or erosion of adjacent land areas, 5) atmospheric fallout, 6) biological debris, 7) wear from tires and brake linings, 8) exhaust emissions, 9) litter, and 10) application of ice control materials.[1]

In contrast to paved surfaces the source of dust generation from unpaved and untreated surfaces is largely from actual road bed material rather than any "surface loading".

In both cases, paved and unpaved, the actual suspension of fugitive dust is the result of vehicular traffic on the surface. Both road bed and surface loading material are mechanically broken down by the tires and subsequently entrained in the ambient air by the air turbulence created by the moving vehicle. In addition to vehicle entrainment, a smaller amount of dust may also be suspended as a result of wind disturbance of the surface loading.

In some instances the unpaved road shoulders can be another source of fugitive dust. This occurs when the roadway is narrow and is ineffectively curbed. Vehicles traveling the road may at times stray from the road surface onto the shoulders and cause significant additional dust generation.

2.1.1.2 Fugitive Dust Emission Factors--

Emission factors for both paved and unpaved surfaces have been determined from field test data on public roadways. Adequate data on the condition of plant roads or parking areas serving private property is not available. Lacking specific data for private plant roads, the public roadway emission factors are modified for use here.

Emission factors for both paved and unpaved surfaces are directly related to the number of vehicle miles travelled (VMT).

The U.S. Environmental Protection Agency provides an average emission factor for dust entrainment from paved roads as 5.6 g/mi.[1] This average emission factor includes tire wear and exhaust emissions (0.53 g/mi), and entrained fugitive dust (5.07 g/mi). Although this "average" value could be used, it would probably not be representative of industrial and commercial roadways as it is based on light duty, four-wheeled vehicles.

A more vehicle-specific emission factor can be determined through modifications to the components of the "average" emission factor.

The method for calculating a specific emission factor for vehicles travelling paved surfaces is given in the following equation:[1]

$$EF = P[(E) + 0.20\ (T/4) + 5.07\ (T/4)] \qquad \text{Equation 1}$$

where:

EF = emission factor, g/VMT,

P = fraction of particulate which will remain suspended (diameter less than 30 μm) from a paved road surface, 0.90 (Reference 1, p. 11.2.5-1),

E = particulate emission originating from vehicle exhaust (see Table 2.1.1-1),

0.20 = tire wear in g/VMT, representing a four-wheeled vehicle,

5.07 = entrained dust in g/VMT, representing a four-wheeled vehicle, and

T = number of tires per vehicle.

The average and specific vehicle emission factors for paved surfaces are given in Table 2.1.1-1. The exhaust emissions and tire wear included in the EPA's average paved road emission factor[1] are representative of a fleet composed primarily of light-duty, four-wheeled gasoline vehicles. However, because of the great variety of vehicles which transit plant property, specific emission factors are presented for ten, twelve, and eighteen-wheeled, heavy-duty gasoline and diesel vehicles.

TABLE 2.1.1-1. EMISSION FACTORS FOR VEHICLES TRAVELLING PAVED SURFACES (g/mi)

Vehicle type	Exhaust (E)[a]	Tire wear[b,c]	Reentrained[c] dust	Initial[d] emission factor	Final emission factor[e]	Emission factor reliability
Average[f]	0.53		5.07	5.6	5.0	g
Light-duty gasoline (4-wheeled)	0.34	0.20	5.07	5.6	5.0	g
Heavy duty gasoline (10-wheeled)	0.91	0.50	12.68	14.1	12.7	g
Heavy duty diesel (12-wheeled)	1.30	0.60	15.21	17.1	15.4	g
Heavy duty diesel (18-wheeled)	1.30	0.90	22.82	25.0	22.5	g

[a] Exhaust emissions are specific for fuel and vehicle type.[1]

[b] The tire wear component is based upon 0.20 g/VMT for a four-wheeled vehicle and can be adjusted upwards for vehicles with large numbers of wheels.[1]

[c] The reentrained dust component is estimated to be directly proportional to the number of tires. An additional multiplication factor of 2.5 should also be applied to the tire wear and reentrained dust columns when considering large wheeled equipment, i.e., mining haul trucks and wheeled-tractors, loaders or dozers.[2]

[d] The initial emission factor is the sum of the exhaust, tire wear, and reentrained dust components.

[e] The final emission factor is the initial emission factor multiplied by a factor of 0.90. The factor of 0.90 accounts for that amount of particulate which will remain suspended.[1]

[f] Reference 1.

[g] Reference 1 fugitive dust emission factor equations and their resulting emission factors are not assigned reliability values.

Fugitive dust from unpaved surfaces can be determined using the EPA's published procedure. This procedure is expressed in the following equation:[1]

$$EF = (P)\ (0.81)\ (s)\ (S/30)\ ((365-W)/365)\ (T/4) \qquad \text{Equation 2}$$

where:

EF = emission factor, lb/VMT,

P = fraction of particulate which will remain suspended (diameter less than 30 μm) from a gravel road bed, 0.62; from a dirt road bed, 0.32 (see Table 2.1.1-2),

s = silt content of road bed material, percent; 12 percent approximate average value (values range between 5 and 15 percent),

S = average vehicle speed, mph,

W = days with 0.01 inch or more of precipitation,[2] and

T = average number of tires per vehicle.

When using Equation 2 for vehicles with oversized tires, a multiplication factor of 2.5 should be included. This factor will account for the comparative difference in the width of tire faces between average road vehicles and oversized tire vehicles. This factor (2.5) can be used to estimate entrained dust emissions from most wheeled construction equipment, i.e., wheeled-tractors, loaders or dozers, and mining haul trucks.[3]

Emission factors or emission factor equations have not been developed specifically for dust generation from road shoulders, and such emissions have not received much attention in the literature. If dust from this source is considered a significant problem, it is suggested that the unpaved road emission factor be used to estimate the emissions from a dirt or gravel shoulder in lieu of a specific emission factor.

2.1.1.3 Characterization of Fugitive Dust Emissions--

The chemical or mineral composition of road dust depends directly on the type of material deposited on the paved surface or the type of material used in the road bed of the unpaved surface.

Size distribution--The particle size range for fugitive dust from plant roadways and parking lots depends upon the type of road surface. Table 2.1.1-2 gives the size distribution of fugitive dust by surface type.

TABLE 2.1.1-2. TYPICAL SIZE DISTRIBUTION OF FUGITIVE DUST PARTICLES BY SURFACE TYPE[a] (percentages)

Size range	Paved surface	Unpaved surfaces gravel	Unpaved surfaces dirt
<5 μm	50	23	8
5-30 μm	40	39	24
>30 μm	10	38	68

[a] Reference 1, p. 11.2.1-4.

Density and composition--The density and composition of fugitive dust from paved and unpaved surfaces will vary widely depending upon the type of material used to construct the pavement or road bed and the type of material deposited on the surface.

Health effects--When considering possible effects on human health, fugitive particulates can be characterized as being either toxic, pneumoconiosis producing, or of general nuisance.[4]

The toxic components of fugitive dust will vary depending upon the type of material on the road surface and the vehicles traveling that surface. Possible toxic components of surface loading on roadways are lead, asbestos, and the combustion products of fuel (this excludes any toxic compounds specific to the material being hauled which may have been spilled on the road surface). Organic and inorganic lead contaminants originate from the combustion of gasoline with lead-based anti-knock ingredients. The inhalation of lead compounds from automotive exhaust is not considered to be a significant cause of acute lead poisioning; however, prolonged exposure to automotive exhaust can produce chronic lead poisoning.

The environmental impact of lead determined directly from auto exhaust and from reentrained dust has been established.[5,6] Lead comprises only 0.5 percent of the road dust on heavily traveled roads.[6] Thus, the lead component in reentrained dust from plant surfaces can probably be considered as insignificant due to a lower traffic volume and the use of diesel and other fuels containing lower lead content.

Neither asbestos from brake lining wear nor combustion products from vehicles have been a subject of specific epidemiological studies that would define their potential health-effect role as a component of road dust. In the absence of specific quantitative information, the presence of lead, asbestos and combustion products in fugitive dust arising from plant roadways can not be addressed from a health effects standpoint.

Pneumoconiosis is an ailment commonly associated with dust inhalation. Literally translated, pneumoconiosis means "dust in lungs "; however, a more functional and contempory definition states that it is "the accumulation of dust in the lungs and the lung tissue reaction to its presence." In the case of fugitive dust, the potential for pneumoconiosis exists only if substances like asbestos and silica are present in large enough concentrations. No documentation exists on quantitative amounts of these substances in road dust.

The most viable impact fugitive road dust has is in its role as a nuisance dust. The term nuisance applies to any particulate producing debility due to its physical presence in the lungs. The effects of nuisance dust are usually reversible and cannot be considered as being toxic. They are more properly an irritant, especially to individuals already possessing some pulmonary ailment, i.e., asthma or emphysema.[4]

2.1.1.4 Control Methods--

A number of control methods are available for minimizing fugitive dust generation from plant roadways and parking areas. These control measures are presented by roadway surface type (paved or unpaved). Control measures available for paved surfaces are sweeping (broom and vacuum), flushing operations, general housekeeping measures, and speed reduction programs. The control measures for unpaved surfaces include the application of chemical stabilizers (dust suppressants), road oiling, physical improvements to the road surface (including paving) and speed reduction.

Techniques, efficiencies and costs for controlling fugitive dust from paved surfaces--Sweeping and flushing paved surfaces are the primary control measures used for reducing fugitive dust from paved surfaces. Accumulated surface loading can be removed with sweeping or flushing measures alone or in combination. Good housekeeping is a preventative measure used to limit the ongoing accumulation of particulate matter on the surface. Sweeping as a control measure is recommended with one note of caution: The actual effectiveness of sweeping control measures has not been clearly established, and it has been suggested that broom sweepers may actually produce and suspend more fines than they remove.[3]

However, estimated control efficiencies for broom sweepers are reported as 70 percent when used on a biweekly schedule.[7] The initial cost of a broom sweeper designed for industrial roadway use ranges from 5,000 dollars for a trailer-type sweeper to 15,000 dollars for a self-propelled unit (includes water spray system).[7] Annual operating costs have been estimated at 22,000 dollars per year.[7] The estimated control efficiency for a vacuum sweeper has been reported at 75 percent. The initial cost for a vacuum sweeper is 27,000 dollars with annual operating expenses running approximately 25,000 dollars per year.[7] These figures have been adjusted to reflect costs in January 1980 dollars as have all the costs presented in this document.

Flushing of paved surfaces with water reduces the amount of material available for reentrainment. Water flushing is considered to be more effective than sweeping. However, flushing paved surfaces adjacent to unpaved road shoulders may increase mud tracking and carry-on. This increased carry-on has the potential to be a significant source of fugitive dust emissions.

A weekly water flushing operation is estimated to have an effective control efficiency of approximately 80 percent. The initial cost of a 3,000 gallon capacity flusher is approximately 13,000 dollars (excludes truck chassis) with an annual operating cost estimated to be 22,000 dollars per year.[7]

Good housekeeping practices, although a control measure in itself, should be used in conjunction with a more direct removal technique such as flushing. Housekeeping measures include 1) rapid removal of spillage, 2) covering of haul truck beds to prevent wind losses, and 3) cleaning truck tires and under carriages to reduce carryout. No estimate of control efficiencies or costs are available.

A summary of these control efficiencies and costs are presented in Table 2.1.1-3.

<u>Techniques, efficiencies and costs for controlling fugitive dust from unpaved surfaces and road shoulders</u>--The options available for controlling fugitive dust from unpaved plant surfaces

TABLE 2.1.1 -3. SUMMARY OF TECHNIQUES, EFFICIENCIES AND COSTS FOR CONTROLLING FUGITIVE DUST FROM PAVED AND UNPAVED SURFACES

Control method	Estimated control efficiency, %	Initial cost, 1980 dollars	Annual operating cost, 1980 dollars
Paved surfaces			
° Sweeping			
- Broom	70	5,000-15,000[a]	22,000/year
- Vacuum	75	27,000	25,000/year
° Flushing			
- Water	80	13,000[b]	22,000/year
Unpaved surfaces			
° Chemical stabilization[c]	90-95	6,000-13,000/mile	5,000-12,000/mile[d,e]
° Road oiling[c]	75	1,200-2,500/mile	(Re-oil once a month)
° Watering[c]	50	12,000	4,000/mile[e,f]
° Surface improvements			
- Aggregate	30	NA	NA
- Oil and double chip	80	11,000/mile	2,500-5,000/mile[e,g]
- Paving	90	34,000-61,000/mile	(Resurface every five years)
° Speed reduction[h]			
- 30 mph	25	NA	NA
- 20 mph	65	NA	NA
- 15 mph	80	NA	NA

[a] The lower value is for a trailer-type sweeper, the upper value is for a self-propelled unit.

[b] Value represents cost of 3,000 gal. capacity unit excluding truck chassis.

[c] Applies to both unpaved roadways and road shoulders.

[d] Frequency of application was unspecified.

[e] Based on a plant having 6.3 miles of unpaved roads, this average was determined from unpaved road mileage at four steel plants, Reference 7, page 6-16.

[f] Represents a frequency of two waters per day.

[g] Value based upon resurfacing once a year.

[h] Assumes an uncontrolled speed of 40 mph.

(unpaved roads, road shoulders and parking lots) are chemical stabilization through the use of dust suppressants, road oiling, surface improvement and speed reduction.

The suppression of fugitive dust from unpaved surfaces can be achieved using a variety of chemical stabilizers. The chemicals used for this purpose are either wetting or binding agents which are diluted with water and sprayed over the unpaved surface. Effective use of a chemical stabilizer can only be achieved when it is used as part of a continual application program with the frequency of application related to the relative use of the roadway. The control efficiency for this measure is estimated to be between 90 and 95 percent.[7] The initial costs are estimated to be between 6,000 and 15,000 dollars per mile of roadway (approximately 130 thousand square feet).[7] Annual operating costs range between 5,000 and 12,000 dollars per mile of roadway.[7] A summary of the types of chemicals used, their costs, and application rates is presented in Appendix B.

Cost estimates for oiling unpaved roadways and parking areas were obtained from private contractors operating in Cincinnati, Cleveland and Columbus.

The initial cost estimate of a contract road oiling project is based upon three factors: 1) the total amount of surface area to be treated; 2) the configuration of the surface area; and 3) the availability of waste oil. The first factor, surface area, is obviously related to the cost of the task. The larger the area to be treated, the more time and material required and, as a result, the higher the final cost. Contractors in Ohio were not willing to discount the cost of the project on a volume basis. The second factor, configuration of the surface area, means that an area with a large number of curves or corners requires excessive stopping and starting of the application vehicle. This action wastes oil and, as a result, increases the total cost of the project. The third factor, availability of waste oil, determines the price the contractor must pay for the raw materials. Despite the current oil problems, waste oil prices have not increased to the same degree as other petroleum products. The contract cost estimates, determined for three metropolitan areas in the State of Ohio, are given in Table 2.1.1-4.

Road oiling contractors use two types of waste oil for application purposes: crankcase oil (oil from garages and service stations) and industrial oil (waste oil from industrial processes). The crankcase oil is preferred over the industrial oil because it contains fewer amounts of contaminants (chemicals and water soluble substances) and, as a result, has a wider range of application.[9] The possible impact on adjacent plant life and landscaping is a factor to be considered when oiling unpaved surfaces. An additional problem with road oiling is that it can significantly increase the amount of surface runoff. Oiling large areas may require special precautions to handle the excess volume of water.[3] The control efficiency for road oiling is estimated to be 75 percent.[7] The initial (contract) cost of

TABLE 2.1.1-4. CONTRACT COST ESTIMATES FOR OILING UNPAVED ROADWAYS (1980 Dollars)

Metropolitan area[a]	Dollars per gallon	Dollars per 10^3 square ft.[b]	Gallons per 10^3 square ft.
Cincinnati	0.21	9.50 - 11.50	50
Cleveland	0.31	11.50	37
Columbus	0.28	13.50	48

[a] Cincinnati area, two responses. Cleveland and Columbus areas, one response each.[10]

[b] Variations in the cost per 10^3 square ft. result from both the differences in the cost of waste oil and each contractor's estimate of the amount of oil necessary to cover the 10^3 square ft. area.

oiling a one mile length of unpaved roadway (approximately 130 thousand square feet) ranges between 1,200 and 1,800 dollars depending on the contractor.[7] Values as high as 2,500 dollars have been reported.[7]

Another method of dust suppression for unpaved surfaces is watering. This method, although often considered less expensive than chemical treatment, in fact has many drawbacks and can be more expensive. The most obvious drawbacks are 1) the need for a continuous application program, 2) decreased efficiency during dry weather conditions, 3) the increased potential to add mud carry-on to nearby paved surfaces and 4) limited applicability during cold winter periods. The estimated control efficiency for this measure is approximately 50 percent.[7] The initial costs for watering are 12,000 dollars (the cost of equipment and truck) with annual operating costs approximately 4,000 dollars per mile per year based upon 2 applications per day.[3,7]

Surface improvements can also be used to control fugitive dust from unpaved roads. These include 1) coverage with a low silt aggregate, 2) oil and double chip surfacing and 3) paving.

Covering an unpaved road with aggregate assumes that the aggregate material (limestone, river gravel, etc.) has a lower silt content than the dirt roadbed, thus reducing the amount of fines available for entrainment. The control efficiency for this technique is very low, approximately 30 percent.[7] Surface coating of this type requires continuous road maintenance to sustain the 30 percent level of effectiveness.[7] Initial and annual operating costs for this technique are not available.

The second surface improvement method, oil and double chip surfacing, achieves a higher degree of control than aggregate and requires much less maintenance. The control efficiency for this technique is 80 percent, and the initial cost per mile (130,000 ft^2) is 11,000 dollars.[7] The annual cost will depend on how often the road will need to be resurfaced. Assuming a resurfacing frequency of once every 2 to 4 years the costs will range between 2,500 and 5,000 dollars per year.[7]

The third method for controlling fugitive dust from unpaved surfaces is to pave the surface. The control efficiency for this measure is the highest of the surface improvement techniques, approximately 90 percent.[7] The initial cost of paving one mile of unpaved surface with asphaltic concrete is between 34,000 and 61,000 dollars depending upon the type of road bed required. The roadway will generally have to be resurfaced at 5 year intervals.[7]

Speed reduction also can be used as a control measure for reducing fugitive dust from unpaved surfaces. This method is attractive in that the initial and operating costs may be very low (no actual cost estimates are available). However, speed reduction measures could require additional trucks and drivers to maintain production levels.[11] Also, the enforcement of speed restrictions is often very difficult to maintain. The effective control efficiencies for speed reduction increase as the speed is reduced. Based on an assumed uncontrolled speed of 40 miles per hour, a speed restriction to 30 mph will result in a 25 percent control efficiency; a 20 mph restriction, 65 percent; a 15 mph restriction, 80 percent.[1]

A summary of the control efficiencies and costs for minimizing dust from paved and unpaved roadways are presented in Table 2.1.1-3.

The tables do not contain figures for the cost-effectiveness of control due to the variability in types of vehicles and mileage of plant roads from plant to plant. Selection of Reasonably Available Control Measures (RACM) is also hampered by the variability of the problem from plant to plant and industry to industry. However, a selection can be made based on a typical situation with the caveat that RACM can differ in unusual economic or logistic situations. For paved roads, the recommended control measure is the use of water flushing supplemented by a good-housekeeping program to minimize spills and carry-on of dirt and mud. The program would consist of such measures as covering trucks, prompt clean up of spills, elimination of carry-on by avoidance of unpaved areas where practicable, and water washing of wheels where necessary.

For control of unpaved areas, the recommended control technique is the use of chemical stabilization or oiling, coupled with speed reduction. Where the plant has large unpaved areas, frequently traveled, and to be used for many years, it may be economically justifiable to pave the road (oil and double chip or asphaltic concrete). This must be justified on a case-by-case basis.

Benefits of control measures--The control of fugitive dust from plant roadways and parking areas does not provide an obvious economic benefit. However, this control may indeed have a few hidden benefits which may result in cost savings to the industry. The primary theme underlying each of the control measures described in this section is to maintain a good surface upon which industry vehicles will operate. Surface improvements can be expected to result in reduced equipment wear. Dust suppression will increase driver visibility and may result in less down time due to equipment cleaning and maintenance. In many cases where a facility is located near residential areas, the control of fugitive dust from roadways and parking areas will increase the aesthetic appeal of the property.

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2.1.2 Aggregate Storage Piles

2.1.2.1 Source Description--

A storage pile is any mound of material (usually mineral) placed in a temporary outdoor location. The storage piles are usually uncovered allowing the stored material to be exposed to the elements. This characteristic lack of cover or housing around a storage pile is a result of the frequent necessity to transfer material from the storage site to a process operation.

Dust emissions can occur at several points in the storage cycle of an aggregate: 1) during load-in (addition) of material onto the pile, 2) during wind disturbance of the pile, 3) during the movement of vehicles in the storage area, and 4) during load-out (removal) of material from the pile.[1]

2.1.2.2 Fugitive Dust Emission Factors--

The fugitive dust generated from aggregate storage piles occurs as a result of the four major emission-producing activities given above. Their relative percent contributions vary depending upon the type of material being stored and the exact method of storage being used. The calculation of fugitive dust emission factors from aggregate storage piles can be approached in two fashions: 1) using a gross overall emission factor equation or 2) using a set of emission factor equations specific for each of the four operating activities.

Gross Overall Emission Factor Equation

The gross estimate of fugitive dust emissions to be expected from aggregate storage piles, based upon the number of tons of material placed in storage, can be determined using Equation 1.[1]

$$EF = 0.33/(PE/100)^2 \qquad \text{Equation 1}^{1}$$

where:

EF = Emission factor, lb/ton of material placed in storage, and

PE = Thornthwaite's precipitation-evaporation index (Figure 2.1.2-1).

Equation 1 represents the fugitive particulate emissions with a diameter less than 30 μm. This particulate size was determined[2] to be the effective cutoff diameter for the capture of aggregate dust by a standard high-volume filter based on a particulate density of 2.0 to 2.5 g/cm^3. The emission values calculated by this equation express only that amount which is likely to remain suspended indefinitely.[1] No details on the development of this equation or the estimated accuracy were available from the reference.

Equation 1 contains one correction parameter, the PE index or Thornthwaite's precipitation-evaporation index, which accounts for the changes of climate throughout the United States.[3] The PE index is an approximation of the average amount of surface moisture characteristic to a particular area. The PE index values for the State of Ohio and adjacent areas are given in Figure 2.1.2-1.

Table 2.1.2-1 shows how the total emission factor in Equation 1 can be divided into the individual contributions of the

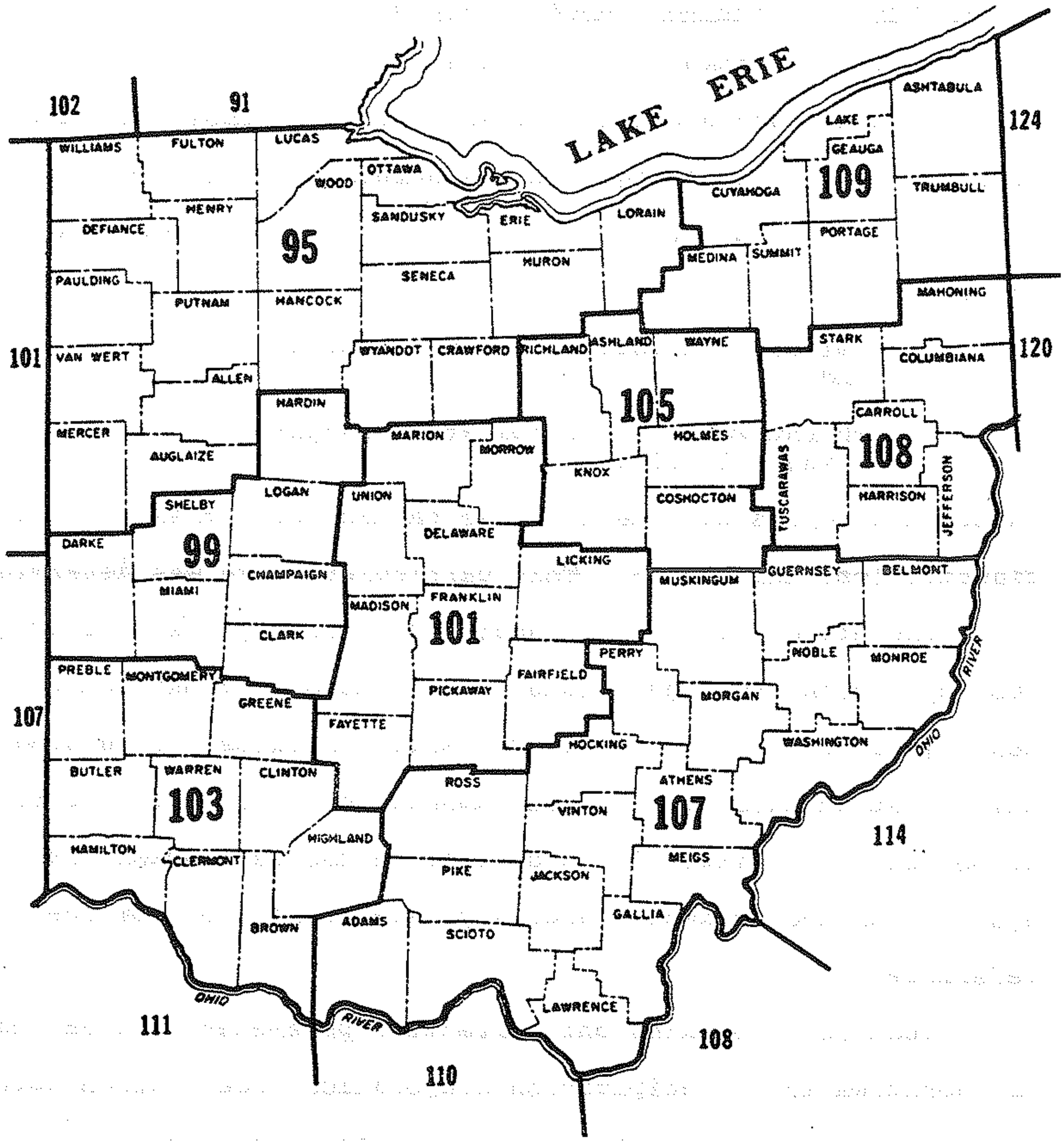

Figure 2.1.2-1. Thornthwaite precipitation-evaporation (PE) indices for the State of Ohio.[3]

TABLE 2.1.2-1. PERCENT CONTRIBUTION OF AGGREGATE STORAGE PILE ACTIVITIES TOWARD THE TOTAL FUGITIVE EMISSION RATE[2]

Source activity	Approximate percent contribution[a]
Loading of the material onto piles	12
Wind disturbance and erosion of stored material	33
Loadout of the material from piles	15
Vehicle movement	40
Total	100

[a] The emission contributions of each source activity are based on field tests of suspended dust emissions from crushed stone, sand and gravel storage piles. A 3-month storage cycle was assumed.[2]

four source activities. This distribution of emissions by source activity is representative of aggregate storage piles in general, but may vary for any specific source or stored material.

Specific Emission Factor Equations

Specific emission factor equations are available for each of the four major sources of fugitive dust associated with the storage cycle of aggregate material.[4] The equations are for specific types of equipment and storage material; thus, they should be used with caution when applied to other situations. Emissions from the first stage in the storage cycle, loading of material onto the pile, can be exemplified by means of a conveyor/stacker (continuous load-in) or a front-end loader (batch load-in). Emissions from the second stage in the cycle, wind disturbance of the pile, are exemplified by using a wind erosion equation. Emissions from the third stage are exemplified by using an equation for determining vehicular traffic around the storage piles. Emissions from the final stage, the load-out of material from the pile, are exemplified by the transfer of aggregate by a front-end loader from the pile to a truck.

The emissions from the operation of a conveyor/stacker (continuous load-in) are determined using Equation 2.[4] The base emission rate is corrected by three variables, the silt content of the material being stored, the moisture content of the material being stored, and the mean wind speed occurring during the operation.

$$EF_{(continuous)} = 0.0018 \frac{(S/5)(U/5)}{(M/2)^2}$$ Equation 2[4]

where:

EF = emission factor, lb/ton of material loaded onto the pile by a continuous operation,

S = silt content of the stored material in weight percent (see Table 2.1.2-2),

M = moisture content of the stored material in weight percent (see Table 2.1.2-2), and

U = mean wind speed, mph (see Table 2.1.2-3).

Emissions from the operation of a front-end loader (batch load-in) are determined using Equation 3.[4] The base emission rate is corrected by four variables: the silt content, mean wind speed, material moisture content and effective loader capacity.

$$EF_{(batch)} = 0.0018 \frac{(S/5)\ (U/5)}{(M/2)^2 (Y/6)}$$ Equation 3[4]

where:

EF = emission factor, lb/ton of material loaded onto the pile by a batch operation,

S = silt content of the stored material, in weight percent (see Table 2.1.2-2),

M = moisture content of the stored material, in weight percent (see Table 2.1.2-2),

U = mean wind speed, mph (see Table 2.1.2-3), and

Y = effective loader capacity, cubic yards.

The effective loader capacity is the working bucket capacity of the front-end loader being used to add material to the storage pile. The "mean wind speed" can be determined for a given study

TABLE 2.1.2-2. REPRESENTATIVE SILT CONTENT, MOISTURE CONTENT AND THE DURATION OF STORAGE PARAMETERS FOR SPECIFIC STORAGE MATERIALS[4,5]

Material in storage	Silt content, weight %	Moisture content, weight %	Duration of storage, days
Coal	4	6	107
Coke	1	1	50
Iron ore	11	1	43
Limestone	2	2	76
Sand	10		
Sinter	1.5	1	90
Slag	2	1	60
Top soil	40		

period (using actual field measurements) or estimated using the data given in Table 2.1.2-3.

The fugitive emissions occurring as a result of wind blown erosion of the storage pile can be determined using equation 4.[4] The base emission rate for wind erosion is adjusted by four correction parameters: the silt content of the storage material, the duration of storage, the number of dry days*, and the percentage of time that wind speeds exceed 12 mph.

$$EF = 0.05\ (S/1.5)(D/90)(d/235)(f/15) \qquad \text{Equation 4}$$

where:

EF = emission factor, lb/ton stored,

S = silt content of the stored material, weight percent (see Table 2.1.2-2),

D = duration of storage, days (Table 2.1.2-2),

d = dry days* per year (Figure 2.1.2-2), and

f = percentage of time wind speed exceeds 12 mph (References 6 and 7).

The percentage of time that the wind speed exceeds 12 mph is most appropriately obtained from actual on-site monitoring. However, should this type of data be unavailable, hourly wind speed for each day (recorded at the nearest metropolitan airport) can be obtained from the National Weather Service.[7]

Fugitive dust emissions occurring from vehicle traffic around storage piles can be determined using the unpaved roadway emission equation given in Section 2.1.1. However, a method of

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* Dry days are those days with <0.01 inches of precipitation.[6]

TABLE 2.1.2-3. THIRTY-YEAR ANNUAL WIND SPEED FOR SELECTED OHIO CITIES[6]

City	Mean wind speed, mph
Akron	9.9
Cincinnati	9.1
Cleveland	10.8
Columbus	8.7
Dayton	10.2
Mansfield	11.0
Toledo	9.5
Youngstown	10.0

calculating vehicle traffic emissions, specific for activity around the storage piles, is given in Equation 5.[4]

$$EF = 0.10\ K\ (S/1.5)(d/235) \qquad \text{Equation } 5^{4}$$

where:

EF = emission factor, lb/ton (of material put through the storage cycle),

K = activity factor, dimensionless (Table 2.1.2-4),

S = silt content of stored material, weight percent (see Table 2.1.2-2), and

d = dry days per year (see Figure 2.1.2-2).

The activity factor (K) is related to the type of loading (or haul) equipment employed and its level of usage as considered typical for various types of materials. The activity factor is a dimensionless number that places a value on the piece of equipment being used for specific materials relative to the equipment used in the original test study (front-end loader) on gravel operations. Table 2.1.2-4 gives values for K.

The final source of fugitive dust emissions that can be determined for a specific portion of the storage pile cycle is the load-out of material from the pile. The base emission rate for load-out of material from the pile by a front-end loader into a truck is adjusted by four correction parameters: the silt content of the storage material, the moisture content of the storage material, the mean wind speed, and the effective loader capacity.

The emission factor for the load-out of material from a storage pile by a front-end loader is presented in Equation 6.[4]

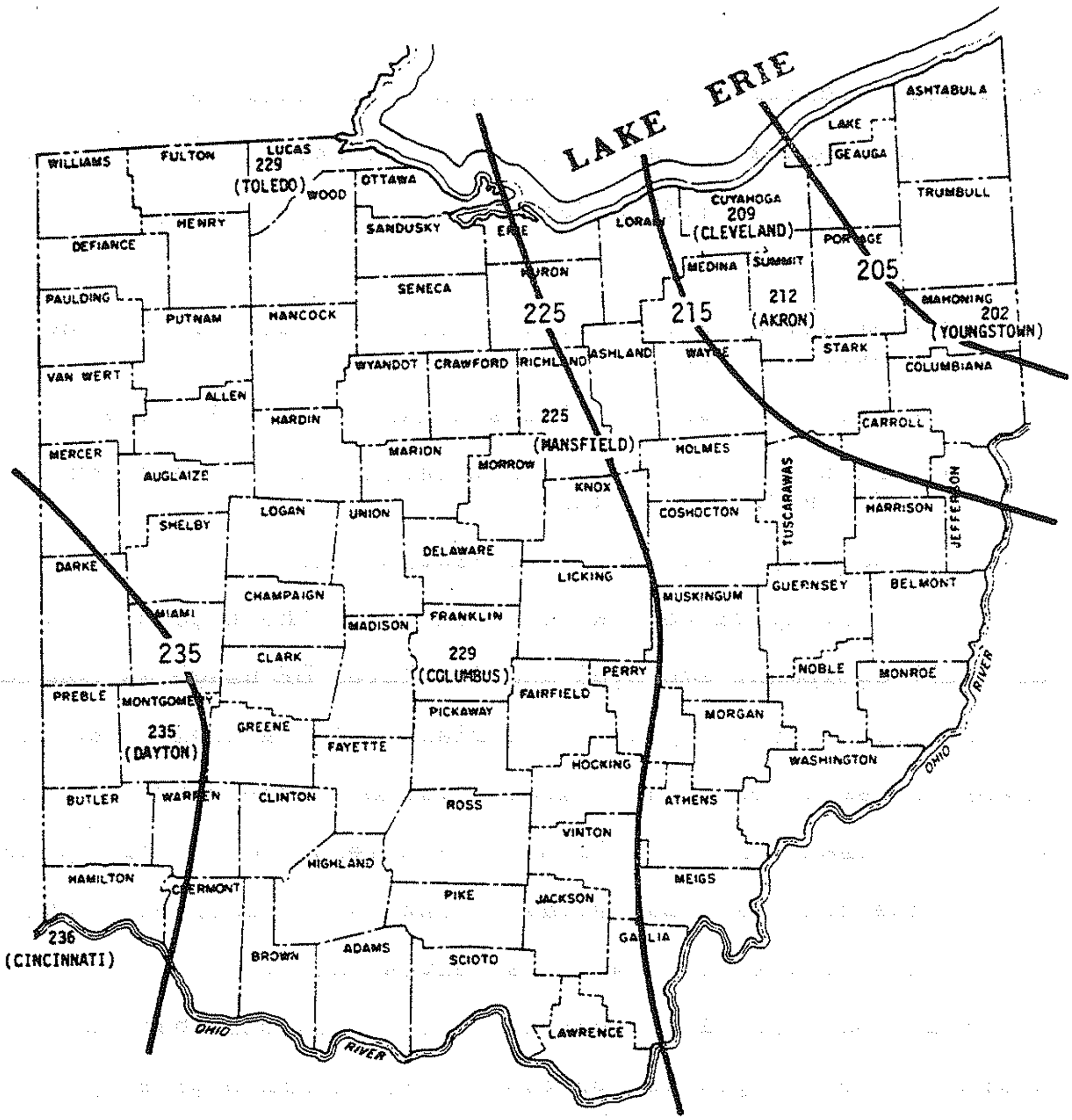

Figure 2.1.2-2. Mean number of dry days (less than 0.01 inch of precipitation) in the State of Ohio.[1,6]

TABLE 2.1.2-4. VEHICULAR ACTIVITY FACTORS[4]

Material	Range	Mean
Coal	0.0-0.25	0.08
Coke	0.0-1.0	0.25
Gravel[a]	0.25	-
Iron ore[b]	0.0-0.25	0.06
Limestone[c]	0.25	-
Sand[d]	1.0	-
Sinter	0.0	-
Slag	1.0	-
Top soil	-	-

[a] Large stone aggregate.

[b] Values are for both lump ore and pellets, 0.25 was determined for pelletized ore.

[c] Dolomite limestone.

[d] Sand and gravel.

$$EF = 0.0018 \frac{(S/5)\ (U/5)}{(M/2)^2 (Y/6)}$$ Equation 6[4]

where:

EF = emission factor, lb/ton of material transferred,

S = silt content of stored material, weight percent (Table 2.1.2-2),

M = moisture content of stored material, weight percent (Table 2.1.2-2),

U = mean wind speed, mph (Table 2.1.2-3), and

Y = effective loader capacity, cubic yards.

The effective loader capacity of the front-end loader will vary depending upon its intended use. A typical front-end loader used for the purpose of loading gravel will have an effective loader capacity of 3 cubic yards.

Details regarding the actual development of Equations 2 through 6 and the accuracy and limitations of application are not available; but given the generalities of application, the estimates should be considered to be within an order-of-magnitude at best.

A summary of the emission factor equations and correction parameters are presented in Table 2.1.2-5.

2.1.2.3 Particle Characterization--

Particle Size, Density, and Composition

The particle size of airborne fugitive dust from aggregate storage piles does not vary greatly and can be stated to be somewhat independent of the material being stored.[8] Typical particulate size ranges for fugitive dust from aggregate storage piles are given in Table 2.1.2-6. Recent information does

TABLE 2.1.2-5. SUMMARY OF EMISSION FACTOR EQUATIONS AND CORRECTION PARAMETERS

Emission category	Emission factor equation
Gross overall emission rate[a]	$EF = 0.33/(PE/100)^2$
Load-in (continuous operation)[b]	$EF = 0.0018 \frac{(S/5)\ (U/5)}{(M/2)^2}$
Load-in (batch operation)[b]	$EF = 0.0018 \frac{(S/5)\ (U/5)}{(M/2)^2 (Y/6)}$
Wind erosion[b]	$EF = 0.05\ (S/1.5)(D/90)(d/235)(f/15)$
Vehicle activity[b]	$EF = 0.10\ K\ (S/1.5)(d/235)$
Load-out[b]	$EF = 0.0018 \frac{(S/5)\ (U/5)}{(M/2)^2 (Y/6)}$

Correction parameters

Symbol - Description	
PE - Thornthwaite's Precipitation Evaporation index	Figure 2.1.2-1
D - Duration of material in storage, days	Table 2.1.2-2
d - Number of dry days per year	Figure 2.1.2-2
f - Percent of time wind speed exceeds 13 mph	Reference 6,7
K - Activity correction	Table 2.1.2-4
M - Material surface moisture content, %	Table 2.1.2-2
S - Material silt content, %	Table 2.1.2-2
U - Mean wind speed, mph	Table 2.1.2-3
Y - Effective loader capacity, yd^3	Specific to equipment

[a] Reference 1.

[b] Reference 4.

TABLE 2.1.2-6. TYPICAL PARTICULATE SIZE RANGES FOR FUGITIVE DUST FROM AGGREGATE STORAGE PILES[a]

Size range	Percent by weight of emissions
<3 µm	30
3-30 µm	23
>30 µm	47

[a] Reference 9.

indicate that, although the particle size distribution may be fairly independent of the material being stored, the condition of the storage pile surface (disturbed or undisturbed) can influence the size distribution. Studies of coal storage piles indicate that an undisturbed pile surface will generate a smaller percentage of particles under 30 μm (approximately 9%) than a disturbed surface (approximately 21%).[10]

The density and composition of the fugitive emissions from aggregate storage piles will be directly related to the material being stored.

Hazardous or Toxic Nature of Fugitive Emissions from Aggregate Storage Piles

The hazardous or toxic nature of fugitive emissions from aggregate storage piles is almost entirely dependent upon the type of material being stored. It is not possible to discuss the nature of a health hazard without first knowing the storage material in question. The reader is directed to the health effects discussion in Section 2.1.1.3 which outlines the health problems associated with fugitive emissions from paved and unpaved surfaces for information on emissions generated during vehicle activity around the storage pile. For other storage pile activities, specific knowledge of the storage material is necessary. The hazardous properties of specific industrial materials can be found in Reference 11.

2.1.2.4 Control Methods--

The control methods available for reducing fugitive dust from activities associated with the storage of material in open piles are presented in this section by each type of activity: load-in, wind disturbance, vehicle traffic and load-out.

Techniques, Efficiencies and Costs for Controlling Fugitive Dust Emissions from Storage Pile Load-In

The control techniques for reducing dust from load-in activities consist of enclosures, chemical stabilization, and operating precautions. The enclosures include silos, stone ladders, wind guards and telescopic chutes. The chemical stabilization includes watering, the application of dust retardant, and the use of crusting agents. The final group of control techniques concern themselves with precautionary operating habits such as reducing the drop height of front-end loader buckets and making operators aware of the necessity of dust control.

Enclosures - Enclosure techniques include storage site enclosure (e.g., silos) and material handling enclosures (e.g., chutes). Storage site enclosures, like silos or warehouses, must be specifically designed for the material being handled. Additional structural considerations such as ability to withstand snow loads, wind or precipitation affect the design of any given silo or enclosing structure. Due to this degree of specificity, it is hard to place an exact efficiency rating or cost estimate on the use of storage silos or buildings. It is expected that a properly built storage silo would substantially reduce load-in emissions when accompanied with control of the emissions from the material transfer into the silo.

Stone ladders are permanent devices which aid to guide material from a stacker to the pile. A stone ladder is a vertical tube with openings at various heights. The storage material will fill the tube until it reaches an opening, at this point the material will begin to flow out on to the pile. The estimated control efficiency for this device as compared to the emissions from a front-end loader is approximately 80 percent, and the initial investment is about 24,500 dollars.[4]

Wind guards are closely related to telescopic chutes except that they are of a fixed length. The wind guard covers the discharge end of a stacker helping to decrease the effective dispersing action of the wind. The estimated control efficiency for a wind guard on a stacker (when compared to a front-end loader) is approximately 50 percent.[4] The initial cost is estimated at between 12,000 and 61,000 dollars.[4]

A telescopic chute consists of a series of thin-walled cylinders which help to guide the material being dropped from the stacker to the pile. The telescopic chute retracts as the pile grows. This feature makes its use suitable for both stationary or mobile stackers. The purpose of a telescopic chute is to reduce a long drop distance to a few feet. The estimated control efficiency for a telescopic chute (compared to a front-end loader) is approximately 75 percent. The initial cost can be approximately 8,500 dollars.[4,8]

Chemical stabilization - The primary forms of chemical stabilization used during load-in activities are watering and wetting agent application. The water or wetting agent is applied by a spraying system at the discharge end of the stationary or mobile stacker. Relative to the use of a front-end loader, a stationary or mobile stacker with a spray system has been estimated by various sources to have a control efficiency of from 75 percent[4] to as high as 80 to 90 percent.[12] The initial investment in equipment is approximately 13,500 dollars.[4] This figure does not include the annual operating costs and assumes the use of water only. The application of chemical wetting, crusting or suppression agents to the storage pile results in higher costs. Depending on the agent used, costs can be between 0.5 and 1.5 cents per square foot of surface area.[4] A summary of common chemical agent costs is presented in Table 2.1.2-7.

Precautions - Operational precautions are assumed to have some potential to decrease the amount of fugitive dust generated when material is dropped from a front-end loader or height adjustable stacker. The ability of the equipment and operator to reduce the drop distance of the storage material can help to reduce the amount of fugitive dust emitted. A properly operated "variable height" stacker can gain a 25 percent control effiency over normal front-end loader operation.[4] The control efficiency gained through lowering the drop distance of a front-end loader was not addressed in the available literature. A summary of the

TABLE 2.1.2-7. CHEMICAL STABILIZING AGENTS FOR USE ON AGGREGATE STORAGE PILES[a,b]

Stabilization agent	Dilution	Application rate per 10^3 ft^2	Application cost, 1980 dollars per 10^3 ft^2
Organic polymers			
° Johnson-March SP-301[c]	Full strength	10 gal. concentrate	16.50[d]
° Apollo			
Pentron DC-3[e]	10% solution	1.2 gal. concentrate	4.20
Pentron DC-5[e]	10% solution	1.2 gal. concentrate	4.50
° Houghton Rexosol 5411-B[c]	2% solution	3 gal. concentrate	8.50
Petroleum resin water emulsion			
° Witco Chemical Coherex[c]	20% solution	20 gal. concentrate	4.90
Latex type synthetic liquid adhesive			
° Dowell M145 chemical binder[c]	4% solution	1.8 gal. concentrate	4.90

[a] Mention of a company or product name should not be construed as an endorsement by either the author of this document or the Ohio Environmental Protection Agency. It should also be noted that the table represents an example of the wide range of chemicals available for use. It does not attempt to include all chemical companies or all of their products.

[b] The figures given in this table are approximations and can be used in only a very cursory comparison of costs (on a usage basis).

[c] Reference 4, pages 6-11.

[d] Based upon a cost of 1.65 dollars per gallon, which assumes that the stabilizer will be purchased in quantities of 45 or more drums (at 55 gal. per drum).

[e] Reference 13.

control techniques and efficiencies for storage pile load-in activities are given in Table 2.1.2-8.

Techniques, Efficiencies and Costs for Controlling Fugitive Dust Due to Wind Disturbance of Aggregate Storage Piles

The control techniques for reducing fugitive dust from wind disturbed storage piles consist of building enclosures, applying chemical stabilizers or in some instances taking precautionary maintenance measures. The enclosures used to reduce wind disturbance include both silos and wind breaks. The chemical stabilization techniques include watering and application of surface crusting agents. The precautionary measure consists of maintaining as low a pile height as possible.

Enclosures - The protection of storage piles from the direct action of wind erosion and dispersion can be accomplished through the use of total (silo) or partial (wind break) enclosures. Silos are not often used for controlling fugitive dust. Instead they are usually constructed for the protective storage of special materials. In one instance, storing coal in a single large silo effectively eliminated from 95 to 100 percent of the wind generated emissions.[4,6]

The cost for constructing silos will vary for different materials. An approximate cost of 75 dollars per ton of material stored has been suggested.[4] Wind breaks, such as trees, shrubs or other vegetation, or man-made structures, have been estimated to provide a control efficiency of 30 percent.[4] The cost of such structures will vary greatly. For vegetative wind breaks, a

TABLE 2.1.2-8. A SUMMARY OF CONTROL TECHNIQUES, EFFICIENCIES AND COSTS FOR FUGITIVE DUST EMISSIONS FROM AGGREGATE STORAGE PILES

Emission source and control techniques	Estimated control efficiency, %[a]	Initial cost, (1980 dollars)	Annual operating costs, (1980 dollars)
Load-in			
° Enclosures			
- Silo	-	(see wind disturbance)	NA
- Stone ladders	80	24,500	NA
- Wind guards	50	12,000 to 61,000	NA
- Telescopic chutes	75	8,500	NA
° Chemical stabilization	75 to (80-90)	13,500	\$4.20 to 16.50/10^3 ft^2
° Precautions	0-25	NA	NA
Wind disturbance			
° Enclosures			
- Silo	95-100	75 per ton of material stored	NA
- Vegetation wind break	30	45-425 per tree	NA
° Chemical stabilization	80-99	13,500+	\$4.20 to 16.50/10^3 ft^2
° Precautions	30	NA	NA
Vehicular traffic	(See Section 2.1.1 Plant Roadways and Parking Areas)		
Load-out			
° Reclaimer systems	80-85	2-6 million[b]	NA
° Dust suppression (includes bucket reclaim system and spray)	95	75,000+	NA

[a] Reported overall efficiencies for various materials. Not tailored to any one type of material stored.

[b] Based upon a mobile stacker/reclaimer system.

single tree can range between 45 dollars for an 8 foot specimen to 425 dollars for a 25 foot specimen.[4]

Chemical stabilization - The act of using a substance to stabilize the surface of an aggregate storage pile is often referred to as "surface stabilization." This process binds the loose surface material into a solid, nonerodible crust through the use of a chemical crusting agent. Also, water (with or without a wetting agent) can be used to keep the surface moist and promote the adhesion of small particles to larger ones. In order to wet the surface of the pile, a system of towers, sprinklers and pipes must be constructed. The initial cost of this equipment has been estimated at approximately 13,500 dollars.[4] An estimate of spray and application costs can be determined through Table 2.1.2-7. The control efficiency of a spraying system is given to be approximately 80 percent using water and up to 99 percent when chemical agents are used.[4]

Precautions - The lowering of the storage pile height takes advantage of the fact that wind speed generally increases with height above ground level. Lower storage piles result in lower surface wind speeds which result in reduced wind erosion. The maintenance of low storage piles can not be directly associated with any change in cost. An estimated control efficiency of 30 percent is assigned to this technique.[4]

Techniques, Efficiencies and Costs for Controlling Fugitive Dust from Vehicular Traffic Around Storage Piles

The requirements for controlling fugitive dust from unpaved access roads on or near aggregate storage piles is not unlike the requirements for other unpaved plant roadways. The reader is referred to Section 2.1.1, Plant Roadways and Parking Areas, for a discussion of controlling dust from unpaved plant surfaces.

Techniques, Efficiencies, and Costs for Controlling Fugitive Dust from Storage Pile Load-Out

The control techniques for reducing dust from load-out activities include the use of reclaimer systems and dust suppressants.

The load-out of material from storage piles can be accomplished with the use of either front-end loaders or reclaiming systems. The reclaiming of material from storage piles is accomplished by use of underground conveyors and raking or bucket equipment. In either of these cases the reclaimer systems minimize the amount of fugitive dust generated during load-out operations (as compared to a front-end loader).

Rake reclaimers move along the surface of the pile directing material toward an underground conveyor system. The bucket system consists of a bucket wheel which moves along the pile perpendicular to its face. The buckets move material from the pile surface onto a conveyor. The reclaiming system may also be passive in nature, in which case material is fed to the conveyor beneath the pile by gravity alone.

The control efficiencies for these systems (as compared to a front-end loader) are 85 percent for the rake reclaimer and approximately 80 percent for the gravity feed and bucket reclaimer.[4,8] Reclaiming systems will vary greatly in cost depending upon the type of system chosen and the desired design capacity. Initial costs of a mobile stacker/reclaimer system range between 2 and 6 million dollars.[4]

The mechanism behind dust suppression is similar in nature to chemical stabilization. The technique consists of the application of water or chemical wetting agents to the storage pile prior to disturbance by load-out equipment. This technique can include simple surface spraying of the pile, or the use of a specialized spray system which wets the storage material as it is being disturbed. The control efficiency of wetting the pile surface prior to disturbance (by a front-end or reclaimer) is not documented in the literature. The actual efficiency is assumed to be low. The control efficiency of a bucket wheel reclaimer with spray system (as opposed to a front-end loader alone) is estimated to be 95 percent.[4] The estimated cost of a spray system for use with an existing mobile bucket wheel reclaimer is at least 75,000 dollars.[4] No annual operating cost estimates are available.

RACM selections for storage piles must be made on a site specific and material basis. Some materials are amenable to wet control techniques with no effects on material quality, while others cannot tolerate increased moisture. RACM for a specific site should also be made by evaluating the severity of the emissions and the costs for the various control alternatives. Specific RACM selections are made for storage activities of various materials in the later industry-specific sections.

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2.1.3 Material Handling

2.1.3.1 Source Description--

Material handling is the description given to the movement of raw process materials from receiving sites (truck depots, vessel docking facilities and rail spurs) to industrial storage sites (aggregate storage piles or silo enclosures) or directly to process operations, the transfer of materials between process operations, and the transfer of products to storage or shipment. The actual material handling is a combination of unloading, transfer, and conveying operations. These three types of operations are common to virtually all process industries. A pictorial representation of these operations is given in Figure 2.1.3-1. This figure depicts the relative position of each material handling operation within a hypothetical industrial setting.

The unloading operations are presented in this section according to the transportation mode of the vehicle being unloaded (truck, vessel or rail car). The types of unloading operations frequently associated with material handling are: dumping by truck; crane-clamshell and bucket ladder removal from vessels; and side dumping, rotary dumping, bottom dumping and pneumatic removal of material from rail cars.

The transfer and conveying of material are accomplished with belt conveyors, screw conveyors, bucket elevators, vibrating conveyors and pneumatic equipment. The actual loss of material or the generation of dust from material handling will occur at

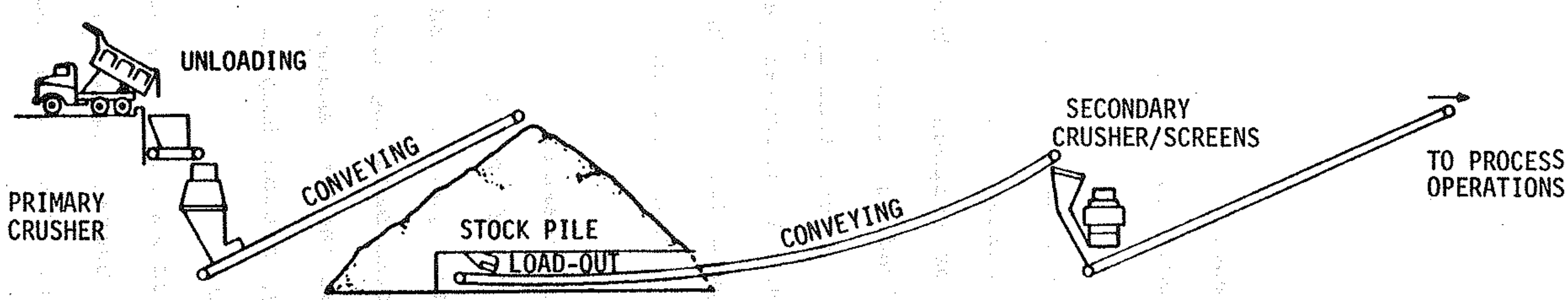

Figure 2.1.3-1. Typical materials handling operation.

the feeding, transfer, and discharge points along the system. Review of the literature indicates that a majority of the material loss generated is due to spillage and is superseded by wind erosion only when the handling system is improperly enclosed.[1]

2.1.3.2 Fugitive Dust Emission Factors--

The fugitive dust emissions generated from the handling of process materials vary depending upon the method of unloading or transferring used and the type of material being handled. In most cases, the available emission factors for material handling are based upon engineering judgment or limited on-site measurements. Table 2.1.3-1 presents the available emission factors for unloading of material. Table 2.1.3-2 gives the emission factors for the conveying and transfer of material. In using these factors for materials not listed, it is best to select the factor for the listed material that would most likely have similar properties to the material in question.

2.1.3.3 Particle Characterization--

Particle Size, Density and Composition--The particulate size of fugitive dust generated from material handling operations can be considered not to vary with the type of aggregate material in storage. It can be assumed that the size distribution of the dust will be somewhat independent of the type of material being handled, because the surface condition of the transported material (crusted or aggregated versus fine or disaggregated) will

TABLE 2.1.3-1. EMISSION FACTORS FOR THE UNLOADING OF MATERIAL

Vehicle	Method of unloading	Material unloaded	Uncontrolled emission factor (lb/ton of material unloaded)	Reliability
Truck	° Dumping	Aggregate	0.02[a]	D
		Rock and gravel	0.04[a]	E
		Granite	0.00034[a]	E
		Grain	2-8[b]	D
			0.64[c]	B
Vessel	° Crane-clamshell bucket	Grain	3-8[b]	D
	° Bucket ladder	d	d	
Rail	° Side dump	d	d	
	° Rotary dump	d	d	
	° Bottom dump	Taconite pellets	0.03[b]	E
		Coal	0.4[b]	E
		Grain	3-8[b]	D
			1.30[c]	B
	° Pneumatic	d	d	

[a] Reference 5, pages 37-40.

[b] Reference 2, page 2-17.

[c] Reference 3, page 12.

[d] Data not available.

TABLE 2.1.3-2. EMISSION FACTORS FOR THE CONVEYING AND TRANSFER OF MATERIAL

Material handling operation	Material being handled	Uncontrolled emission factor (lb/ton handled)	reliability
Conveying and transfer	Coal	0.04 - 0.96[a]	E
		0.02[b]	D
		0.02[e]	E
	Coke	0.023 - 0.13[a]	D
	Grain	2.0 - 4.0[a]	E
		0.11 - 1.40[c]	B
	Granite	Negligible[b]	E
	Iron ore	2.0[a]	E
		0.046[c]	E
	Lead ore	1.64 - 5.0[a]	E
	Sand	0.3[a]	E
Transfer (only)	Coal (spillage)	0.8[c,d]	E

[a] Reference 2, p. 2-7.
[b] Reference 1, page 3-42.
[c] Reference 3, page 12.
[d] Value includes dust and large aggregate, much of which will never be suspended.
[e] Reference 5, pages 44-47.

influence the final size distribution found in the fugitive dust emissions[2,3] (see Table 2.1.2-6, column b).

The density and composition of the fugitive emissions from material handling activities will be directly related to the type of material involved.

Hazardous or Toxic Nature of Fugitive Emissions From Material Handling Activities--The hazardous or toxic nature of fugitive emissions from material handling activities is almost entirely dependent upon the type of material being handled. As in the case of particulate characteristics, it is not possible to discuss the nature of a health hazard without first knowing the material in question. The hazardous properties of specific industrial materials can be found in Reference 4.

Data Availability--Review of the literature has produced only two examples of particulate size distribution for aggregate material that would be unloaded or transported by a material handling system (see Table 2.1.2-6). Knowledge of exactly what portion of the fugitive emissions from other handling operations will remain in suspension is needed. A few of the conveying and transfer emission factors are indicated as including large portions of "spillage," material which is much too large to ever become suspended.

2.1.3.4 Control Methods--

The control methods available for reducing fugitive dust from material handling activities are specific to the site of dust release, i.e., the site of unloading, conveying operations, or points of transfer. The control methods, efficiencies and costs discussed in this section will be addressed according to the individual sites of dust generation.

Techniques, Efficiencies and Costs for Controlling Fugitive Dust From Unloading Activities--The minimization of dust from unloading activities can be accomplished through 1) the total or partial enclosure of the unloading facility and the removal of the particulate to a bag filter system, 2) enclosure without bag filter system, and 3) use of a water or chemical spraying system.[1,5]

The control of fugitive dust from truck dumping activities can be accomplished with either the enclosure or spray system techniques. The application of control practices to truck dumping sites are dependent largely on the industry or material involved. A 90 to 95 percent reduction of fugitive dust from truck dumping activity can be accomplished when the site is enclosed and the captured particulate is vented to a control device.[5] A 50 percent control efficiency can be achieved with a water spray system.[5] Cost estimates for these spray systems were not available.

Fugitive dust emissions can be controlled through the enclosure of rail car unloading stations accompanied by dust collection with bag filters. This method of control can effectively reduce 99 percent of the fugitive dust. This type of system is estimated to have an initial cost of approximately $120,000.[1] No annual operating costs are available. Depending on the type of material involved, fugitive dust from rail car unloading operations can also be controlled using spray systems. This measure results in an effective control efficiency of 80 percent at an annual cost of $37,000.[1] The use of chemical stabilizers may improve the efficiency of this control measure. The addition of chemicals to the spray system, however, will increase the cost of operation (see Table 2.1.2-7).

Data on dust suppressants, their costs, and application rates are presented in Appendix B.

<u>Techniques, Efficiencies, and Costs for Controlling Fugitive Dust From Conveying and Transfer Activities</u>--The control of dust from conveying and transfer operations can be accomplished through methods similar to those used during unloading operations. Conveying or transfer emissions can be minimized through the use of enclosures or spray systems. Enclosure of conveying systems can be either partial (top) or total. The control efficiency of a partial enclosure system is rated at 70 percent with an initial cost of $43.00 per foot of conveyor.[1] The total enclosure of a conveying system which includes the use of a dust collection system, e.g., bag filter, can result in a control efficiency increase to 99 percent with an initial cost of $86.00 per foot of conveyor.[1] No annual operating costs were available for either of these control measures.

Transfer stations located along the course of a conveying operation can be significant sources of fugitive dust. The control of dust from these sources is also accomplished using enclosures and/or spray systems. The total enclosure of a transfer point can effectively reduce fugitive emissions by 70 percent at an initial cost of $3,700.[1] The addition of a bag filter to a transfer point enclosure can raise the control efficiency to approximately 99 percent. This additional equipment will increase the initial cost to approximately $22,000.[1] Effective control of dust from transfer stations can also be accomplished using water and chemical spray systems. The spray system has an added advantage in that the aggregate subject to chemical spray is adequately treated to effect dust suppression throughout the entire material handling system. The control efficiency of spray systems at transfer points is estimated to be between 70 and 95 percent.[1] The initial cost of implementing a spraying system for a single transfer point is approximately $18,000. The cost of one multiple system was estimated at $245,000 (based on a plant handling 2.2 million tons of material a year). The annual operating cost of a single transfer station ranges between 0.02 to 0.05 dollars per ton of material handled.[1] PEDCo estimates that the capital costs for a system such as shown in Figure 2.1.3-1 is approximately $70,000, with annualized costs of $23,700.

A summary of the control measures for unloading, conveying, and transfer operations is presented in Table 2.1.3-3.

Reasonably Available Control Measures (RACM) for material handling operations must, of course, be site specific and material specific. In most cases, where the material characteristics will not suffer from increased moisture content, water or

TABLE 2.1.3-3. A SUMMARY OF CONTROL TECHNIQUES, EFFICIENCIES, AND COSTS FOR FUGITIVE EMISSIONS FROM UNLOADING, CONVEYING, AND TRANSFER OPERATIONS

Control method	Estimated control efficiency, %	Initial cost (1980 dollars)	Annual cost (1980 dollars)
Unloading			
Truck			
° Enclosure			
- total with fabric filter	95	76,000[a]	17,000[a]
- partial with fabric filter	90	50,000[a]	12,500[a]
° Spray system-water	50	b	b
Vessel			
° Enclosed bucket elevator leg, vent to fabric filters	95	51,600[a]	11,600[a]
Rail			
° Enclosures			
- total with fabric filter	99[c]	120,000[d]	b
- total without fabric filter	70	b	b
° Spray systems with chemicals	80	37,000[d]	b
Conveying			
° Partial (top) enclosure	70[e]	43/ft[d]	b
° Total enclosures	99[f]	86/ft[d]	b
Transfer			
° Enclosures	70 - 99[g]	4,000 to 22,000[d]	b
° Spray systems with chemicals	70 - 95	18,000 to 245,000[d,h]	0.02 to 0.05 per ton of material treated[i]

[a] Reference 6, pages 6-23 through 6-75.

[b] Unavailable.

[c] Enclosure is accompanied with high efficiency (99+%) bag filter.

[d] Reference 1, page 6-3.

[e] "Weather-tight" system; no active dust collection system.

[f] Value utilized active dust collection system.

[g] Lower value represents simple enclosure; high value includes bag filter.

[h] Lower value represents cost of control at a single transfer station; high value represents total cost for a large multiple transfer station system.

[i] Annual cost applies to single transfer station only.

chemical sprays offer good control efficiencies at reasonable costs. However, where material characteristics or specifications preclude wetting, the emissions should be controlled by enclosure and ventilation to a fabric filter. Again a case-by-case assessment must be made to ascertain the severity of the emissions and the relative economics of control. Details on RACM selections for specific materials and operations are presented in the industry-specific sections of this report.

Benefits of Control Measures--Material handling operations move what is usually considered to be a "valuable" commodity from one point to another within a given industrial setting. Because the material has been acquired at some cost to the industry, the loss of a portion of this material constitutes an expensive waste. In some cases, e.g., grain elevators, the cost of installing collection devices can be partially offset by the market value of the material which has been captured. This type of side benefit associated with collection devices may have applications in a number of other industries.

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2.1.4 Mineral Extraction

Mineral extraction (mining) operations generate large amounts of fugitive dust. The fugitive dust emissions associated with these activities are in addition to the emissions from the ore beneficiation process. The fugitive dust sources vary depending on the method of extraction, which is often dependent upon the type of mineral to be removed. Table 2.1.4-1 lists the major types of minerals mined in the State of Ohio.

2.1.4.1 Source Description--

Eleven mineral extraction operations that have been identified as generating fugitive dust are listed in Table 2.1.4-2. Six of these fugitive sources are treated in one or more of the other sections of this report. Five sources are discussed in this section. The five fugitive dust sources specific to mining are 1) overburden removal, 2) drilling and blasting, 3) off-highway truck loading, 4) waste disposal, and 5) reclamation. The following descriptions of the mining operations are general in nature. Site specific operations may vary from these descriptions.

Overburden removal--Overburden removal consists of those activities performed to remove material overlying a mineral deposit. An operation of this type includes the reduction of surface plant life and removal of top soil, subsoil, and other undesirable strata. Overburden removal is most often associated with surface (strip and pit) mining operations.

TABLE 2.1.4-1. MINERAL MINING IN OHIO[1]

Mineral	Mining method	Quantity (10^6 short tons)
Coal	Surface	24.8
	Other[a]	22.0
Clay and shale	Surface	2.7
	Underground	0.7
Limestone and dolomite	Surface	44.0
	Underground	0.9
Other stone[b]	Surface	1.4
Sand and gravel	Surface	37.2
Salt	Underground	5.1

[a] Includes underground, auger, and strip-auger mines.

[b] Includes sandstone and quartzite.

TABLE 2.1.4-2. REVIEW OF FUGITIVE DUST FROM MINERAL EXTRACTION INDUSTRY

Source description	Section of guideline containing source information
Overburden removal	Section 2.1.4
Drilling and Blasting	Section 2.1.4
Truck loading	Section 2.1.4
Haul roads	Section 2.1.1
Truck dumping	Section 2.1.3
Crushing	Sections 2.18, 2.19
Transfer and conveying	Section 2.1.3
Cleaning	Sections 2.18, 2.19
Storage	Section 2.1.2
Waste disposal	Section 2.1.4
Reclamation	Section 2.1.4

Three methods of strip mining are practiced in the United States; area, contour, and auger.[2] Area strip mining is performed on flat terrain. Trenching equipment removes overburden from the strip of land presently being worked, depositing it in the trench left by the previous stripping operation. Only the initial stripping operation produces overburden which requires disposal or storage. Figure 2.1.4-1 gives a pictorial representation of overburden removal during area strip mining.

The second stripping method, contour mining, is employed when the land has a slope greater than 15 degrees. Contour stripping is the excavation of a hillside to form a level platform or "bench". One side of the bench runs along the exposed wall of the hill. The opposite side faces the downslope of the hill. Overburden is removed from the present bench excavation and deposited (or backfilled) into the previously worked area. This operation (bench excavation, mineral extraction, backfill) continues up the slope until the desired mineral deposit has been removed. The initial stripping operation produces the only overburden requiring storage or disposal. This excess overburden has to be moved to a level storage area. Overburden remaining on the downslope of a hill increases the potential for landslide. Figure 2.1.4-1 gives a pictorial representation of overburden removal during contour mining.

The third stripping method, auger mining, uses large drills (augers) to pull minerals from horizontal deposits. This technique is usually done in conjunction with contour mining. Contour mining transforms the hillside into a series of benches. The

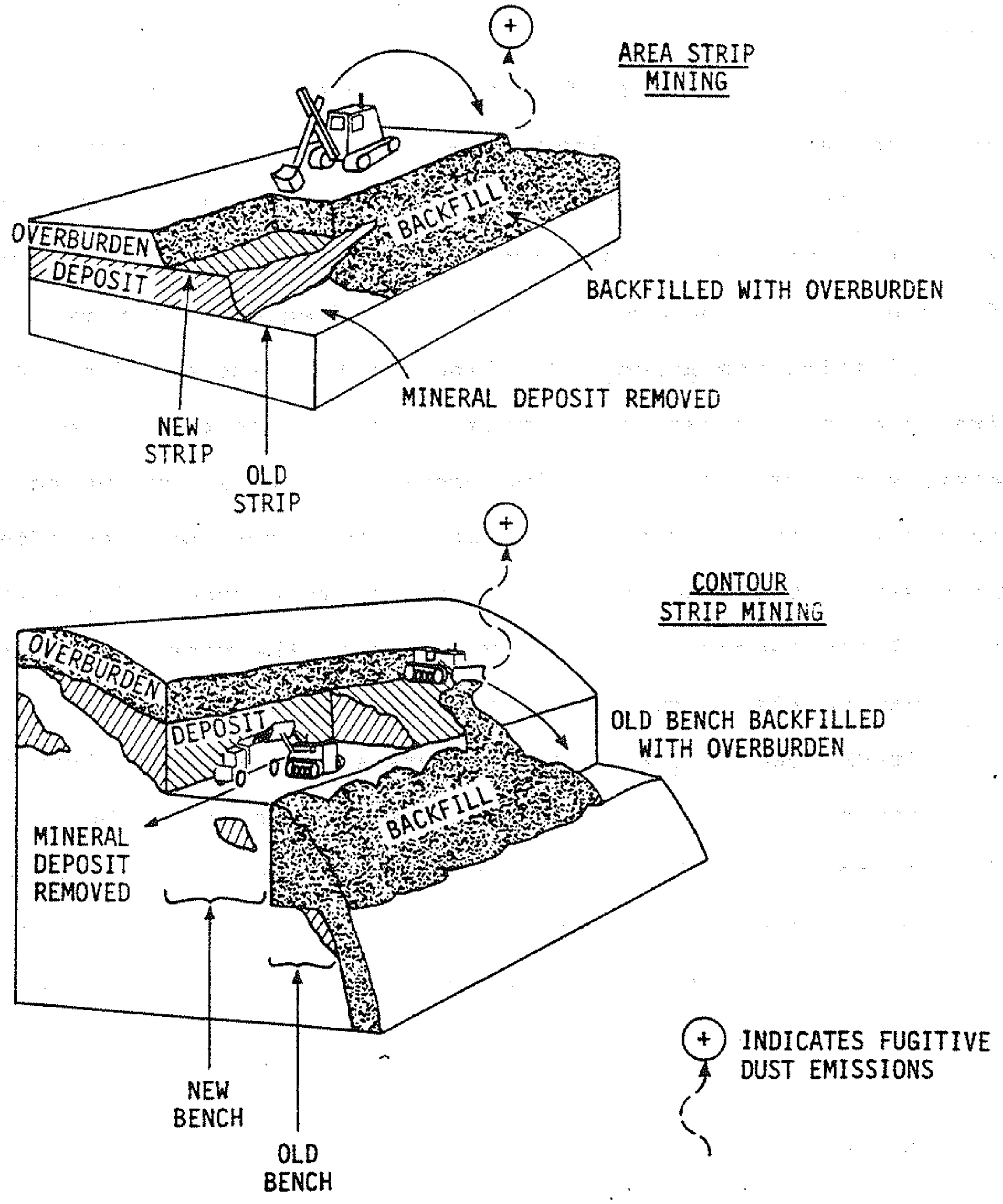

Figure 2.1.4-1. Overburden removal operations for area and contour strip mining.

auger then extracts the exposed mineral seams on each bench. The handling of overburden is the same as during a contour mining operation.

A fourth type of surface mining, open pit mining, requires very limited (one-time) overburden removal. The overburden material is usually removed and transported to an off-site storage area until reclamation activities begin. Overburden removal for open pit mining operations is an infrequent activity.

Blasting operations--Drilling and blasting are done to fracture hard, consolidated material so it can be more easily and efficiently removed. Blasting operations are a routine part of open-pit mining or quarrying, but are performed only as often as necessary. Blasting is usually limited to a once-a-day activity in isolated, temporarily inactive areas of the mine. This is done to minimize the disruption of other mining activities.

Truck loading operations--Minerals or overburden from surface mining will at some point be loaded onto off-highway trucks for transport. Although conveyor systems are often employed in place of trucks, mining operations dealing with coal, stone, gravel, and clay very often use dump trucks. Truck loading is usually performed using crawler-mounted shovels or front-end loaders.

Waste disposal operations--Large amounts of waste material are generated during the mining and benefication of minerals. Examples of waste material from mining operations are low-grade ore, slack coal, extraneous unmarketable rock, tailings, and mud slime. Waste material having the same characteristics as the mineral being mined can be disposed of as backfill. Other waste material may be in slurry form and require disposal in holding ponds. Waste disposal operations are distinguished from overburden disposal, because in most cases disposed waste is not reclaimed.[2]

Land reclamation--Surface mining will cause considerable alteration of the land at the mining site. Effective reclamation should include a preplanned program which allows the reclaiming practice to become a concurrent part of daily mine operations. An effective program should also allow for segregation of the strata within the overburden into different quality materials. Placement of topsoil, sub-soil, and inferior material into separate storage promotes proper backfill practices. If properly stratified (topsoil, over subsoil, over inferior fill), a reclaimed mining area will accept revegetation.

2.1.4.2 Fugitive Dust Emission Factors--

Fugitive dust is generated at each of the mineral extracting sources. In many instances a single mine may have more than one source of fugitive dust associated with it. The fugitive dust emission factors available for the mineral extraction industry are presented according to their specific source of generation.

Fugitive dust emission factors for overburden removal--Two primary fugitive dust sources are associated with overburden removal: 1) dumping of dragline buckets or shovels into adjacent trenches or 2) removal and transfer of soil with scrapers and bulldozers. Specific sampling has not been performed on either

TABLE 2.1.4-3. FUGITIVE DUST EMISSION FACTORS FOR OVERBURDEN REMOVAL OPERATIONS

Description of overburden removal	Fugitive dust emission factor: Uncontrolled	Fugitive dust emission factor: Controlled	Reliability rating
Area stripping[a] (undetermined)	0.002 lb/ton coal mined		D
Area stripping[b] (with scraper)	0.004 lb/ton of overburden removed		E
Area stripping[b] (with dragline)	0.05 lb/ton of overburden		E
Area stripping[c] (with dragline)	0.173 lb/ton of overburden		E
Contour stripping[a]	0.003 lb/ton coal mined		D
Unspecified[d]	0.26 lb/ton coal mined	0.009 lb/ton coal mined[e]	E

[a] Nationally averaged emission factor, Reference 2, page 21.

[b] North Dakota lignite surface mine, Reference 2, page 22.

[c] 0.173 lb/ton or 0.38 lb/yd^3 of overburden represents combined emission rates of four Western coal mines in Colorado, Wyoming, Montana, and North Dakota, Reference 3, page 2.

[d] Mining practices in the Southwestern United States, Reference 2, page 22.

[e] Control measure is a water spray system, and represents a 95 percent reduction in fugitive dust, Reference 2, page 22.

of these sources; however, estimates of the source emissions are available. Table 2.1.4-3 lists the available fugitive dust emission factors for overburden removal. The removal of overburden has been cited as the largest source of fugitive dust at a mineral mining facility.[2] However, quantifying the actual degree of dust generation has been difficult.

The conclusion drawn from the major references cited in this section[2,3,4] is that dust emissions from overburden removal activities vary with the composition, texture, and moisture content of the overburden material. The overburden removal emission factor will also vary depending on the excavation procedures and type of earthmoving equipment used. Although many site specific variables affect the overburden removal emission factor, the emission rate for any specific mine is more closely related to the amount of overburden moved.[2]

The applicability of most of the emission factors in Table 2.1.4-3 toward Ohio mining operations is questionable, because they were determined for western mining operations. The two emission factors determined as national averages [area stripping (undetermined) and contour stripping] are probably more applicable to Ohio mining conditions.

Fugitive dust emission factors for drilling and blasting operations--

Fugitive dust emissions from drilling operations have been quantified by sampling at various mining operations. An emission factor of 0.008 pounds per ton of material quarried was found by sampling at one granite quarry.[2] Another sampling study at two western coal mining operations revealed emission factors of 0.22 pounds per hole drilled in a coal deposit and 1.5 pounds per hole drilled for overburden.[3]

Estimating fugitive dust emissions from blasting operations is a difficult procedure. The nature of blasting prevents monitoring equipment and manpower from being placed close to the dust source. The elevation of large amounts of normally non-suspendible matter inhibits accurate visual estimates of the dust potential. Much of the material propelled into the air from a blast will not remain suspended for more than a few seconds.

The emission estimates given in Table 2.1.4-4 express the wide variety of values possible in blasting operations. Although it appears that fugitive dust from blasting operations would be the major source of particulate at mining sites, the actual time weighted contribution may be quite small due to the intermittent blasting schedule.

Fugitive dust emission factors for truck loading operations--Dust is generated by the dumping of mineral ores from the shovel bucket into the waiting haul truck. Independent estimates of dust emissions from this source vary over a wide range. This variability can be attributed to differences in the moisture content and amount of fines in the material being hauled. It is also suspected that the dust emission rate will vary according to the types of equipment involved and the climate conditions of the mining site. Table 2.1.4-5 lists the estimated fugitive dust emission factors available for truck loading operations at mineral mining sites.

Fugitive dust emission factors from disposal of wastes--The activities associated with waste disposal are not unlike the other activities found within a mining operation. Fugitive dust generated from these sources can be estimated using the same procedures described for the other mining activities. As an

TABLE 2.1.4-4. FUGITIVE DUST EMISSION FACTORS FOR DRILLING AND BLASTING OPERATIONS

Description of operation	Uncontrolled suspended particle emission rate	Reliability rating
Overburden blasting[a]	58.5 lb/blast	E
Deposit blasting		
Coal[a]	49.8 lb/blast	E
Other[b]	0.001-0.16 lb/ton of ore or stone mined	E
Drilling		
Granite[c]	.008 lb/ton material quarried	E
Coal[d]	.22 lb/hole drilled (in coal)	E
	1.5 lb/hole drilled (in overburden)	E

[a] Determined from measurements made at four Western coal mining sites, Reference 3, page 69.

[b] Lower value represents blasting at a Western copper mine; the higher value represents blasting a granite quarry, Reference 2, pages 26-27.

[c] Reference 3, page 2.

[d] Reference 2, page 25.

TABLE 2.1.4-5. FUGITIVE DUST EMISSION FACTORS FOR TRUCK LOADING OPERATIONS

Description of truck loading operation	Uncontrolled emission rate, lb/ton loaded	Reliability rating
Crushed rock (front-end loader)	0.05	E
Lignite coal[a] (shovel)	0.02	E
Coal[b] (shovel)	0.05	E
Coal[c] (shovel)	0.10	E
Coal[d] (shovel)	0.04	E
Granite[c] (unspecified)	Negligible	E

[a] Lignite coal from North Dakota mining sites, Reference 2, page 31.

[b] Coal from Colorado mines, Reference 2, page 31.

[c] Unspecified location, Reference 2, page 31.

[d] Coal from Colorado mining operations, Reference 3, page 69.

example, truck loading of waste material for transport to a dumping site will produce dust emissions very similar to truck loading of the mineral for transport to beneficiation processes. The dust sources associated with waste disposal are truck loading (Section 2.1.4, Mineral Extraction, Fugitive Dust Emission Factors for Truck Loading Operations), transport of material on unpaved roadways (Section 2.1.1, Plant Roadways and Parking Areas), and dumping of haul trucks (Section 2.1.3, Material Handling). The only fugitive dust sources not previously addressed which require attention under this waste disposal section are those associated with berm or leach pad construction. Dust from these sources can be quantified using the heavy earthwork construction emission factor presented in Table 2.1.4-6.

Fugitive dust emission factors for reclamation activities--Area strip mine reclamation in Midwestern states poses the fewest reclamation problems. These lands can be returned to their original topography by soil segregation, backfilling and grading as deposits are removed. Compaction of the soil can be controlled with conventional equipment. Ground preparation for revegetation is aided by a climate that provides sufficient annual precipitation.

When continuous reclamation is practiced, earth moving by dragline and scrapers produces a large amount of fugitive dust. However, these emissions are already included as part of the overburden removal operation. If the topsoil is stored and later redistributed, or if a smaller dragline or bulldozer is used to

TABLE 2.1.4-6. FUGITIVE DUST EMISSIONS FOR HEAVY EARTHWORK CONSTRUCTION AROUND WASTE DISPOSAL SITES

Description of operation	Uncontrolled emission factor	Reliability factor
Heavy earthwork construction	1.2 ton/acre/month[a]	D

[a] The emission factor is presented in tons per acre of land exposed to construction per month of construction activity. This value was determined for a construction project operated at a "medium" level of activity, disturbing soil with approximately 30 percent silt content, and in a semi-arid climate (PE $\sim$ 50, see Figure 2.1.1-1). Although it would be useful to be able to adjust this emission rate (according to specific activity levels, soil silt contents, and climate) the test data used in its generation are not sufficient to determine the exact influence of each correction parameter (Reference 5, page 11.2.4-1).

grade the spoils area before applying the topsoil layer, emissions from these activities can be estimated with the same emission factors as applied to overburden removal.

All other emissions associated with the reclamation operation are due to wind erosion over the unreclaimed or partially reclaimed land. The United States Department of Agriculture's (USDA) wind erosion equation has been used in several recent studies to estimate emissions from wind erosion across cleared or unprotected soil surfaces. The wind erosion equation was originally developed to estimate soil losses from cropland, but has been adapted to predict the suspended particulate fraction of total soil losses and has been applied to evaluate exposed soil surfaces other than cropland.

$$EF = a\ I\ K\ C\ L'\ V' \qquad \text{Equation 1}$$

where:

EF = emission factor, ton/acre/yr,

a = portion of total wind erosion losses that would be measured as suspended particulate,

I = soil erodibility, ton/acre/yr,

K = surface roughness factor,

C = climatic factor,

L' = unsheltered field width factor, and

V' = vegetative cover factor.

In this equation, K, C, L', and V' are all dimensionless.

Some recent work has indicated that the variable "a", as well as "I", is related to soil type. Values for "a" and "I" that might be applied to surface-mined areas during or following regrading are summarized in Table 2.1.4-7.

TABLE 2.1.4-7. SUMMARY OF VARIABLES FOR THE WIND EROSION EQUATION[6]

Surface soil type	a	I, ton/acre/yr (uncontrolled)
Rocky, gravelly	0.025	38
Sandy	0.010	134
Fine	0.041	52
Clay loam	0.025	47

Values of K can vary between 0.5 and 1.0, with 0.5 denoting a surface with deep furrows and ridges, which protect against wind erosion, and 1.0 denoting a smooth erodible surface. Unless the surface of a regraded spoil area has been plowed or roughened, a K factor of 1.0 should be used in the wind erosion equation.

Climatic factors (C) for use in the equation have been determined for most parts of the country by USDA, as shown in Figure 2.1.4-2 (the values in the figure should be multiplied by 0.01).[6] For exposed areas greater than about 2,000 ft wide, the field width (L) no longer affects the emission rate, and L' = 1.0. For smaller reclamation areas in irregular terrain where the field width is only about 1000 ft, the L' value is approximately 0.7. Because recently regraded surfaces have little or no vegetation, V' in the equation is almost always 1.0.

By substituting the appropriate data into the wind erosion equation, the annual emission rate for any specific situation can

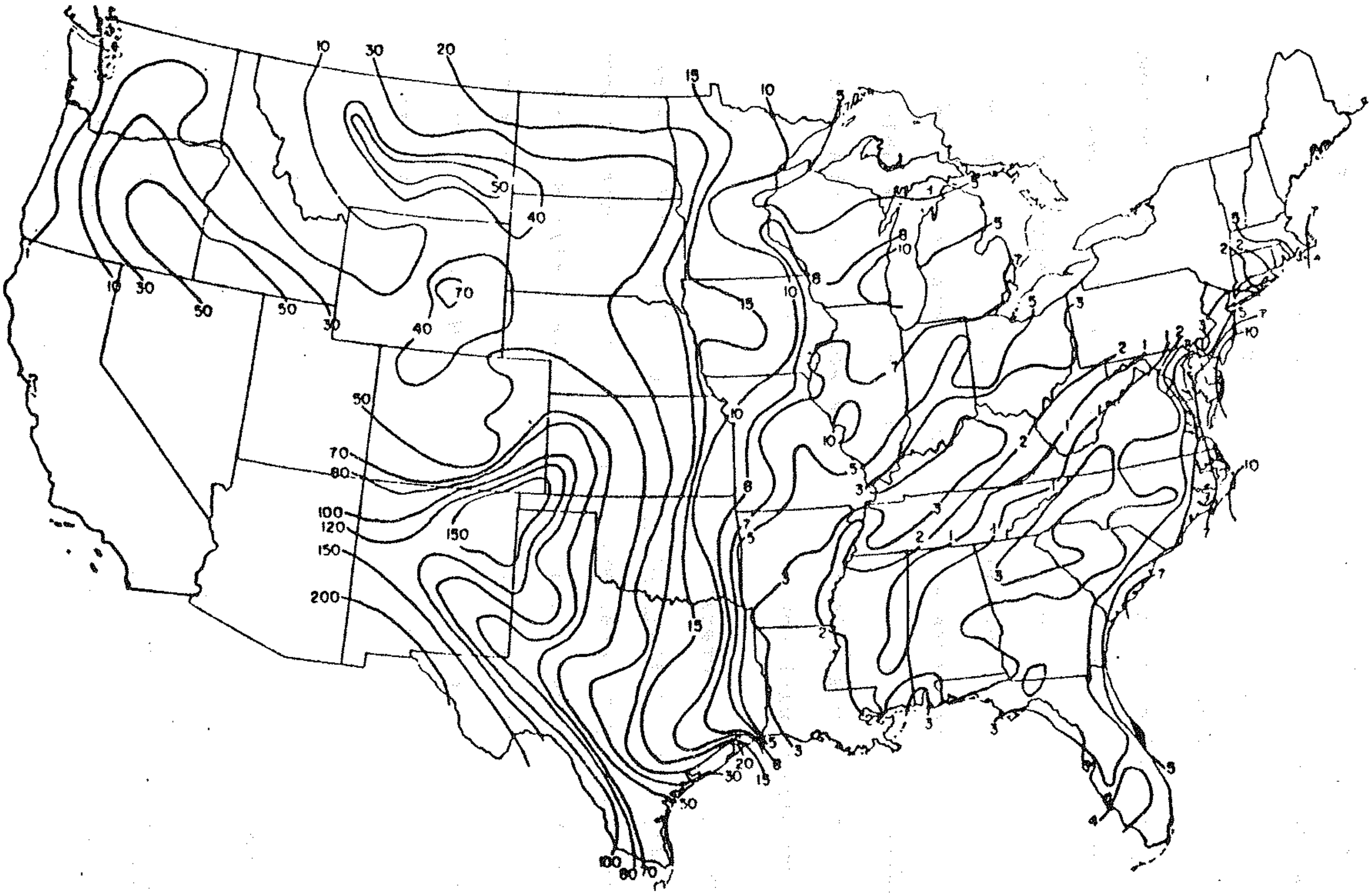

Figure 2.1.4-2. Climatic factors for use in the wind erosion equation.[6]

be calculated. This estimated emission rate (E) is then multiplied by the number of barren acres at the mine during a particular year to determine total fugitive dust due to wind erosion. For a more detailed explanation of the modified wind erosion equation, see Appendix A of Reference 6.

This method of estimating wind erosion emissions is acknowledged to have limited accuracy, but no other method has been proposed. All efforts to quantify wind erosion emissions that were found in the literature used some published USDA data on annual soil losses per acre as their basis. Because the wind-erosion emission rates per unit time are very low and highly variable, it is not possible to check the accuracy of the estimates by comparison with source sampling results.

2.1.4.3 Particle Characterization--

Particle size, density, and composition--The particle size distribution for any mineral extraction source is dependent upon the material being mined. The variation between size distributions of different minerals is not available. However, extensive particle size distributions for sources at a Western coal mining site has been measured. These size distributions are presented in Table 2.1.4-8.

The composition of fugitive dust from mineral extraction sources cannot be determined unless the composition of the mineral deposit and its overburden are known.

Hazardous or toxic nature of fugitive dust from mineral extraction activities--The health effects associated with particulate emissions from surface mining sources may be similar to

TABLE 2.1.4-8. PARTICULATE SIZE DISTRIBUTION FOR SELECTED MINE EMISSION SOURCES[a]

	Source description			
Size range, µm	Overburden removal, %	Truck loading, %	Exposed areas,[b] %	Other,[c] %
<3	5	4.5	5	5.5
3-30	7	8.5	8	9.5
>30	88	87	87	85

[a] Characteristic of five Western coal mines, Reference 3, page 5.

[b] Exposed areas, waste and reclamation area prior to revegetation.

[c] Other mining activities, excluding the three categories given above,viz., haul roads, truck dumping, and storage areas.

the effects of particulates from other fugitive dust emission sources (see Section 2.1.1). Neither type of particulate matter has been studied extensively enough to characterize its impact on public health or welfare. Urban particulates have been studied more extensively, and correlations between ambient particulate concentrations and morbidity and mortality rates have led to the establishment of ambient air criteria.

In the case of some fugitive dust source types for which emission factors have been derived, particle size determinations were made as part of the emission testing studies. A significant portion of the emissions for these sources were determined to be in the size range of particles that are transported outside of the source boundaries. If the mining operations in an area are substantial, and other types of industry are medium or light in comparison, then the emissions from the mining operations might be expected to have a considerable impact on the local air quality. Directional sampling and tracer studies could provide the necessary data to determine the total particulate impact from mining on regional health and welfare.[2]

Data availability--The description and quantification of fugitive dust from mineral extraction sources is incomplete when compared to the availability of information for other dust sources. No fugitive dust information was found specifically for Ohio mining operations. The majority of available data comes from the Western portion of the United States.

2.1.4.4 Control Methods--

The currently available control measures for mineral extraction are presented by fugitive emission source. The methods for controlling fugitive dust from mining operations have not been researched and developed appreciably; consequently, they are not extensively documented in the literature. The control methods identified are limited to some form or combination of three basic techniques: watering, chemical stabilization, and enclosure (in the form of wind barriers).

Overburden removal--Little information is available on control methods for reducing fugitive dust emissions from overburden removal activities. The minimization of disturbed land surface has been cited as a precautionary measure capable of reducing fugitive emissions from overburden removal operations.[4]

Wind erosion of exposed soil surfaces is a major source of dust at surface coal mines because of the number of large areas laid bare by the mining operations. Reducing the area exposed to the wind reduces the potential for windblown dust. No control efficiency or cost estimate values were given for this technique.

Drilling--There are several methods of controlling fugitive dust emissions from drilling operations. One such method is a water injection system, where water is injected into the drilled hole by using a piston pump. Another method employs a water ring which sprays a fine mist of water around the top of the drilled hole. Lastly, dust ejector systems are available, where compressed air is used to eject the dust particles from the hole and into a tube which takes the dust away from the drilling area. A water spray or foam may be added in this tube for dust suppression, or a fabric filter may be used at the tube exit for more effective dust control.

The only available cost information for dust controls on drilling operations indicates that for a water injection system, the cost was $4,295 for one system and $5,170 for another. Comparable costs for a fabric filter collection system were given as $13,335 and $15,925.

Blasting--Review of the literature[2,4] indicates that two preventative methods are prescribed to reduce fugitive emissions from blasting operations.

1) Restricting the area to be blasted--Proper sequencing of blasts and judicious charge placement greatly reduce the outward flux of particulates during blasting. The area of mineral or overburden blasted during any one day is determined largely by the production schedule. At most coal mines, only enough deposit is blasted to meet each day's requirements. Because the blasting schedule is closely tied to overburden and mineral removal, there is little latitude in the total amount of area to be blasted. Consequently, there is no additional cost for this control measure.

2) Prevention of overshooting during blasting--Because of the cost of blasting materials, the charge needed for a particular blast sequence is calculated very carefully. In effect, the mine operators observe practices that prevent overblasting. Therefore, there is no incremental cost of this control measure.

Truck loading--A number of control measures are available for reducing fugitive dust emissions from truck loading activities. The control efficiencies and cost estimates for each method are individually addressed.

1) Preventing truck overloading--Preventing the overloading of haul trucks will reduce spillage and windage losses. The cost of implementing this measure consists of any inspection costs necessary to prevent overloading, and the added cost of additional trucks and drivers to haul the material.

In reality, this control measure may be counterproductive. Reducing the amount of coal in each truck means additional trucks have to be purchased or each existing truck has to make more trips to maintain the same production level. Consequently, any emission reduction realized by the control measure may be more than offset by the emission increase from the additional vehicle-miles travelled.

2) Enclosures and spray systems--Covering the load of ore or modifying the surface properties of the material controls fugitive dust while the truck is in motion. These methods prevent the slipstream from removing loose particles. In addition, enclosing or covering the material eliminates spills and possible reentrainment of the spilled materials.

At most large mines, the haul cycle is designed to use workers and equipment in a efficient manner. Adding an additional step in the cycle, such as covering or uncovering a truck, requires additional time and probably additional manpower.

No cost data could be found for covering or treating the minerals in haul trucks, only an estimate of cost could be made. The costs associated with covering haul trucks are dependent on the cost of the covering and the additional labor-related costs of handling the cover. One report indicates that the cost of tarpaulins ranges from $0.04 to 0.70 per square foot, and the incremental cost of the additional labor is about $3.50 per truckload of material.[4] The labor cost is based on an estimate of 10 to 20 minutes extra time required to affix and remove the cover. Assuming a 5 million ton-per-year operation, a fleet of 25 50-ton trucks with 200 square feet surface area each, labor at $3.50 per truck load, and $0.70 per square foot for tarpaulins, the cost of this measure would be $368,000 per year.

The comparable costs for a spray system are $65,000. This value is an estimate derived from chemical spray systems for coal railway cars.[4] It should be noted that no actual operating data were obtained for this control measure. Therefore, the actual cost of this measure for haul trucks may differ significantly from the estimate given. In addition, because of the mobile nature of the coal removal operation, this control measure may not be feasible for haul trucks or may have severe safety restrictions.

3) <u>Substitution of covered conveyor system for haul trucks</u>--The use of covered conveyors in place of transporting coal or other minerals and overburden by truck is an effective method of dust control, because travel on haul roads is a more significant source of dust than conveyors.

Although completely enclosed conveyor systems emit little dust, they have a high initial cost. The design constraints of the system are the significant variables in the cost of a conveyor. As an example, cost data obtained from one mine shows that the cost per linear foot for an overland conveyor ranges from $925 to $1,450.[4] The cost of covering this conveyor is $65 per foot. A range of costs for covering conveyors is reported to be $40 to $80 per foot in a recent publication. In addition, the cost of enclosing transfer points is about $3,500 for a single enclosure and up to $20,000 if that enclosure includes a baghouse.[4]

Waste disposal--Waste disposal operations consist of approximately four potential fugitive dust sources. They are truck loading, haul roads, truck dumping, and leach pad and berm construction controls. The first source, truck loading, has been treated in this section of the document under "Truck loading operations". Haul road dust controls are discussed in Section 2.1.1, "Plant Roadways and Parking Areas". Truck dumping controls are presented in Section 2.1.3 under "Material Handling". The only fugitive dust source not previously treated is leach pad and berm construction.

Leach pad and berm construction are activities associated with the building of waste ponds to hold benefication slurry. The construction activities are essentially an earthmoving operation. As a result, the source of fugitive dust and its method of control are very difficult to define. The literature did not address control measures specific for this source. However, it is expected that the same technique described for overburden removel may have a potential application.[4]

TABLE 2.1.4-9. A SUMMARY OF CONTROL TECHNIQUES, EFFICIENCIES AND COST FOR FUGITIVE EMISSIONS FROM MINERAL EXTRACTION ACTIVITIES

Emission source and control technique	Estimated control efficiency, %	Initial cost (1980 dollars)	Annual cost (1980 dollars)
Overburden removal			
° Minimizing area of disturbed land	NA	NA	NA
Drilling			
° Water injection	NA	4,700[a]	NA
° Dust ejection to fabric filter	NA	14,600[a]	NA
Blasting			
° Restricting area to be blasted	Not applicable	No cost	No cost
° Prevention of overshooting during blasting	Not applicable	No cost	No cost
Truck loading			
° Prevent truck overloading	Questionable	NA	NA
° Enclosure (covering)	85	0.04-0.70 sq ft[b]	3.50/truckload[b]
° Spray system	50	8500[b]	65,000/yr[b,c]
° Substitution of covered conveyor system for haul trucks	95-99	925-1450/ft[d]	NA
Waste disposal			
° Truck loading controls	(See above) (Section 2.1.1 Plant Roadways and Parking Areas) (Section 2.1.3 Material Handling)		
° Haul roads controls			
° Truck dumping controls			
° Leach pad and berm construction controls	NA	NA	NA

NA - Not available.

[a] Reference 4, page 45. Based on an average of the two cost figures given.

[b] Reference 5, pages 39 and 40.

[c] Operating and maintenance costs for one million ton per year facility.

[d] Reference 4, pages 40 and 41.

A summary of the control techniques, efficiencies and cost for fugitive emissions from mineral extraction activities are presented in Table 2.1.4-9.

Benefits of control measures--The control fugitive dust from mineral extraction activities does not provide obvious economic benefit to the industry. However, as in the case of dust from plant roadways and parking areas (Section 2.1.1) this control may have a few hidden benefits. The majority of the control measures cited for this section are, in the final analysis, merely "good" operating procedures. Minimizing the disturbed land and properly handling the soil and waste will in the long run insure easier and more successful, cost-effective land reclamation while reducing the particulate loading of the ambient air.

The RACM for mining activities should be selected on a site specific basis. However, generally the good operational practices applicable to each of the activities should be required on a routine basis.

REFERENCES FOR SECTION 2.1.4

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2. Evaluation of Fugitive Dust Emissions from Mining. PEDCo Environmental, Inc. Prepared for U.S. Environmental Protection Agency, Office of Research and Development, Cincinnati, Ohio. EPA-600/9-76-001.

3. Survey of Fugitive Dust from Coal Mines. PEDCo Environmental, Inc. Prepared for U.S. Environmental Protection Agency, Region VIII, Denver, Colorado, February 1978.

4. Cost Estimates for Monitoring, Modeling, and Fugitive Dust Controls for Surface Coal Mines. PEDCo Environmental, Inc. Cincinnati, Ohio. Prepared for the U.S. Department of the Interior, Washington D.C. July 1979. Draft.

5. Compilation of Air Pollutant Emission Factors Supplements Nos. 1-8. U.S. Environmental Protection Agency, Office of Air and Waste Management and Office of Air Quality Planning and Standards. Research Triangle Park, North Carolina. August 1977.

6. Development of Emission Factors for Fugitive Dust Sources. Midwest Research Institute, Kansas City, Missouri. Prepared for U.S. Environmental Protection Agency, Research Triangle Park, North Carolina. June 1974. EPA-450/3-74-037.

2.2 IRON AND STEEL MILLS

An integrated iron and steel mill has three major operational areas: coke production, iron production, and steel production. Fugitive emission sources, control techniques, and RACM for each of these areas are discussed in the following sections.

2.2.1 Coke Manufacturing

2.2.1.1 Process Description[1,2,3]--

Coke is the nonvolatile residue from the distillation of coal in the absence of air. The three processes available for coal distillation are the beehive process, the byproduct process, and the form coke process. Since the byproduct process accounts for more than 98 percent of the coke produced, only this process will be discussed.

The raw coal is pulverized to sizes from 0.006 to 0.125 inches and transferred to prepared coal storage bins. Coals with low, medium or high volatilities are blended, and oil or water may be added for control of the density of the coking coal. The mixture is then transported to the coal storage bunkers on the coke oven batteries. (The preheated coal coking process transfers blended coal to the preheater directly.)

A weighed portion or specific volume of coal is discharged from the coal bunker into a larry car, a vehicle fitted with coal hoppers that rides on top of the battery on a wide-gauge railroad track. The coal is transferred into the ovens from the hoppers through coal-charging ports in the top of the ovens. In a coke-oven battery there may be from 20 to 100 slot ovens arranged side-by-side in a row, with common sidewalls. One oven is charged at a time such that the charges will be staggered throughout the day.

After charging, lids are placed on the ports for the duration of the 15 to 40 hour coking cycle. The shorter cycles are for production of blast furnace coke, and the longer cycles are for foundry coke. During a cycle the ovens are maintained at a temperature of approximately 1100°C (2000°F). Gases evolved during the heating are exhausted through flues or standpipes on each oven and collected in a large duct that extends the length of a battery (the battery main). These gases are piped through the main to the byproduct recovery plant where coal distillates such as tar, light aromatic compounds and ammonia are separated from the gas stream. The coke-oven gases leaving the byproduct recovery plant are used as fuel.

Upon completion of the coking cycle, doors are removed from each end of the oven and the incandescent coke is pushed into a hot-coke car by a large ram. The hot-coke car, or quenching car, transports the coke to a quenching tower, a chimney-like structure, in which the coke is deluged with water. The damp, quenched coke is then deposited onto a sloping wharf where it drains and cools to a uniform moisture content and temperature. The coke is then screened into three size ranges referred to as blast-furnace coke, nut coke, and breeze, which is the undersize. Some plants grind nut coke to make additional breeze for sintering operations; others sell it for use in the electric smelting of alloys.

A process flow diagram for coke manufacturing is shown in Figure 2.2.1-1. Sources of fugitive emissions include coal unloading, coal storage, coal conveying and transfer, coal pulverizing and screening, charging, coking, pushing, quenching, and coke handling. Each of these potential process fugitive particulate emission sources is identified in the Figure. Plant roads, a dust source category common to all coke manufacturing plants, are not specifically included in Figure 2.2.1-1, but are addressed in Section 2.1.

2.2.1.2 Fugitive Dust Emission Factors

The estimated emission factors for the coke manufacturing fugitive particulate sources are summarized in Table 2.2.1-1.

Most of these emission factors are based upon multiple test data and are considered of average reliability (i.e., a fair estimate is possible on a source specific basis).

The emission factors for coal unloading and transfer, conveying, pulverizing and screening operations are based upon data for crushed rock unloading and handing. These data were adjusted to account for size and moisture content differences between rock and coal and to derive more appropriate emission factors for coal. The reliability of these emission factors is considered very poor.

The emission factors for coal storage activities are based upon limited test data and engineering judgment. The reliability of these emission factors is poor.

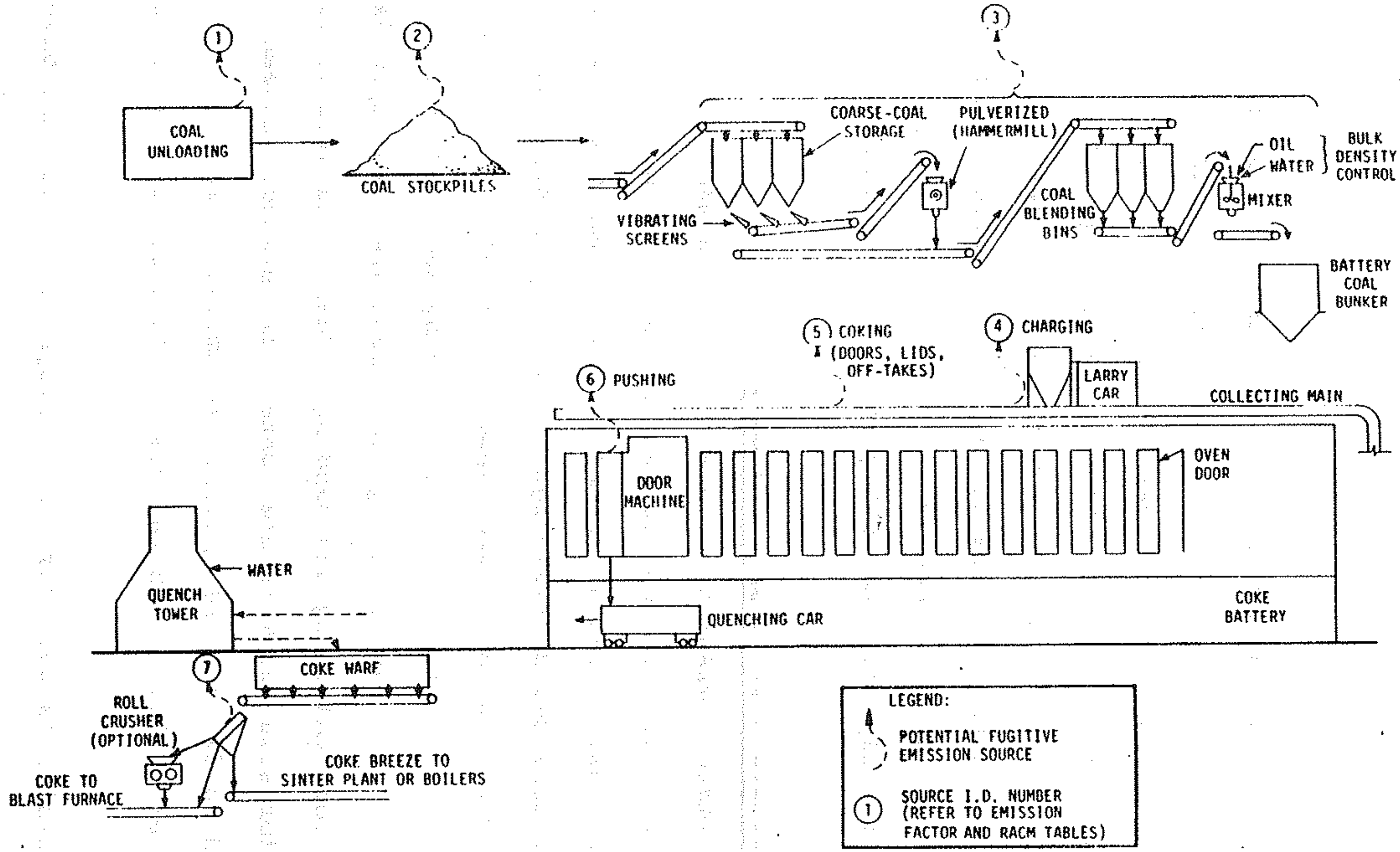

Figure 2.2.1-1. Process flow diagram of coke manufacturing and associated fugitive particulate emission sources.

TABLE 2.2.1-1 FUGITIVE DUST EMISSION FACTORS FOR COKE MANUFACTURING

Source	Emission factor	Reliability rating	Reference
(1) Coal unloading	0.4 lb/ton coal unloaded	E	4
(2) Coal storage			
Loading onto pile	0.08 lb/ton coal loaded	D	5
Vehicular traffic	0.16 lb/ton coal stored	D	5
Loading out	0.10 lb/ton coal loaded	D	5
Wind erosion	0.09 lb/ton coal stored	D	5
(3) Coal conveying, transfer, pulverizing and screening	0.04 to 0.96 lb/ton coal processed	E	6
(4) Charging	0.85 lb/ton coal charged	C	7
(5) Coking (doors, offtake piping and lids)	0.51 charged lb/ton coal charged	D	7
(6) Pushing (uncaptured plume)			
Green coke	3.0 to 4.0 lb/ton coal charged	C	8
Moderately green	2.1 lb/ton coal charged	C	9
Clean coke	0.47 lb/ton coal charged	A	7
(7) Coke handling	0.023 to 0.13 lb/ton coke handled	E	10,11

The emission factors for charging, coking, and pushing were developed from multiple test data and have a good reliability.

The source of the emission factor for coke handling is unclear, but it is assigned a very poor reliability rating.

2.2.1.3 Particle Characterization--

Fugitive particulate emissions from coking operations consist basically of coal and coke dust and polycyclic organic hydrocarbons (condensibles). Coal dust emissions from stockpiling, handling and transfer have a mean particulate diameter of 1-10 μm.[12]

In addition to emissions of coal and coke dust, coke ovens emit a variety of polycyclic organic compounds that are carcinogenic and mutagenic. The amount of organic compounds in the emissions is greatest during the charging operation and from oven leaks.[12]

Considerable analysis of particle sizes has been done for emissions from the pushing operation. The data show that for pushing emissions captured by a shed (large particles that settled under the shed were not included) the particle size distribution was 27-80 percent <10 μm and 15-26 percent <2 μm. One set of data on emissions captured by a hood (large particles included) shows 11 percent <10 μm and 4 percent <2 μm.[12].

2.2.1.4 Control Methods--

Coal unloading operations may be controlled by complete enclosure with or without venting to a fabric filter or by wet dust suppression by application of water with or without a chemical wetting agent.

The coal storage pile emissions can be controlled by periodic application of a chemical wetting agent or plain water, or by enclosure of the pile. Loading in activities can be controlled by enclosure, application of water or a wetting agent, use of telescoping chutes, use of a special stacker or use of a stone ladder. Load-out activities can be controlled by use of an underpile conveyor, use of water and/or chemical sprays, or use of a stacker/reclaimer.

The coal transfer, conveying, pulverizing and screening operations can be controlled by use of enclosed conveyors, use of water and/or chemical sprays, or use of enclosures vented to fabric filters.

The control of unloading operations, storage pile activities, and transfer and conveying operations are discussed in greater detail in Section 2.1.

Basically two methods are available for control of charging emissions: charging on-the-main/staged charging and closed pipeline charging.

Charging consists of drawing the evolved gases into the battery main, and then into the recovery system by a steam ejector located at the top of the oven ascension pipe. Many factors influence the performance of this type of system, which ranges over a continuum from essentially uncontrolled to excellent control. Among these factors are the (1) strength of aspiration; (2) degree to which oven openings to the atmosphere are kept closed throughout a charge; (3) use of aspiration at both ends of the oven; (4) maintenance of a free space at the top of the oven for the evolved gases to pass freely to the ascension pipes; (5) maintenance of a free passage through the ascension pipe; and (6) control of timing of steps in charging operations. The control efficiency for the best form of this system (staged charging) has been estimated as 99+ percent for any specific charge.[13]

Pipeline charging is a closed system. Coal is charged through pipes permanently connected to the ovens. Evolved gases and entrained coal fines are recovered in a charging main and recycled to the coal preheater plant. Some potential for emissions from oven leaks still exists, and emissions from the coal preheating plant (discharging through a stack) should be considered. Though operating problems have been experienced with the first installation now in operation, the potential control efficiency is judged to be 100 percent.[13]

Emissions from leaks during the coking cycle can be reduced by good maintenance, resealing, and sealing practices. For oven lids and luted doors, prompt sealing after they are returned to position, and resealing when necessary, is one of the best techniques. Oven door hoods over individual doors and a shed over the coke side of a battery (which is a technique to capture pushing emissions) also will effectively capture emissions from doors on that side of the battery. Gas cleaning efficiencies in excess of 85 percent for door emissions have been achieved with wet electrostatic precipitators.

A variety of systems are in use, under construction, planned, or in the development stage for capture of pushing emissions. Most of these systems fall into one of three roughly defined categories; (1) sheds over the coke side of a battery; (2) enclosures or hoods on the hot coke car; and (3) bench-mounted hoods over the hot coke car.

Sheds are literally a building over the entire coke side of a battery. Emissions from the pushing operation are contained in the shed and evacuated through a control device. The capture efficiency has been estimated in two cases as 91 percent and 85 percent.[14,15]

Enclosures on the hot coke car vary in design. All embody a close-fitting enclosure that minimizes any openings to the atmosphere. Size and location of these openings and the amount of draft applied to the enclosure affect capture efficiency. Although no measurements have been made, visual observations indicate capture performance comparable to a shed.[16,17] Enclosed quench cars differ by whether they remain stationary or are movable during pushing and whether draft is created by fans or other means.

The third category, hoods, exhibits great variety in design and performance. Generally, areas open to the atmosphere are greater than the enclosed cars, and typically the openings are at the interface between the hood and the car. Large gas volumes are required, although not as large as for a shed. Capture efficiency varies widely with design and increases when larger hoods, greater gas volumes, and smaller open areas are used. Capture efficiency for the better designs (the closest fitting hoods with sufficient gas volume) may equal the capture performance of sheds or enclosed hot coke cars, especially if operating practices minimize "green" coke.[18,19]

The control devices used with the above capture systems are scrubbers or wet electrostatic precipitators. Both have demonstrated better than 98 percent control or reduction of emissions when installed on a shed. A venturi scrubber has achieved 99 percent removal efficiency on hood emissions and can be expected to perform equally as well on an enclosed car. The Aronetics wet scrubber has achieved better than 99 percent collection on fine ferroalloy fume and is presently used on at least one enclosed quench car.[20]

A factor that affects the performance of any pushing emission control system is the "greenness" of the coke pushed. "Green" coke is coke that has not been coked sufficiently due to problems with heat distribution, quality of the coal, or length of the coking time. It has high levels of volatile matter, and will result in a greater quantity of uncontrolled emissions during a push, hence a greater load for the control system. Any evaluation of control system performance should consider this fact.

One other significant factor is the emissions from the hot coke car as it travels to the quench station after a push. When a shed is used, these emissions are captured until the car exits the shed. For enclosed cars and hoods, capture varies with design. Those designs where the car is covered and exhausted to control equipment will control emissions until the car reaches the quench station. Where no cover is used, the emissions are uncontrolled once the car moves away from the oven pushed and until it reaches the quench station.

Table 2.2.1-2 summarizes the available control technologies, their effectiveness, estimated costs, and RACM selections.

2.2.1.5 Recommended Reasonably Available Control Measures (RACM)--

The RACM selections for coke manufacturing fugitive emission sources are presented in Table 2.2.1-2.

The selected control technique for unloading of coal is a wet suppression system utilizing a chemical wetting agent for better dust control. The system gives better control than water alone, and is less costly than the more efficient application of a fabric filter.

Coal storage pile load-in activities can be controlled to a high degree by use of a telescopic chute to reduce the free fall distance to the pile, supplemented by a wet suppression system. Other activities at the storage piles can best be controlled by use of a wet suppression system which gives the highest degree of control at the lowest cost.

For the coal conveying, transfer, pulverizing, and screening activities, the selected RACM is the use of enclosures. This option is the least costly of the available control methods and is estimated to be 70 percent effective. With application of wet suppression at the coal pile load out, the emission potential in

TABLE 2.2.1-2. A SUMMARY OF THE CONTROL ALTERNATIVES, EFFICIENCIES AND COSTS, AND THE RACM SELECTIONS FOR FUGITIVE DUST EMISSIONS FROM SOURCES IN COKE MANUFACTURING

Fugitive dust sources	Control alternatives	Control efficiency, %	Control costs, Jan., 1980 $		Cost benefit, $/lb	RACM selection
			Capital	Annualized		
(1) Coal unloading (rail car)	Enclosure, vent to fabric filter	99[a]	120,000[a]	42,000[b]	0.07	Wet suppression (chemical)
	Wet suppression (chemical)	80[a]	37,000[a]	36,000[a]	0.07	
	Enclosure	70[c]	60,000[d]	12,000[e]	0.03	
(2) Coal storage Loading onto piles	Enclosure (stone ladder)	70-99[f]	25,000[g]	5,000[e]	0.05	Telescopic chutes, wet suppression
	Telescopic chutes	75[g]	9,000[g]	2,000[e]	0.02	
	Wet suppression (chemical)	80-90[h]	73,000[g]	30,000[i]	0.28	
	Wind guards	50[g]	37,000[g]	8,000[e]	0.13	
Loading out	Under pile conveyor	80[j]	6,300,000[k]	1,260,000[e]	9.84	Wet suppression (chemical)
	Wet suppression (chemical)	95[g]	73,000[g]	30,000[i]	0.19	
	Bucket wheel reclaimer	80[g]	4,500,000[g]	900,000[e]	7.03	
Wind erosion	Enclosures	100[g]	8,400,000[l]	1,680,000[e]	11.67	Wet suppression (chemical)
	Wet suppression	99[g]	14,000[g]	10,000[g]	0.07	
(3) Coal conveying, transfer, pulverizing, and screening	Wet suppression (chemical)	70-95[m]	200,000[m]	660,000[m]	0.94	Enclosure
	Enclosure	70[m]	69,000[m]	14,000[e]	0.03	
(4) Charging	Charging on-the-main/staged charging	85[o]	489,000[p]	390,000[n]	0.34	Charging on-the-main/staged charging
	Pipeline charging	100[q]	r	r	Not Available	

(continued)

TABLE 2.2.1-2. (continued)

Fugitive dust sources	Control alternatives	Control efficiency, %	Control costs, Jan., 1980 $		Cost benefit, $/lb	RACM selection
			Capital	Annualized		
(5) Coking	Door and topside maintenance	85[s]	0[p]	739,000[t]	1.07	Maintenance
	Hoods, wet ESP	85+[u]	v	v	Not Available	
(6) Pushing	Shed, wet scrubber	88[w]	3,669,000[x]	1,173,000[x]	1.77	Enclosed hot coke car, wet scrubber
	Shed, wet ESP	88[w]	6,299,000[x]	1,555,000[x]	2.35	
	✓ Enclosed hot coke car, wet scrubber	88[w]	2,617,000[x]	579,000[x]	0.88	
	Hood, mobile wet scrubber	88[w]	1,823,000[x]	735,000[x]	1.11	
	Hood, stationary wet scrubber	88[w]	2,924,000[x]	1,065,000[x]	1.61	
(7) Coke handling	Enclosure	70[m]	58,000[m]	12,000[e]	0.63	Enclosure
	Enclosure, vent to fabric filter	99[m]	174,000[m]	102,000[n]	3.79	
Haul roads	Wet suppression	50[y]	z	z		Oiling of unpaved roads. Cleaning of paved roads
	Watering	50[y]	z	z		
	Oiling	85[y]	z	z		
	Paving	85[y]	z	z		

TABLE 2.2.1-2 (continued)

[a] Reference 21.
[b] Reference 22. Based on 21,000 scfm, A/C of 6.5:1, 8000 h/yr operation.
[c] Reference 23.
[d] Reference 24. Based on 10 Ga steel enclosure of car dump.
[e] Includes capital charges and maintenance at 20% of capital.
[f] Reference 24.
[g] Reference 25.
[h] Reference 26.
[i] Reference 27. Based on 600 ton/h and 3000 h/yr operation.
[j] Reference 28.
[k] Reference 25. Based on avg. cost of $47.5/ton and 140,000 tons stored.
[l] Reference 25. Based on avg. cost of $60/ton and 140,000 tons stored.
[m] Reference 21.
[n] Reference 29. Assumed 1.6 x 10^6 tons/yr coal processed.
[o] Reference 30. Retrofit installation with modified larry car.
[p] Reference 31. Assumed 1 battery at 340,000 t/yr of coke.
[q] Assumed for a closed system.
[r] No costs available. Not feasible for retrofit installation.
[s] Reference 32.
[t] Reference 33.
[u] Reference 34.
[v] No cost or design data available.
[w] Reference 35.
[x] Reference 36. Based on 1 battery at 340,000 ton/yr of coke.
[y] Reference 37.
[z] See Section 2.1.

subsequent handling operations will be reduced and enclosure should be adequate control. The enclosure system chosen here would involve covering the top and sides of the handling and transfer activities.

The RACM selected for charging of coke ovens is the use of staged charging while charging "on-the-main." This is the only known effective control technique which can be applied in retrofit applications. This control method has been specified in the Consent Orders for several coke oven batteries in Ohio.

The RACM selected for control of fugitive emissions during the coking cycle is implementation of a door and topside maintenance program. Such a program would consist of prompt sealing of charging lids, immediate replacement of defective (non-sealing) lids, cleaning of sealing rings, door jambs, and doors after every push, careful handling of doors during removal and repositioning, conscientious tightening of door latches, repair and adjustment or replacement of leaking doors, and maintenance of a sufficient spare door inventory (8 to 10%). This program is most effective in reducing coking emissions and has been specified in the Consent Orders for several Ohio coke oven batteries.

The RACM selected for control of pushing emissions is the use of an enclosed hot car, vented to an attached control car with a wet scrubbing system. This technique is effective and the least costly of the available control measures. Also, it has been specified as a control method in the Consent Orders mentioned previously.

The recommended control technique for coke handling emissions is the enclosure of conveyors and transfer points. This option is effective and economical compared to use of fabric filters.

Haul roads may be a significant source of emissions at a coke plant. The suggested control techniques for haul roads are the regular sweeping and cleaning of paved roads, regular oiling of unpaved roads, and paving of heavily used unpaved roads. These are discussed in detail in Section 2.1.

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APPENDIX FOR SECTION 2.2.1

Avg. coal usage per year at Ohio plants is 1.6×10^6 tpy.

(1) Coal unloading

Emissions = .04 (1.6×10^6 tpy) = 640,000

Enclosure, vent to fabric filter

$$\text{Capital cost} = \$100{,}000 \ \frac{(249.6)}{(204.1)} = \$120{,}000 \ (\text{MRI, p. 6-3})$$

$$\text{Annual cost} = \$32{,}000 \ \frac{(249.6)}{(192.1)} = \$42{,}000$$

@ 21,000 scfm (IGCI)

$$C/B = \frac{\$42{,}000/\text{yr}}{.99\ (640{,}000)} = \$0.07/\text{lb}$$

Wet suppression (chemical)

$$\text{Capital cost} = \$30{,}000 \ \frac{(249.6)}{(204.1)} = \$37{,}000$$

Annual cost = \$0.02 (1.6×10^6) + 0.17 (37,000)
= \$36,000

$$C/B = \frac{\$36{,}000/\text{yr}}{.8\ (640{,}000)} = \$0.07/\text{lb}$$

Enclosure

Railcar dump 40' x 21' x 30' enclosure
Cost of enclosure plus doors=\$2.38/lb GARD
Mass = 1.2 (5.625 lb/ft^2)[2(40' x 30') + (21' x 40') + 2(21' x 30')] = 25,000 lbs

Capital cost = \$60,000
Annualized = 0.20 (60,000) = \$12,000

$$C/B = \frac{\$12{,}000/\text{yr}}{.7\ (640{,}000)} = \$0.03/\text{lb}$$

(2) Coal storage

Loading onto piles

Emissions = 128,000 lbs/yr

Enclosure (stone ladder)

$$\text{Capital cost} = \$20{,}000 \ \frac{(249.6)}{(204.1)} = \$25{,}000$$

Annual cost = .2 (25,000) = $5,000

$$C/B = \frac{\$5{,}000/yr}{.85\ (128{,}000)} = \$0.05/lb$$

Telescopic chutes

Capital cost = $9,000
Annual cost = 2,000

$$C/B = \frac{\$2{,}000/yr}{.75\ (128{,}000)} = \$0.02/lb$$

Wet suppression (chemical)

$$\text{Capital cost} = \$60{,}000 \ \frac{(249.6)}{(204.1)} = \$73{,}000 \quad \text{MRI}$$

$$\text{Annual cost} = \$24{,}250 \ \frac{(249.6)}{(204.1)} = \$30{,}000$$

@ 600 tph and 3,000 hpy, NMI

$$C/B = \frac{\$30{,}000/yr}{.85\ (128{,}000)} = \$0.28/lb$$

Wind guards

Capital cost = $37,000
Annual cost = $8,000

$$C/B = \frac{\$8{,}000/yr}{.5\ (128{,}000)} = \$0.13/lb$$

Loading out
Emissions = 160,000 lbs/yr

Underpile conveyor

Capital cost = $6,300,000
Annual cost = $1,260,000

$$C/B = \frac{\$1{,}260{,}000/yr}{.8\ (160{,}000)} = \$9.84/lb$$

Wet suppression (chemical)
See loading onto piles

$$C/B = \frac{\$30{,}000/yr}{.95\ (160{,}000)} = \$0.19/lb$$

Bucket wheel reclaimer

Capital cost = $4,500,000
Annual cost = $900,000

$$C/B = \frac{\$900{,}000/yr}{.8\ (160{,}000)} = \$7.03/lb$$

Wind erosion
Emissions = 144,000 lbs/yr

Enclosures

Capital cost = ($60/ton)(140,000) = $8,400,000 MRI
Annual cost = 0.2 (8,400,000) = $1,680,000

$$C/B = \frac{\$1{,}680{,}000/yr}{1.0\ (144{,}000)} = \$11.67/lb$$

Wet suppression (chemical)

$$\text{Capital cost} = \$11{,}000\ \frac{(249.6)}{(204.1)} = \$14{,}000 \quad \text{MRI}$$

$$\text{Annual cost} = \left(\frac{.004 + 0.1}{2}\right)(120{,}000\ ft^2)\frac{(249.6)}{(204.1)}$$

$$= \$10{,}000$$

$$C/B = \frac{\$10{,}000/yr}{.99\ (144{,}000)} = \$0.07/lb$$

(3) Coal conveying, transfer, pulverizing, and screening
Emissions = 800,000 lbs/yr

Wet suppression (chemical)

Capital cost = $200,000
Annual cost = $660,000

$$C/B = \frac{\$660{,}000/yr}{.88\ (800{,}000)} = \$0.94/lb$$

Enclosure

Assume 1000' of conveyor, 5 transfer stations, 1 pulverizer and 1 screening operation.
Capital cost = [5(3,000) + 2 (3,000) + 35 (1000)]

$$\times \frac{(249.6)}{(204.1)} = \$69{,}000 \quad \text{(MRI)}$$

Annual cost = $14,000 (2% maintenance)

$$C/B = \frac{\$14{,}000/yr}{.70\ (800{,}000)} = \$0.03/lb$$

(4) Charging

Assume Ohio avg. battery size = 340,000 tpy coke

Emissions = 1,360,000 lbs/yr

Charging on-the-main/staged charging

$$\text{Capital cost} = \$400,000 \ \frac{(249.6)}{(204.1)}$$

$$= \$489,000 \quad \text{(Reference 31, p. 4-6)}$$

Annual cost = $390,000 p. 4-10

$$C/B = \frac{\$390,000/yr}{.85\ (1,360,000)} = \$0.34/lb$$

Pipeline charging

No data

(5) Coking

Emissions = 816,000 lbs/yr

Door and topside maintenance

Capital cost = $0

Annual cost = $739,000

$$C/B = \frac{\$739,000/yr}{.85\ (816,000)} = \$1.07/lb$$

Hoods, wet ESP

No data

(6) Pushing

Emissions = 752,000 lbs/yr (clean coke)

Shed, wet scrubber

From Reference 27, p. 7-7 (cost are for a 823,000 tpy system at 1975 $)

$$\text{Adjusted cost} = \text{cost (@ 823,000)} \ \left(\frac{340}{823}\right)^{0.6} \frac{(249.6)}{(182.4)}$$

Capital cost = $3,669,000

Annual cost = $1,173,000

$$C/B = \frac{\$1,173,000/yr}{.88\ (752,000)} = \$1.77/lb$$

Shed, wet ESP

Capital cost = $6,299,000

Annual cost = $1,555,000

$$C/B = \frac{\$1,555,000/yr}{.88\ (752,000)} = \$2.35/lb$$

Enclosed hot coke car, wet scrubber

Capital cost = \$2,617,000
Annual cost = \$579,000

$$C/B = \frac{\$579{,}000/yr}{.88\ (752{,}000)} = \$0.88/lb$$

Hood, mobile wet scrubber

Capital cost = \$1,823,000
Annual cost = \$735,000

$$C/B = \frac{\$735{,}000/yr}{.88\ (752{,}000)} = \$1.11/lb$$

Hood, stationary wet scrubber

Capital cost = \$2,924,000
Annual cost = \$1,065,000

$$C/B = \frac{\$1{,}065{,}000/yr}{.88\ (752{,}000)} = \$1.61/lb$$

(7) Coke handling
Emissions = .08 (340,000 tpy) = 27,200 lbs/yr

Enclosure

Assume 1000' of conveyor and 4 transfer points

$$\text{Capital cost} = [35\ (1{,}000) + 3{,}000\ (4)]\ \frac{(249.6)}{(204.1)}$$
= \$58,000 (p. 6-3, MRI)

Annual cost = .2 (58,000) = \$12,000

$$C/B = \frac{\$12{,}000/yr}{.7\ (27{,}200)} = \$0.63/lb$$

Enclosure, vent to fabric filter

$$\text{Capital cost} = [70\ (1{,}000) + 18{,}000\ (4)]\ \frac{(249.6)}{(204.1)}$$
= \$174,000

Annual cost = 73,000 + .17 (174,000)
= \$102,000

$$C/B = \frac{\$102{,}000/yr}{.99\ (27{,}200)} = \$3.79$$

2.2.2 Iron Production

2.2.2.1 Process Description--

Pig iron is the result of smelting iron-bearing materials in the presence of fluxes and a carbonaceous agent, usually coke, in a blast furnace. About 90 percent of the pig iron produced in the United States is consumed in making steel; the remainder is used for iron and steel castings. Typically a blast furnace in Ohio would produce about 650,000 tons per year of iron. Figures 2.2.2-1 and 2.2.2-2 illustrate cross sections of a typical blast furnace and a blast furnace plant with auxiliary equipment, respectively.

Fine particles, whether in natural ores or in concentrates, are undesirable as part of the blast furnace feed. The most desirable size for blast furnace feed is between 0.25 and 1.0 inch. Of the numerous methods available for agglomeration, sintering is most often used in the steel mill.

In the sintering process, a mixture of iron ore fines, iron-bearing materials or concentrates, coke fines, and steel plant waste materials (such as blast furnace flue dust, mill scale, etc.) are mixed and then spread on a traveling grate. The bed of material on the grate is ignited on the top by burners fired with oil, natural gas or coke-oven gas. As the grate moves slowly toward the discharge end, air is pulled down through the bed to support combustion. As the coke in the bed burns, the heat generated agglomerates the small particles. At the discharge end of the machine, the sinter is crushed to proper size, then cooled and finally screened. In some cases, limestone fines are also added to the sinter feed to produce a self-fluxing sinter. This replaces part of the limestone normally charged into the blast furnace.

Figure 2.2.2-1. Blast furnace cross section.[37]

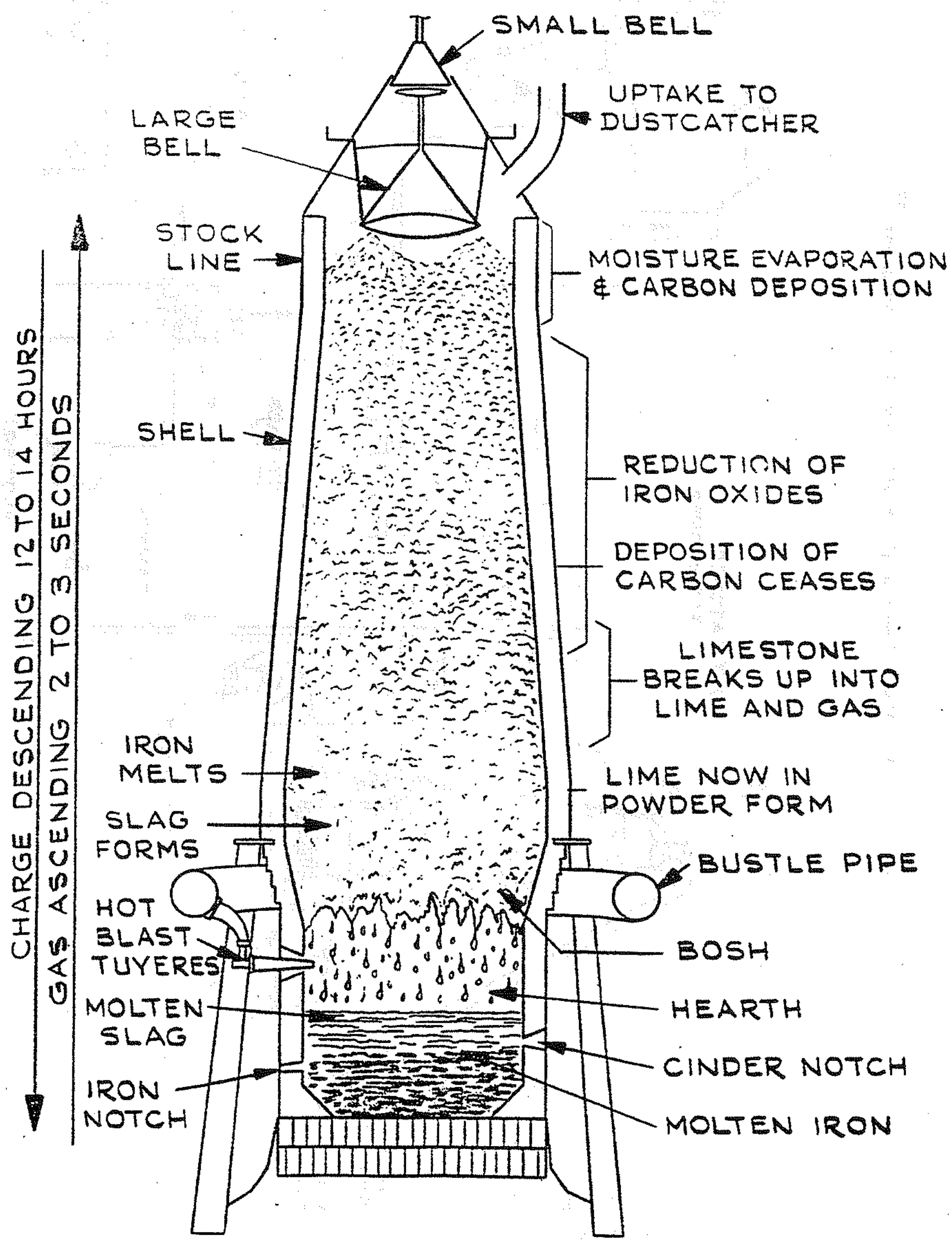
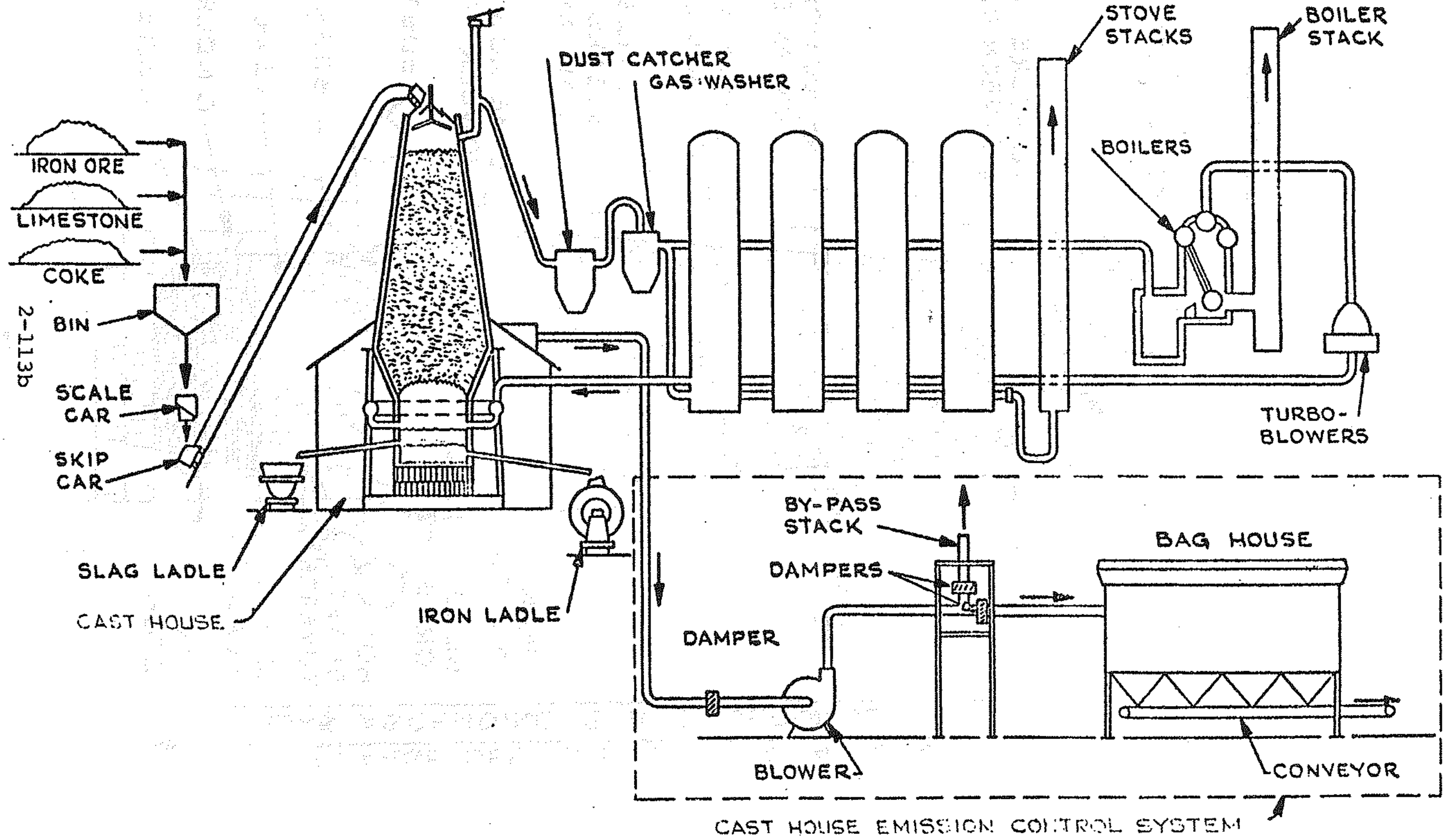


Figure 2.2.2-2. Blast furnace plant with auxiliary equipment.[37]



Very little sinter is stored in open piles. It is usually carried directly to bins at the blast furnace where it is weighed and transferred to the top of the furnace by a skip car hoist or by belt conveyor. Coke, raw iron ore and limestone are also stored in bins at the furnace and are charged in the same manner.

The blast furnace reduces the iron ore and iron-bearing materials to produce pig iron. Iron-bearing materials (iron ore, sinter, pellets, mill scale, slag, scrap iron), coke and fluxes (limestone, dolomite, etc.) are charged into the top of the furnace and referred to as burden. Heated air is blown into the furnace near its base or hearth line through tuyeres. In some instances fuel oil or powdered coke is also blown into the bottom. The burden descends down the furnace and the iron ore and iron-bearing materials are reduced and melted by the countercurrent flow of the hot reducing gases created by the combustion of coke. Occasionally, slips may occur as the burden descends. Slips occur when a portion of the burden wedges or bridges in the upper part of the furnace and a void is created as the material underneath continues to move downward. The void tends to increase in size until the "bridge" collapses, causing a sudden drop of the materials above and a sudden release of emissions.

Hot metal is tapped from the furnace through a hole or notch and poured into submarine or torpedo railroad cars for delivery to the steel-making furnaces. Slag from the blast furnace is either tapped from a higher notch than the hot metal or removed from the furnace through the iron notch during a cast. The slag is guided into runners or troughs and discharged into either a slag pit adjacent to the blast furnace or into a slag thimble for transport to a slag dump or other disposal area. The slag going to the slag pit adjacent to the blast furnace can be water-sprayed or air-cooled and then removed by trucks. Slag granulators are also used for processing slag as it flows from the blast furnace. Processed slag finds use as a fill material or aggregate.

A process flow diagram for iron production is shown in Figure 2.2.2-3. Sources of fugitive emissions in iron production include the unloading, handling and transfer, and storage of iron ore and limestone; the handling and transfer, and storage of coke and blast furnace flue dust; sinter machine operations; sinter handling and transfer, and storage; blast furnace operations; and slag handling, crushing and storage. Each potential fugitive emission point is identified in the Figure. A common dust source found at iron-producing facilities, but not specifically included in the Figure, is plant haul roads. This general emission category is addressed in Section 2.1.

2.2.2.2 Fugitive Dust Emission Factors--

The estimated emission factors for iron production fugitive particulate sources as identified above are summarized in Table 2.2.2-1. Most of these emission factors are based upon very limited testing and/or engineering judgment and are of poor reliability. However, some of the major sources have been tested to the extent that the developed emission factors have fair to

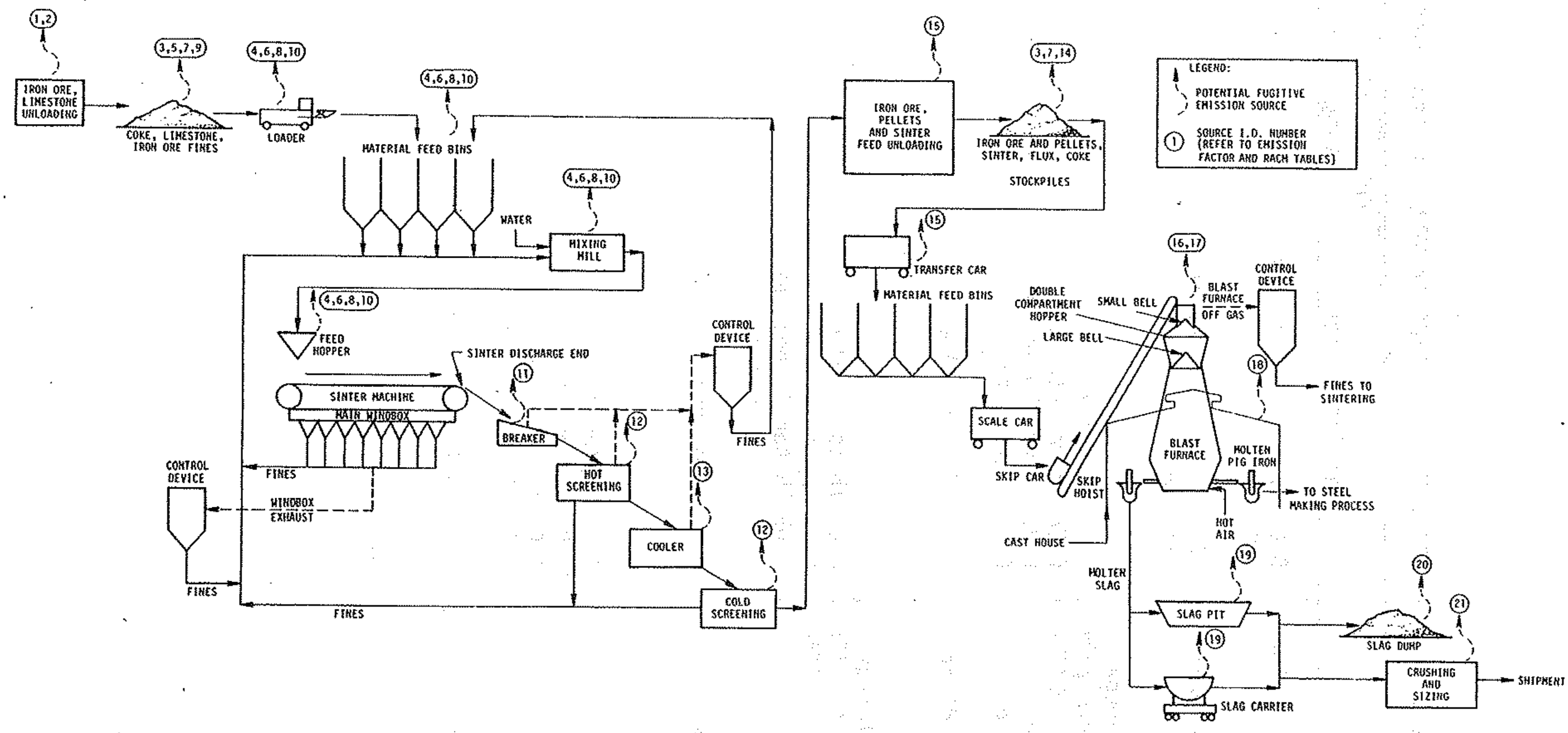


Figure 2.2.2-3. Simplified process flow diagram of iron production and associated fugitive particulate emission sources.

TABLE 2.2.2-1 FUGITIVE DUST EMISSION FACTORS FOR IRON PRODUCTION

Source	Emission factor	Reliability rating	Reference
(1) Iron ore unloading (ship or rail)	0.02 to 0.03 lb/ton ore unloaded	E	1
(2) Limestone unloading (ship or rail)	.03-0.4 lb/ton limestone unloaded	E	2
(3) Iron ore storage			
Loading onto pile	0.21 lb/ton loaded	D	3
Vehicular traffic	0.08 lb/ton stored	D	3
Loading out	0.30 lb/ton loaded out	D	3
Wind erosion	0.25 lb/ton stored	D	3
(4) Iron ore handling and transfer	2.0 lb/ton handled	D	4
(5) Limestone storage			
Loading onto pile	0.04 lb/ton loaded	D	5
Vehicular traffic	0.12 lb/ton stored	D	5
Loading out	0.05 lb/ton loaded out	D	5
Wind erosion	0.10 lb/ton stored	D	5
(6) Limestone handling and transfer	0.8 lb/ton handled	E	6
(7) Coke storage			
Loading onto pile	0.02 lb/ton loaded	D	3
Vehicular traffic	0.03 lb/ton stored	D	3
Loading out	0.03 lb/ton loaded out	D	3
Wind erosion	0.008 lb/ton stored	D	3
(8) Coke handling and transfer	0.11 lb/ton pig iron produced	E	7
(9) Blast furnace flue dust storage	Negligible	D	8
(10) Blast furnace flue dust handling and transfer	0.03 lb/ton flue dust	E	8

(continued)

Table 2.2.2-1 (continued)

	Source	Emission factor	Reliability rating	Reference
11	Sinter machine windbox discharge	Negligible	E	9
12	Sinter machine discharge (breaker and screens)	6.8 lb/ton sinter	B	10
13	Sinter cooler (not vented thru a stack)	0.32 to 0.8 lb/ton sinter	E	9,11
14	Sinter storage			
	Loading onto pile	0.25 lb/ton loaded	D	5
	Vehicular traffic	0.10 lb/ton stored	D	5
	Loading out	0.41 lb/ton loaded out	D	5
	Wind erosion	0.30 lb/ton stored	D	5
15	Sinter handling and transfer	0.4 lb/ton sinter	E	5
16	Blast furnace charging	Negligible	E	5
17	Blast furnace upsets (slips)	87.0 lb/slip	D	10
18	Blast furnace tapping - iron and slag	0.3 lb/ton iron produced	B	10
19	Slag handling	0.02 to 0.1 lb/ton slag	C	5
20	Slag storage			
	Loading onto pile	0.04 lb/ton loaded	B	3
	Vehicular traffic	0.12 lb/ton stored	B	3
	Loading out	0.05 lb/ton loaded out	B	3
	Wind erosion	0.03 lb/ton stored	B	3
21	Slag crushing	2.0 lb/ton crushed	A	5

good reliability.

The emission factors for storage activities (including iron ore, limestone, coke, sinter and slag) are based upon limited data for similar activities and engineering judgment. The reliability of these emission factors would be poor.

Emission factors for iron ore and limestone unloading were derived using engineering judgment from data on other materials. The reliability of these factors is believed to be poor.

The source of the emission factor for handling and transfer of iron ore is not clearly stated in the referenced source, but has been given a reliability rating of poor indicating that some limited data was available.

The emission factors for handling and transfer of limestone, coke, sinter, blast furnace flue dust and slag are based on engineering judgment and have a reliability rating of poor.

The negligible emission factor for blast furnace flue dust storage is based on the fact that most plants utilize a closed storage system. The reliability of this emission factor should be fair.

The emission factors for the sinter machine windbox discharge and cooler are based on observation and engineering judgment and have a reliability rating of poor. The emission factor for the sinter machine discharge and screens is based upon test data and should have good reliability.

The emission factors for blast furnace charging and upsets were based upon test data and engineering judgment and have fair reliability. The factor for tapping emissions is based upon limited test data and appears to have good reliability.

The emission factor for slag crushing is based upon data for stone crushing and should, therefore, be considered of poor reliability.

2.2.2.3 Particle Characterization--

Fugitive particulate emissions from iron production consist basically of coke, limestone, iron ore dusts and iron oxides. Coke dust emissions from stockpiling, handling and transfer have a mean particulate diameter of 3-10 μm.[4] Limestone dust from stockpiling, handling and transfer has a mean particulate diameter of 3-6 μm, of which 45-70 percent is less than 5 μm.[4]

Fugitive emissions from sintering consist mostly of ore dusts and metal oxides with a mean particle diameter of 48-180 μm.[3,12,13] Only 1-10 percent are less than 5 μm.[3,12,13] Exit temperatures range from 100 to 300°F. At the discharge end of the sintering process and during cooling, fugitive iron oxides emitted have a mean particle diameter of 48-180 μm, of which 40 to 80 percent are less than 100 μm size, and 10 percent are less than 5 μm.[3,12,13]

Fifteen to ninety percent of the fugitive metal fumes, iron oxides and incandescent particulates expelled during blast furnace operations and tapping have a mean diameter less than 70 μm.[4,12] Exit temperatures range from 3000 to 4000°F.[4,12] Sixty percent of the emissions from hot metal transfer from the blast furnace to the steel furnaces have a particle diameter less than 100 μm, with 10 percent less than 5 μm in size.[13]

2.2.2.4 Control Methods--

Fugitive emissions from handling and transfer of raw materials can be controlled by wet suppression, enclosure of the operations and by improvements in operating parameters and procedures. For example, conveyor belt systems may be partially covered to prevent windblown fugitive emissions or totally enclosed to prevent all fugitive emissions. Attentive operating techniques that preclude overload of transport systems and reduce free fall distances from grab buckets and clam shells will also reduce fugitive emissions. A more detailed treatment of storage, handling and transfer sources is given in Section 2.1.

Fugitive emissions generated during sinter machine windbox discharge can be effectively controlled by several methods. Wet suppression by means of applying a fine water spray to materials as they are discharged from the windbox will reduce the generation of fugitive emissions. Minimal free-fall distance between the discharge point and the receiving system serves to decrease the amount of fugitive emissions generated. Confining the windbox discharge and receiving systems will keep fugitive emissions from dispersing. The use of a fixed hood constructed around the discharge or over the receiving system will effectively capture fugitive emissions which can then be vented to a baghouse. Normally these fugitive emissions are negligible.

Fugitive emissions from the sinter machine discharge and sinter screens may be controlled through confinement by enclosure.

These emissions result from incomplete collection of emissions by the primary control device. If the system has primary controls of sufficient capacity, increasing the exhaust rate may increase collection efficiency. However, this may require changes such as a new fan and motor. Depending on the specific situation, the redesign of an existing control system may be considered. Preventive maintenance including repair and/or replacement of faulty parts will help alleviate fugitive emission problems. A fixed hood constructed over screening operations will effectively remove the emissions from this source. Fugitive emissions from the sinter cooler can be controlled by confining the cooler and venting to a mechanical collector or a fabric filter. Wet suppression may be used for controlling fugitive emissions from sinter machine discharge, screening or cooling. However, since the sinter is very hot during these operations, the effectiveness may be minimal. Wet suppression is sometimes used on the sinter as it comes from the cooler. The application rate must be closely regulated since the increased moisture content in the sinter will necessitate higher heat requirements in the blast furnace.

Operating practices and control of raw material quality can help prevent slips in blast furnaces. Operators of blast furnaces will often vary the sequence of skip car loads (coke, ore, stone, etc.) in order to minimize slips. Since no two blast furnaces perform alike, the proper sequence must be determined for each furnace. Two techniques have been suggested for fugitive emission control of furnace slips. One suggestion envisions venting the bleeder valve to ground level into a water hot well where particulates would settle out as the gases bubbled out. A second suggestion pertained to a box over the bleeder valve that is fitted with baffles to induce the settling of particles. It should be noted that these two methods may be considered feasible, but are not known to have been used.

Tapping of iron and slag can both be controlled by the use of fixed or movable hoods. The choice of a fixed or movable hood will depend on space limitations as well as related operations which may make one type more desirable. At times because of furnace design, a hood must be placed some distance above a tapping area. Under such conditions movable curtains will aid in confining and directing fugitive emissions into the hood. Close covers over iron and slag runners are another way of effecting fume capture. The control equipment serving the exhaust from these operations is usually a baghouse.

Wet suppression by means of a water spray, with or without chemical additives, is a potential means of controlling fugitive emissions during handling and dumping of slag. However, wet suppression is limited to those instances where the slag is relatively cool. Generation of fugitive emissions during slag dumping can be reduced if the free-fall distance is kept to a minimum. Confinement of the slag dumping area or installation of wind break walls will help in preventing the generation of wind-blown fugitive emissions. If the dumping area is a relatively small area, it may be possible to install a fixed hood and vent fugitive emissions to a baghouse.

Wet suppression during slag crushing will normally effectively control fugitive emissions. Alternate controls include use of a fixed hood over the crusher or use of a closed building with evacuation to a fabric filter.

Table 2.2.2-2 summarizes the available control technologies, their effectiveness, estimated costs, and RACM selections.

2.2.2.5 Recommended Reasonably Available Control Measures (RACM)--

The RACM selections for iron production fugitive emission sources are presented in Table 2.2.2-2.

The selected control technique for iron ore unloading is wet suppression by means of sprays at the receiving point. This method is effective (80% control) and economical when compared to the other control options.

The selected control for limestone unloading is also a wet suppression system. This system would be integrated with the overall control strategy for unloading operations, transfer points and stockpile load-in, wind erosion and load-out activities. Application points would be at the receiving point, all transfer points, stock pile loading and unloading points, and over the stockpile. The system is effective (95% control) and the least costly of the available control options.

Control of load-in emissions from iron ore storage piles is effectively achieved by use of telescopic chutes or stone ladders supplemented by wet suppression. Emissions from wind erosion, load-out activities and transfer points may be controlled

TABLE 2.2.2-2. A SUMMARY OF THE CONTROL ALTERNATIVES, EFFICIENCIES AND COSTS, AND THE RACM SELECTIONS FOR FUGITIVE DUST EMISSIONS FROM SOURCES IN IRON PRODUCTION

Fugitive dust sources	Control alternatives	Control efficiency, %	Control costs $ (Jan. 1980) Capital	Control costs $ (Jan. 1980) Annualized	Cost benefit, $/lb	RACM selection
(1) Iron ore unloading (barge or rail)	Wet suppression (chemical)	80[a]	37,000[a]	32,000[a]	0.19	Wet suppression (chemical)
	Partially enclosed bucket	low[b]	b	b	Not available	
	Enclosure of receiving point	70[a]	60,000[c]	12,000[d]	0.08	
	Enclosure of receiving point, exhaust to fabric filter	99[a]	120,000[a]	42,000[e]	0.20	
(2) Limestone unloading (barge or rail)	Enclosure of receiving point	50[f]	15,000[g]	3,000[d]	2.08	Wet suppression (chemical)
	Enclosure of receiving point, exhaust to fabric filter	99[h]	87,000[g,]	21,000[e]	7.37	
	Wet suppression (chemical)	95[j]	64,000[k]	15,000[l]	1.27	
(3) Iron ore storage						
Loading onto pile	Enclosure (stone ladders)	80[m]	25,000[m]	5,000[d]	0.04	Telescopic chutes and wet suppression
	Wind guards	50[m]	37,000[m]	7,000[d]	0.08	
	Wet suppression (chemical)	75[m]	73,000[m]	30,000[n]	0.22	
	Telescopic chutes	75[m]	9,000[m]	2,000[d]	0.01	
Loading out	Under pile conveyor	80[o]	13,680,000[p]	2,736,000[d]	13.26	Wet suppression (chemical)
	Bucket wheel reclaimer	80[m]	4,500,000[m]	900,000[d]	4.36	
	Wet suppression (chemical)	95[m]	73,000[m]	30,000[n]	0.12	
Wind erosion	Enclosures	100[m]	17,280,000[q]	3,456,000[d]	16.07	Wet suppression (chemical)
	Wet suppression (chemical)	99[m]	14,000[m]	10,000[m]	0.05	
(4) Iron ore handling and transfer	Enclosure	70[a]	65,000[a]	13,000[d]	0.01	Wet suppression (chemical)
	Enclosure, vent to fabric filter	99[a]	218,000[a]	67,000[e]	0.04	
	Wet suppression (chemical)	95[a]	110,000[a]	52,000[a]	0.03	
(5) Limestone storage						
Loading onto piles	Enclosure	70-99[c,o]	950,000[r]	162,000[d]	98.83	Wet suppression (chemical)
	Wet suppression (chemical)	80-90[c,d]	s	s	1.27	
	Adjustable chutes	75[c,o]	44,000[t]	8,000[d]	22.22	
Loading out	Wet suppression (chemical)	80-90[c,o]	x	x	1.27	Wet suppression (chemical)
	Gravity feed onto conveyor	80[c,o]	570,000[u]	14,000[d]	237.50	
Wind erosion	Enclosure	95-99[c,o]	v	v	98.83	Wet suppression (chemical)
	Wet suppression (chemical)	90[c,o]	6,000[w]	8,000[t]	7.41	
	Watering	50[c,o]	5,000[w]	2,600[t]	4.33	
(6) Limestone conveying and transfer	Wet suppression (chemical)	90[x]	x	x	1.27	Wet suppression (chemical)
	Enclosure, vent to fabric filter	95[y]	117,000[a]	32,000[e]	3.51	

(continued)

_E 2.2.2-2 (continued)

Fugitive dust sources	Control alternatives	Control efficiency, %	Control costs $ (Jan. 1980) Capital	Control costs $ (Jan. 1980) Annualized	Cost benefit, $/lb	RACM selection
(7) Coke storage Loading onto pile	Enclosure (stone ladders)	80[m]	25,000[m]	5,000[d]	0.82	Telescopic chutes, wet suppression (chemical)
	Wind guards	50[m]	37,000[m]	7,000[d]	1.84	
	Wet suppression (chemical)	75[m]	73,000[m]	30,000[n]	5.26	
	Telescopic chutes	75[m]	9,000[m]	2,000[d]	0.35	
Loading out	Under pile conveyor	80[o]	13,680,000[p]	2,736,000[d]	300.00	Wet suppression (chemical)
	Bucket wheel reclaimer	80[m]	4,500,000[m]	900,000[d]	98.70	
	Wet suppression (chemical)	95[m]	73,000[m]	30,000[n]	2.77	
Wind erosion	Enclosure	100[m]	17,280,000[q]	3,436,000[d]	1,130.00	Wet suppression (chemical)
	Wet suppression (chemical)	99[m]	14,000[m]	10,000[m]	3.32	
(8) Coke handling and transfer	Enclosure	70[a]	65,000[a]	13,000[d]	0.23	Wet suppression (chemical)
	Enclosure, vent to fabric filter	99[a]	218,000[a]	67,000[e]	0.85	
	Wet suppression (chemical)	95[a]	110,000[a]	52,000[a]	0.69	
(9) Blast furnace flue dust storage	Negligible source					No control
(10) Blast furnace flue dust handling and transfer	Enclosure	70[a]	20,000[a]	4,000[d]	7.33	Wet suppression (chemical)
	Enclosure, vent to fabric filter	99[a]	70,000[a]	15,000[e]	19.42	
	Wet suppression (chemical)	95[a]	37,000[a]	9,000[a]	12.15	
(11) Sinter machine windbox discharge	Negligible source					No control
(12) Sinter machine discharge (breaker and screens)	Enclosure	50[f]	25,000[a]	5,000[d]	0.002	Enclosure/hooding, vent to fabric filter
	Enclosure or hooding, vent to fabric filter	99[a]	343,000[z]	122,000[a]a	0.02	
(13) Sinter cooler (not vented thru a stack)	Enclosure or hooding, vent to fabric filter	99[a]	bb	bb	0.02	Enclosure/hooding, vent to fabric filter
	Enclosure	50[f]	25,000[a]	5,000[d]	0.03	
(14) Sinter storage Loading onto piles	Enclosure	70-99[c,o]	950,000[r]	162,000[d]	0.45	Wet suppression (chemical)
	Wet suppression (chemical)	80-90[c,o]	64,000[cc]	15,700[dd]	0.04	
	Adjustable chutes	75[c,o]	44,000[t]	7,500[d]	0.06	
Loading out	Wet suppression (chemical)	80-90[c,d]	ee	ee	0.04	Wet suppression (chemical)
	Gravity feed onto conveyor	80[c,o]	2,993,000[ff]	599,000[d]	2.54	
Wind erosion	Enclosure	95-99[c,o]	v	v	0.45	Wet suppression (chemical)
	Wet suppression (chemical)	90[c,o]	6,000[w]	8,000[t]	0.04	
	Watering	50[c,o]	5,000[w]	2,600[t]	0.02	

(continued)

TABLE 2.2.2-2 (continued)

Fugitive dust sources	Control alternatives	Control efficiency, %	Control costs $ (Jan. 1980) Capital	Annualized	Cost benefit, $/lb	RACM selection
(15) Sinter handling and transfer	Enclosure	70[a]	37,000[a]	7,000[d]	0.03	Wet suppression (chemical)
	Enclosure, vent to fabric filter	99[a]	117,000[a]	38,000[e]	0.13	
	Wet suppression (chemical)	95[a]	55,000[a]	34,000[a]	0.13	
(16) Blast furnace charging	Negligible source					No control
(17) Blast furnace upsets (slips)	Operation practices and control of raw materials	Unknown	None	None	0.00	Operating practices and control of raw materials
	Vent bleeder valve to water well	Unknown	gg	gg	gg	
	Baffled enclosure of bleeder valve	Unknown	gg	gg	gg	
(18) Blast furnace tapping (cast house emissions)	Hooding tap holes and troughs to skimmers, fabric filter	65[f]	4,611,000[hh]	1,355,000[ii]	9.65	Building evacuation, fabric filter or hooding tap holes and troughs to skimmer, fabric filter
	Hooding tap holes to runners, fabric filter	94[f]	7,313,000[hh]	2,550,000[ii]	12.56	
	Building evacuation, fabric filter	99[f]	5,779,000[jj]	1,627,000[kk]	7.61	
(19) Slag handling	Wet suppression	50[f]	55,000[a]	34,000[a]	0.58	No control
	Hooding, wet scrubber	95[f]	4,942,000[hh]	1,030,000[ii]	9.17	
(20) Slag storage						
Loading onto piles	Enclosure	70-99[c,o]	950,000[r]	162,000[d]	1.30	Wet suppression (chemical)
	Wet suppression (chemical)	80-90[c,o]	64,000[cc]	15,700[dd]	0.10	
Loading out	Wet suppression (chemical)	80-90[c,d]	ee	ee	0.10	Wet suppression (chemical)
Wind erosion	Enclosure	95-99[c,o]	v	v	1.30	Wet suppression (chemical)
	Wet suppression (chemical)	90[c,o]	6,000[w]	8,000[t]	0.15	
	Watering	50[c,o]	5,000[w]	2,600[t]	0.09	
(21) Slag crushing	Wet suppression	50[f]	31,000[hh]	12,000[ii]	0.01	Wet suppression (chemical)
	Hooding, fabric filter	90[f]	279,000[hh]	118,000[ii]	0.03	

(continued)

TABLE 2.2.2-2 (continued)

[a] Reference 14.
[b] Reference 15. No data available on costs.
[c] Reference 16. Based on 10 Ga steel enclosure.
[d] Includes only maintenance and capital charges at 20% of capital.
[e] Reference 17. Based on 3000 h/yr operation.
[f] Estimated.
[g] Reference 18.
[h] Reference 19.
[i] Reference 20.
[j] Reference 21.
[k] Reference 22. Based on control of unloading, stockpile load-in and load-out, and transfer operations.
[l] Reference 23. Based on 3000 h/yr operation.
[m] Reference 24.
[n] Reference 25. Based on 600 tons/h and 3000 h/yr operation.
[o] Reference 26.
[p] Reference 24. Based on $47.5/ton and 288,000 tons stored.
[q] Reference 24. Based on $60/ton and 288,000 tons stored.
[r] Reference 27. Based on 12,000 tons stored.
[s] Costs are included in the figure for limestone unloading.
[t] Reference 27.
[u] Reference 24. Based on 47.5/ton and 12,000 tons stored.
[v] Costs included in figures for enclosure of loading onto piles.
[w] Reference 28. Adjusted to 100,000 tons per year throughput.
[x] Reference 29.
[y] Reference 30.
[z] Reference 31. Based on 0.76×10^6 ton/yr of sinter produced.
[aa] Reference 32. Based on 0.76×10^6 ton/yr of sinter produced.
[bb] Costs included with control of sinter machine discharge and screens.
[cc] Reference 22. Based on 150 ton/h throughput and control of loading in and loading out activities.
[dd] Reference 33. Based on 3000 h/yr operation.
[ee] Costs included in loading onto piles figures.
[ff] Reference 24. Based on 47.5/ton and 63,000 ton stored.
[gg] No cost data available.
[hh] Reference 34. Based on 760,000 ton/yr hot metal capacity.
[ii] Reference 35. Based on 760,000 ton/yr hot metal capacity.
[jj] Reference 36.
[kk] Reference 36. Plus capital charges at 20 percent of total investment.

by wet suppression as a least expensive alternative, but one which still provides good control efficiency (95%). The coke storage and handling/transfer emissions can also be effectively controlled by the same techniques (i.e., stone ladders or telescopic chutes and wet suppression).

No control is recommended for blast furnace flue dust storage since this is an enclosed operation. Application of wet sprays at transfer points, however, is recommended.

No control of the sinter machine windbox discharge is selected since this is a negligible source.[9] Sinter screens and coolers are usually controlled as point sources. However significant emissions may occur if the processes are not hooded properly for good capture efficiency. The recommeded control technique is the proper hooding and venting of these operations to a fabric filter.

The control recommended for sinter storage pile activities is wet suppression since it is effective (80-90% control) and not as costly as most other options. Application would occur at the load-in point, the load-out point and over the entire stockpile.

Control of sinter handling and transfer can be accomplished by use of a wet suppression system with sprays at transfer points.

No control is recommended for blast furnace charging since this is a negligible source.[5] Blast furnace slips can best be controlled by careful operation of the furnace and by quality control of the raw materials. No other control option has been demonstrated on a blast furnace.

The RACM selection for fugitive emissions from blast furnace tapping (cast house emissions) is either hooding the tap holes and troughs to skimmers and venting to a fabric filter or evacuating the building to a fabric filter. Although the cost-benefit value for building evacuation to a fabric filter was less than that for hooding the tap holes and troughs to skimmers and venting to a fabric filter, it is expected that the cost-benefit will be much higher at some facilities due to the larger air volumes required for ventilation. Therefore, it is anticipated that many of the affected facilities will choose the option of hooding the tap holes and troughs to skimmers and venting to a fabric filter.

Control options for slag handling are either ineffective or very costly, and no control is recommended for this relatively minor source.

Wet suppression is the recommended control technique for slag storage and crushing operations. Application points would include the load-in and load-out points, the entire storage pile, and the inlet and outlet of the crusher. It is the least costly of the effective control options.

Roads are a major source of fugitive emissions at iron and steel mills. The recommended control techniques are the regular sweeping and cleaning of paved roads, paving of roads with frequent traffic, and the regular oiling or use of wet suppression (chemical) for less traveled, unpaved roads. Details on these control options and costs are presented in Section 2.1.

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APPENDIX FOR SECTION 2.2.2

Average capacities of Ohio iron production facilities from Appendix B of Reference 31

Sinter capacity (avg.) = 0.76×10^6 tpy
Blast furnaces capacity (avg.) 1.74×10^6 tpy/plant or
0.65×10^6 tpy/furnace
Hearth diameter (avg.) = 25'3"
Working volume = 40,460 ft^3

Average storage pile amounts from MRI (p. 4-15)

		Annual Throughput (10^6 tons)
Coke	20,000 tons	0.38
Iron ore pellets	100,000 tons	0.24
Lump iron ore	188,000 tons	0.62
Ore bedding	15,000 tons	0.29
Slag	162,000 tons	1.97
Sinter	63,000 tons	0.72

(1) Iron ore unloading
Total unloaded = 860,000 tpy
Emissions = (0.25 lb/ton)(0.86×10^6 tpy) = 215,000 lbs/yr

Wet suppression

Capital cost = \$37,000 (see Coke)
Annual operating cost @ \$0.03/ton = \$25,800
Annualized cost = \$32,000

$$C/B = \frac{\$32{,}000/yr}{(0.8)(215{,}000\ lbs/yr)} = \$0.19/lb$$

Enclosure of receiving point

See Coke (1)

$$C/B = \frac{\$12{,}000/yr}{(0.7)(215{,}000\ lbs/yr)} = \$0.08/lb$$

Enclosure of receiving point, exhaust to fabric filter

See Coke (1)

$$C/B = \frac{\$42{,}000/yr}{(0.99)(215{,}000\ lbs/yr)} = \$0.20/lb$$

(2) Limestone unloading
Emissions = (0.24 lb/ton)(12,000 tpy) = 2,880 lbs/yr

Enclosure of receiving point

See Lime (1) Option C

$$C/B = \frac{\$3,000/yr}{(0.5)(2,880 \text{ lbs/yr})} = \$2.08/lb$$

Enclosure of receiving point, exhaust to fabric filter

See Lime (1)

$$C/B = \frac{\$21,000/yr}{(0.99)(2,880 \text{ lbs/yr})} = \$7.37/lb$$

Wet suppression

See Lime (1)

$$C/B = \frac{\$15,700/yr}{0.95\ (2,880) + 0.90(480) + 0.9(600) + 0.9(9,600)}$$

$$= \$1.27/lb$$

(3) Iron ore storage

Load-in: Emissions = (0.21 lb/ton)(0.86 x 10^6 tpy) = 180,600 lbs/yr

Enclosure (stone ladders) (Reference 25)

$$\text{Capital cost} = \$20,000 \frac{(249.6)}{(204.1)} = \$25,000$$

Annual cost = 0.20 (25,000) = \$5,000

$$C/B = \frac{\$5,000/yr}{(.8)(180,600 \text{ lbs/yr})} = \$0.04/lb$$

Wind guards (Reference 25)

$$\text{Capital cost} = \$30,000 \frac{(249.6)}{(204.1)} = \$37,000$$

Annual cost = 0.2 (37,000) = \$7,000

$$C/B = \frac{\$7,000/yr}{(0.5)(180,600 \text{ lbs/yr})} = \$0.08/lb$$

Wet suppression (Reference 25)

$$\text{Capital cost} = \$60,000 \frac{(249.6)}{(204.1)} = \$73,000$$

$$\text{Annual cost} = \$24,250 \frac{(249.6)}{(204.1)} = \$30,000$$

$$C/B = \frac{\$30,000/yr}{(0.75)(180,600 \text{ lbs/yr})} = \$0.22/lb$$

Telescopic chutes (Reference 25)

$$\text{Capital cost} = \$7,000 \frac{(249.6)}{(204.1)} = \$9,000$$

Annual cost = 0.2(9,000) = \$2,000

$$C/B = \frac{\$2,000/yr}{(0.75)(180,600 \text{ lbs/yr})} = \$0.01/lb$$

Load-out: Emissions = (0.3 lb/ton)(0.86 x 10^6 tpy) = 258,000 lbs/yr

Underpile conveyor (Reference 25)

Capital cost = ($47.5/ton)(288,000) = $13,680,000
Annual cost = (0.2)(13,680,000) = $2,736,000

$$C/B = \frac{\$2,736,000/yr}{(0.8)(258,000\ lbs/yr)} = \$13.26/lb$$

Bucket wheel reclaimer (Reference 25)

$$\text{Capital cost} = \frac{(2.2 \times 10^6) + (5.3 \times 10^6)}{2} \frac{(249.6)}{(204.1)} = \$4,500,000$$

Annual cost = .2(4,500,000) = $900,000

$$C/B = \frac{\$900,000/yr}{(.8)(258,000\ lbs/yr)} = \$4.36/lb$$

Wet suppression (Reference 25)

$$\text{Capital cost} = \$60,000 \frac{(249.6)}{(204.1)} = \$73,000$$

$$\text{Annual cost} = \$24,250 \frac{(249.6)}{(204.1)} = \$30,000 \text{ (Reference 26)}$$

$$C/B = \frac{\$30,000/yr}{(.95)(258,000\ lbs/yr)} = \$0.12/lb$$

Wind erosion: Emissions = 0.25 (0.86 x 10^6 tpy) = 215,000 lbs/yr

Enclosures (Reference 25)

Capital cost = ($60/ton)(288,000 tons stored)
= $17,280,000

Annual cost = .2(17,280,000) = $3,456,000

$$C/B = \frac{\$3,456,000/yr}{1.0\ (215,000\ lbs/yr)} = \$16.07/lb$$

Wet suppression

$$\text{Capital cost} = \$11,000 \frac{(249.6)}{(204.1)} = \$14,000$$

Annual cost = $0.051/ft^2$ (150,000 ft^2) + 0.17 (14,000)
= 10,000

$$C/B = \frac{\$10,000/yr}{.99\ (215,000\ lbs/yr)} = \$0.05/lb$$

(4) Iron ore handling and transfer

Emissions = 2(0.86 x 10^6 tpy) = 1,720,000 lbs/yr

Enclosures

$35/ft of conveyor + $3,000/transfer pt.
Assume 1000 ft of conveyor and 6 transfer stations

$$\text{Capital cost} = \$53,000 \ \frac{(249.6)}{(204.1)} = \$65,000$$

Annual cost = .2 (65,000) = $13,000

$$C/B = \frac{\$13,000/yr}{.7\ (1,720,000\ lbs/yr)} = \$0.01/lb$$

Enclosure, vent to fabric filter

$70/ft of conveyor plus 18,000/transfer pt.

$$\text{Capital cost} = 178,000 \ \frac{(249.6)}{(204.1)} = \$218,000$$

$$\text{Annual cost} = \$55,000 \ \frac{(249.6)}{(204.1)} = \$67,000$$

$$C/B = \frac{\$67,000/yr}{.99\ (1,720,000\ tpy)} = \$0.04/lb$$

Wet suppression

$$\text{Capital cost} = 6(\$15,000)\frac{(249.6)}{(204.1)} = \$110,000$$

Annual cost = 6(.03)(288,000 tons) = $52,000

$$C/B = \frac{\$52,000/yr}{.95\ (1,720,000\ tpy)} = \$0.03/lb$$

(5) Limestone storage

Loading in: Emissions = .04 (12,000) = 480 lbs/yr

Enclosure

See Lime (2)

$$C/B = \frac{\$162,000/yr}{.99\ (480) + .97\ (1200)} = \$98.83/lb$$

Wet suppression

See Lime (2)
C/B = $1.27/lb

Adjustable chutes

See Lime (2)

$$C/B = \frac{\$8,000/yr}{(.75)(480\ lbs/yr)} = \$22.22/lb$$

Loading out: Emissions = .05 (12,000) = 600 lbs/yr

Wet suppression

See Lime (2)
C/B = \$1.27/lb

Gravity feed onto conveyor

See Lime (2)

$$C/B = \frac{\$114,000/yr}{0.8\ (600\ lbs/yr)} = \$237.5/lb$$

Wind erosion: Emissions = 0.10 (12,000) = 1,200 lbs/yr

Enclosure

See Lime (2)
C/B = \$98.83/lb

Wet suppression

See Lime (2)

$$C/B = \frac{\$8,000/yr}{.09\ (1,200\ lbs/yr)} = \$7.41/lb$$

Watering

See Lime (2)

$$C/B = \frac{\$2,600/yr}{0.5\ (1,200\ lbs/yr)} = \$4.33/lb$$

(6) Limestone conveying and transfer
Emissions = 9,600 lbs/yr

Wet suppression

See Lime (1)
C/B = \$1.27/lb

Enclosure, vent to fabric filter

Assume 650' conveyor and 4 transfer stations
Capital cost = 70 (650) + 18,000 (4) = \$117,000
Annual cost = .2 (117,000) = \$32,000

$$C/B = \frac{\$32,000/yr}{.95\ (9,600\ lbs/yr)} = \$3.51/lb$$

(7) Coke storage

Load-in: Emissions = .02 (0.38 x 10^6) = 7,600 lbs/yr

Enclosure (stone ladders)

See iron ore storage

$$C/B = \frac{\$5,000/yr}{0.8\ (7,600\ lbs/yr)} = \$0.82/lb$$

Wind guards

See iron ore storage

$$C/B = \frac{\$7,000/yr}{0.5\ (7,600\ lbs/yr)} = \$1.84/lb$$

Wet suppression

See iron ore storage

$$C/B = \frac{\$30,000/yr}{0.75\ (7,600\ lbs/yr)} = \$5.76/lb$$

Telescopic chutes

See iron ore storage

$$C/B = \frac{\$2,000/yr}{0.75\ (7,600\ lbs/yr)} = \$0.35/lb$$

Load-out: Emissions = .03 (0.38×10^6) = $11,400

Under pile conveyor

See iron ore storage

$$C/B = \frac{\$2,736,000/yr}{0.8\ (11,400\ lbs/yr)} = \$300.00/lb$$

Bucket wheel reclaimer

See iron ore storage

$$C/B = \frac{\$900,000/yr}{0.8\ (11,400\ lbs/yr)} = \$98.70$$

Wet suppression

See iron ore storage

$$C/B = \frac{\$30,000/yr}{0.95\ (11,400\ lbs/yr)} = \$2.77/lb$$

Wind erosion: Emissions = .008 (0.38×10^6) = 3,040 lbs/yr

Enclosure

See iron ore storage

$$C/B = \frac{\$3,436,000/yr}{1.0\ (3,040\ lbs/yr)} = \$1,130/lb$$

Wet suppression

See iron ore storage

$$C/B = \frac{\$10,000/yr}{0.99\ (3,040\ lbs/yr)} = \$3.32/lb$$

(8) Coke handling and transfer

Emissions = 0.11 (0.72×10^6) = 79,200 lbs/yr

Enclosure

See iron ore

$$C/B = \frac{\$13,000/yr}{.7\ (79,200\ lbs/yr)} = \$0.23/lb$$

Enclosure, vent to fabric filter

See iron ore

$$C/B = \frac{\$67,000/yr}{.99\ (79,200\ lbs/yr)} = \$0.85/lb$$

Wet suppression

See iron ore

$$C/B = \frac{\$52,000/yr}{.95\ (79,200\ lbs/yr)} = \$0.69/lb$$

9 Blast furnace flue dust storage
No control

10 Blast furnace flue dust handling and transfer
Emissions = .03(26,000 tpy) = 780 lbs/yr

Enclosure

Assume 300' of conveyor and 3 transfer pts.

$$\text{Capital cost} = [35\ (300) + 2\ (3,000)]\ \frac{(249.6)}{(204.1)} = \$20,000$$

Annual cost = .2 (20,000) = $4,000

$$C/B = \frac{\$4,000/yr}{.7\ (780\ lbs/yr)} = \$7.33/lb$$

Enclosure, vent to fabric filter

$$\text{Capital cost} = [70\ (300) + 2\ (18,000)]\ \frac{(249.6)}{(204.1)} = \$70,000$$

$$\text{Annual cost} = \$12,300\ \frac{(249.6)}{(204.1)} = \$15,000$$

$$C/B = \frac{\$15,000/yr}{.99\ (780\ lbs/yr)} = \$19.42/lb$$

Wet suppression

$$\text{Capital cost} = 2\ (15,000)\frac{(249.6)}{(204.1)} = \$37,000$$

Annual cost = .03 (100,000 tons) + (37,000)(.17)
= $9,000

$$C/B = \frac{\$9,000}{.95\ (780\ lbs/yr)} = \$12.15/lb$$

11 Sinter machine windbox discharge
No control

(12) Sinter machine discharge and screens

Emissions = 6.8 lb/ton (0.72×10^6 tpy) = 4.9×10^6 lbs/yr

Enclosure

Assume 70 ft of conveyor and one transfer point

$$\text{Capital cost} = [18{,}000 + (70)(35)] \frac{(249.6)}{(204.1)} = \$25{,}000$$

Annual cost = .2 (25,000) = $5,000

$$C/B = \frac{\$5{,}000/\text{yr}}{.5\ (4.9 \times 10^6\ \text{lbs/yr})} = \$0.002/\text{lb}$$

Enclosure or hooding, vent to fabric filter

$$\text{Capital} = 17{,}460.9\ (.76 \times 10^6)^{0.199} \frac{(249.6)}{(204.1)} = \$343{,}000$$

$$\text{Annual} = 14{,}986\ (0.76 \times 10^6)^{0.199} \frac{(249.6)}{(204.1)} = \$122{,}000$$

$$C/B = \frac{\$122{,}000/\text{yr}}{.99\ (4.9 \times 10^6) + .99\ (403{,}200)} = \$0.02/\text{lb}$$

(13) Sinter cooler

Emissions = 0.56 lb/ton (0.72×10^6) = 403,200 lbs/yr

Enclosure or hooding, vent to fabric filter

Costs included with (12)

C/B = $0.02/lb

Enclosure

See (12)

$$C/B = \frac{\$5{,}000/\text{yr}}{.5\ (403{,}200\ \text{lbs/yr})} = \$0.03/\text{lb}$$

(14) Sinter storage

Load-in: Emissions = 0.25 (0.72×10^6) = 180,000 lbs/yr

Enclosure

See Lime (2)

$$C/B = \frac{\$162{,}000/\text{yr}}{.85\ (180{,}000) + .97\ (216{,}000)} = \$0.45/\text{lb}$$

Wet suppression

$$\text{Capital cost} = \$52{,}500 \frac{(249.6)}{(204.1)} = \$64{,}000$$

$$\text{Annual cost} = \$12{,}800 \frac{(249.6)}{(204.1)} = \$15{,}700$$

$$C/B = \frac{\$15{,}700/\text{yr}}{.85\ (180{,}000) + .85\ (295{,}000)} = \$0.04/\text{lb}$$

Adjustable chutes

See Lime (2)

$$C/B = \frac{\$7{,}500/yr}{.75\ (180{,}000)} = \$0.06/lb$$

Load-out: Emissions = 0.41 (0.72×10^6) = 295,000 lbs/yr

Wet suppression

See load-in
C/B = $0.04/lb

Gravity feed onto conveyor

Capital cost = $47.50 (63,000) = $2,993,000
Annual cost = .2 (2,993,000) = $599,000

$$C/B = \frac{\$599{,}000/yr}{.8\ (295{,}000)} = \$2.54/lb$$

Wind erosion: Emissions = 0.3 (0.72×10^6) = 216,000 lbs/yr

Enclosure

See Lime (2)
C/B = $0.45/lb

Wet suppression

See Lime (2)

$$C/B = \frac{\$8{,}000/yr}{.9\ (216{,}000)} = \$0.04/lb$$

Watering

See Lime (2)

$$C/B = \frac{\$2{,}600}{.5\ (216{,}000)} = \$0.02/lb$$

(15) Sinter handling and transfer
Emissions = 0.4 (0.72×10^6) = 288,000 lbs/yr

Enclosure (Reference 15)

$$\text{Capital cost} = 35\ (600) + 3\ (3{,}000)\frac{(249.6)}{(204.1)} = \$37{,}000$$

Annual cost = (37,000)(.2) = $7,000

$$C/B = \frac{\$7{,}000}{.7\ (288{,}000)} = \$0.03/lb$$

Enclosure, vent to fabric filter

See Limestone

$$C/B = \frac{\$38,000/yr}{.99\ (288,000)} = \$0.13/lb$$

Wet suppression (Reference 15)

$$\text{Capital cost} = (15,000)(3)\ \frac{(249.6)}{(204.1)} = \$155,000$$

$$\text{Annual cost} = .03\ (.76 \times 10^6\ \text{tons})\frac{(249.6)}{(204.1)} + .17\ (55,000) = \$34,000$$

$$C/B = \frac{\$34,000/yr}{.94\ (288,000)} = \$0.13/lb$$

(16) Blast furnace charging
No control

(17) Blast furnace upsets (slips)
No cost data

(18) Blast furnace tapping (cast house emissions)
Emissions = 0.3 (0.72×10^6) = 216,000 lbs/yr

Hooding tap holes and troughs to skimmer, fabric filter

(Reference 31)

$$\text{Capital cost} = 127,706\ (0.76 \times 10^6\ \text{tpy})^{0.250}\ \frac{(249.6)}{(204.1)} = \$4,611,000$$

$$\text{Annual cost} = 75,076.6\ (0.76 \times 10^6\ \text{tpy})^{0.135}\ \frac{(249.6)}{(204.1)} + 0.17\ (4,611,000) = \$1,355,000$$

$$C/B = \frac{\$1,355,000/yr}{.65\ (216,000)} = \$9.65/lb$$

Hooding tap holes to runners, fabric filter

$$\text{Capital cost} = 156,588.9\ (0.76 \times 10^6\ \text{tpy})^{0.269}\ \frac{(249.6)}{(204.1)} = \$7,313,000$$

$$\text{Annual cost} = 291,321.4\ (0.76 \times 10^6\ \text{tpy})^{0.096}\ \frac{(249.6)}{(204.1)} + 0.17\ (7,313,000) = \$2,550,000$$

$$C/B = \frac{\$2,550,000/yr}{.94\ (216,000)} = \$12.56/lb$$

Building evacuation, fabric filter

$$\text{Capital cost} = 1{,}646.4\ (0.76 \times 10^6\ \text{tpy})^{0.588}\ \frac{(249.6)}{(204.1)} = \$5{,}779{,}000$$

$$\text{Annual cost} = 158.2\ (0.76 \times 10^6\ \text{tpy})^{0.599}\ \frac{(249.6)}{(204.1)} + 0.17\ (5{,}779{,}000) = \$1{,}627{,}000$$

$$C/B = \frac{\$1{,}627{,}000/\text{yr}}{.99\ (216{,}000)} = \$7.61/\text{lb}$$

(19) Slag handling

$$\text{Emissions} = 0.06\ (1.97 \times 10^6) = 118{,}200\ \text{lbs/yr}$$

Wet suppression

See (15)

$$C/B = \frac{\$34{,}000/\text{yr}}{.5\ (118{,}200)} = \$0.58/\text{lb}$$

Hooding, wet scrubber

$$\text{Capital cost} = 5{,}287.8\ (0.76 \times 10^6)^{0.446}\ \frac{(249.6)}{(204.1)} = \$4{,}942{,}000$$

$$\text{Annual cost} = 12{,}259.9\ (0.76 \times 10^6)^{0.316}\ \frac{(249.6)}{(204.1)} = \$1{,}030{,}000$$

$$C/B = \frac{\$1{,}030{,}000}{.95\ (118{,}200)} = \$9.17/\text{lb}$$

(20) Slag storage

Load-in: $\text{Emissions} = .04\ (1.97 \times 10^6) = 78{,}800\ \text{lbs/yr}$

Enclosure

See (14)

$$C/B = \frac{\$162{,}000/\text{yr}}{.85\ (78{,}800) + .97\ (59{,}100)} = \$1.30/\text{lb}$$

Wet suppression

See (14)

$$C/B = \frac{\$15{,}700}{.85\ (78{,}800) + .85\ (98{,}500)} = \$0.10/\text{lb}$$

Load-out: Emissions = .05 (1.97×10^6) = 98,500 lbs/yr

Wet suppression

See (14)
C/B = \$0.10/lb

Wind erosion: Emissions = .03 (1.97×10^6) = 59,100 lbs/yr

Enclosure

See (14)
C/B = \$1.30/lb

Wet suppression

See (14)

$$C/B = \frac{\$8,000/yr}{.9\ (59,100)} = \$0.15/lb$$

Watering

See (14)

$$C/B = \frac{\$2,600/yr}{.5\ (59,100)} = \$0.09/lb$$

(21) Slag crushing
Emissions = 2.0 (1.97×10^6) = 3,940,000 lbs/yr

Wet suppression (Reference 35)

$$\text{Capital cost} = 25,316.9 \frac{(249.6)}{(204.1)} = \$31,000$$

$$\text{Annual cost} = 10,006.7 \frac{(249.6)}{(204.1)} = \$12,000$$

$$C/B = \frac{\$12,000/yr}{.5\ (3,940,000)} = \$0.01/lb$$

Hooding, fabric filter (Reference 35)

$$\text{Capital cost} = 10,829.9\ (760,000)^{0.226} \frac{(249.6)}{(204.1)} = \$279,000$$

$$\text{Annual cost} = 26,494.3\ (760,000)^{0.057} \frac{(249.6)}{(204.1)} + .17\ (279,000) = \$118,000$$

$$C/B = \frac{\$118,000/yr}{.9\ (3,940,000)} = \$0.03/lb$$

2.2.3 Steel Manufacture

2.2.3.1 Process Description[1]--

Steel is usually made from scrap steel and/or molten iron (hot metal). Impurities present in the scrap and pig iron (such as sulfur and phosphorous) are reduced with fluxes. The content of carbon alloys such as manganese or silicon are adjusted as necessary. The three main types of steel-producing furnaces are electric arc, open hearth and basic oxygen.

Open hearth[1]--In the open hearth process for making steel, a mixture of scrap steel, fluxes and hot metal is melted in a shallow rectangular basin or hearth. The charging machine places the scrap materials and fluxes in the furnace. The molten metal is conveyed from the blast furnace by means of a refractory-lined trough from a ladle into the furnace. Burners are located at the end walls of the furnace and are alternately used between heats. Heat for the furnace is supplied by burning fuel oil, tar-pitch mixtures, coke-oven gas or natural gas. Impurities are removed in the slag layer on top of the molten metal. If oxygen is used, it is injected into the furnace through the roof to speed the refining process, save fuel, decrease tap-to-tap time and increase steel production rates. A complete cycle (one heat) usually takes about ten hours for conventional furnaces; but with the use of oxygen lancing or an oxygen-enriched fuel, the heat time may be reduced to six hours, depending on the amount of oxygen introduced. The steel is then tapped into a ladle through a port at the rear of the furnace. Typically, in Ohio, an open hearth furnace would produce 189,000 tons of steel per year.[2] (A cross-section of an open hearth furnace is shown in Figure 2.2.3-1.)

Basic oxygen[1]—Hot metal is delivered to the basic oxygen shop in submarine or torpedo cars from the blast furnace. The metal is transferred to a charging ladle at the reladling station where the car and metal are weighed in order to charge the proper amount of hot metal. A crane transports the molten iron to the steel-making.

The basic oxygen process requires no external source of heat. A cylindrical-base, lined furnace with a dished bottom and truncated cone-shaped top is charged with scrap steel. A transfer ladle adds molten pig iron to the furnace, and an oxygen lance is lowered into the furnace. The flow of oxygen striking the surface of the liquid bath immediately starts exothermic reactions by oxidation of carbon, silicon, manganese and some of the iron. Fluxes and other additives can be added to the furnace during the operation through a hood opening.

At the completion of the blow (30-45 minutes), the lance is withdrawn, the temperature is read, and a sample of steel withdrawn for chemical analysis. When the temperature and composition are satisfactory, the furnace is tilted, the molten steel is transferred into the ladle atop the transfer car, and alloy composition is adjusted with additives. The average basic oxygen furnace in Ohio produces 1,450,000 tons of steel per year.[3] (A basic oxygen furnace is illustrated in Figure 2.2.3-2.)

Electric—In an electric arc furnace, the heat is supplied by electrical energy. With the power turned off, the electrodes

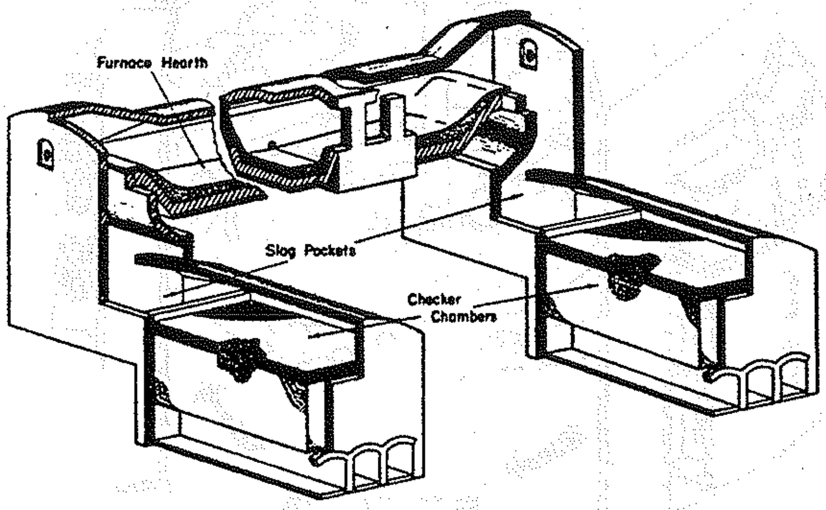

Figure 2.2.3-1. Cross-section of an open-hearth furnace.[33]

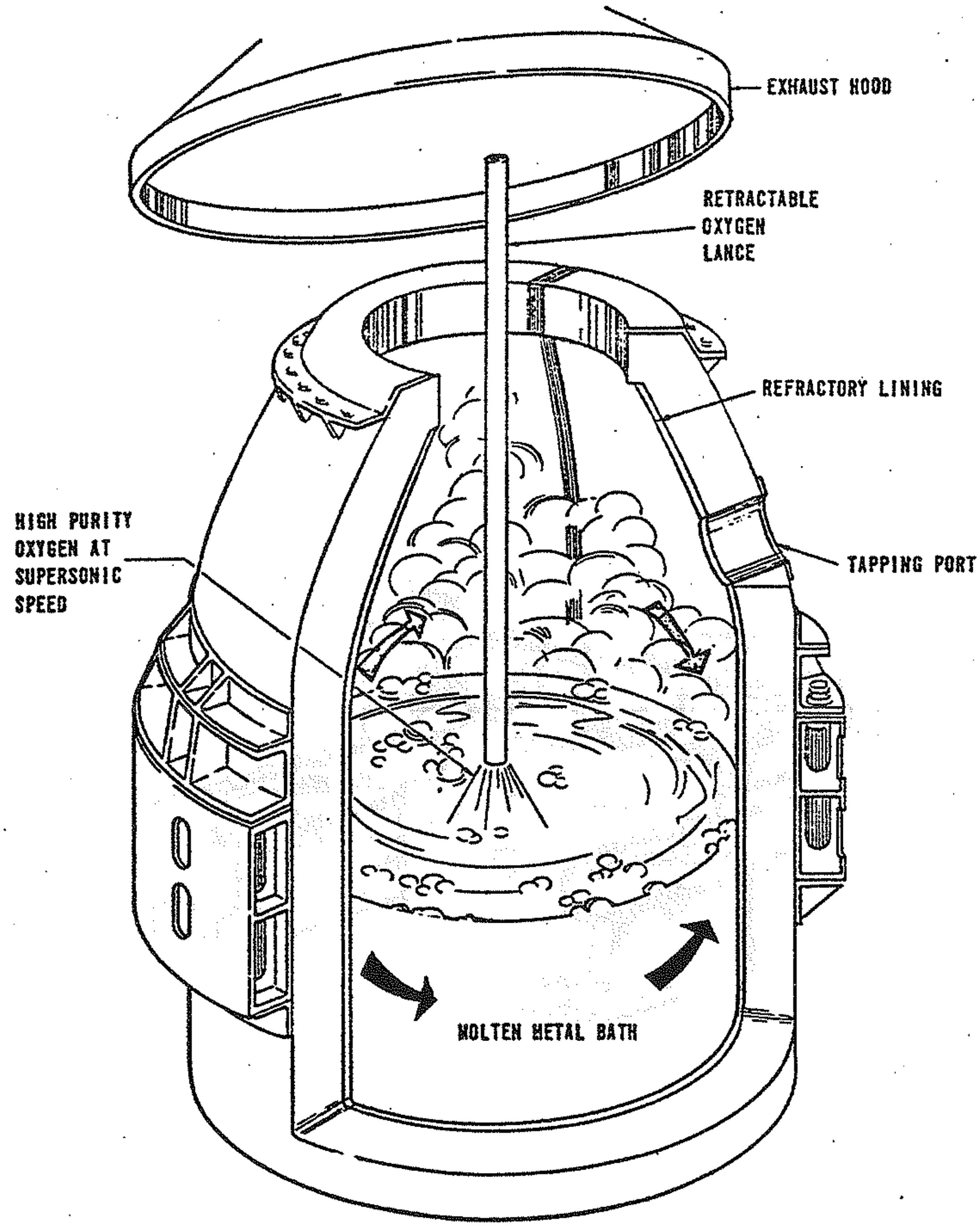

Figure 2.2.3-2. Cross-section of a basic oxygen furnace.[34]

and roof are swung out of the way. Solid scrap and other components of the charge (sometimes including hot metal) are placed in the furnace by means of an overhead crane. Alloying materials are added as and when required.

After charging is complete, the roof is returned and the electrodes are lowered. The power is turned on and the current passes from the electrodes through the charge. Since the arcs melt the portion of the charge directly beneath each electrode, the electrodes "bore" through the solid charge and the liquid metal forms a pool on the hearth. The charge is now heated by radiation from the pool, by heat from the arcs and by the heat generated in the scrap due to electrical resistance to current flow. Second and third charges may be added to the melt. During these charges considerable fugitive emissions are evolved.[4] Melting continues until the charge is completely melted. Composition of the steel is then adjusted by adding alloys, blowing oxygen into the bath and by using fluxes to remove impurities. The molten steel is then tapped into a ladle by tilting the furnace. Cycles or "heats" vary considerably depending on the type of steel produced. They range from 1.5 to 5 hours for carbon steel to 5 to 10 hours for alloy steels. An electric arc furnace in Ohio averages about 293,000 tons of steel output per year.[5] (An electric arc furnace is shown in Figure 2.2.3-3.)

The finished steel from whatever type of furnace, is tapped into ladles and transported by overhead crane to a pouring platform where the steel is either teemed (poured) into a series of

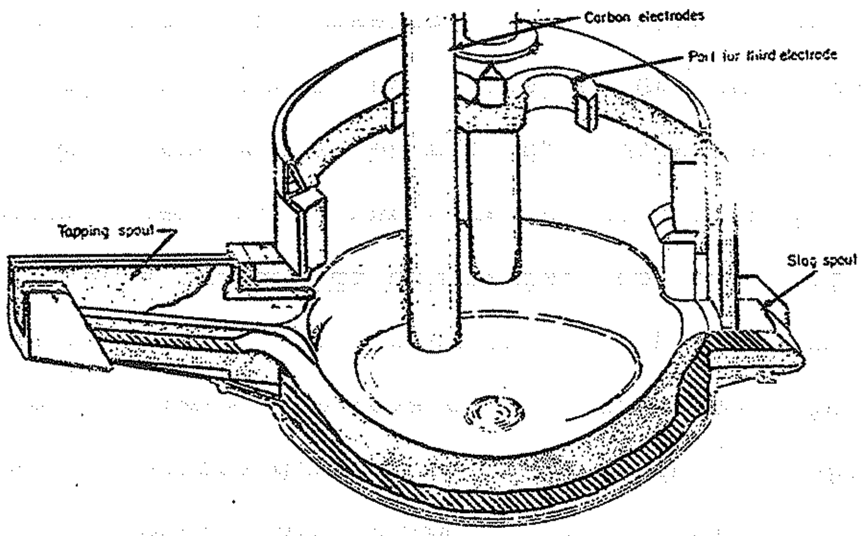

Figure 2.2.3-3. Cross-section of an electric arc furnace.[35]

molds or passes directly to a continuous casting unit. Before teeming or casting, the steel may be vacuum degassed to lower the free gas content of the steel. When teemed into molds, the molten steel solidifies to form an ingot. Continuous casting is a process whereby the molten steel is teemed into a tundish, and the flow from the tundish is controlled as the molten steel discharges into one or more molds of the continuous caster. The solidified steel is withdrawn from the bottom of the molds as a continuous strand and subsequently cut to desired lengths as the casting continues.

After the ingots are cool, they are stripped from the molds and transferred to a heating furnace (called a soaking pit) where the temperature of the ingot is raised and equalized to soften the steel for rolling on the primary rolling mills. The products of the primary mills, known as the semifinished products, are called blooms, slabs and billets.

Surface defects are removed in a process called scarfing, and may be done either by hand or mechanically. The mechanical hot scarfer is installed directly in the mill line and is composed of a number of scarfing torches (oxyacetylene). The machine is designed to remove a thin layer (one-eighth inch or less) of metal from all four sides of red-hot steel billets, blooms or slabs as they travel through the machine. Scarfing is also done manually in some mills, and usually the material to be scarfed is cold. Prior to rolling, the material must be reheated in a horizontal furnace.

Slabs may be further processed into plates or coils. The coils are usually processed in the sheet and tin mills. Oxides and scale are chemically removed from the surface of the metal by pickling. The conventional facility for pickling strip is a horizontal continuous line of equipment consisting of a tank or tanks divided into separate sections for pickling, washing, etc., with uncoiling and welding equipment on the entry end and rewind and shearing equipment on the exit end.

After pickling, the coils in the sheet and tin mills may receive one of many treatments. These include cold reduction, batch or continuous annealing, tempering, tin plating, galvanizing, tin-free coating, chroming, slitting, leveling, shearing, etc. Blooms and billets are processed into structural shapes, tubes, bars, rebars and wire.

A process flow diagram for steel production is shown in Figure 2.2.3-4. Sources of fugitive emissions include scrap steel handling operations, flux material handling operations, hot metal reladling, basic oxygen furnace operations, open hearth furnace operations, electric arc furnace operations, ingot casting, steel reladling and scarfing. Each potential process fugitive emission point is identified in the Figure. A dust source common to all steel-producing facilities, but not specifically included in the Figure is plant haul roads. Haul roads are addressed in Section 2.1.

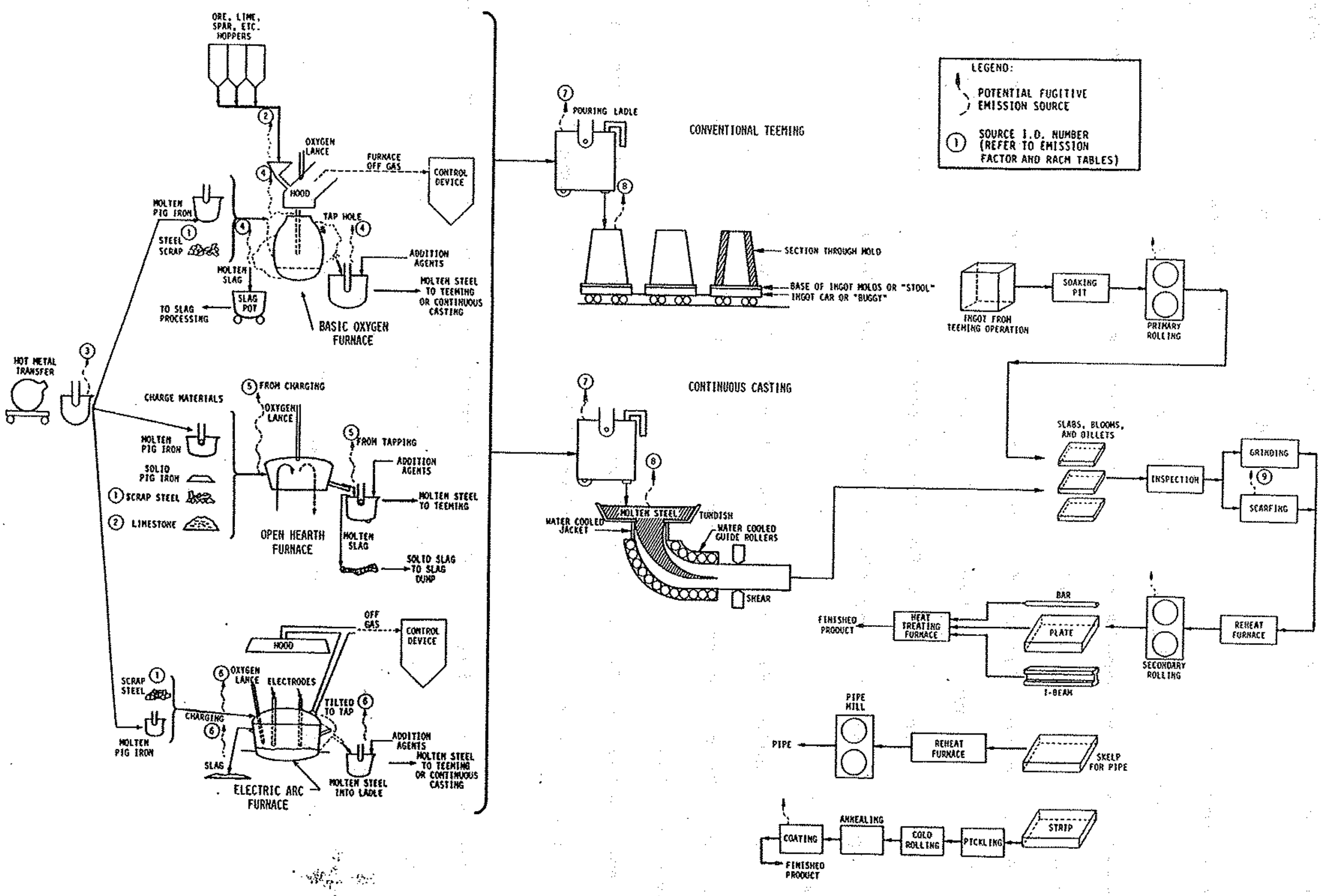

Figure 2.2.3-4. Simplified process flow diagram for steel manufacture and associated fugitive particulate emission sources.

2.2.3.2 Fugitive Dust Emission Factors--

The estimated emission factors for steel manufacturing fugitive emissions are summarized in Table 2.2.3-1. Most of these emission factors are based on test data and are considered of fair to very good reliability for site specific estimates.

The source of the emission factors for scrap steel and flux material handling operations is unclear, and these factors should be considered of poor reliability.

The emission factor for molten pig iron transfer to charging ladles is based upon 8 tests and is of very good reliability.

The emission factors for basic oxygen furnace operations are based upon 39 tests, and the reliability of these factors is good to very good.

The emission factor for open hearth furnace operations is based upon 28 measurements, and the reliability should be considered as fair.

The emission factor for electric arc furnace operations is based upon 2 tests, and the reliability should be considered as fair.

The emission factors for continuous casting and conventional teeming and molten steel reladling are based on 9 tests and should be considered of very good reliability.

No emission factor was available for hand scarfing.

TABLE 2.2.3-1. FUGITIVE DUST EMISSION FACTORS FOR STEEL MANUFACTURING

Source	Emission factor	Reliability rating	Reference
(1) Scrap steel unloading transfer, and storage	Negligible	E	6
(2) Ore and flux material unloading, transfer, and storage	Negligible	E	6
(3) Molten pig iron transfer to charge ladles	0.19 lb/ton hot metal	A	7
(4) Basic oxygen furnace - roof monitor (total)	0.5 lb/ton steel	B	7
Charging (at source)	0.6 lb/ton hot metal	A	7
Leakage	Negligible	E	4
Tapping - steel and slag (at source)	0.92 lb/ton steel tapped	A	7
(5) Open hearth furnace - roof monitor (total, including charging and tapping)	0.168 lb/ton steel	C	8
(6) Electric arc furnace - roof monitor (total, including charging, tapping, and slagging)	1.2 lb/ton steel	C	7
(7) Molten steel reladling	0.81 lb/ton leaded steel	A	8
	0.07 lb/ton unleaded steel	A	8
(8) Continuous casting/ conventional teeming	0.81 lb/ton leaded steel	A	8
	0.07 lb/ton unleaded steel	A	8
(9) Scarfing (hand)	NA		

NA = Not available.

2.2.3.3 Particle Characterization--

Fugitive particulate emissions from steel production consist basically of iron oxide fume. According to the American Conference of Governmental Industrial Hygienists the level at which iron oxide fumes could produce human health effects is 5 mg/m^3.[9]

Emissions from a Basic Oxygen Furnace (BOF) may have exit temperatures of 560-3000°F,but this temperature quickly decreases. Fugitive emissions have a mean diameter of 0.5 µm,of which 85-99 percent are less than 5 µm.[10,11,12] Fugitive hot metal charging fumes from the BOF process are 35 percent iron oxide and 30 percent kish (graphite).[10,11,12] Fugitive tapping fumes are 75 percent iron oxide and are less than 10 µm.[10,11,12] Fugitive hot metal reladling fumes are 55 percent iron oxides less than 3 µm and 42 percent graphite greater than 75 µm.[10,11,12] Fugitive emissions from slagging are usually less than 100 µm.[10,11,12]

Fugitive particulate emission from the open hearth furnace process may have exit temperatures of 460-1800°F which also quickly cool before dispersing. Such fugitive emissions from an 80 foot height above the release point will have a vertical velocity of 175 fpm and a temperature of 52°F above ambient.[10,12] The fugitive particulate emissions have a mean diameter of 0.3-5.0 µm, of which 50-99 percent are less than 5 µm.[10,12]

Fugitive particulate emissions from an electric arc furnace process may have exit temperatures of 1000-3000°F but quickly cool before dispersing. Such fugitive emissions at a 90 to 137 foot height will have a vertical velocity of 200 to 500 fpm and a temperature in the range of ambient to 80°F above ambient.[10,13] The fugitive particulate emissions have a mean diameter of 0.3-5 μm (1.3 μm average), of which 59-99 percent are less than 5 μm.[10,13]

Fugitive emissions from scarfing are usually less than 2 μm and have an exit temperature of about 42°F above ambient.[12,14]

2.2.3.4 Control Methods--

Fugitive emissions from hot metal or molten steel reladling can be effectively controlled by a close-fitting, retractable ladle hood and a control device. For example, in one instance reladling for a 320 ton capacity furnace is controlled by a 125,000 acfm ladle hood and high energy scrubber. In comparison, canopy or local hoods to control the same reladling station would require a 300,000 acfm flow.[15]

For the BOF shop, once the emissions escape and disperse within the building they become difficult to capture, and the only effective means necessitates building evacuation. While this may be a preferred alternative from an operational viewpoint, and because of near complete capture of emissions, the disadvantages are the high ventilation rate and larger control equipment size required together with higher costs. Flow rates for such a system would be in excess of 995,000 acfm.[14] An alternative to building evacuation is complete enclosure of the furnace and tapping areas to control charging, tapping, ladle alloy additions and slagging. Furnace enclosures with drafts of approximately 350,000 acfm are currently operating effectively.[4] (Figure 2.2.3-5 illustrates a BOF total evacuation system.)

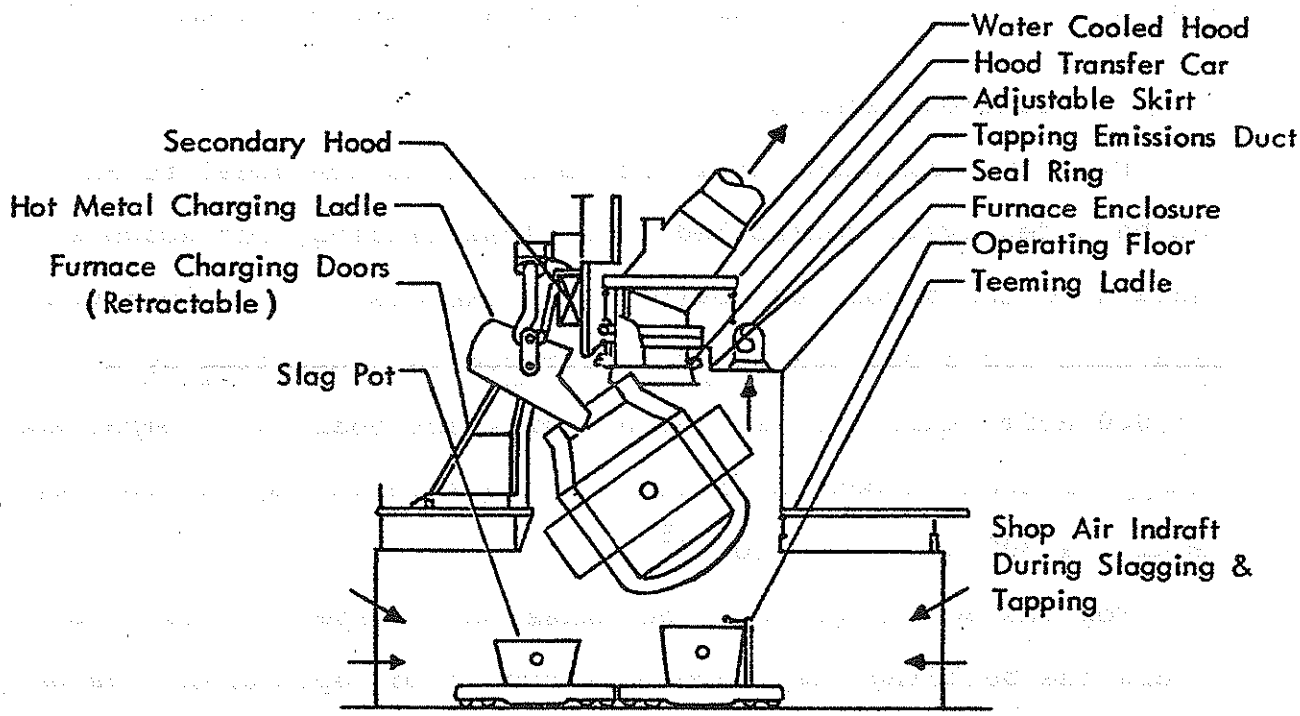

Figure 2.2.3-5. BOF total furnace enclosure system.[36]

Other control techniques for BOF shops include local or canopy hooding of the individual emission points. Secondary hoods can be used to control charging and tapping emissions. The collected emissions can be ducted to an existing or to a new collecting device. Many steel mills are redesigning and modifying existing systems rather than installing new facilities. Additional ductwork, larger air movers, and hooding changes are the main alterations to improve capture efficiency. "Puffing" emissions from the BOF during oxygen lancing will not occur if adequate draft is maintained. Similarly, the capture of charging emissions is enhanced by use of a "jaw" damper that increases draft at the charging aisle side of the main exhaust hood. (A BOF canopy hood system is shown in Figure 2.2.3-6.)

To control open hearth furnaces, complete or partial building evacuation is possible, but like the BOF shop, would require a very large airflow rate. Such a system would control all emission points to some degree. Canopy or local hooding of the charging doors and tapping area is an alternative and could be used to control furnace leaks as well. These hoods could be ducted to an existing control device or to separate systems.

Another control option for open hearth furnace fugitive emissions is operating precautions. Such precautions include computerization of checker reversals to optimize combustion, and the installation of pressure sensing devices for maintenance of a negative pressure environment in the furnace.

There are several control options for electric furnace melt shops. These include:

1. local hoods above the furnace,
2. roof or canopy hoods, and
3. building evacuation.

Each of these systems has advantages and disadvantages. Local and roof or canopy hoods can control charging and tapping

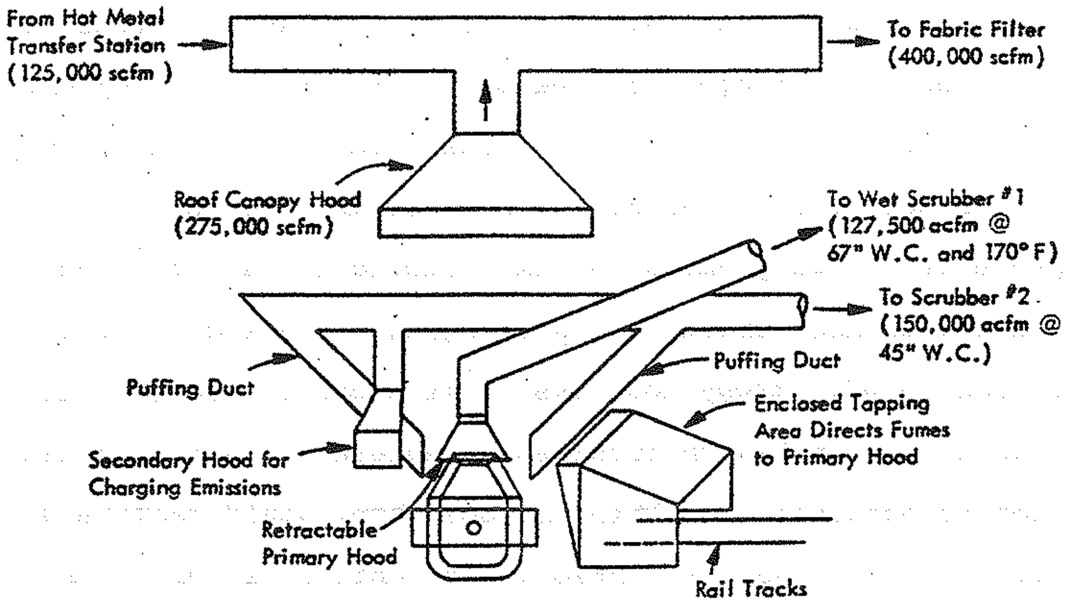

Figure 2.2.3-6. BOF canopy hood system.[37]

emissions but must be located so as to not interfere with normal operations.[16,17,18] Building evacuation can capture all fugitive emissions but at the expense of moving large volumes of air through larger size control equipment. Several electric furnace shops exhaust over 1 million ft^3/min. One installation handles 1.6 million ft^3/min at a capital cost of over $10 million.[18,19] Generally, flow rates for building evacuation range from about 3000 to 4000 scfm per ton of furnace capacity.[13] (Figure 2.2.3-7 depicts a building evacuation system on an electric furnace.)

A common control system is the use of both direct furnace evacuation and canopy hoods.[16,18,20] In designing the system, the canopy hood should be positioned as close above the source as possible without interfering with crane or other furnace tending operations. Thirty to forty feet between the furnace and the canopy is often necessary. Sheet metal partitions can be installed on three sides of the furnace to contain emissions and create a chimney effect. Flow rates are approximately 1,500 to 4,000 scfm per ton of furnace capacity. (Figure 2.2.3-8 shows an electric furnace canopy hood system.)

When a system such as direct shell evacuation is not used to capture emissions during melting and refining, canopy hoods alone may not be adequate and building evacuation may be necessary.

A promising capture technique is to enclose the furnace and evacuate the enclosure. This contains all emissions within the enclosure and accordingly requires less exhaust volume than for total building evacuation.

Building evacuation systems are estimated to achieve nearly 100 percent capture of the emissions from electric arc furnaces.

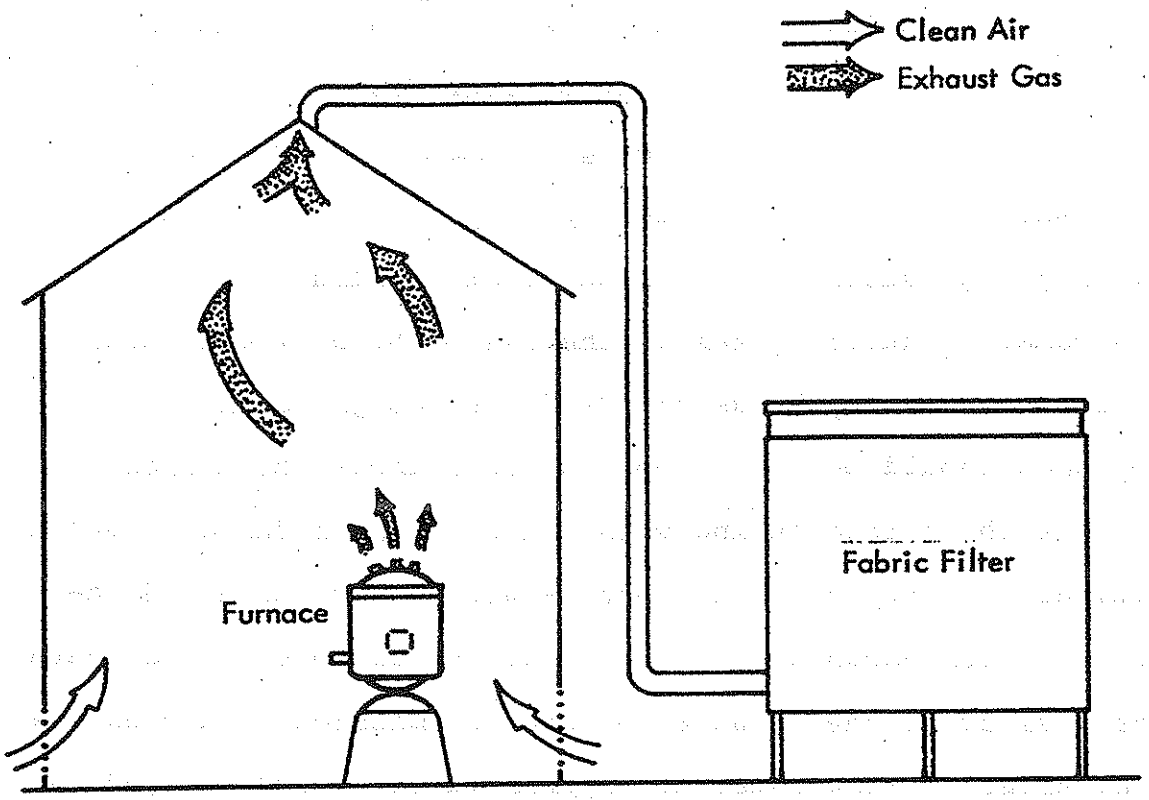

Figure 2.2.3-7. Electric furnace building evacuation system.[38]

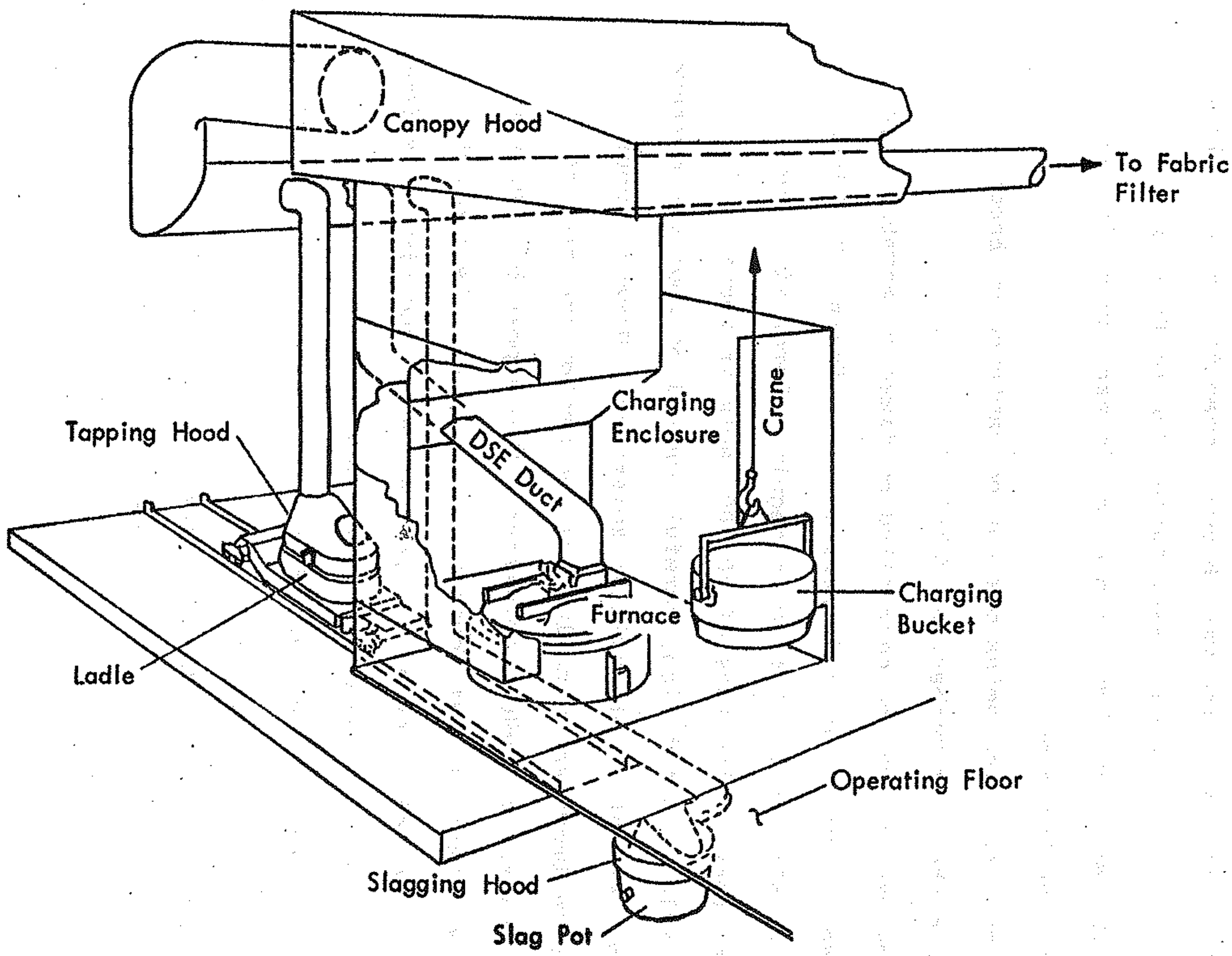

Figure 2.2.3-8. Electric furnace canopy hood system.[39]

A baghouse will collect 95 percent of the emissions. Canopy hoods have been estimated to capture 50 to 90 percent of the fugitive emissions from charging and tapping.[21] This estimate is based on judgment from visual observations; and, consequently, the range is wide. The efficiency will also vary between specific installations and from day to day for a given installation due to factors such as the volume of the emission plume, manner of furnace operation and cross drafts in the building.

Fugitive hand scarfing emissions can be captured by hooding and ducting to either a scrubber, or fabric filter.

Continuous casting can be controlled by fixed or movable hoods depending on space limitation and operating procedures. Building evacuation is an alternative but again requires large air flows. It is estimated that a flow rate of 500,000 acfm is required for each pouring aisle. In addition, careful control of pour temperature can help curtail evolution of fugitive emissions. However, pour temperature is an important metallurgical parameter and can not always be manipulated to reduce emissions. Where possible the use of mold release materials that contain little or no oils and other volatiles will also help prevent the generation of fugitive emissions. Conventional teeming operations are either uncontrolled or are inadvertently captured at steel manufacturing operations employing building evacuation control systems.

The available control techniques, their effectiveness, estimated costs, and RACM selections are summarized in Table 2.2.3-2.

TABLE 2.2.3-2. A SUMMARY OF THE CONTROL ALTERNATIVES, EFFICIENCIES AND COST, AND THE RACM SELECTIONS FOR FUGITIVE DUST EMISSIONS FROM SOURCES IN STEEL MANUFACTURING

Fugitive dust sources	Control alternatives	Control efficiency, %	Control costs, Jan. 1980, $		Cost benefit, $/lb	RACM selection
			Capital	Annualized		
(1) Scrap steel unloading, transfer and storage	Negligible source					No control
(2) Flux material unloading, transfer and storage	Negligible source					No control
(3) Molten pig iron transfer to charge ladles	Hooding, fabric filter	98[a]	968,000[b]	304,000[c]	2.72	Hooding, fabric filter
(4) Basic oxygen furnace, (charging, leaking, tapping, etc.)	Building evacuation, fabric filter	99[d]	9,432,000[e]	3,124,000[f]	4.35	Local hoods, vent to existing control device
	Furnace enclosure, fabric filter	92[g]	5,627,000[h]	1,452,000[i]	0.72	
	Local hoods, vent to existing furnace control device	60[g]	1,085,000[h]	290,000[i]	0.22	
(5) Open hearth furnace (charging, tapping, leaking, etc.)	Building evacuation, fabric filter	99[d]	9,432,000[e]	3,124,000[f]	98.61	Operating precautions
	Furnace enclosure, fabric filter	92[j]	5,627,000[j]	1,452,000[j]	49.32	
	Local hooding, vent to existing furnace control device	60[j]	1,085,000[j]	290,000[j]	15.10	
(6) Electric arc furnace (charging, leaking, tapping, etc.)	Building evacuation, fabric filter	99[g]	9,421,000[k]	3,264,000[l]	9.37	Furnace evacuation, fabric filter
	Canopy hoods, fabric filter	97[g]	5,763,000[k]	1,957,000[l]	5.73	
	Furnace evacuation, fabric filter	90[g]	2,228,000[k]	846,000[l]	2.67	
(7) Molten steel reladling	Hooding, fabric filter	98[a]	968,000[b]	304,000[c]	0.64 (leaded steel) 7.39 (unleaded steel)	Hooding, fabric filter (leaded steel) No control (unleaded steel)
(8) Continuous casting	Hooding, fabric filter	92[m]	2,476,000[n]	750,000[o]	1.68 (leaded steel) 19.40 (unleaded steel)	Hooding, fabric filter (leaded steel) No control (unleaded steel)
Conventional teeming	None	NA	NA	NA	NA	No control
(9) Scarfing (hand)	Hooding, control device	NA	NA	NA	NA	Hooding, control device[p]

(continued)

TABLE 2.2.3-2. (continued)

[a] Reference 22.

[b] Reference 23. Based on 189,000 tons of steel/yr.

[c] Reference 24. Based on 189,000 tons of steel/yr.

[d] Reference 25.

[e] Reference 26.

[f] Estimated.

[g] Reference 27.

[h] Reference 28. Based on 1,450,000 tons of steel/yr.

[i] Reference 29. Based on 1,450,000 tons of steel/yr.

[j] Assumed equivalent to BOF costs.

[k] Reference 28. Based on 293,000 tons of steel/yr.

[l] Reference 29. Based on 293,000 tons of steel/yr.

[m] Reference 30.

[n] Reference 31. Based on 511,500 tons of steel/yr.

[o] Reference 32. Based on 511,500 tons of steel/yr.

[p] Hooding, control device (wet or dry electrostatic precipitator, fabric filter, wet scrubber, etc.) is required only if hand scarfing is performed extensively; otherwise, no control is recommended.

2.2.3.5 Recommended Reasonably Available Control Measures (RACM)--

The RACM selections for steel manufacturing fugitive emission sources are presented in Table 2.2.3-2.

No controls are suggested for the scrap steel and flux material unloading, transfer and storage operations since these sources are very minor.

The control recommended for the transfer of molten pig iron to charge ladles is hooding the transfer area and collecting the emissions in a fabric filter.

The selected RACM for basic oxygen furnace charging, leaking and tapping emissions is the installation of local hoods that are vented to the existing primary control device for the furnace. This option presents the most reasonable cost of the three control techniques available and is more easily implemented than the other alternatives. If the capacity of the existing control device is inadequate, a new device may be required. However, this should also be less expensive than full enclosure of the furnace, although no cost data is available.

The RACM selected for open hearth furnace charging, leaking and tapping is operating precautions which consist of automating checker reversals and installing pressure sensors to maintain a negative pressure within the furnace. This should adequately control furnace leaks and provide some degree of control over charging emissions. Tapping emissions would be uncontrolled under this control option. This control method was selected because none of the other alternatives was deemed to be cost-effective, and such precautions are to be employed at one major Ohio open hearth furnace operation.

The RACM selected for electric arc furnace charging, leaking and tapping emissions is direct furnace evacuation to a fabric filter. This option offers very good control (90%) in addition to being the least expensive of the available control options.

The control recommended for the molten steel reladling station or continoous casting operations for leaded steels is hooding to a fabric filter. No control is recommended for these sources where unleaded steel is handled since the emissions are less, and other controls are not cost effective. No control is also recommended for conventional teeming due primarily to the infeasibility of installing controls on such operations.

The RACM recommended for fugitive emissions from hand scarfing is hooding and local exhaust to control device such as a wet or dry electrostatic precipitator, fabric filter or wet scrubber. However, this RACM selection is only for those operations which perform hand scarfing extensively. For those operations which perform hand scarfing infrequently (not on a regular production basis), installation of such controls will not be cost-effective; and, therefore, no control is warranted.

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APPENDIX FOR SECTION 2.2.3

Average OHF capacity in Ohio = 189,000 tpy
" BOF " " " = 1,450,000 tpy
" EAF " " " = 293,000 tpy

(1) Scrap steel unloading, transfer, and storage
No control

(2) Flux material unloading, transfer and storage
No control

(3) Molten pig iron transfer to charge ladles

Hooding, fabric filter (Reference 22)

Average process size = 600,000 tpy (avg. of OHF, BOF and EAF capacities)
Emissions = 0.19 (600,000) = 114,000 lbs/yr

$$\text{Capital cost} = 39{,}837.9\ (189{,}000)^{0.246}\ \frac{(249.6)}{(204.1)} = \$968{,}000$$

$$\text{Annual cost} = 15{,}910.3\ (189{,}000)^{0.162}\ \frac{(249.6)}{(204.1)} + .17\ (968{,}000) = \$304{,}000$$

$$C/B = \frac{\$304{,}000/yr}{.98\ (114{,}000)} = \$2.72/lb$$

(4) Basic oxygen furnace (charging, leaking, tapping)
Emissions = 0.5 (1,450,000) = 725,000 lbs/yr

Building evacuation, fabric filter (Reference 25)

$$\text{Capital cost} = \$7{,}713{,}000\ \frac{(249.6)}{(204.1)} = \$9{,}432{,}000$$

$$\text{Annual cost} = 1{,}243{,}600\ \frac{(249.6)}{(204.1)} + .17\ (9{,}432{,}000) = \$3{,}124{,}000$$

$$C/B = \frac{\$3{,}124{,}000/yr}{.99\ (725{,}000)} = \$4.35/lb$$

Charging / tapping emissions = 1.52 (1,450,000) = 2,204,000 lbs/yr

Furnace enclosure, fabric filter (Reference 27)

$$\text{Capital cost} = 8{,}578.1\ (1{,}450{,}000)^{0.443}\ \frac{(249.6)}{(204.1)} = \$5{,}627{,}000$$

$$\text{Annual cost} = 536.9\ (1{,}450{,}000)^{0.467}\ \frac{(249.6)}{(204.1)} + .17\ (5{,}627{,}000) = \$1{,}452{,}000$$

$$C/B = \frac{\$1{,}452{,}000/yr}{.92\ (2{,}204{,}000)} = \$0.72/lb$$

Local hoods, vent to existing furnace control device (Reference 27)

$$\text{Capital cost} = 163.8\ (1{,}450{,}000)^{0.606}\ \frac{(249.6)}{(204.1)} = \$1{,}085{,}000$$

$$\text{Annual cost} = 1{,}559.4\ (1{,}450{,}000)^{0.283}\ \frac{(249.6)}{(204.1)} + .17\ (1{,}085{,}000) = \$290{,}000$$

$$C/B = \frac{\$290{,}000/yr}{.6\ (2{,}204{,}000)} = \$0.22/lb$$

(5) Open hearth furnace (charging, tapping, leaking)

Emissions = 0.168 (189,000) = 32,000 lbs/yr

Building evacuation, fabric filter

See BOF

$$C/B = \frac{\$3{,}124{,}000/yr}{.99\ (32{,}000)} = \$98.61/lb$$

Furnace enclosure, fabric filter

See BOF

$$C/B = \frac{\$1{,}452{,}000/yr}{.92\ (32{,}000)} = \$49.32/lb$$

Local hooding, vent to existing furnace control device

See BOF

$$C/B = \frac{\$290{,}000/yr}{.60\ (32{,}000)} = \$15.10/lb$$

(6) Electric arc furnace (charging, leaking, tapping)

Emissions = 1.2 (293,000) = 352,000 lbs/yr

Building evacuation, fabric filter (Reference 27)

$$\text{Capital cost} = 11{,}932.0\ (293{,}000)^{0.514}\ \frac{(249.6)}{(204.1)}$$
$$= \$9{,}421{,}000$$

$$\text{Annual cost} = 905.7\ (293{,}000)^{0.581}\ \frac{(249.6)}{(204.1)}$$
$$+ 0.17\ (9{,}421{,}000)$$
$$= \$3{,}264{,}000$$

$$C/B = \frac{\$3{,}264{,}000/yr}{.99\ (352{,}000)} = \$9.37/lb$$

Canopy hoods, fabric filter (Reference 27)

$$\text{Capital cost} = 1{,}438.9\ (293{,}000)^{0.643}\ \frac{(249.6)}{(204.1)}$$
$$= \$5{,}763{,}000$$

$$\text{Annual cost} = 106.3\ (293{,}000)^{0.709}\ \frac{(249.6)}{(204.1)}$$
$$+ .17\ (5{,}763{,}000)$$
$$= \$1{,}957{,}000$$

$$C/B = \frac{\$1{,}957{,}000/yr}{.97\ (352{,}000)} = \$5.73/lb$$

Furnace evacuation, fabric filter (Reference 27)

$$\text{Capital cost} = 95.5\ (293{,}000)^{0.783}\ \frac{(249.6)}{(204.1)}$$
$$= \$2{,}228{,}000$$

$$\text{Annual cost} = 22.7\ (293{,}000)^{0.773}\ \frac{(249.6)}{(204.1)}$$
$$+ 0.17\ (2{,}228{,}000)$$
$$= \$846{,}000$$

$$C/B = \frac{\$846{,}000/yr}{.9\ (352{,}000)} = \$2.67/lb$$

(7) Molten steel reladling
Emissions (leaded) = 0.81 (600,000) = 486,000 lbs/yr

Hooding, fabric filter

See (3)

$$C/B = \frac{\$304{,}000/yr}{.98\ (486{,}000)} = \$0.64/lb$$

Emissions (unleaded) = 0.07 (600,000) = 42,000 lbs/yr

Hooding, fabric filter

See (3)

$$C/B = \frac{\$304,000/yr}{.98\ (42,000)} = \$7.39/lb$$

(8) Continuous casting

Emissions (leaded) = 486,000 lbs/yr
Emissions (unleaded) = 42,000 lbs/yr

Hooding, fabric filter (Reference 30)

$$\text{Capital cost} = 1,457,337\ (511,500)^{0.025}\ \frac{(249.6)}{(204.1)} = \$2,476,000$$

$$\text{Annual cost} = 226,810.3\ (511,500)^{0.013}\ \frac{(249.6)}{(204.1)} + .17\ (2,476,000) = \$750,000$$

$$C/B\ (\text{leaded}) = \frac{\$750,000/yr}{.92\ (486,000)} = \$1.68/lb$$

$$C/B\ (\text{unleaded}) = \frac{\$750,000/yr}{.92\ (42,000)} = \$19.40/lb$$

(9) Scarfing
No data