2.3 LIME PLANTS

2.3.1 Process Description[1]

Lime (CaO or $CaO \cdot MgO$) is manufactured by calcining limestone ($CaCO_3$ or $CaCO_3 \cdot MgCO_3$) to release carbon dioxide. Three grades of limestone are used in lime manufacture: high calcium or calcite where the magnesium carbonate content is less than 5 percent; magnesium limestone where magnesium carbonate is 5 to 50 percent; and dolomitic limestone or dolomite where magnesium carbonate is 30 to 40 percent. Regardless of grade, the basic process remains the same and is illustrated in Figure 2.3-1.

More than 90 percent of the lime plants are located in close proximity to a limestone quarry. At the quarry, the natural limestone deposits are extracted through a series of physical operations. The basic operations are drilling and blasting. The stone may be crushed and screened before shipment to the lime plant. Quarrying operations are discussed in Section 2.18.

In the United States, limestone is calcined in either rotary or vertical (shaft) kilns. Rotary kilns predominate and require secondary crushing of the feed limestone. Most vertical kilns require only primary crushing of the feed although some are designed to require secondary crushing.

Rotary kilns are long, inclined steel cylinders lined with refractory brick and supported on rollers. The feed limestone flows countercurrent to hot combustion gases, with pebble-size limestone added at one end and hot combustion gases entering the other end. Rotary kilns may be fueled with coal, oil or gas.

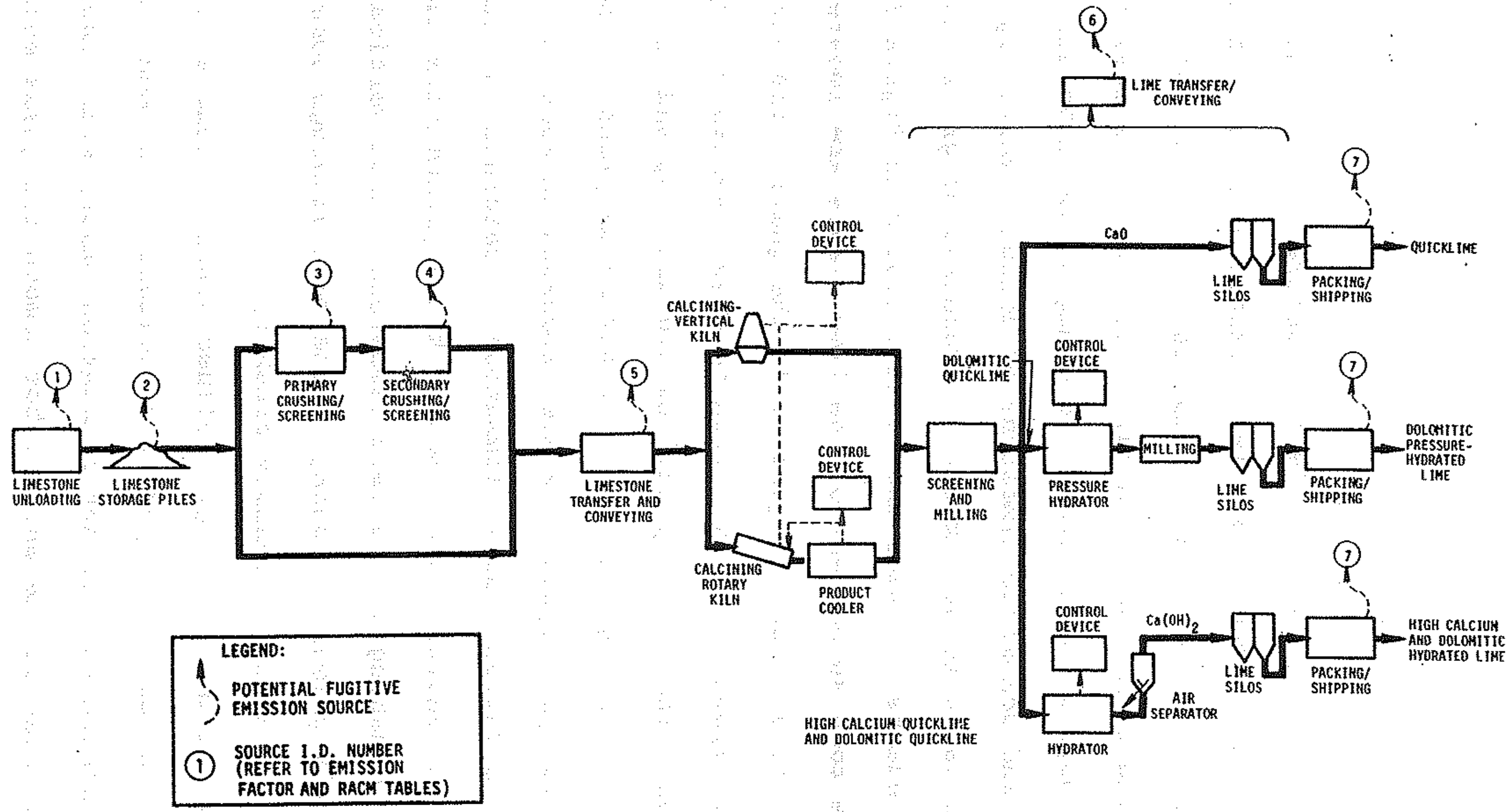

Figure 2.3-1. Process flow diagram and fugitive emission sources for lime manufacturing.

TABLE 2.3-1. FUGITIVE DUST EMISSION FACTORS FOR LIME MANUFACTURING

	Source	Emission factor	Reliability rating	Reference
(1)	Unloading	0.03 - 0.4 lb/ton unloaded	E	2
(2)	Limestone storage[a]			
	Loading onto pile	0.04 lb/ton loaded	D	3
	Vehicular traffic	0.12 lb/ton stored	D	3
	Loading out	0.05 lb/ton loaded out	D	3
	Wind erosion	0.10 lb/ton stored	D	3
(3)	Primary crushing	0.5 lb/ton crushed	C	4
(4)	Secondary crushing and screening	1.5 lb/ton crushed[b]	C	5
(5)	Limestone conveying and transfer	0.8 lb/ton lime produced	E	6
(6)	Product transfer and conveying[c]	0.1 lb/ton lime produced	E	7
(7)	Packaging and shipping[d]	0.25 lb/ton shipped	E	8

[a] Assuming PE = 101, $K_1 = 0.75$, $K_2 = 0.75$, $K_3 = 0.75$, S = 2, D = 60.

[b] Based upon raw material entering primary crusher.

[c] Includes leaks from mills and feed/discharge exhausts.

[d] Includes storage silo vents.

factors is EPA's "Technical Guidance for Control of Industrial Process Fugitive Particulate Emissions." The emission factor reliability rating indicates that these are engineering estimates applicable only to a group of such sources and of questionable accuracy for site-specific estimates.

The emission factor for unloading operations is based upon those developed for similar processes through engineering judgment or visual observation. This estimate would be considered of fair reliability on a source-specific basis. It is unclear from the referenced source how the emission factor for storage piles was derived,but it has a rather low reliability rating indicating that it is based on limited data and engineering judgment. The emission factors for primary crushing operations and for secondary crushing and screening are based upon very limited data for crushing of granite and would be considered of fair reliability. The emission factor for raw material transfer and conveying is based on data from a similar operation and on engineering judgment and should,therefore,be considered of poor reliability. The factor for packaging and shipping is based upon data for hydraulic cement and engineering judgment. The reliability of this factor is also poor.

Haul roads are discussed in detail in Section 2.1 and are not addressed here.

2.3.3 Particle Characterization

Fugitive particulate emissions from limestone storage, handling and transfer typically have a mean particle diameter of

There are three distinct zones in a rotary kiln: the feed and drying zone, the central or preheating zone and the calcining zone. Product coolers are used to recover heat from the calcined lime.

Vertical kilns, which are fueled by oil or natural gas, have four distinct zones from top to bottom: the stone storage zone, the preheating zone, the calcining zone and the cooling and discharge zone. The flow of stone in the kiln is countercurrent to the flow of cooling air and combustion gases. The stone is charged at the top and preheated by the hot exhaust gases from the calcining zone. Air blown into the bottom of the kiln cools the lime before it is discharged. This air is heated sufficiently by the time it reaches the calcining zone to be used as secondary combustion air.

In both vertical and rotary kilns, the temperature in the feed end is kept below 1000°F, and the temperatures in the preheating and calcining zones are between 2000° and 2400°F. Higher temperatures are found in shorter kilns. At these temperatures, limestone disassociates to quicklime and carbon dioxide.

$$CaCO_3 \rightarrow CaO + CO_2$$

Most of the calcined lime or quicklime is screened, milled and transferred pneumatically or by belt conveyor to storage silos, where it is kept until it is shipped. Fines from calcination can be briquetted, fed to a hydrator or pulverized, as the market demands.

About 10 percent of all the lime produced is converted to hydrated (slaked) lime.

$$CaO + H_2O \rightarrow Ca(OH)_2$$

In the hydration process, water is added to crushed or ground quicklime in a mixing chamber (hydrator). The slaked lime is dried by the heat of the hydration reaction, and is conveyed to an air separator in preparation for final shipment. Dolomitic, pressure-hydrated lime has an additional milling step prior to shipment. Atmospheric hydrators are operated continuously; pressure hydrators are operated in a batch mode.

For shipping, the quicklime and hydrated lime products are packaged in bags and handled in bulk by truck, rail, ship or barge.

Lime manufacturing plants have capacities between 50 and 650 tons per day. Plants usually operate 24 hours per day for 6 or 7 days a week.

At the lime plant, the sources of fugitive emissions include raw material unloading, open storage piles, crushing, screening, conveying and transfer operations, packaging and shipping operations and haul roads. These are indicated in Figure 2.3-1. Quarrying the limestone also produces fugitive emissions, but these sources are treated in Section 2.1.4.

2.3.2. Fugitive Dust Emission Factors

The estimated emission factors for the lime manufacturing fugitive dust sources as identified in Section 2.3.1 are summarized in Table 2.3-1. The source of most of these emission

3 to 6 µm, 45 to 70 percent of which are less than 5 µm.[9]

The following information pertaining to stack emission characteristics is presented since it is likely that the data closely parallels that of fugitive emissions.[10,11]

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

Data on the characteristics of the particles emitted from other sources are not available.

The American Conference of Governmental Industrial Hygienists has identified limestone particles as nontoxic nuisance particulates if other toxic impurities are not present.[12] However, data on other toxic materials that may be associated with limestone were not available. Lime dust has been identified as a potential health hazard at concentrations above 5 $\mu g/m^3$.[13]

2.3.4 Control Methods[14]

Emissions from limestone unloading are generally not controlled. Building enclosures may be used to reduce emissions. Liquid sprays are also sometimes used to suppress emissions during unloading. Occasionally, the unloading area is vented to a baghouse.

The limestone is nearly always stored in stockpiles, a source of fugitive particulate emissions, but in some cases it may be stored in silos. Liquid spraying of the material before discharge onto the storage pile is often practiced to reduce the emission potential. Telescoping chutes, adjustable stacker conveyors and stone ladders are possible ways to reduce emissions from loading onto the raw material storage piles. All of these devices reduce the free-fall distance and, hence, the fugitive emissions. These devices are described in Section 2.1.

Emissions from conveying are minimal, but the belts are sometimes partially covered as an emission reduction measure. Emissions caused by transfer of materials from one conveyor belt to another are most often controlled by enclosure or water sprays, with an increasing trend toward control by venting the transfer point to a baghouse.

Primary crushers and secondary crushers and screens are often located below grade. This constitutes a windbreak and reduces the carry-out and impact of the emissions. Suppression of dusts by water sprays at the feed points of these operations is very common. Emissions from primary crushers are sometimes controlled by wet scrubbers or fabric filters. An increasing number of plants are venting the discharge points of secondary crushing and screening to a fabric filter.

Particulates entrained in the air displaced during loading of the silos are controlled by fabric socks on the vents. In pneumatic systems the lime silo transport air is often exhausted through a fabric filter.

During packaging and processing for bulk shipment, the emissions that arise are frequently controlled by aspiration through fabric filters. Many lime plants use a gravity-feed fill spout mechanism that has outer concentric aspiration ducts to vent the dust to a fabric filter. This device has been markedly successful in reducing emissions during packing and shipping.[15]

Transfer, conveying and screening of the finished quicklime and slaked lime can be a considerable fugitive emission problem if these sources are not properly enclosed and exhausted. Nearly all plants completely enclose the conveyor systems, which are most often belt-type; and many of them also enclose transfer points and screens and exhaust the emissions to fabric filters.

Table 2.3-2 summarizes the available control techniques, their effectiveness, estimated costs and RACM selections.

2.3.5. Recommended Reasonably Available Control Measures (RACM)

The RACM selections for lime plant fugitive sources are presented in Table 2.3-2. As indicated, the recommended control for truck unloading, stockpiling, primary crushing, secondary crushing/screening and transfer and conveying operations of the limestone is a wet dust suppression system utilizing a chemical wetting agent. This system gives good control efficiency (estimated 90%[29]) and reduces visible emissions to almost zero opacity.[22] The system of enclosures with venting to fabric filters for the sources mentioned above would be slightly more

TABLE 2.3-2. A SUMMARY OF THE CONTROL ALTERNATIVES, EFFICIENCIES AND COSTS, AND THE RACM SELECTIONS FOR FUGITIVE DUST EMISSIONS FROM LIME PLANTS

Fugitive dust sources	Control alternatives	Control efficiency, %	Control costs, Jan., 1980 $		Cost benefit, $/lb	RACM selection
			Capital	Annualized		
(1) Limestone unloading (truck)	Enclosure, vent to fabric filter	99[a,b]	87,400[c]	21,000[d]	0.22	Wet suppression (chemical)
	Wet suppression (chemical)[e]	95[f,g]	64,000[h]	15,700[i]	0.01	
	Enclosure	50[j]	15,000[k]	2,600[l]	0.05	
(2) Limestone storage piles						
Loading onto piles	Enclosure	70-99[m]	950,000[n]	162,000[l]	2.75	Wet suppression (chemical)
	Wet suppression (chemical)	80-90[m]	o	o	0.01	
	Adjustable chutes	75[m]	44,000[p]	7,500[l]	0.56	
Loading out	Wet suppression (chemical)	80-90	o	o	0.01	Wet suppression (chemical)
	Gravity feed onto conveyor	80[m]	q	q	Not Available	
Wind erosion	Enclosure	95-99[m]	r	r	2.75	Watering
	Wet suppression (chemical)	90[m]	6,000[s]	8,000[p]	0.20	
	Watering	50[m]	5,000[s]	2,600[p]	0.12	
(3) Primary crushing and screening	Wet suppression (chemical)	90[t]	o	o	0.01	Wet suppression (chemical)
	Enclosure, vent to fabric filter	95[u]	130,000[v]	33,000[w]	0.03	

(continued)

TABLE 2.3-2. (continued)

Fugitive dust sources	Control alternatives	Control efficiency, %	Control costs, Jan., 1980 $ Capital	Annualized	Cost benefit, $/lb	RACM selection
(4) Secondary crushing and screening	Wet suppression (chemical)	90[t]	o	o	0.01	Wet suppression (chemical)
	Enclosure, vent to fabric filter	95[u]	x	x	0.03	
(5) Limestone conveying and transfer	Wet suppression (chemical)	90[t]	o	o	0.01	Wet suppression (chemical)
	Enclosure, vent to fabric filter	95[u]	x	x	0.03	
(6) Product transfer, conveying and screening	Enclosure, vent to fabric filter	95[y]	45,000[z]	12,000[aa]	0.50	Enclosure, vent to fabric filter
	Pneumatic conveying	99[bb]	99,000[cc]	21,200[dd]	0.85	
(7) Packaging and shipping	Vent to fabric filter	99[ee]	64,000[ff]	18,000[gg]	0.29	Vent to fabric filter
	Choked feed, aspiration to fabric filter	99[m]	96,000[hh]	23,500[i]	0.38	
Haul roads	Wet suppression (chem.)	50[ii]	jj	jj		Wet-suppression (chemical), oiling or paving; and good housekeeping
	Watering	50[ii]	jj	jj		
	Oiling	85[ii]	jj	jj		
	Paving	85[ii]	jj	jj		

(continued)

TABLE 2.3-2. (continued)

a Reference 16.
b No visible emissions after control per Reference 17.
c Based upon 20'x20'x15' enclosure and a jet pulse baghouse treating 10,000 acfm @ 70° with a 6.5 to 1 air/cloth ratio.
Data from References 18 and 19.
d Reference 20. Based on 3000 h/yr operation.
e Note that wet suppression systems are not applicable to throughput rates less than 75 ton/h.
f Reference 21.
g Visible emissions reduced to 0% (5% opacity observed on rare occasions). Reference 22.
h Reference 23. Based on 150 ton/h throughput capacity. Includes application at unloading, primary crusher inlet and outlet, secondary crusher inlet and outlet, stockpile loadout, and transfer points.
i Reference 24. Based on 3000 h/yr operation.
j Estimated.
k Reference 25. Based on 20'x20'x30' enclosure.
l Includes capital charges only.
m Reference 26.
n Reference 27. Based on average storage at 12,000 tons.
o The costs are included in the figure for wet suppression of unloading.
p Reference 27.
q Costs not available. A common practice at rock processing plants (limestone).
r Costs included in enclosure for loading onto piles.
s Reference 28.
t Reference 29.
u Reference 30.
v Reference 16. Based on 20,000 acfm and control of secondary crushing and screening, and limestone conveying and transfer.
w Reference 20. Based on 3000 h/yr operation.
x Costs for this system included in figures for primary crushing control.
y Assumed same as control of limestone transfer and conveying.
z Reference 16. Based on 5000 acfm.
aa Reference 20. Based on 3000 h/yr operation.
bb Assumed with control of conveying air by fabric filter.
cc Estimated based on Reference 31.
dd Estimated based on Reference 31, assuming 5,000 for operation and maintenance.
ee Estimated based on Reference 32. Includes aspiration of filler spouts.
ff Reference 16. Based on 10,000 acfm.
gg Reference 20. Based on 3000 h/yr operation
hh Reference 27.
ii Reference 33.
jj See Section 2.1.

effective (95%[30]) but would be much more costly to install. Comparative capital costs are $70,000 for the wet suppression system versus $217,400 for the fabric filter system on a 150 ton per hour limestone processing rate. Annualized costs are $23,700 for the wet suppression system versus $54,000 for the fabric filter system. A diagram of a wet suppression system as applied on limestone handling operation at a lime plant is given in Figure 2.3-2. A further justification is the fact that many lime plants utilize wet dust sprays in one form or another.[34]

The recommended control for lime product transfer, conveying and screening operations is enclosure with venting to a fabric filter designed to achieve .030 gr/dscf outlet or no visible emissions. Most plants already utilize enclosures on the product conveyors transfer points and screens and may vent these to fabric filters.[35] This system offers not only control of the emission source but also the added benefit of product recovery. The costs may be much less than indicated if a plant can vent the collected emissions to an existing collection device on associated product operations (i.e.,grinders, screens, air separators and elevators).

The recommended control technique for packaging and shipping operations varies by type of operation. For loading of trucks and rail cars, concentric aspiration to a fabric filter is the recommended control based on economics and control efficiency. For bagging operations, the recommended control is the venting of the bagging equipment to a fabric filter. While

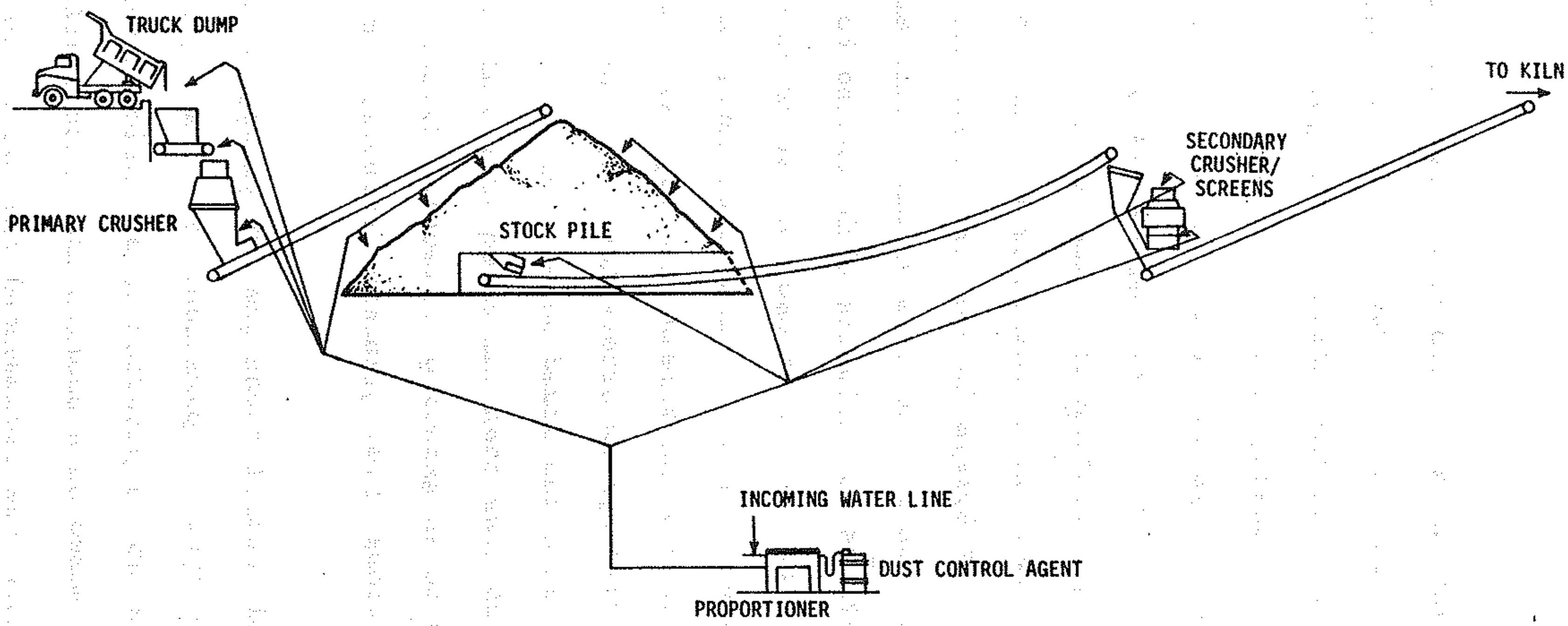

Figure 2.3-2. Wet dust suppression system applied on a lime plant.

Note: Wet suppression at fine mesh screens must be regulated properly to avoid blinding of screens.

expensive, this technique is very effective and offers the advantage of product recovery. It has been applied at several lime plants.[36] Both systems should be designed to achieve zero percent opacity or 0.030 gr/dscf outlet.

The control of haul road fugitive emissions can be either oiling, the use of wet suppression (chemical) or permanent paving. For roadways used constantly, a paving program followed by a good housekeeping program can best reduce emissions. Good housekeeping would include covering of haul trucks, periodic sweeping of the paved surface and prompt cleanup of spills. For temporary roads, a program of oiling or wet suppression (chemical) is recommended. This program is used at many lime plants and can be very economical if waste crusher oil can be utilized.[37]

REFERENCES FOR SECTION 2.3

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19. GARD, Inc. Capital and Operating Costs of Selected Air Pollution Control Systems. EPA-450/3-76-014, May 1976, pp. 4-24 to 4-28, 4-34 to 4-36, 4-89.

20. Op. cit. Reference 13. p.3-5.

21. Ibid. p. A-13.

22. Op. cit. Reference 15, p. 3-39.

23. Op. cit. Reference 13. p. 4-9.

24. Ibid. p. 4-12.

25. Op. cit. Reference 17. p. 4-25.

26. Op. cit. Reference 1. pp. 2-38 and 2-39.

27. Ibid. p. 2-39 and 2-40.

28. PEDCo Environmental, Inc. Source Evaluation in Region IV Non-Attainment Areas to Determine TSP Emission Reduction Capabilities. Prepared for U.S. Environmental Protection Agency, Research Triangle Park, North Carolina. Contract No. 68-02-2603, Task No. 2, June 1978. p. 2-87.

29. Op. cit. Reference 15. p. 3-15.

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

31. Minick, L. J. Control of Particulate Emissions from Lime Plants. In: 63rd Annual Meeting of the Air Pollution Control Association, St. Louis, June 1979. p. 19.

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

33. Ibid. p. 2-27.

34. Op. cit. Reference 29. p. 8.

35. Op. cit. Reference 1. p. 2-305, 2-307.

36. Op. cit. Reference 29. Appendix III.

37. Ibid. p. 16.

1 Limestone unloading (truck)

Emissions = (0.215 lb/ton)(150 tph)(3,000 hpy) = 96,750 lbs/yr

Enclosure, vent to fabric filter

Assume an enclosure area = 20' x 15' x 20'
Total area (10 Ga plate skirts) = 1400 ft^2
Mass = (1,400 ft^2)(5.625 lb/ft^2)(1.2) = 9,450 lbs
Cost (labor & materials) = (0.208/lb + 0.30/lb)(9,450)
= \$4,800

Top L/W = 1.333   L = 20'   Area = 800 ft^2
Mass = (800 ft^2)(5.625 lb/ft^2)(1.2) = 5,400 lbs
Cost (materials) = (20ft)(11/ft) + (.208/lb)(5,400)
= \$1,350
Cost (labor) = \$1,200
Total cost = \$2,550
Total enclosure direct cost = \$7,350
1 elbow @ \$260
Installed = 1.75 (260) = \$500
Total direct costs (enclosure & elbow) = \$7,850

$$\text{Turnkey} = 1.4\ (7{,}850)\ \frac{(249.6)}{(192.1)} = \$14{,}000$$

Baghouse turnkey cost (@ 10,000 acfm @ 70°F)

$$= \$60{,}000\ \frac{(249.6)}{(204.1)} = \$73{,}400 \quad \text{NMI}$$

Capital cost = \$73,400 + 14,000 = \$87,400
Annual cost (p. 3-5, NMI @ 3,000 hpy)

$$= \$15{,}000\ \frac{(249.6)}{(204.1)} + (.17)(14{,}000)$$

$$= \$21{,}000$$

$$C/B = \frac{\$21{,}000/yr}{.99\ (96{,}750)} = \$0.22/lb$$

Wet suppression (chemical)

Design at 75 tph throughput
Dust suppressant spray at unloading, primary crusher inlet and outlet, stockpile loadout, secondary crusher inlet and outlet and conveyor transfer points.

$$\text{Capital cost} = \$52{,}000\ \frac{(249.6)}{(204.1)} = \$64{,}000 \text{ p. 4-8, NMI}$$

$$\text{Annual cost} = \$12{,}810\ \frac{(249.6)}{(204.1)} = \$15{,}700 \text{ p. 4-11, NMI}$$

$$C/B = \frac{\$15{,}700/yr}{91{,}913 + 15{,}300 + 19{,}125 + 202{,}500 + 607{,}500 + 181{,}500} = \$0.01/lb$$

Enclosure

Assume a required 20' x 20' x 30' enclosure of 10 Ga steel (density = 5.625 lb/ft^2)

Mass = [(20' x 20')3 + (20' x 30')(2)](5.625)
= 13,500

Assume 20% excess for structurals

Mass = (13,500)(1.2) = 16,200 lbs

Cost (materials) = (16,200)(.208/lb) p. 4-25, GARD
= $3,400

Cost (labor) = (16,200)(0.30/lb) p. 4-25, GARD
= $4,900

Total direct capital cost = $8,300

Indirect capital cost @ 40% = $3,300

$$\text{Capital cost} = 11{,}600 \; \frac{(249.6)}{(192.1)} = \$15{,}000$$

Annual cost = 0.17(15,000) = $2,600

No O & M cost

$$C/B = \frac{\$2{,}600/yr}{.5\ (96{,}750)} = \$0.05/lb$$

2 Limestone storage piles
Emissions = 18,000 lbs/yr

Loading onto piles

Enclosure

Cost for enclosure ranges between 3.04 to 7.22 ft^3 of capacity (Reference 1, p. 2)

Use average value of $\$5.13/ft^3$

Assume avg. of 12,000 tons in storage
(10 days)(8 hpd)(150 t/h)

Density of limestone = 169 lb/ft^3

$$\text{Volume of pile} = \frac{12{,}000\ (2{,}000)}{169} = 142{,}000\ ft^3$$

Capital cost = (142,000 ft^3)($\$5.13/ft^3$) = $730,000

$$\$730{,}000 \; \frac{(249.6)}{(192.1)} = \$950{,}000$$

Annual cost = .17(950,000) = $162,000

$$C/B = \frac{\$162{,}000/yr}{0.85\ (18{,}000) + 0.97\ (45{,}000)} = \$2.75/lb$$

Adjustable chutes

$$\text{Capital cost} = \frac{26{,}000 + 42{,}000}{2} = \$34{,}000 \quad \text{Ref. 1, p. 2-40}$$

$$= 34{,}000 \frac{(249.6)}{(192.1)} = \$44{,}000$$

Annual cost = .17 (34,000) = $7,500

$$C/B = \frac{\$7{,}500/yr}{.75\ (18{,}000)} = \$0.56/lb$$

Wet suppression (chemical)

See (1)
C/B = $0.01/lb

Loading out
Emissions = 22,500 lbs/yr

Wet suppression (chemical)

See (1)
C/B = $0.01/lb

Gravity feed onto conveyor
Costs not available

Wind erosion
Emissions = 45,000 lbs/yr

Enclosure

See enclosure for loading onto piles in (2)
C/B = $2.75/lb

Wet suppression (chemical)

Assume 109,000 tons/yr throughput
Initial cost = $5,000 (Reference 28, p. 2-87)

$$\text{Capital cost} = \$5{,}000 \frac{(249.6)}{(204.1)}$$

$$= \$6{,}000$$

Annual cost (@ $0.05/ton) =

$$[(109{,}000)(.05) + .17\ (6{,}000)] \frac{(249.6)}{(204.1)}$$

$$= \$8{,}000$$

Watering

Capital cost = \$5,000 (Reference 28)
Annual cost (@ \$0.01/ton) =
(109,000)(.01) + \$1,000 = \$2,100

$$\$2{,}100 \frac{(249.6)}{(204.1)} = \$2{,}600/\text{lb}$$

$$C/B = \frac{\$2{,}600/\text{yr}}{.5\ (45{,}000)} = \$0.12/\text{lb}$$

(3) Primary crushing and screening
Emissions = 225,000 lbs/yr

Wet suppression (chemical)

See (1)
C/B = \$0.01/lb

Enclosure, vent to fabric filter

Costs include controls for primary crushing, secondary crushing/screening and conveyor/transfer points (@ 110,000 tpy; 20,000 acfm), NMI

$$\text{Capital cost} = 105{,}412 \frac{(249.6)}{(204.1)} = \$130{,}000$$

$$\text{Annual cost} = 26{,}867 \frac{(249.6)}{(204.1)} = \$33{,}000$$

$$C/B = \frac{\$33{,}000/\text{yr}}{.95\ (225{,}000) + .95\ (675{,}000) + .95\ (201{,}600)}$$

$$= \$0.03/\text{lb}$$

(4) Secondary crushing and screening
Emissions = 675,000 lbs/yr

Wet suppression (chemical)

See (1)
C/B = \$0.01/lb

Enclosure, vent to fabric filter

See (3)
C/B = \$0.03/lb

(5) Limestone conveying and transfer
Emissions = 201,600 lbs/yr

Wet suppression (chemical)

See (1)
C/B = $0.01/lb

Enclosure, vent to fabric filter

See (3)
C/B = $0.03/lb

(6) Product transfer, conveying and screening
Emissions = 25,200 lbs/yr

Enclosure, vent to fabric filter

Assume airflow of 5,000 acfm(NMI)

$$\text{Capital cost} = 37{,}000 \frac{(249.6)}{(204.1)} = \$45{,}000$$

$$\text{Annual cost} = 9{,}800 \frac{(249.6)}{(204.1)} = \$12{,}000$$

$$C/B = \frac{\$12{,}000/yr}{.95\ (25{,}200)} = \$0.50/lb$$

Pneumatic conveying

Capital cost = $99,000 (Reference 31)
Annual cost = $21,200 (Reference 31)

$$C/B = \frac{\$21{,}200/yr}{.99\ (25{,}000)} = \$0.85/lb$$

(7) Packing and shipping
Emissions = 63,000 lbs/yr

Vent to fabric filter

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

$$\text{Annual cost} = \$14{,}500 \frac{(249.6)}{(204.1)}$$
$$= \$18{,}000$$

$$C/B = \frac{\$18{,}000/yr}{.99\ (63{,}000)} = \$0.29/lb$$

Choked feed, aspiration to fabric filter

Capital cost = $96,000
Annual cost = $23,500

$$C/B = \frac{\$23{,}500/yr}{.99\ (63{,}000)} = \$0.38/lb$$

2.4 POWER PLANTS

2.4.1 Process Description

Steam-electric generating plants in the United States may utilize a variety of fuels including coal, oil, gas and fissionable material. However, from a fugitive dust standpoint, only the plants fired with coal are of significance. The basic flow diagram of the power generation cycle for use of coal is illustrated in Figure 2.4-1.

The first step in the coal-fired power plant cycle is extraction of the coal. Coal is mined by several different methods including strip mining, underground mining and auger mining. After extraction the coal may be physically cleaned before loading for transportation to the power plant.

Coal may be transported to the power plant by trucks, pipeline, conveyor, rail or barge. After delivery, the coal is usually stored in storage piles. The coal is then moved from the storage pile to feed hoppers by a system of hoppers, stackers and conveyors. From the feed hoppers the coal is crushed, weighed, pneumatically conveyed to pulverizers and thereafter combusted in the boilers.

In the burning of coal, impurities present in the feed coal may not be combusted. The mineral ash and other noncombusted materials are usually collected and either slurried with water and pumped to a disposal pond or collected dry and trucked to a disposal area.

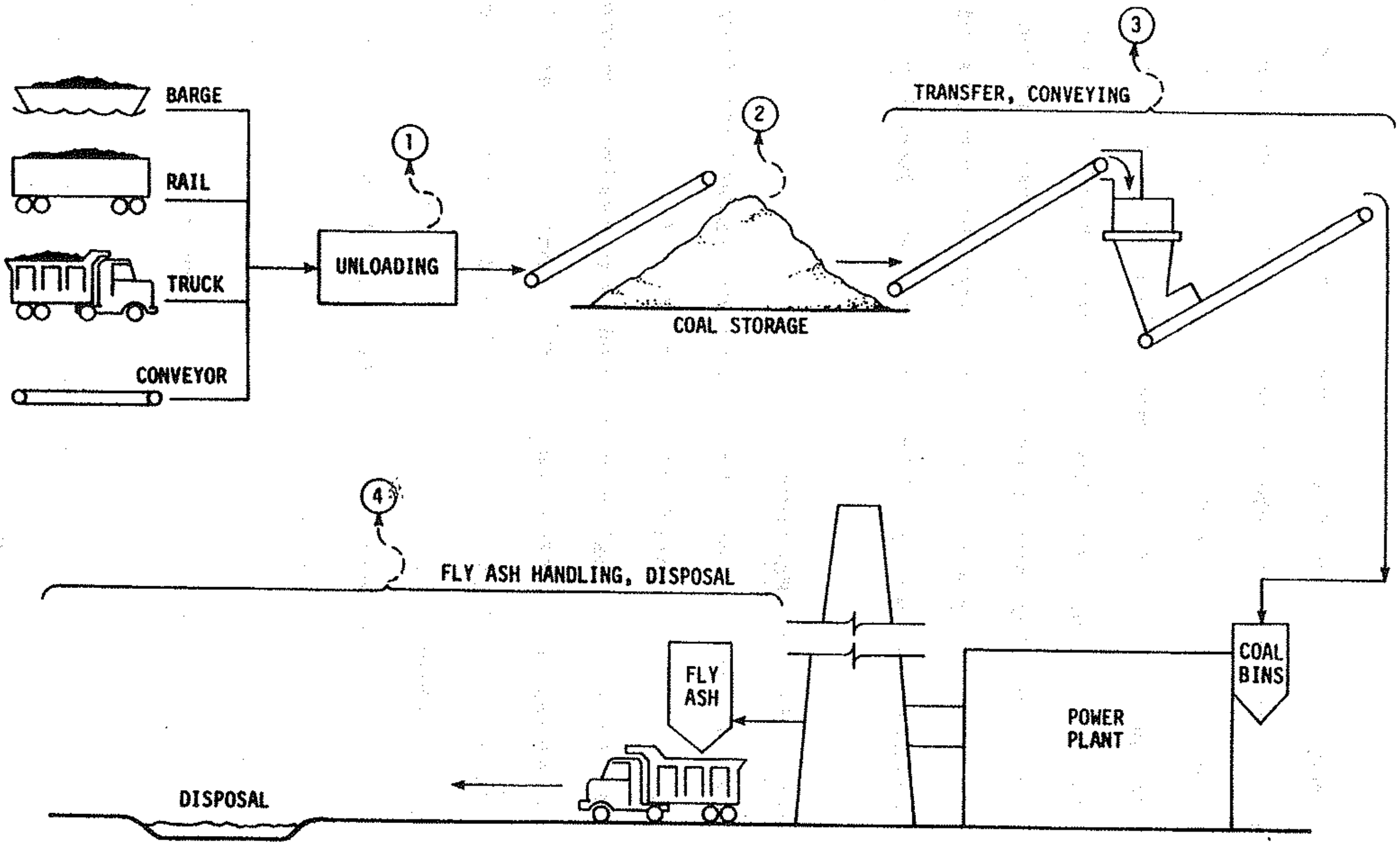

Figure 2.4-1. Simplified process flow diagram of coal-fired power plants and associated fugitive particulate emission sources.

A typical power plant has a generating capacity of about 500 MW, equivalent to consumption of roughly 230 tons of bituminous coal per hour.

Fugitive dust may be emitted from several sources in the coal-fired power plant cycle. At the mine, potential sources include overburden removal, coal extraction, stockpiles, conveying, loading and hauling. At the power plant site, possible sources include coal unloading, stockpiling, coal handling and transfer, and dry ash handling and disposal. Coal preparation plants at either the mine or power plant site can be sources of fugitive emission generation at crushing, sizing and handling operations.

2.4.2 Fugitive Dust Emission Factors

The estimated emission factors for fugitive emissions from coal-fired power plants are summarized in Table 2.4-1.

The emission factors for coal mining and processing sources were excluded since these are addressed in Sections 2.1.4 and 2.19.

The emission factors for rail car, truck and conveyor unloading are of unspecified origin; therefore, the reliability should be considered as very poor. The emission factor for barge unloading is based upon limited testing and field observations. Its reliability should be considered as fair. The coal storage and the transfer and conveying emission factors are discussed in Section 2.2.1.

The emission factor for fly ash handling and disposal is described by the source as an engineering estimate without

TABLE 2.4-1. FUGITIVE DUST EMISSION FACTORS FOR COAL-FIRED POWER PLANTS

Source	Emission factor	Reliability rating	Reference
(1) Coal delivery			
Railcar unloading	0.4 lb/ton unloaded	E	1
Barge delivery	0.046 lb/ton unloaded	C	2
Truck unloading	0.4 lb/ton unloaded	E	1
Conveyors	0.04 to 1.0 lb/ton unloaded	E	1,2
(2) Coal storage			
Loading onto pile	0.08 lb/ton coal loaded	D	3
Vehicular traffic	0.16 lb/ton coal stored	D	3
Loading out	0.10 lb/ton coal loaded out	D	3
Wind erosion	0.09 lb/ton coal stored	D	3
(3) Transfer and conveying	0.04 to 1.0 lb/ton coal handled	E	1,2,4
(4) Fly ash handling and disposal	20 to 100 lb/ton ash handled	E	5

details as to the derivation; the reliability should be considered as very poor.

2.4.2 Particle Characterization

No data were located on particle size distributions for fugitive emissions from coal-fired power plants.

The concentration limit at which coal dust may cause detrimental health effects is 2 mg/m^3 if the respirable dust fraction contains less than 5 percent quartz.[6] No data were located on the toxicity of fly ash. It would be expected to contain a higher percentage of quartz than coal but would not necessarily be more toxic (at 10% quartz the Threshold Limit Value is 0.83 mg/m^3).[7] Both the above concentrations are based on the respirable dust fraction only-not the total dust fraction (respirable and non-respirable). More data are required on the respirable quartz fraction before conclusions could be made regarding toxicity.

2.4.4 Control Methods

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

The coal storage pile wind erosion emissions can be controlled by periodic application of either a water solution containing a chemical wetting agent or water alone, or by enclosure of the pile. Loading-in activities can be controlled by application of a wetting agent or use of mechanical aids such as a telescoping chute, special stacker or stone ladder. Load-out activities can be controlled by use of an underpile conveyor, water or chemical sprays, or a stacker/reclaimer. The coal transfer, conveying, crushing and screening operations can be controlled by use of enclosed conveyors, water or chemical sprays, or enclosures vented to fabric filters.

Fly ash handling and disposal operations present no problems if the ash is wet. However, handling of dry fly ash generally requires control. Handling of the fly ash can be controlled by application of a wetting agent, covering the ash content of trucks during hauling, and minimizing free fall of the ash during loading. At the disposal site, emissions from dumping operations can be controlled by wet suppression, enclosure of the dump area, and minimizing the free fall distance of the ash. Emissions from wind erosion at the disposal site may be controlled by covering with dirt or stable material, revegetation or chemical stabilization.

Other potential fugitive dust sources at power plants are the haul roads. These are addressed in Section 2.1.

Table 2.4-2 summarizes the available control technologies, their effectiveness, estimated costs, and RACM selections.

2.4.5 Recommended Reasonably Available Control Measures (RACM)

The RACM selections for power plant fugitive sources are presented in Table 2.4-2. As indicated, the recommended control for unloading (for all types of coal delivery), stockpiling, crushing, and transfer and conveying operations of the coal is a wet dust suppression system utilizing a chemical wetting agent. This system give good control efficiency (estimated 80 to 99%)

TABLE 2.4-2. A SUMMARY OF THE CONTROL ALTERNATIVES, EFFICIENCIES AND COSTS, AND THE RACM SELECTIONS FOR FUGITIVE DUST EMISSIONS FROM SOURCES AT COAL-FIRED POWER PLANTS (500 MW)

Fugitive dust sources	Control alternatives	Control efficiency, %	Control costs, Jan. 1980, $		Cost benefit, $/lb	RACM selection
			Capital	Annualized		
(1) Coal delivery (Railcar)	Enclosure	70[a]	60,000[b]	12,000[c]	0.03	Wet suppression (chemical), for railcar and other delivery methods
	Enclosure, vent to fabric filter	99[d]	120,000[d]	42,000[e]	0.07	
	Wet suppression (chemical)	80[d]	104,000[f]	38,000[g]	0.03	
(2) Coal storage						
Loading onto piles	Telescopic chutes	75[h]	9,000[h]	2,000[c]	0.02	Wet suppression (chemical)
	Wind guards	50[h]	37,000[h]	8,000[c]	0.13	
	Wet suppression (chemical)	80-90[d]	i	i	0.03	
Loading out	Bucket wheel reclaimer	80[h]	4,500,000[h]	900,000[c]	7.45	Wet suppression (chemical)
	Underpile conveyor	80[j]	6,300,000[k]	1,260,000[c]	10.43	
	Wet suppression (chemical)	95[h]	i	i	0.03	
Wind erosion	Enclosures	100[h]	8,400,000[l]	1,680,000[c]	12.35	Wet suppression (chemical)
	Wet suppression (chemical)	99[h]	14,000[h]	10,000[h]	0.07	
(3) Transfer and conveying	Enclosures	70[a]	69,000[a]	14,000[c]	0.03	Wet suppression (chemical)
	Enclosures, vent to fabric filter	99[a]	196,000[a]	86,000[c]	0.11	
	Wet suppression (chemical)	70-95[a]	i	i	0.03	

Fugitive dust sources	Control alternatives	Control efficiency,%	Control costs, Jan.1980, $		Cost benefit, $/lb	RACM selection
			Capital	Annualized		
(4) Fly ash handling and disposal	Wet suppression	50 to 100[m]	n	n	NA	Wet suppression, covering of haul trucks, covering of disposal area with dirt, minimize free fall distances
	Cover haul trucks	No estimate[m]	n	n	NA	
	Minimize free fall distances	No estimate[m]	n	n	NA	
	Enclosure of dump areas	No estimate[m]	n	n	NA	
	Revegetation of disposal area	25 to 100[m]	n	n	NA	
	Covering of disposal area with dirt	100[m]	n	$650/acre[o]	NA	
Haul roads	Watering	50[p]	q	q	NA	Oiling or paving
	Wet suppression	50[p]	q	q	NA	
	Oiling	85[p]	q	q	NA	
	Paving	85[p]	q	q	NA	

NA = Not available

[a] Reference 8.

[b] Reference 9. Based on 10 Ga steel enclosure of car dump.

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

[d] Reference 10.

[e] Reference 11. Based on 21,000 scfm, A/C of 6.5:1, 8000 h/yr operation.

[f] Reference 12. Based on 1000 tons/h capacity. Includes spray application at unloading, transfer points, stockpile load-in, stockpile load-out, and crusher inlet and outlet (Sources 1, 2, and 3).

[g] Reference 13. Based on 1,514,000 tons of coal per year.

[h] Reference 14.

[i] Costs included above, see footnote f.

[j] Reference 15.

[k] Reference 14. Based on 150,000 tons stored.

[l] Reference 16. Based on 150,000 tons stored.

[m] Reference 17.

[n] No data available.

[o] Reference 18.

[p] Reference 9.

[q] See Section 2.1.

and should reduce visible emissions to almost zero opacity (based on the effectiveness achieved at similar stone processing operations). A system of enclosures with venting to fabric filters for the sources mentioned above would be more effective (≈99%) but would be much more costly to install. Comparative capital costs on a 500 MW plant are $118,000 for the wet suppression system versus $316,000 for the fabric filter system. Annualized costs are $48,000 for the wet suppression system versus $128,000 for the fabric filter system. A diagram of a wet suppression system as applied on the coal handling operations at a power plant is given in Figure 2.4-2.

The selected RACM for control of fly ash handling and disposal is the use of wet suppression, covering of haul trucks to and from disposal site and covering of the disposed fly ash with dirt. These measures should effectively reduce fugitive emissions at a fairly low cost. At most large power plants, however, these measures will be unnecessary since the fly ash is in a wetted state and is stored under water in ash ponds.

The control of haul road fugitive emissions can be either permanent paving with adequate housekeeping or oiling. For roadways in relatively constant use, a paving/cleaning program can best alleviate emissions. However the cost may be prohibitive. A program of oiling can provide good control at a reasonable cost and is recommended for little used roads or roads where a paving program would be impractical due to high costs.

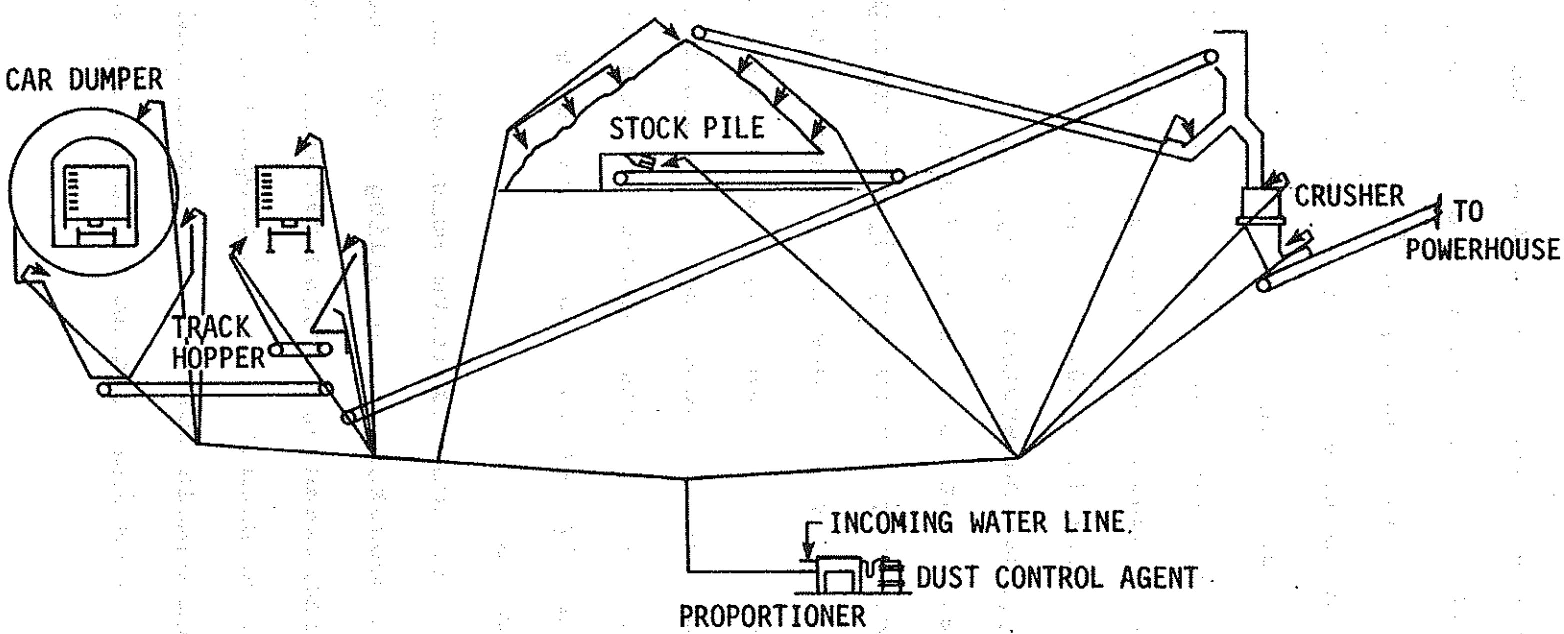

Figure 2.4-2. Wet dust suppression system applied on a coal-fired power plant.

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6. Threshold Limit Values for Chemical Substances and Physical Agents in the Workroom Environment with Intended Changes for 1976. American Conference of Governmental Industrial Hygienists. Cincinnati, Ohio. 1976. p. 33.

7. Ibid. p. 32.

8. Op. cit. Reference 2. p. 6-2.

9. PEDCo Environmental, Inc. Technical Guidance for Control of Industrial Process Fugitive Particulate Emissions. EPA-450/3-77-010, March 1977. p. 2-38.

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12. Ibid. p. 4-9.

13. Ibid. p. 4-12.

14. Op. cit. Reference 2. p. 6-6.

15. Op. cit. Reference 9. p. 3-39.

16. Op. cit. Reference 2. p. 6-7.

17. Op. cit. Reference 9. p. 2-47

18. Ibid. p. 2-48.

APPENDIX FOR SECTION 2.4

(1) Coal delivery (railcar)

Emissions = (0.4 lb/ton)(1,514,000) = 605,600 lbs/yr

Enclosure

See Coke 1

$$C/B = \frac{\$12,000/yr}{.7\ (605,600)} = \$0.03/lb$$

Enclosure, vent to fabric filter

See Coke (1)

$$C/B = \frac{\$42,000/yr}{.99\ (605,600)} = \$0.07/lb$$

Wet suppression (chemical)

Coal throughput = 288 tph
@ 60% capacity factor = 1,514,000 tpy
Assume maximum capacity on coal handling of 1,000 tph

$$\text{Capital cost} = \$80,000\ \frac{(249.6)}{(192.1)} = \$104,000 \text{ p. 4-9, NMI}$$

$$\text{Annual cost} = \$29,000\ \frac{(249.6)}{(192.1)} = \$38,000 \text{ p. 4-12, NMI}$$

$$C/B = \frac{\$38,000/yr}{.8(605,600) + .85(121,000) + .95(151,000) + .99(136,000) + .83(787,000)} = \$0.03/lb$$

(2) Coal storage

Loading onto piles
Emissions = .08 lb/ton (1,514,000 tpy) = 121,000 lbs/yr

Telescopic chutes

See Coke (2)

$$C/B = \frac{\$2,000/yr}{.75\ (121,000)} = \$0.02/lb$$

Wind guards

See Coke (2)

$$C/B = \frac{\$8,000/yr}{.5\ (121,000)} = \$0.13/lb$$

Wet suppression (chemical)

See (1)

C/B = \$0.03/lb

Loading out
Emissions = 0.10 lb/ton (1,514,000) = 151,000 lbs/yr

Bucket wheel reclaimer

See Coke (2)

$$C/B = \frac{\$900,000/yr}{.8\ (151,000)} = \$7.45/lb$$

Underpile conveyor

See Coke (2)

$$C/B = \frac{\$1,260,000/yr}{.8\ (151,000)} = \$10.43/lb$$

Wet suppression (chemical)

See (1)

C/B = $0.03/lb

Wind erosion

Emissions = .09 lb/ton (1,514,000 tpy) = 136,000 lbs/yr

Enclosures

See Coke (2)

$$C/B = \frac{\$1,680,000/yr}{1.0\ (136,000)} = \$12.35/lb$$

Wet suppression (chemical)

See Coke (2)

$$C/B = \frac{\$10,000/yr}{.99\ (136,000)} = \$0.07/lb$$

(3) Transfer and conveying

Emissions = 0.52 lb/ton (1,514,000 tpy) = 787,000 lbs/yr

Enclosures

See Coke (2)

$$C/B = \frac{\$14,000/yr}{.7\ (787,000)} = \$0.03/lb$$

Enclosures, vent to fabric filter

See Coke (3)

$$C/B = \frac{\$86,000/yr}{.99\ (787,000)} = \$0.11/lb$$

Wet suppression (chemical)

See (1)

C/B = $0.03/lb

(4) Fly ash handling and disposal

No costs available

2.5 GRAIN TERMINALS

2.5.1 Process Description

Grain elevators are used for storage, treatment and transfer of agricultural grain crops as they are moved from the farm to the market. The harvested grain is usually trucked to local country elevators, then transferred by truck, rail car or barge to larger terminal elevators, which have storage capacities of 2 million bushels or more. The grains handled include corn, wheat, rye, oats, barley, flax seed, grain sorghum and soybeans.

At the terminal elevator the grain is conditioned (dried, screened and cleaned) and stored before shipment to a grain processor, feed manufacturer or other user. Some terminal elevators simply receive grain from nearby country elevators and ship it to other terminal elevators. These facilities, sometimes called "subterminal" elevators, may handle up to 20 times their storage capacity each year. Most terminal elevators, however, handle annual quantities that are only a few times their storage capacity. Figures 2.5-1 and 2.5-2 are flow diagrams of typical grain elevator operations.

The initial operation at a terminal elevator is the unloading of the truck (see Figure 2.5-3), box car (see Figure 2.5-4), hopper car or barge that delivers the grain. The grain is discharged into a receiving hopper, usually located below grade. The grain is then conveyed by a weather-protected belt conveyor to the foot of one of several bucket elevators. The bucket elevators, together with distributors and processing equipment, are housed in the major structure of the facility, called the "headhouse".

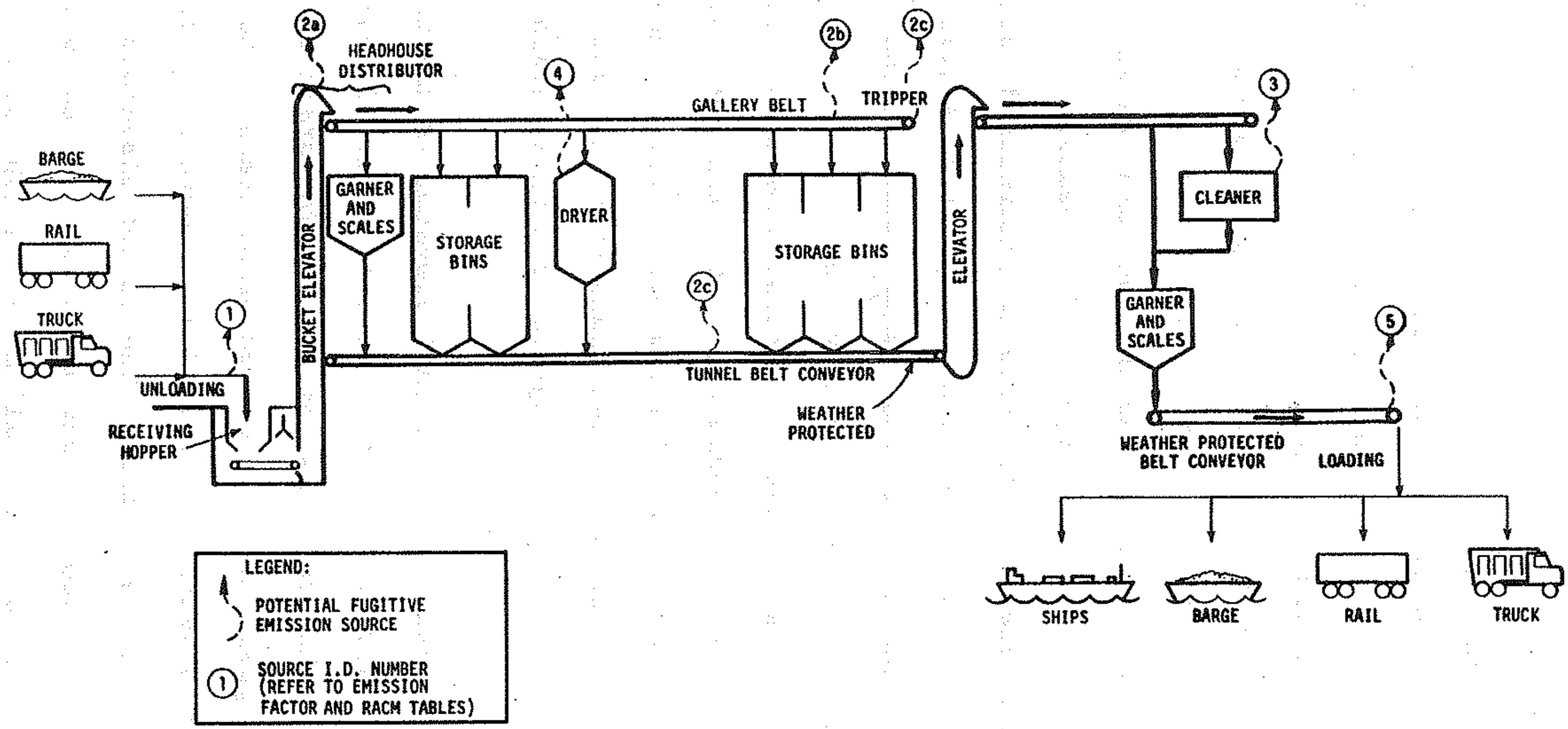

Figure 2.5-1. Simplified process flow diagram for grain terminals and associated fugitive particulate emission sources.

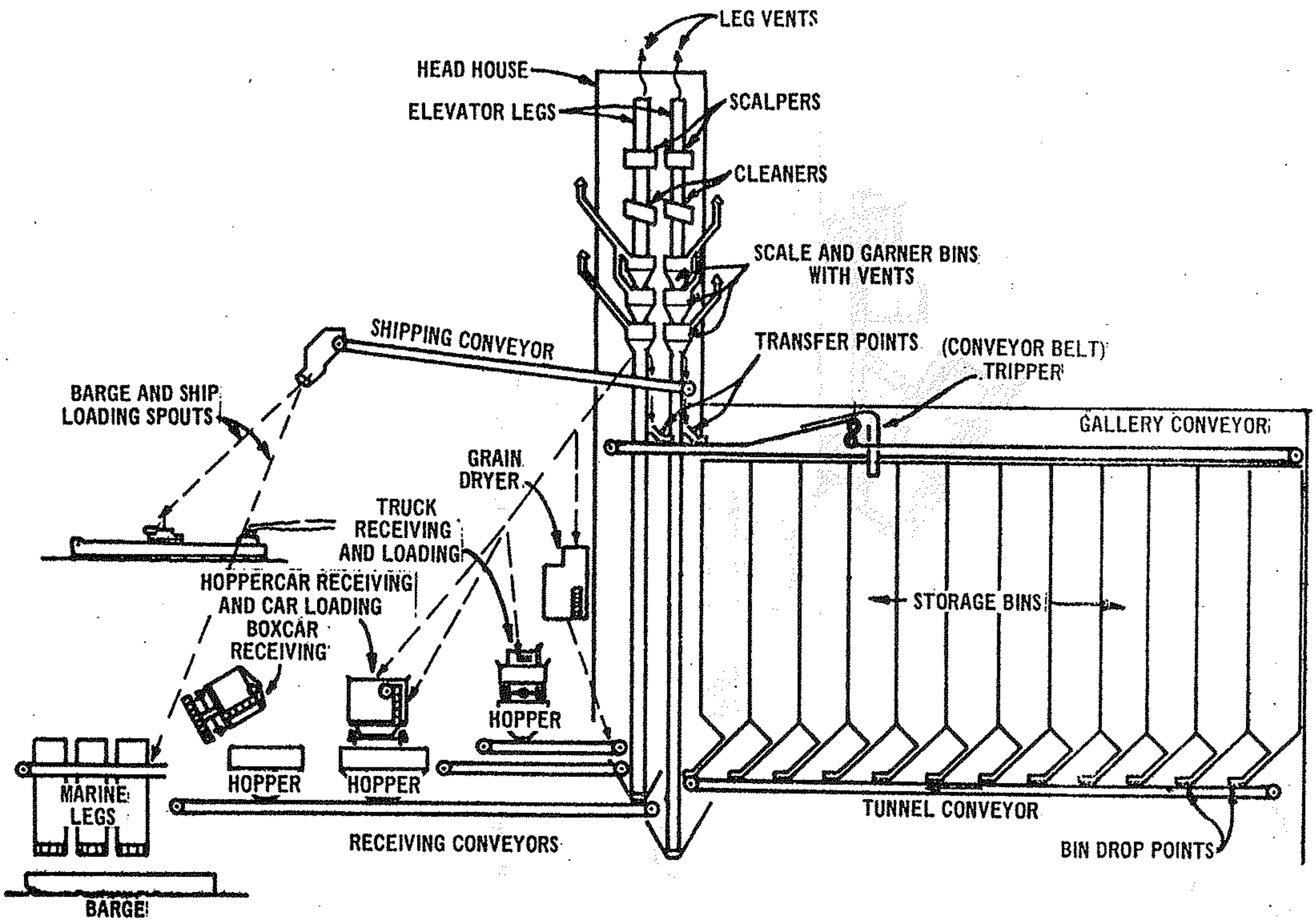

Figure 2.5-2. Grain terminal elevator.[26]

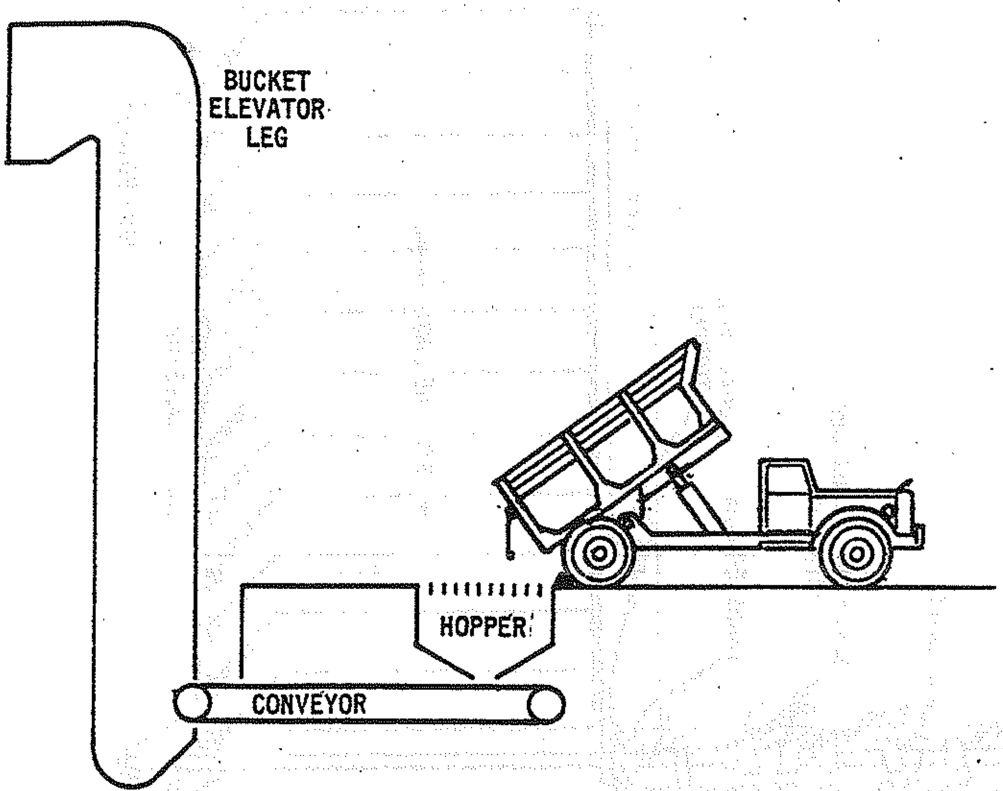

Figure 2.5-3. Truck unloading.[27]

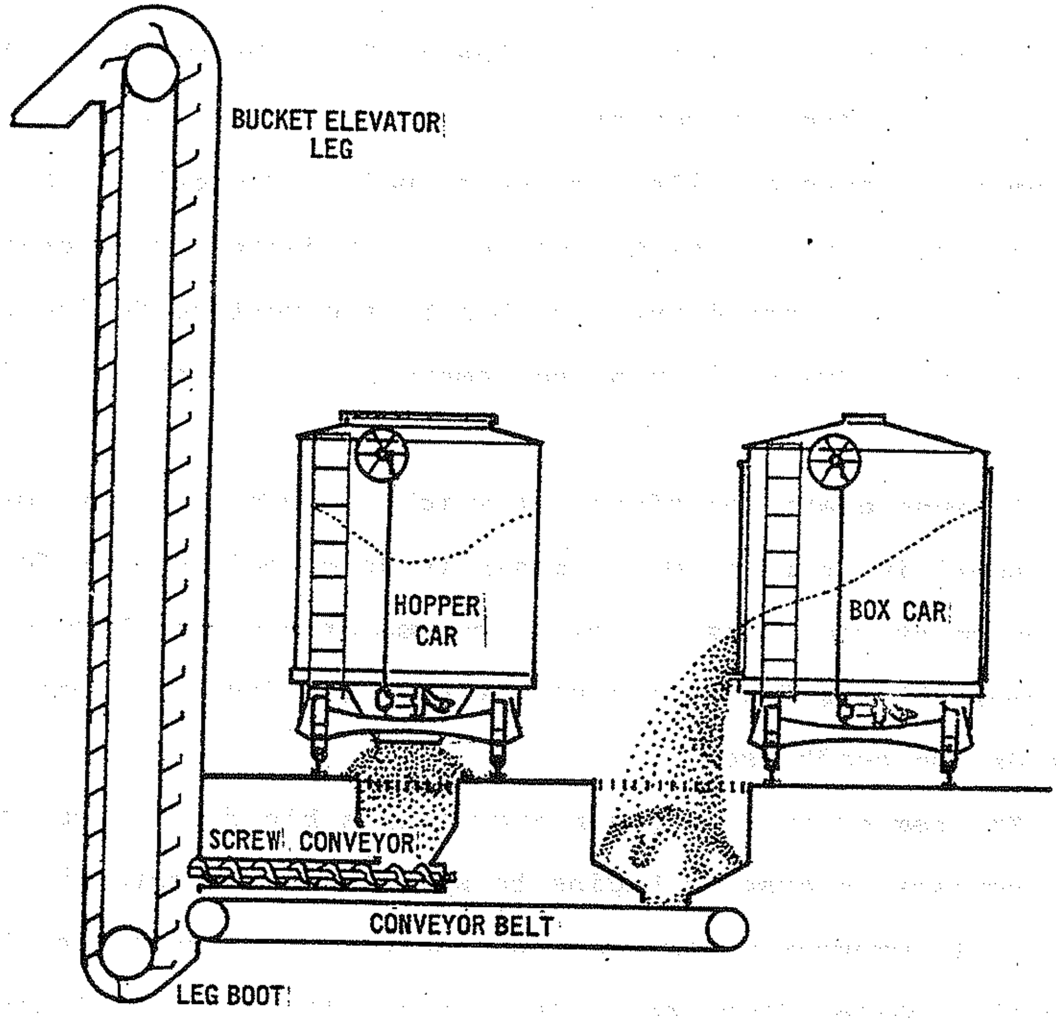

Figure 2.5-4. Railcar unloading.[28]

The elevator carries the grain to the top level of the headhouse (called the "gallery"), where it is discharged into a distributor, usually a system of movable spouts, which directs it into a collecting bin (called a "garner") to be weighed. Alternatively, the distributor can route the grain into cleaning equipment or onto a gallery conveyor belt. The gallery belt carries the grain across the gallery to a designated storage bin, where it is discharged into the bin by a diverting device called a "tripper." Grain cleaning equipment is illustrated in Figure 2.5-5.

Because grain containing 14 weight percent moisture or more will spoil in storage, moist grain is dried before transfer to long-term storage bins. Rack or column dryers (see Figure 2.5-6) are generally used at grain elevators. The dryer is located outside the headhouse.

The temperature of grain stored in a bin for a long period may increase because it begins to spoil or is infested by molds or fungi. To prevent deterioration, the grain may be cooled by an operation called "turning". In turning, the grain is dropped from the storage bin onto a belt conveyor system running beneath the bins (the "tunnel" belt conveyor), then conveyed to a bucket elevator, lifted to the top, and discharged via a gallery belt conveyor into an empty bin. The tunnel belt conveyor system is usually uncovered.

When dirty grain is received at the elevator, cleaners are used to remove foreign materials such as dust, sticks, stones,

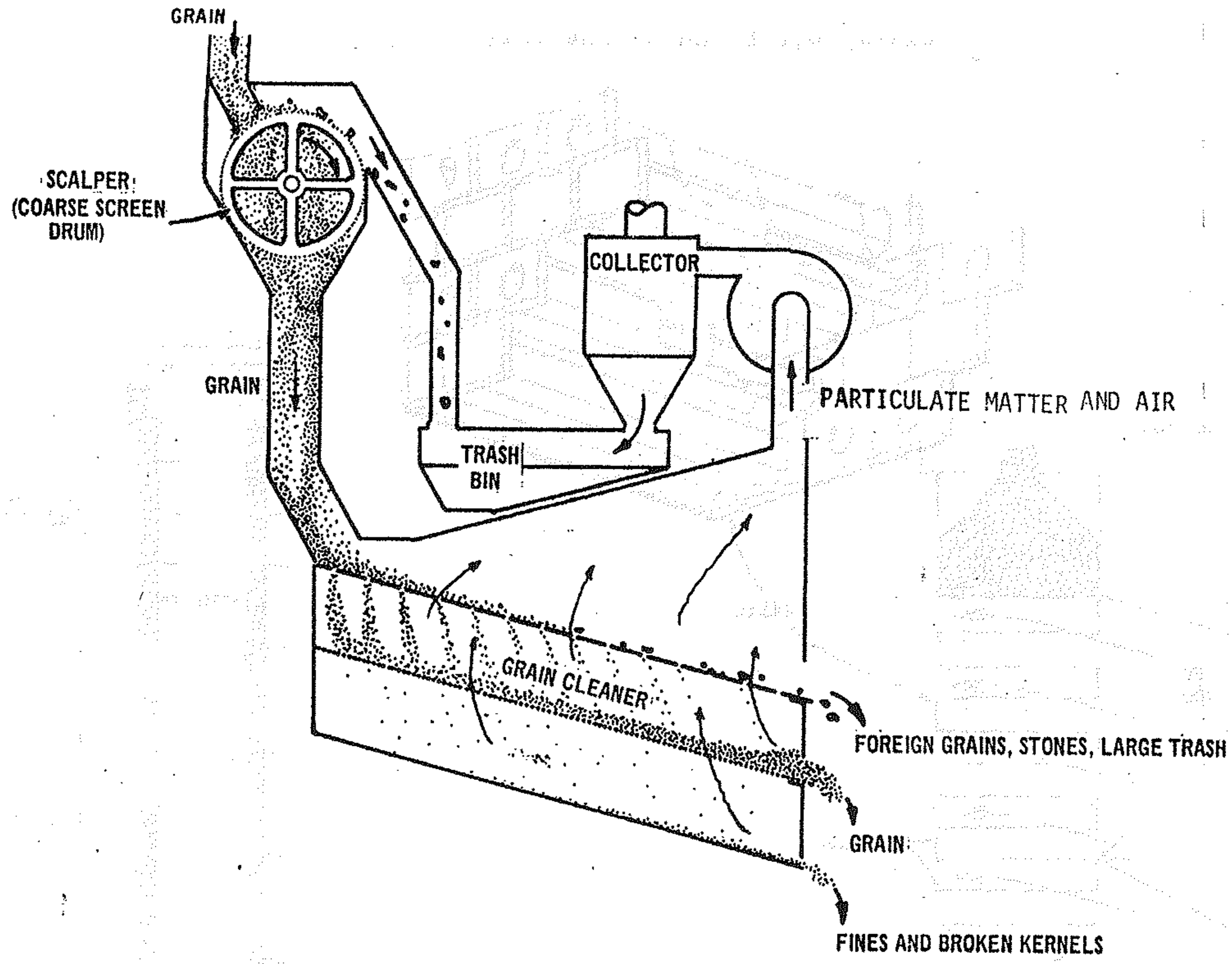

Figure 2.5-5. Grain cleaning equipment.[29]

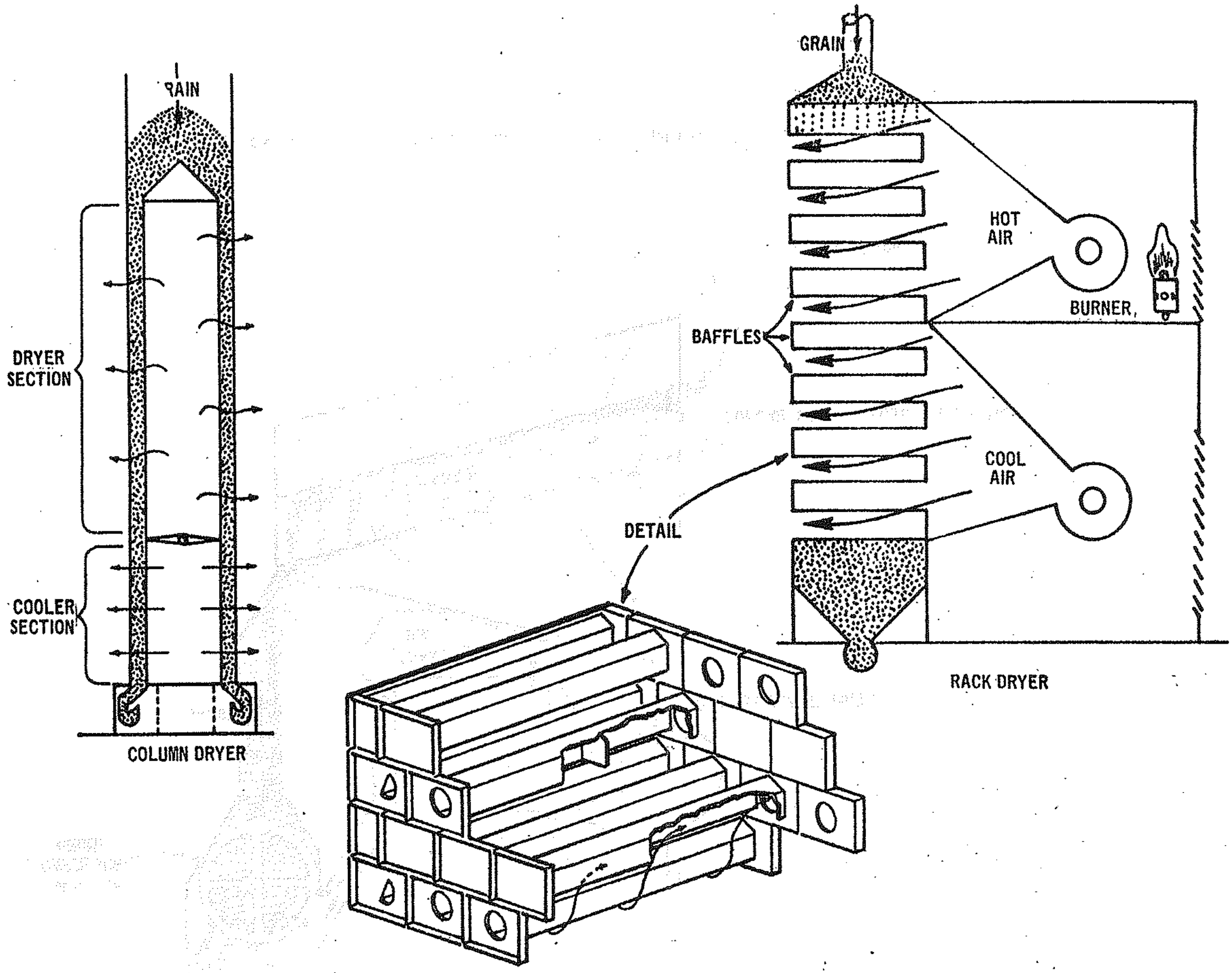

Figure 2.5-6. Rack and column grain dryers.[30]

stalks, stems and weed seeds. Often the grain is first transferred to a temporary storage bin, dropped onto a tunnel conveyor, and lifted by a bucket elevator to the grain cleaner and garner. Equipment used to clean grain includes simple screening devices and aspiration (suction) type cleaners. The screening devices remove large sticks, tools and other trash; and the aspirators remove chaff and similar lightweight impurities. The cleaned grain is elevated to the gallery conveyor and routed to an empty bin.

Grain to be shipped from the elevator facility is dropped from the storage bins onto the tunnel belt conveyor. The conveyor discharges to the foot of a bucket elevator, which lifts it to a distributor. From there it passes to a loadout scale. After weighing, the grain is discharged through a loading spout into rail cars, trucks, barges or ships. Figures 2.5-7 and 2.5-8 depict these loading operations.

Sources of fugitive dust at grain terminals include grain receiving, screening and cleaning, transfer and conveying, drying and shipping. These sources are indicated in Figure 2.5-1.

2.5.2 Fugitive Dust Emission Factors

Estimated emission factors for grain terminal fugitive emission sources are summarized in Table 2.5-1. The emission factors are based upon a limited number of tests on grain elevators. It was found that the emission rates can vary greatly depending upon the types of grain being handled. Field run grains such as soybeans, oats and sorghum are very dusty compared to wheat or

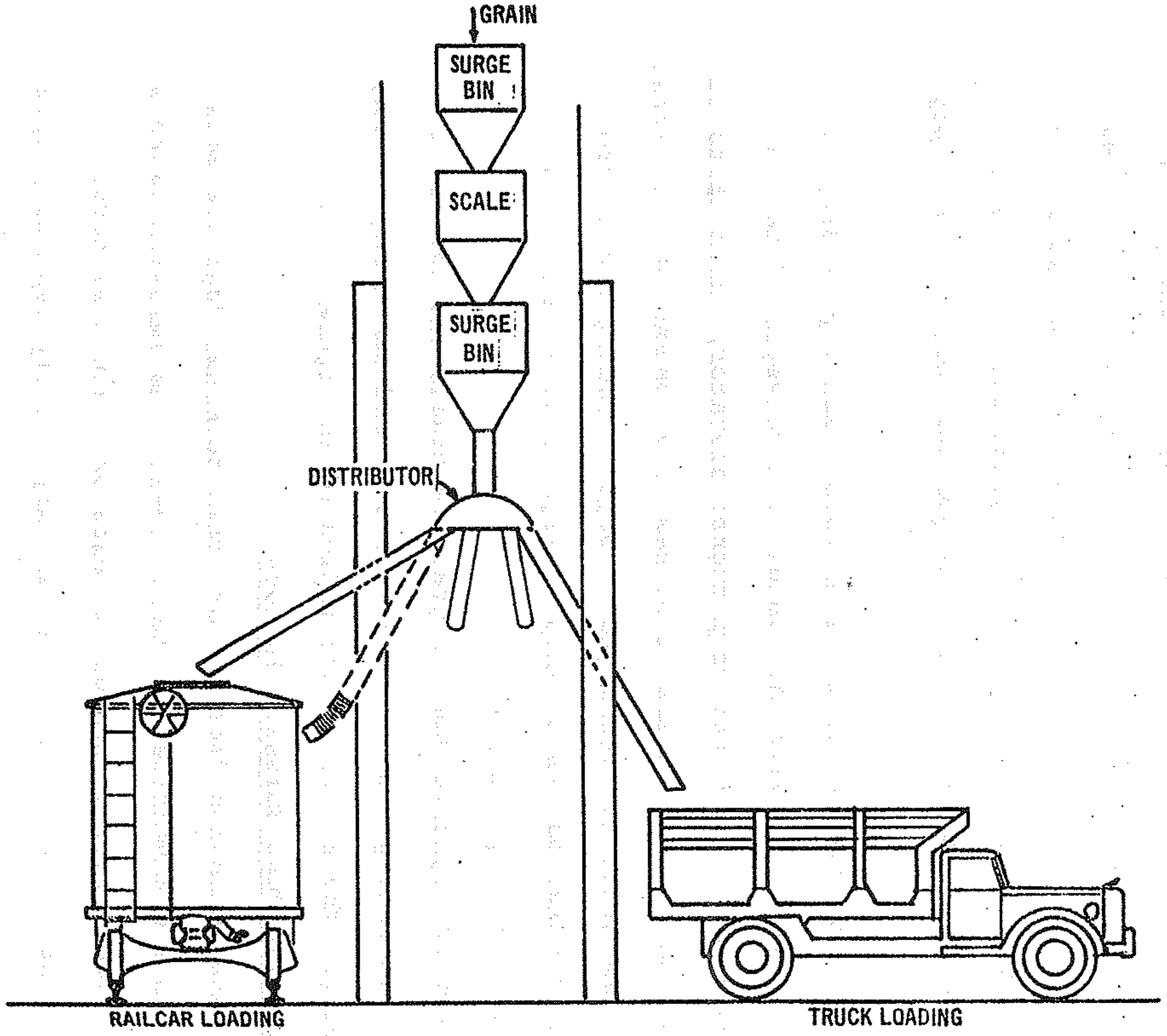

Figure 2.5-7. Railcar and truck loading.[31]

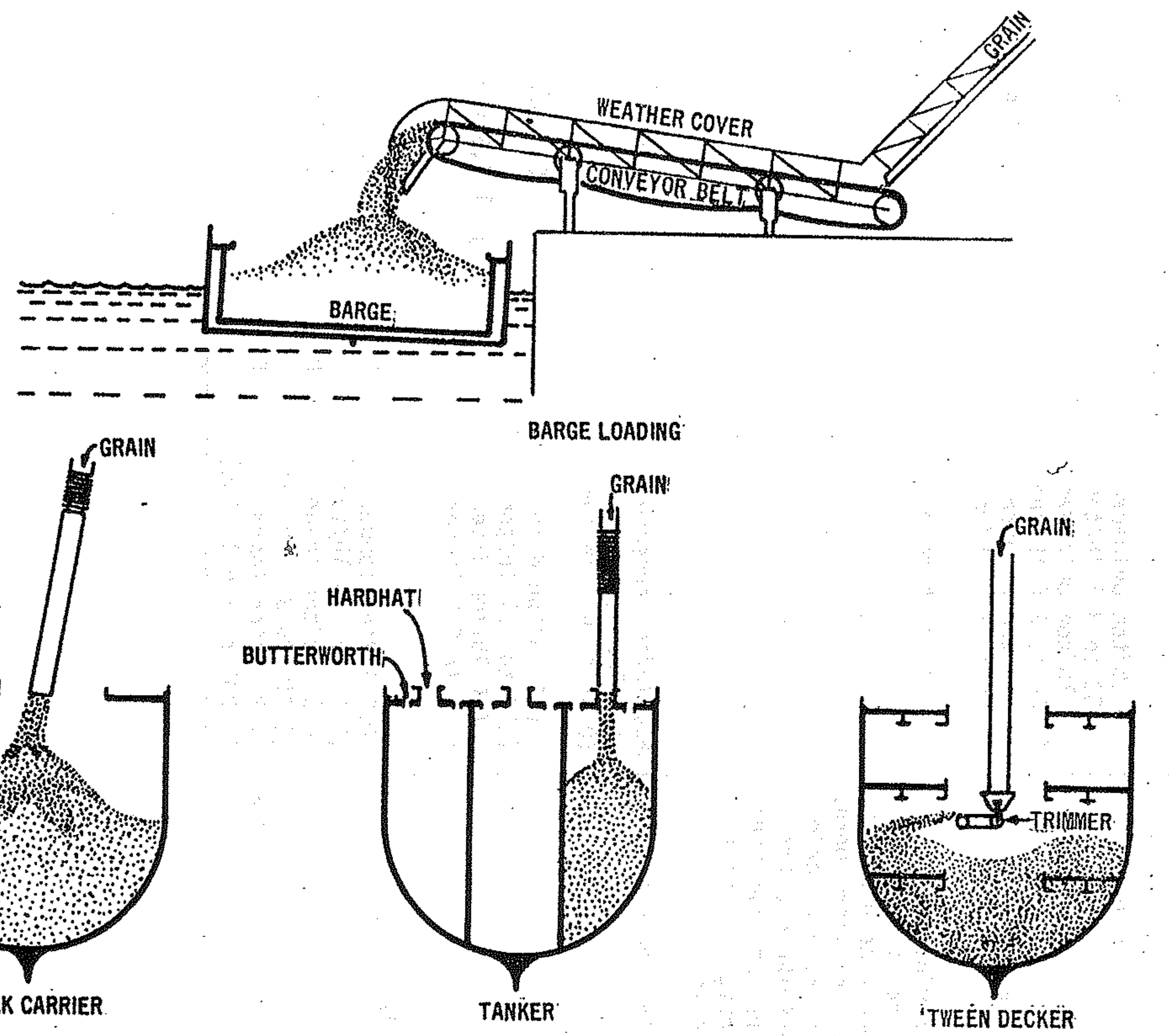

Figure 2.5-8. Barge and ship loading.[32]

TABLE 2.5-1. FUGITIVE DUST EMISSION FACTORS FOR GRAIN TERMINALS

Source	Emission factor	Reliability rating	Reference
(1) Receiving			
Truck unloading	0.6 lb/ton unloaded (0.32 to 3.5 lb/ton)	D	1,2,3,4,5
Railcar unloading	1.3 lb/ton unloaded (0.04 to 3.0 lb/ton)	D	1,2,3,4,5
Barge unloading	1.7 lb/ton unloaded (0.08 to 3.5 lb/ton)	D	1,2,3,4,5
(2) Transferring and conveying (total)	6.0 lb/ton handled	D	6
2a. Receiving elevator leg, elevator head, garner, and scales	a		
2b. Distributor, trippers, and spouting	a		
2c. Storage bin vents and turning	a		
(3) Screening and cleaning	6.0 lb/ton screened and cleaned (0.19 to 9.2 lb/ton)	D	1,2,3,5
(4) Drying:			
Column	0.5 lb/ton dried (.19 to 1.1 lb/ton)	D	1,2,3,4,5,7
Rack	4.0 lb/ton dried (1.8 to 8.0 lb/ton)	D	1,2,3,4,5,7
(5) Shipping			
Truck loading	0.3 lb/ton loaded (0.14 to 3.5 lb/ton)	D	2,3,4,5
Railcar loading	0.27 lb/ton loaded (0.015 to 3.0 lb/ton)	D	1,2,3,4,5
Barge or ship loading	1.2 lb/ton loaded (0.002 to 3.5 lb/ton)	D	1,2,3,4,5

[a] Included in total estimate.

corn. However, the data are insufficient to quantify the differences. Therefore, the emission factors cannot be considered accurate for any specific operation and have a poor reliability.

2.5.3 Particle Characterization

The fugitive dust from grain elevators contains a small amount of spores of smuts and molds, insect parts, weed seeds, various pollens and siliceous dust from vegetation and soil in the vicinity where the grain was grown. But most of the dust is bristles and other particles from the outer coats of grain kernels produced by the abrasion of the individual kernels of grain.

Grain dust has a specific gravity normally in the range 0.8 to 1.5 as compared to various other industrial dusts which usually have specific gravities between 2.0 and 2.5.[2] Grain dust is mostly in the range of 10 to 100 μm in size.[1]

In Table 2.5-2 are presented the results of tests of the inlet of a cyclone which vented an elevator leg.[8] These cyclone inlet emissions can be considered an approximation of the particle size distribution of the fugitive particulate emissions from an uncontrolled elevator leg vented to atmosphere.

Monitoring in the vicinity of a terminal resulted in the measurement of suspended particulate matter at a concentration of 240 $\mu g/m^3$.[9] These particles had a size distribution of 99.5 percent less than 2 microns and 50 percent less than 0.03 microns in diameter.[9] Such particles at concentrations above 100 $\mu g/m^3$ are known to have adverse health effects on humans.[9]

TABLE 2.5-2. PARTICULATE SIZE DISTRIBUTION FOR DUST FROM AN ELEVATOR LEG CYCLONE (INLET TEST)[8]

US Sieve mesh	Size opening (μm)	Cumulative weight, percent greater than
100	149	32.7
170	88	44.7
200	74	48.7
325	44	68.0
-	20	91.0
-	10	99.1
-	5	99.9
-	1	99.9

Also, respiratory ailments could result from the insects, molds and fungi associated with grain handling. Workers inside elevators can be subjected to airborne dust concentrations of 100 to 400 mg per cubic meter. Such levels are well above the threshold where respiratory problems occur.[9]

During corn drying, "bees wings", which are the filmy outer skin of the corn kernel, are emitted along with normal grain dust. Essentially all bees wing emissions are over 50 μm in diameter, and the mass mean diameter is probably in the region of 150 μm.[2]

2.5.4 Control Methods

Effective dust control during truck unloading operations generally requires the use of undergrate aspiration and a suitable enclosure or shed over the receiving pit. The aspirated air is directed to a control device which may be either a cyclone or a fabric filter.[10] Figure 2.5-9 illustrates such a system.

The type of enclosure for the unloading affects the quantity of fugitive dust emitted. Some grain elevators use only a two-sided enclosure with a roof. The most suitable structure for fugitive emission control is a three-sided and a top enclosure or drive-through tunnel where a door is lowered each time a truck is unloaded. Ultimate control is obtained when the truck unloading is conducted in a totally enclosed shed or drive-through tunnel with two quick-closing doors. With this enclosed type control structure most windage fugitive emission losses can be prevented during truck unloading; however, the cost may be prohibitive.[11]

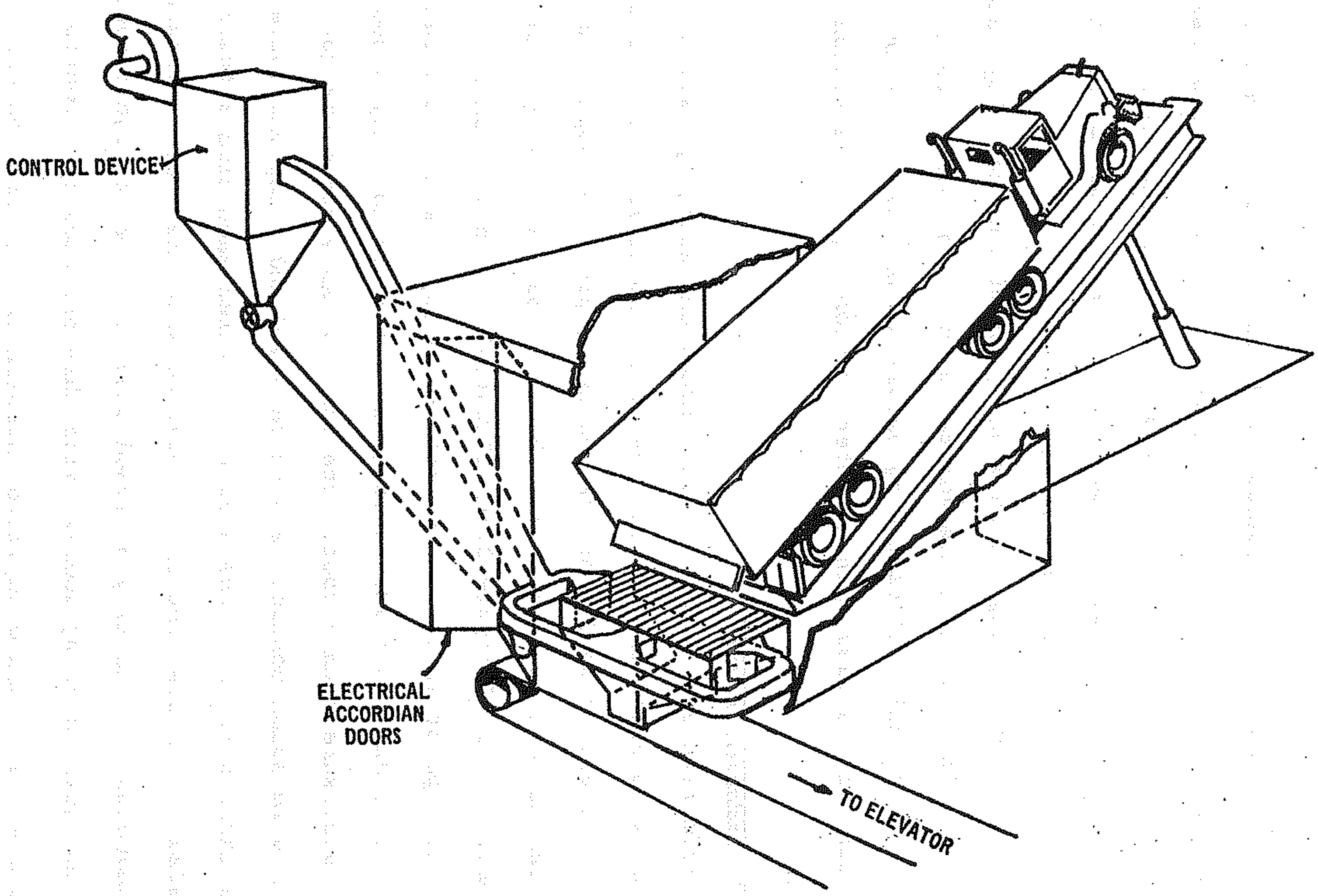

Figure 2.5-9. Truck unloading control system.[33]

Best railcar unloading emissions control requires total enclosure sheds or drive-through tunnels with quick closing doors. Control problems for hopper cars are different than those for boxcars. Two unloading control methods have been used for hopper cars. One method uses undergrate aspiration vented to a cyclone or fabric filter in a manner similar to controls for truck unloading. The second method uses a small receiving hopper to effect choke unloading. Boxcar unloading is usually carried out by "breaking" a grain door inside the car. This produces a surge of grain and dust as the grain falls into the receiving hopper. The grain remaining has to be scooped out. Each scoop of grain can result in a cloud of dust. Another common boxcar unloading technique used at terminal elevators is a mechanical boxcar dump which tilts the boxcar to dump the grain into a receiving pit. This rapid unloading method creates a large cloud of dust which may be difficult to control. The emissions from these two boxcar unloading methods may be controlled by undergrate aspiration to a fabric filter or a cyclone. However, large volumes of air are necessary to effect a 95 percent dust capture efficiency.[11] Figure 2.5-10 depicts a control system for both hopper and boxcar unloading, while Figure 2.5-11 gives a more detailed view of the boxcar unloading control system.

Barge unloading is primarily done by a retractable bucket type elevator (marine leg). This is lowered into the hold of the barge. Some generation of fugitive dust occurs in the hold as the grain is scooped out and also at the top of the marine leg where the grain is discharged onto a conveyor. Control for barge

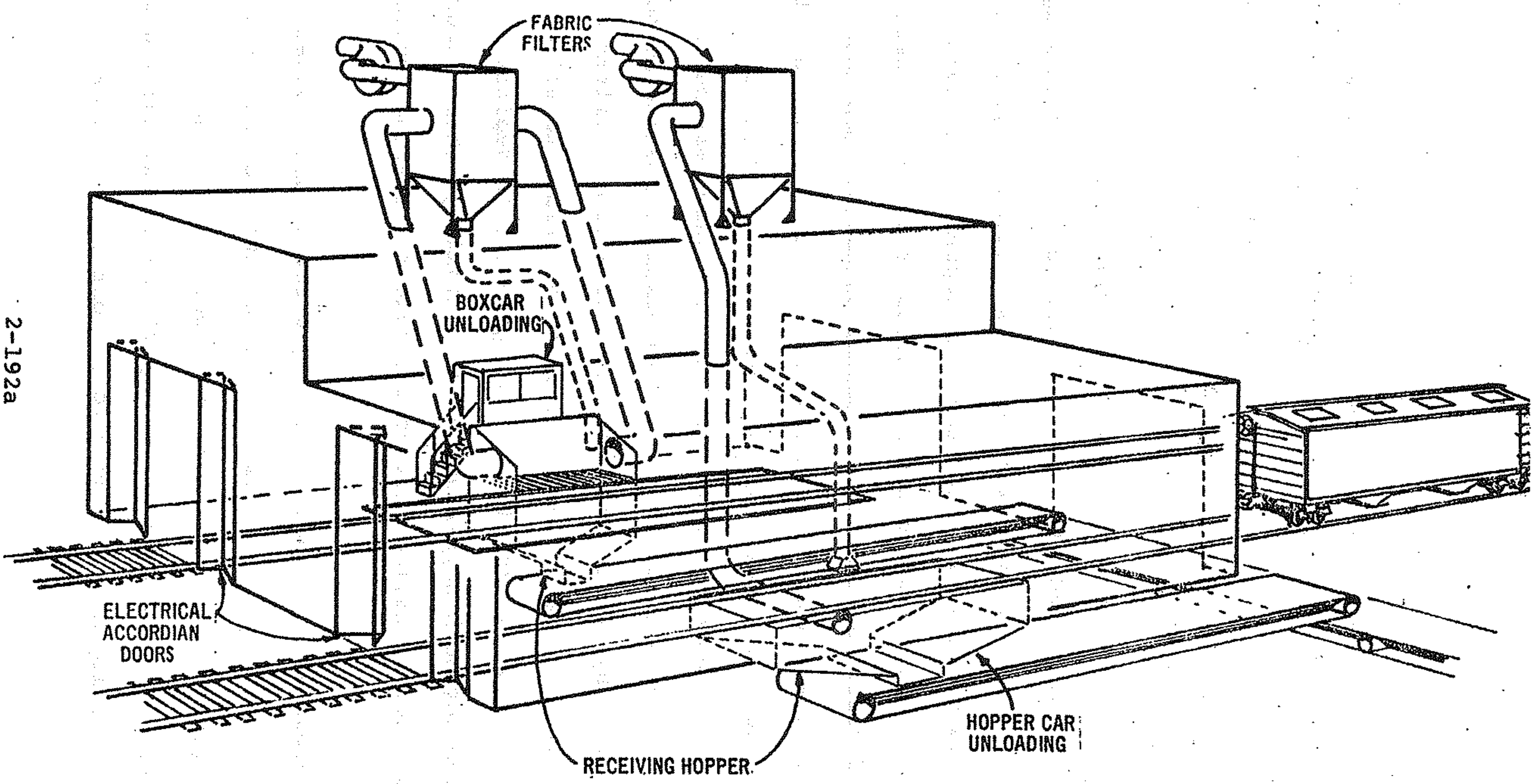

Figure 2.5-10. Railcar unloading control systems.[34]

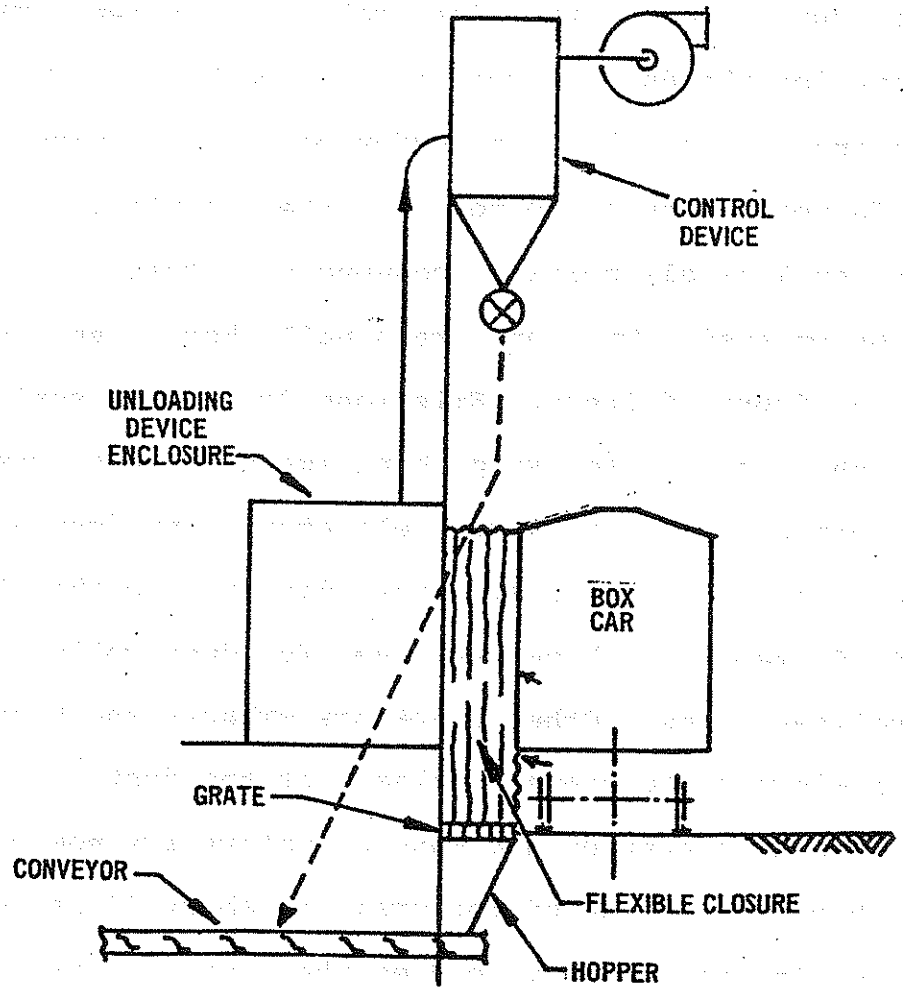

Figure 2.5-11. Boxcar unloading control system.[35]

unloading is best carried out by completely enclosing the leg and aspirating the dust through a fabric filter or cyclone.[11] Figure 2.5-12 illustrates such a system.

The control of emissions from the transferring and conveying of grain in an elevator is often carried out by ducting many individual dust sources to a common dust collector system. This is commonly done for the dust sources in the headhouse. Thus, aspiration systems serving elevator legs, transfer points, bin vents, etc., may all be ducted to one collector. In these control systems it is desirable to enclose all possible conveyors so that little particulate matter can be emitted. Trippers are usually hooded and ventilated to cyclones or fabric filters. Emissions from grain scale weighing hoppers and their associated surge bins (garners) also may be vented to a common collector. Many elevators vent dust, generated by the flow of grain into storage bins, directly to the atmosphere. Small fabric filter units have been used for dust collection in some metropolitan areas. Other elevators exhaust the bins internally in the grain elevator to prevent release of the dust.[8] Grain turning is a dusty operation and many elevators are now aerating their grain bins. Aeration of the grain is about 40 percent less dusty than turning and greatly reduces the need for transferring grain for cooling.[1] Figures 2.5-13 and 2.5-14 show how emissions are captured from elevator legs and transfer points, respectively.

Grain screening and cleaning emissions are controlled by hooding or enclosing the equipment and exhausting to a cyclone or fabric filter. Some screens with air-tight enclosures require no ventilation to control devices.[11] A control system for handling and cleaning operations is depicted in Figure 2.5-15.

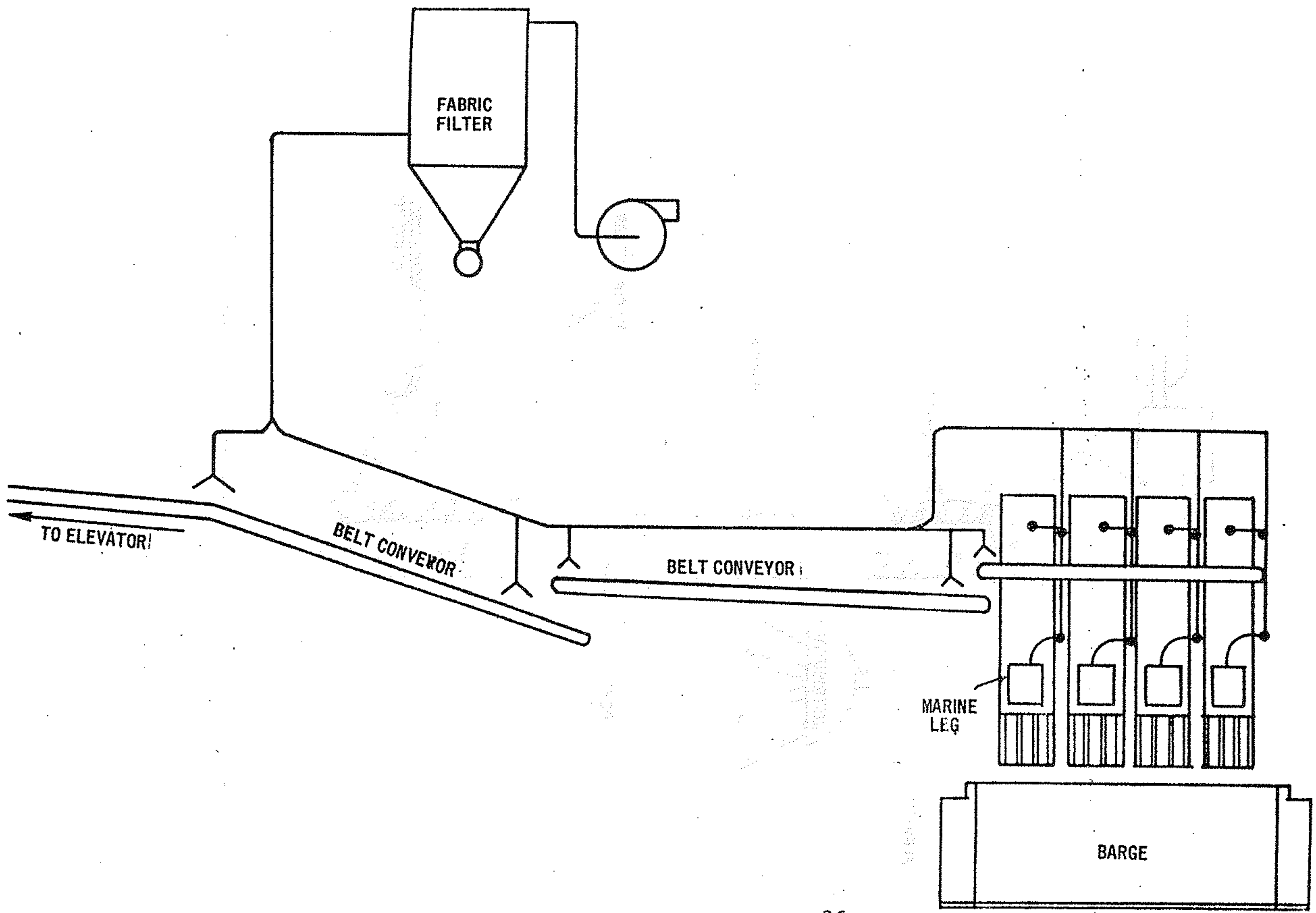

Figure 2.5-12. Barge loading control system.[36]

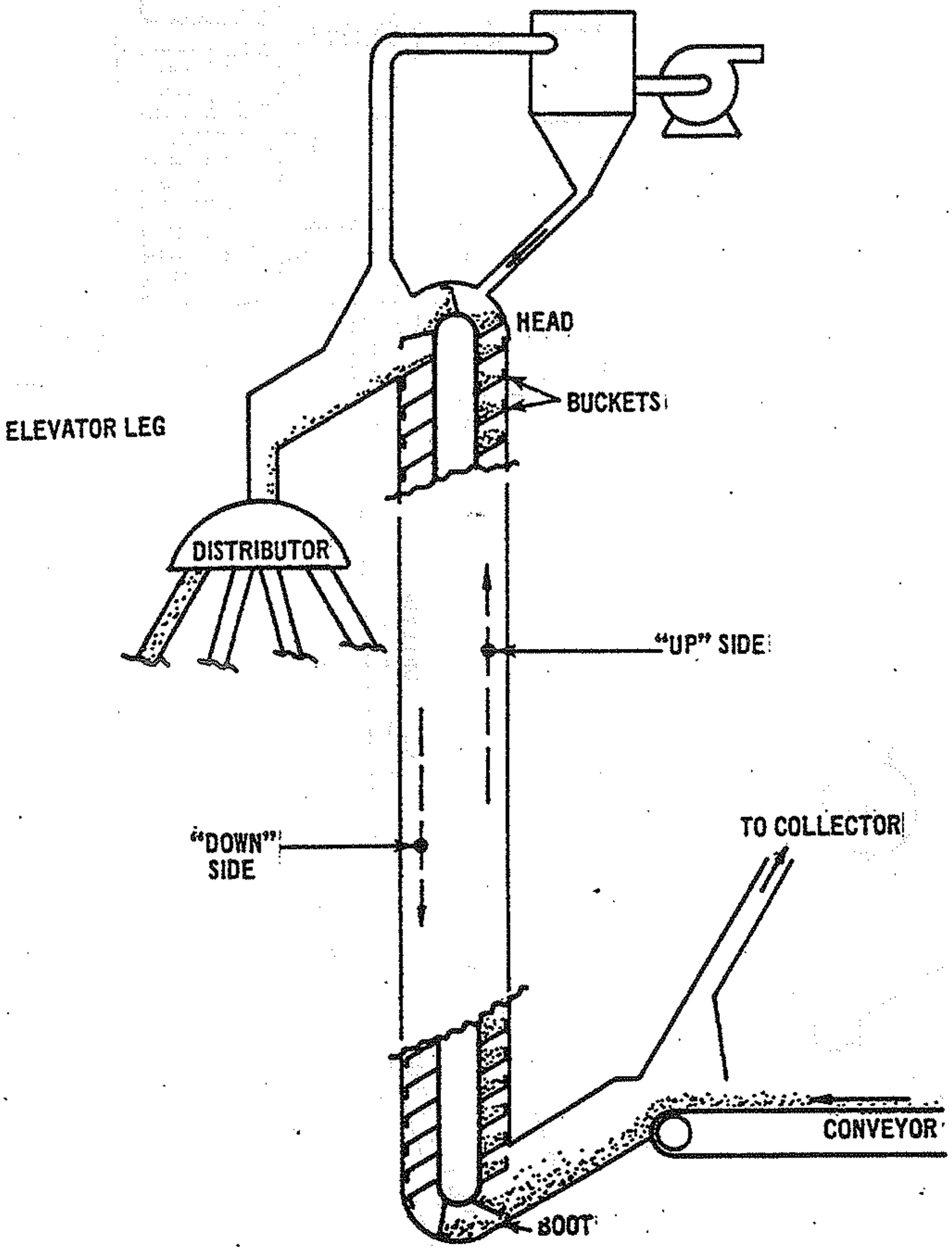

Figure 2.5-13. Elevator leg control system.[37]

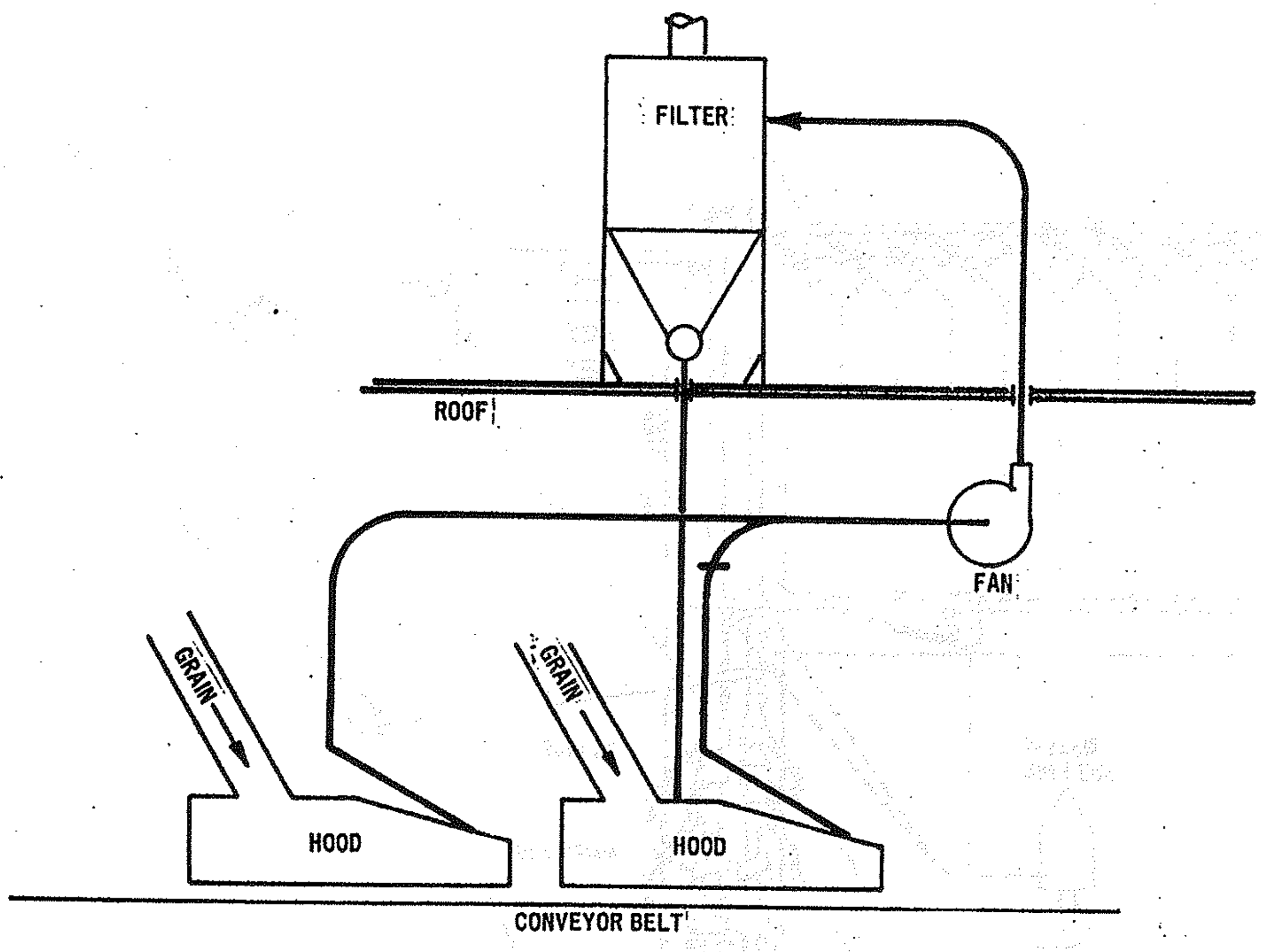

Figure 2.5-14. Transfer point control system.[38]

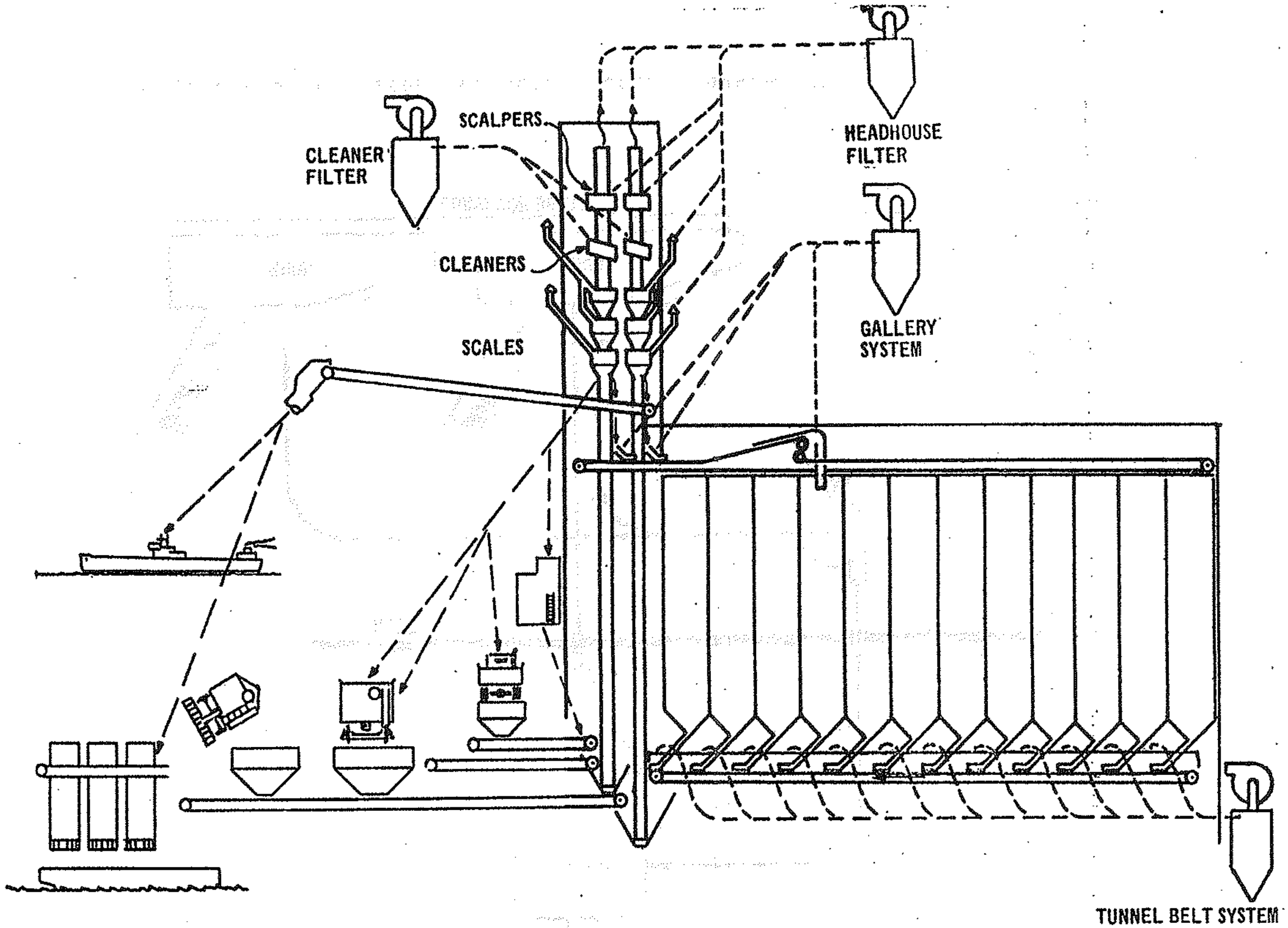

Figure 2.5-15. Grain handling and cleaning control system.[39]

Grain dryers present a difficult problem for air pollution control. Large volumes of air are exhausted from the dryers, the exhausts have large cross sectional areas, the dust has a low specific gravity, and the exhaust stream has a high moisture content. Rack or column dryers are commonly employed to dry grain at elevators. Column dryers have a lower emission rate than rack dryers since some of the dust is trapped by the columns of grain. The dryers may use screen systems to control particulate matter. The screens must be continuously vacuumed to keep them clean and prevent air flow blockage. Another screen cleaning technique is a sliding-bar, self-cleaning system. A screen filter control system with vacuum cleaning is shown in Figure 2.5-16.

As in truck unloading, the truck loading operation is best controlled if the loading is done in a three-sided and top enclosed shed with a closeable door. The loading involves the free fall of grain into the truck with considerable dust emissions. The dust emissions are reduced by using telescoping spouts (see Figure 2.5-17) or spouts with a canvas sock extension. Control in truck loading of grain is difficult because of variation in the sizes of trucks and the required movement of the loading spout. Aspiration inside an enclosure is used in a few cases by installation of a hood at the discharge end of the spout. The particulate matter is captured and ventilated to a cyclone or fabric filter.

Boxcar grain loading control is not common. One method of control is to cover the door area of the boxcar with a hood and ventilate the particulate matter to a fabric filter or cyclone. (See Figure 2.5-18.) Control of hopper car loading of grain is similar to the methods used for trucks. The loading is often

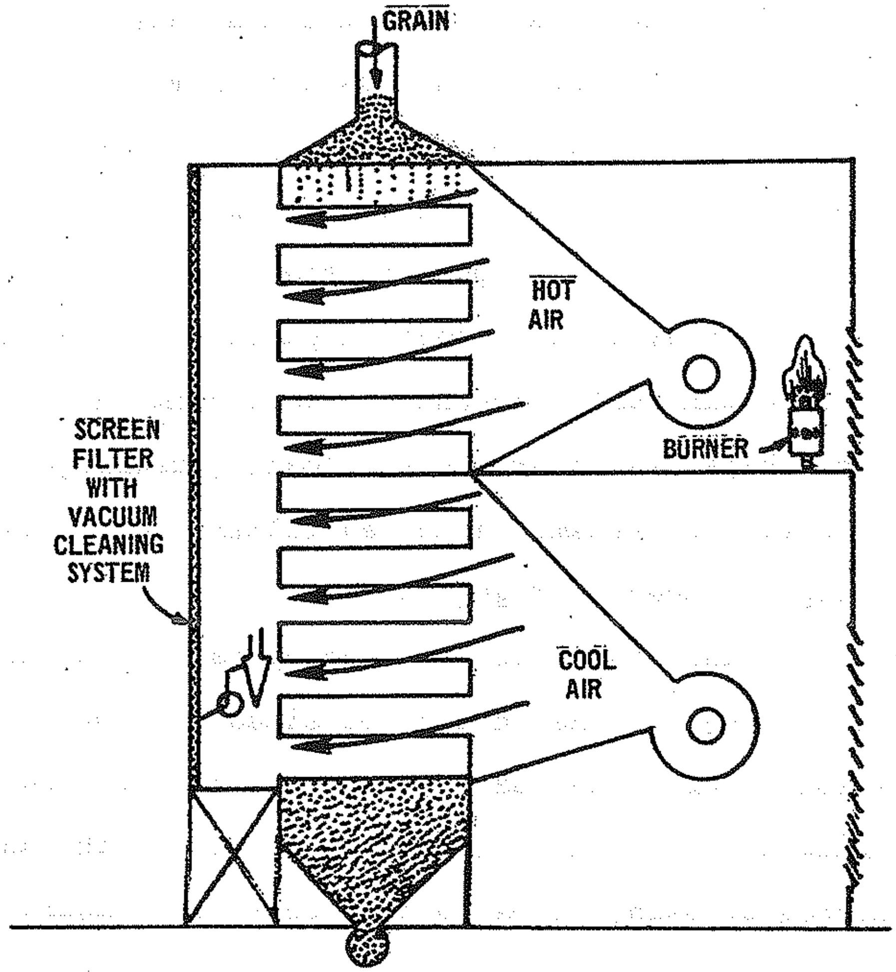

Figure 2.5-16. Rack dryer with screen filter.[40]

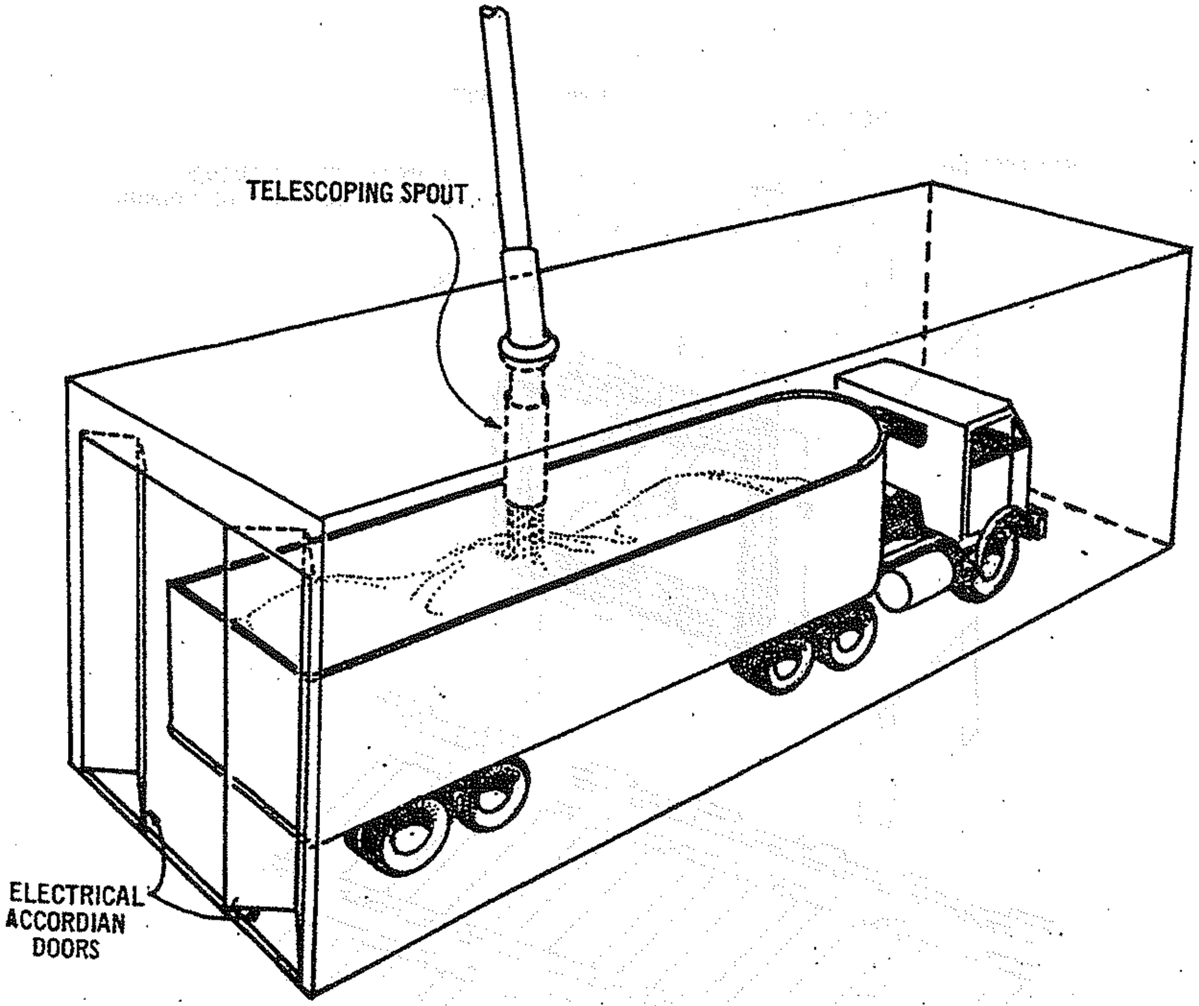

Figure 2.5-17. Truck loading control system.[41]

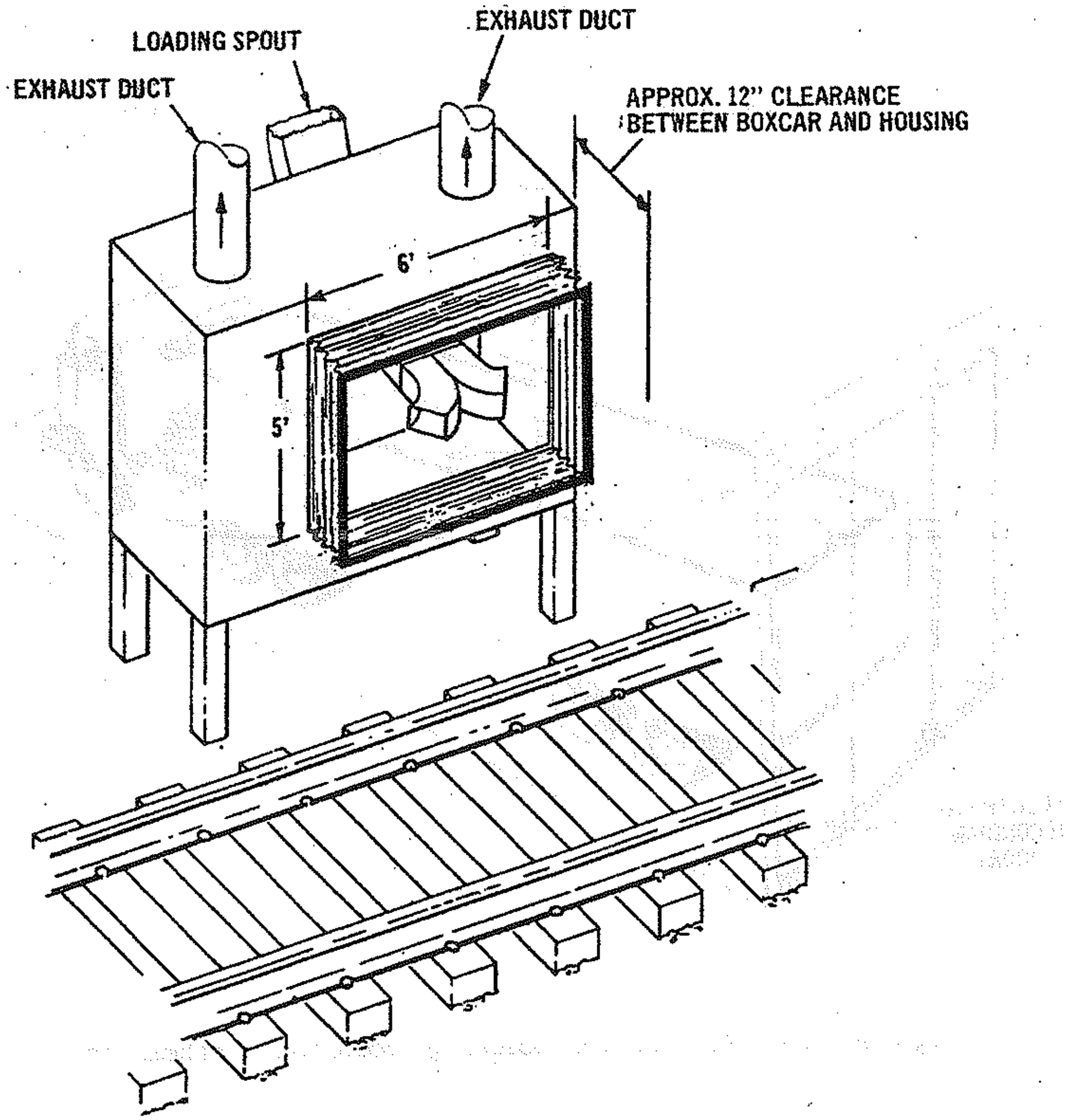

Figure 2.5-18. Boxcar loading control system.[42]

done in a semi-enclosed area. A hood can be installed at the discharge of the loading spout. (See Figure 2.5-19.) The dust generated in hopper car grain loading is ventilated from the hood to a fabric filter or cyclone. Telescoping spouts or choke-feed are also used.

The emissions from loading of barges can be minimized by reducing the freefall distance of the grain. A telescoping spout kept extended to the grain surface (i.e., to provide a choked feed) will reduce emissions. Additional control may be obtained by aspirating the end of the spout and exhausting to a fabric filter or a cyclone. (See Figure 2.5-20.)

For ship loading, a bullet-type or "dead box" system at the end of the loading spout can be used to slow the flow of grain. This may be equipped also with ventilation to cyclone or fabric filter collection to capture any dust generated. Another approach to control the loading of ships is to cover the entire hold with canvas, except where the loading spout enters, and to ventilate from beneath the cover to a fabric filter. However, this control alternative is not feasible during the "topping off" period (i.e., filling the top four feet of the hold), since very rapid movement of the loading spout is necessary to evenly distribute the grain. The system may also be infeasible under severe weather conditions and under high winds.

Table 2.5-3 summarizes the available control techniques, their effectiveness, estimated costs, and RACM selections.

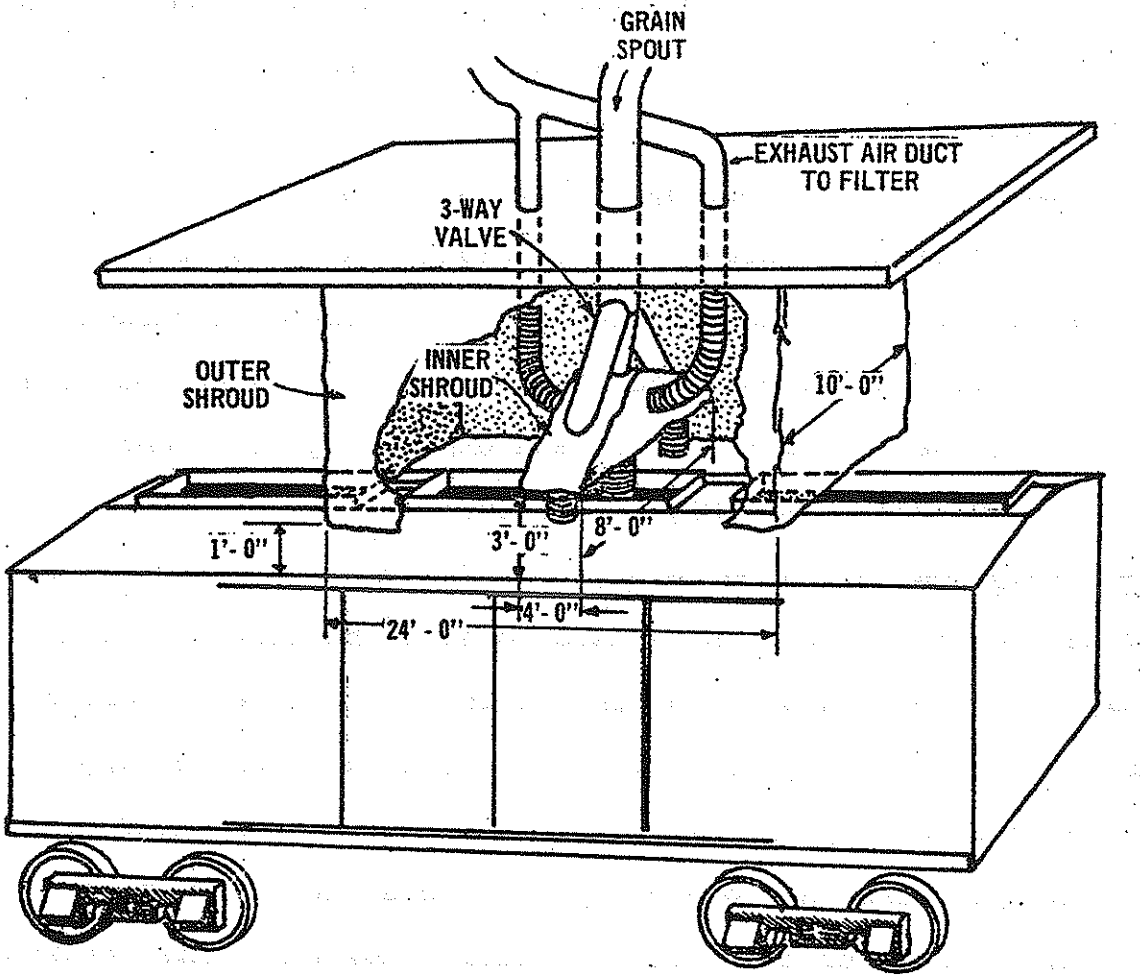

Figure 2.5-19. Hopper car loading control system.[43]

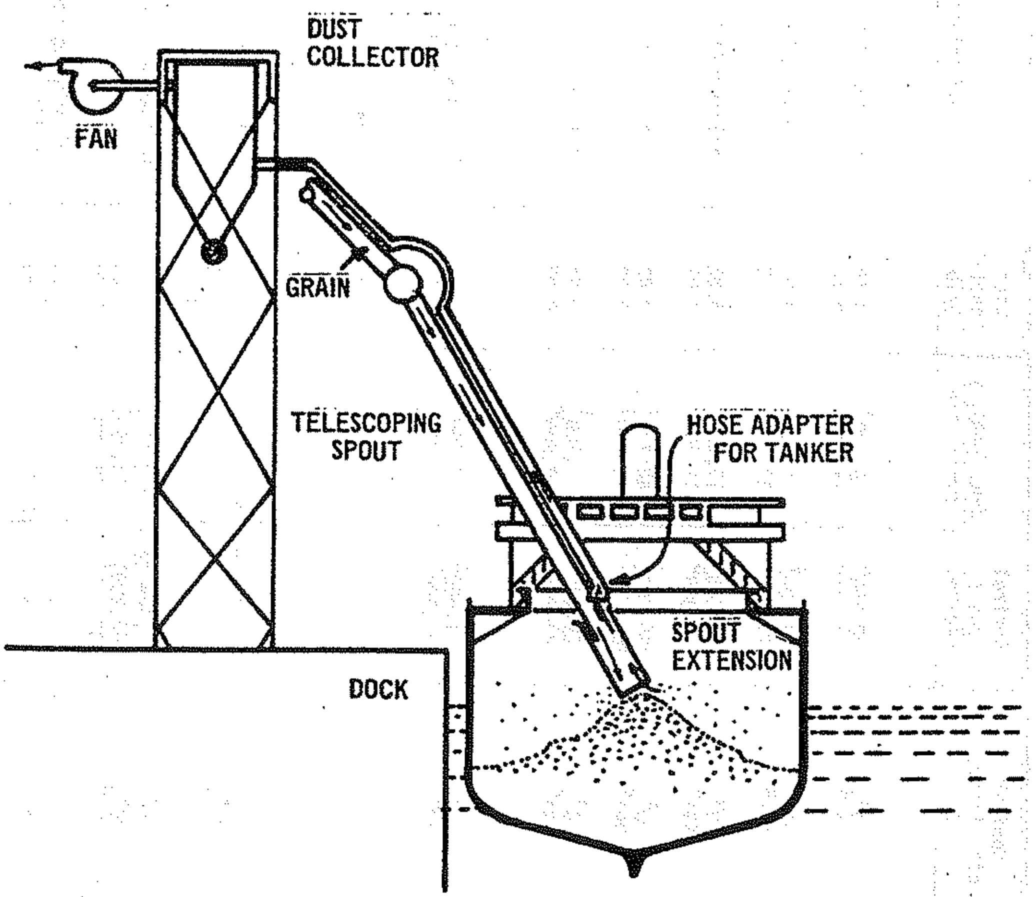

Figure 2.5-20. Barge or ship loading control system.[44]

TABLE 2.5-3. A SUMMARY OF THE CONTROL ALTERNATIVES, EFFICIENCIES AND COSTS, AND THE RACM SELECTIONS FOR FUGITIVE DUST EMISSIONS FROM SOURCES AT GRAIN TERMINALS

Fugitive dust source	Control alternatives	Control efficiency, %	Control costs, Jan. 1980, $ capital	Control costs, Jan. 1980, $ annualized	Cost benefit, $/lb	RACM selection
(1) Receiving:						
Truck unloading	Hopper vented to cyclone Enclosure[c]/fabric filter	90[a] 99+[d]	28,200[b] 53,500[b]	6,100[b] 11,700[b]	0.10 0.17	Enclosure/fabric filter
Railcar unloading	Enclosure[e]/cyclone Enclosure[e]/fabric filter	90[a] 99+[g]	34,200[f] 71,800[b]	6,200[f] 33,900[b]	0.01 0.05	Enclosure/fabric filter
Barge unloading	Enclosure/cyclone Enclosure/fabric filter	90[g] 99+[d]	39,200[h] 55,000[b]	11,200[h] 12,300[b]	0.02 0.02	Enclosure/fabric filter
(2) Transferring and conveying:	Vent to cyclones Vent to fabric filters	90[a] 99+[d]	260,600[i] 265,300[j,k]	68,700[i] 73,500[j,k]	0.03 0.03	Vent to fabric filters
(3) Cleaning:	Vent to cyclone Vent to fabric filter	90[a] 99+[d]	29,400[l] 43,400[m]	6,200[l] 9,600[m]	0.01 0.02	Vent to fabric filter
(4) Drying:						
Rack	Screens (24 mesh) Vacuum screen system (50 mesh)	63[o] 93[o]	11,000[n] 51,800[o]	2,300[n] 11,300[o]	0.02 0.07	Vacuum screen system (50 mesh)
Column	Limit perforation plate hole diameter to 0.084 in.	Unavailable	-	-	N.A.	0.084 in. perforation plate hole diameter
(5) Shipping:						
Truck loading	Adjustable chutes Enclosure/cyclone Enclosure/fabric filter	75[p] 90[a] 99+[d]	(See Section 2.1) q q	 q q	 0.31 0.53	Enclosure / fabric filter
Railcar loading	Adjustable chutes Hood/cyclone Enclosure /fabric filter	75[p] 90[a] 99+[d]	(See Section 2.1) 62,200[f] 103,900[f]	 13,000[f] 22,100[f]	 0.26 0.40	Enclosure / fabric filter
Barge loading	Telescoping spout/choked feed/cyclone Telescoping spout/choked feed/fabric filter	90[a] 99+[d]	t t	t t	0.03 0.03	Telescoping spout/choked feed/fabric filter
Ship loading	Tarpaulin cover[u]/cyclone Tarpaulin cover[u]/fabric filter Choke feed[w]/cyclone Choke feed[w]/fabric filter	90[u] 99+[d] 90[a] 99+[d]	41,200[b,v] 57,000[b,v] 65,700[o] 86,100[o]	11,300[b,v] 12,400[b,m] 13,600[o] 19,600[o]	0.01 0.01 0.01 0.02	Tarpaulin cover/fabric filter[u] or choke feed/fabric filter

(continued)

TABLE 2.5-3 (continued)

[a] Reference 12. High efficiency cyclone percent collection.

[b] References 13 and 14. Terminal capacity = 40,000,000 bushels annual throughput. Capital costs include purchase, auxiliaries, direct and indirect equipment installation. Annual costs include capitalization, electrical (at $0.03/kWh), maintenance, property taxes/insurance/administrative costs at 4% total capital investment.

[c] Shed with one (1) quick closing door.

[d] Reference 5. Fabric filter efficiency.

[e] Shed with one (1) end closed.

[f] References 13 and 14. Based on terminal with capacity of 15,000,000 bushels annual throughput.

[g] Assumed cyclone efficiency.

[h] References 13, 14, and 16. Costs estimated for (2) cyclones of 3/16 inch thick carbon steel each at 10,000 ACFM. Capital cost includes purchase price plus direct and indirect installation. Annual cost considers direct (at 11% turnkey) and indirect (overhead at 1% direct operating and capitalization at 17% turnkey) costs.

[i] References 13 and 14. Particulate control costs based on facility with 15,000,000 bushel annual throughput capacity and 10% retrofit penalty.

[j] References 13 and 14. Based on emissions control for scale and surge bins operations only. Facility capacity throughput of 15,000,000 bushels annually. No retrofit penalty.

[k] References 13 and 14. Also includes costs for barge loading controls. Facility capacity throughput of 15,000,000 bushels annually. No retrofit penalty.

[l] References 13 and 14. Based on facility with 15,000,000 bushel annual throughput capacity. No retrofit penalty.

[m] References 13 and 14. Based on facility with 15,000,000 bushel annual throughput capacity. No retrofit penalty.

[n] Estimated at 20% of vacuum system costs.

[o] References 13 and 14.

[p] Reference 17.

[q] Costs should be similar to truck unloading emissions control.

[r] References 13 and 14. Based on facility with 15,000,000 bushels annual throughput capacity. No retrofit penalty.

[s] Shed with open ends, plus special loading spout.

[t] Costs included in above figures for transferring/conveying.

[u] Usage except during topping-off periods in the ship hold or for loading of tween-deckers or tankers.

[v] Reference 18. Costs included for 6825 ft^2 (195 ft x 35 ft - typical barge size) tarpaulin at $0.29 per ft^2. Steel reinforced polyethylene, 4 mils thick.

[w] Reference 19. Typical choke-feed system includes "dead box" or bullet-type loading spouts.

2.5.5 Recommended Reasonably Available Control Measures (RACM)

RACM selections for grain terminal fugitive emission sources are summarized in Table 2.5-3.

The selected control technique for truck unloading is the use of a three-sided shed with one quick-closing door, ventilated to a fabric filter. This system, while less cost effective than venting the hopper to a cyclone, achieves a much better level of control, capable of achieving 0 percent opacity.[20]

For the unloading of railcars, the selected control measure is enclosure of the receiving area with ventilation to a fabric filter. This system is cost effective and no visible emissions result when it is applied.[21]

The selected control technique for unloading barges is the enclosure of the marine leg, receiving hoppers, and conveyor belt, and ventilation to a fabric filter. This system is cost effective and the most efficient of the available control techniques.

For control of transferring and conveying operations, the selected control technique is the venting of emission sources to fabric filters. This would include conveyor transfer points, trippers, turnheads, leg vents, scale bins, surge bins and the head house. This system is cost effective and can achieve an emission level of zero percent opacity.[22]

Control of cleaning operations is best achieved by ventilation to a fabric filter. This method consists of hooding or enclosing the equipment to collect the particulate matter which is then collected by a fabric filter.

The recommended control for rack dryers is the use of 50 mesh, vacuum cleaned screens. This system can achieve zero percent opacity at a fairly low cost.[23] For column dryers, an equipment standard of 0.084 inch or less diameter perforation plate holes is proposed. This system is effective and can achieve zero percent opacity.[23]

The proposed control technique for truck loading operations is the use of a three-sided shed equipped with one quick closing door and ventilation to a fabric filter. This system is the most effective of those available, although only able to achieve a ten percent opacity level.[24]

Recommended control of railcar loading operations is enclosure of the loading area via a three-sided shed with hooding and ventilation to a fabric filter. This system can achieve zero percent opacity.[25]

The proposed control technique for barge loading operations is the use of telescoping spouts to provide choked feed and aspiration from the spout to a fabric filter. This system is cost effective while providing the best control level of the available control methods.

The recommended control method for loading of ships is the use of tarpaulin covers with aspiration to a fabric filter. This system is not applicable to the loading of tankers or tween-deckers. Also, the tarpaulin must be removed for topping off the ship. Alternately, a system using choke feeding with ventilation to a fabric filter is recommended where severe weather or other operational contingencies do not favor use of tarpaulins.

Haul roads may be a major source of fugitive emissions around grain terminals. For a detailed treatment of haul roads and recommended control measures, refer to Section 2.1.

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41. Ibid. p. 4-23.

42. Ibid. p. 4-27.

43. Ibid. p. 4-25.

44. Ibid. p. 4-29.

APPENDIX FOR SECTION 2.5

(1) Receiving

Assume capacity = 40,000,000 bu/yr
Avg. wt. = 58 lb/bu
Emissions = (0.6 lb/ton)(40,000,000 bu/yr)(58 lb/bu)(t/2000 lbs)
= 696,000 lbs/yr
10% by truck; 69,600 lbs/yr

<u>Truck unloading</u>

<u>Hopper vented to cyclone</u>

Capital cost = $28,200
Annual cost = $6,100

$$C/B = \frac{\$6,100/yr}{.9\ (69,600)} = \$0.10/lb$$

<u>Enclosure/fabric filter</u>

Capital cost = $53,500
Annual cost = $11,700

$$C/B = \frac{\$11,700/yr}{.99\ (69,600)} = \$0.17/lb$$

<u>Railcar Unloading</u> (50% by rail)
Emissions = (1.3 lb/ton)(20,000,000 bu/yr)(58 lb/bu)(t/2000 lbs)
= 754,000 lbs/yr

<u>Enclosure / cyclone</u>

Capital cost = $34,200
Annual cost = $6,200

$$C/B = \frac{\$6,200/yr}{.9\ (754,000)} = \$0.01/lb$$

<u>Enclosure / fabric filter</u>

Capital cost = $71,800
Annual cost = $33,900

$$C/B = \frac{\$33,900/yr}{.99\ (754,000)} = \$0.05/lb$$

<u>Barge unloading</u> (40% by barge)
Emissions = (1.7 lb/ton)(16,000,000 bu/yr)(58 lb/bu)(t/2000 lbs)
= 788,800 lbs/yr

Enclosure / cyclone

Capital cost = $39,200
Annual cost = $11,200

$$C/B = \frac{\$11,200/yr}{.9\ (788,800)} = \$0.02/lb$$

Enclosure / fabric filter

Capital cost = $55,000
Annual cost = $12,300

$$C/B = \frac{\$12,300/yr}{.99\ (788,800)} = \$0.02/lb$$

(2) Transferring and conveying
Assume 15,000,000 bu/yr
Emissions = (6.0 lb/ton)(15,000,000)(58 lb/bu)(t/2000 lbs)
+ (1.2 lb/ton)(0.35)(15,000,000)(58)(1/2000)
= 2,792,700 lbs/yr

Vent to cyclones

Capital cost = $260,600
Annual cost = $68,700

$$C/B = \frac{\$68,700/yr}{.9\ (2,792,700)} = \$0.03/lb$$

Vent to fabric filters

Capital cost = $265,300
Annual cost = $73,500

$$C/B = \frac{\$73,500/yr}{.99\ (2,792,000)} = \$0.03/lb$$

(3) Cleaning
Emissions = (6 lb/ton)(0.221)(15 x 10^6)(58)(1/2000)
= 576,800 lbs/yr

Vent to fabric filter

Capital cost = $43,400
Annual cost = $9,600

$$C/B = \frac{\$9,600/yr}{.9\ (576,800)} = \$0.02/lb$$

Vent to cyclone

Capital cost = $29,400
Annual cost = $6,200

$$C/B = \frac{\$6,200/yr}{.9\ (576,800)} = \$0.01/lb$$

(4) Drying

Basis: 1.5×10^6 bu/yr

Emissions (Rack dryer) = (1.5×10^6) (4 lb/ton) (58) (1/2000)
= 174,000 lbs/yr

Screens (24 mesh)

Capital cost = \$11,000
Annual cost = \$2,300

$$C/B = \frac{\$2,300/yr}{.63\ (174,000)} = \$0.02/lb$$

Vacuum screen system

Capital cost = \$51,800
Annual cost = \$11,300

$$C/B = \frac{\$11,300/yr}{.93\ (174,000)} = \$0.07/lb$$

No data for column dryers

(5) Shipping

Truck loading

Emissions = (0.3 lb/ton) (15,000,000) (58) (1/2000) (.17)
= 22,200 lbs/yr

Adjustable chutes

See Section 2.1

Enclosure / cyclone

Capital cost = \$28,200
Annual cost = \$6,100

$$C/B = \frac{\$6,100/yr}{.9\ (22,200)} = \$0.31/lb$$

Enclosure / fabric filter

Capital cost = \$53,500
Annual cost = \$11,700

$$C/B = \frac{\$11,700/yr}{.99\ (22,200)} = \$0.53/lb$$

Railcar loading

Emissions = (0.27 lb/ton) (15,000,000) (58) (1/2000) (0.48)
= 56,400 lbs/yr

Adjustable chutes

See Section 2.1

Hood / cyclone

Capital cost = \$62,200
Annual cost = \$13,000

$$C/B = \frac{\$13{,}000/yr}{.9\ (56{,}400)} = \$0.26/lb$$

Enclosure / fabric filter

Capital cost = \$103,900
Annual cost = \$22,100

$$C/B = \frac{\$22{,}100/yr}{.99\ (56{,}400)} = \$0.40/lb$$

Barge loading

Choke feed / cyclone

See (2)
C/B = \$0.03/lb

Choke feed / fabric filter

See (2)
C/B = \$0.03/lb

Ship loading

Emissions = (1.2 lb/ton)(40,000,000)(58)(1/2000)(.94)
= 1,308,500 lbs/yr

Tarpaulin cover / cyclone

Capital cost = \$41,200
Annual cost = \$11,300

$$C/B = \frac{\$11{,}300/yr}{.9\ (1{,}308{,}500)} = \$0.01/lb$$

Tarpaulin / fabric filter

Capital cost = \$57,000
Annual cost = \$12,400

$$C/B = \frac{\$12{,}400/yr}{.99\ (1{,}308{,}500)} = \$0.01/lb$$

Telescoping spout / choked feed / cyclone

Capital cost = \$65,700
Annual cost = \$13,600

$$C/B = \frac{\$13,600/yr}{.9\ (1,308,500)} = \$0.01/lb$$

Telescoping spout / choked feed / fabric filter

Capital cost = \$86,100
Annual cost = \$19,600

$$C/B = \frac{\$19,600/yr}{.99\ (1,308,500)} = \$0.02/lb$$

2.6 COUNTRY GRAIN ELEVATORS

2.6.1 Process Description

Country grain elevators receive and store grain with subsequent shipment to terminal elevators, mills and other processing plants. In addition to storage, the country elevator sometime includes facilities to clean the grain, to dry it, or both. Grains handled includes corn, oats, wheat, rye, soybeans and burley.

The grain received at the country elevator is primarily received by truck or tractor from farms that are within a 10-12 mile radius.

Storage capacities of country elevators can range from 4,000 to 750,000 bushels.[1] The average size in the U.S. in 1974 was 441,000 bushels.[1] On the average, country elevators handle about 2 times as much grain as their storage capacity. For example, a country elevator with an average storage capacity of 441,000 bushels would handle about 880,000 bushels of grain per year.

The country elevators most often consist of upright concrete bins. Simplified and stylized diagrams of upright country elevators are shown in Figures 2.6-1 and 2.6-2. These elevators are usually designed to make maximum use of gravity flow to simplify the operation and minimize the use of mechanical equipment. The major piece of mechanical equipment required is the bucket elevator, or "leg", which elevates the grain to the top of the elevator where it is discharged into the distributor head and

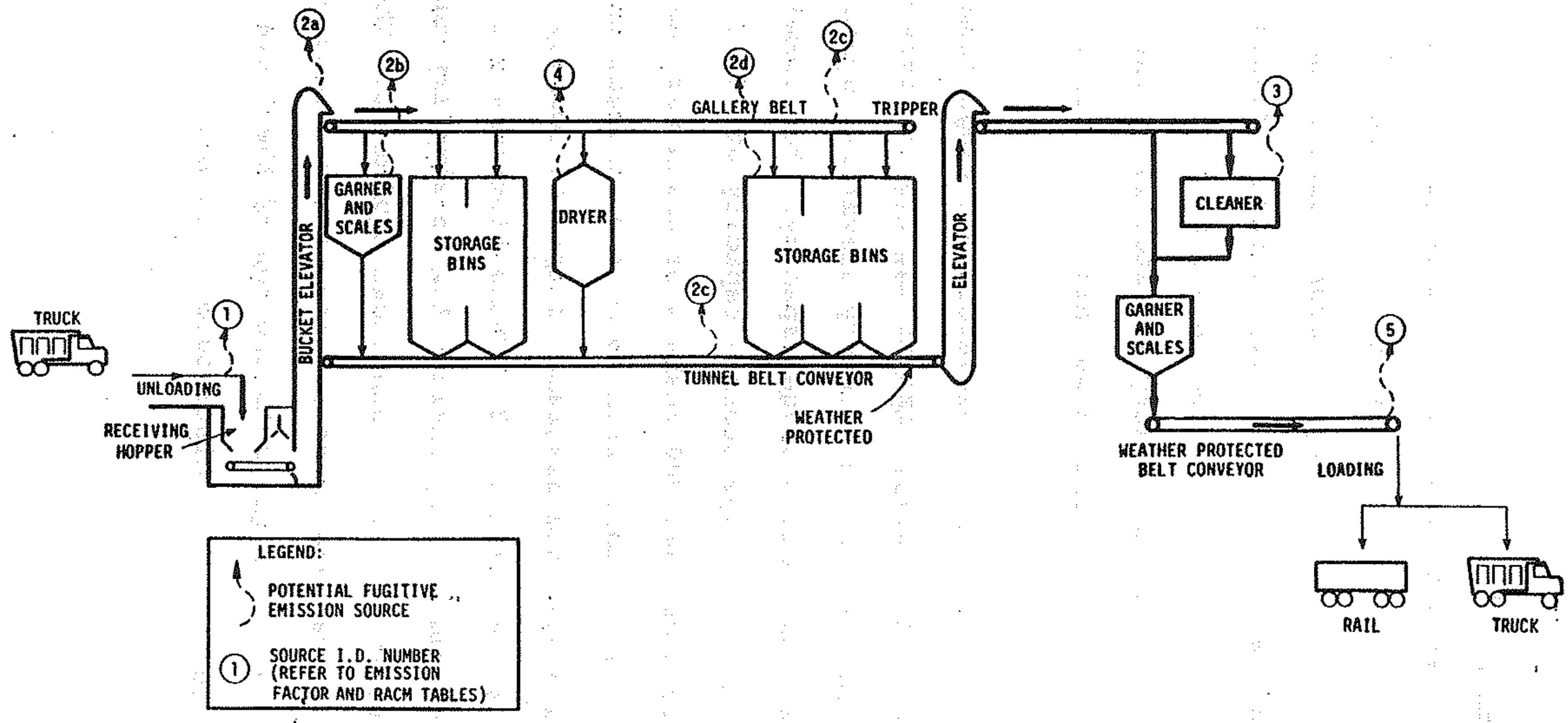

Figure 2.6-1. Simplified process flow diagram for country grain elevators and associated fugitive particulate emission sources.

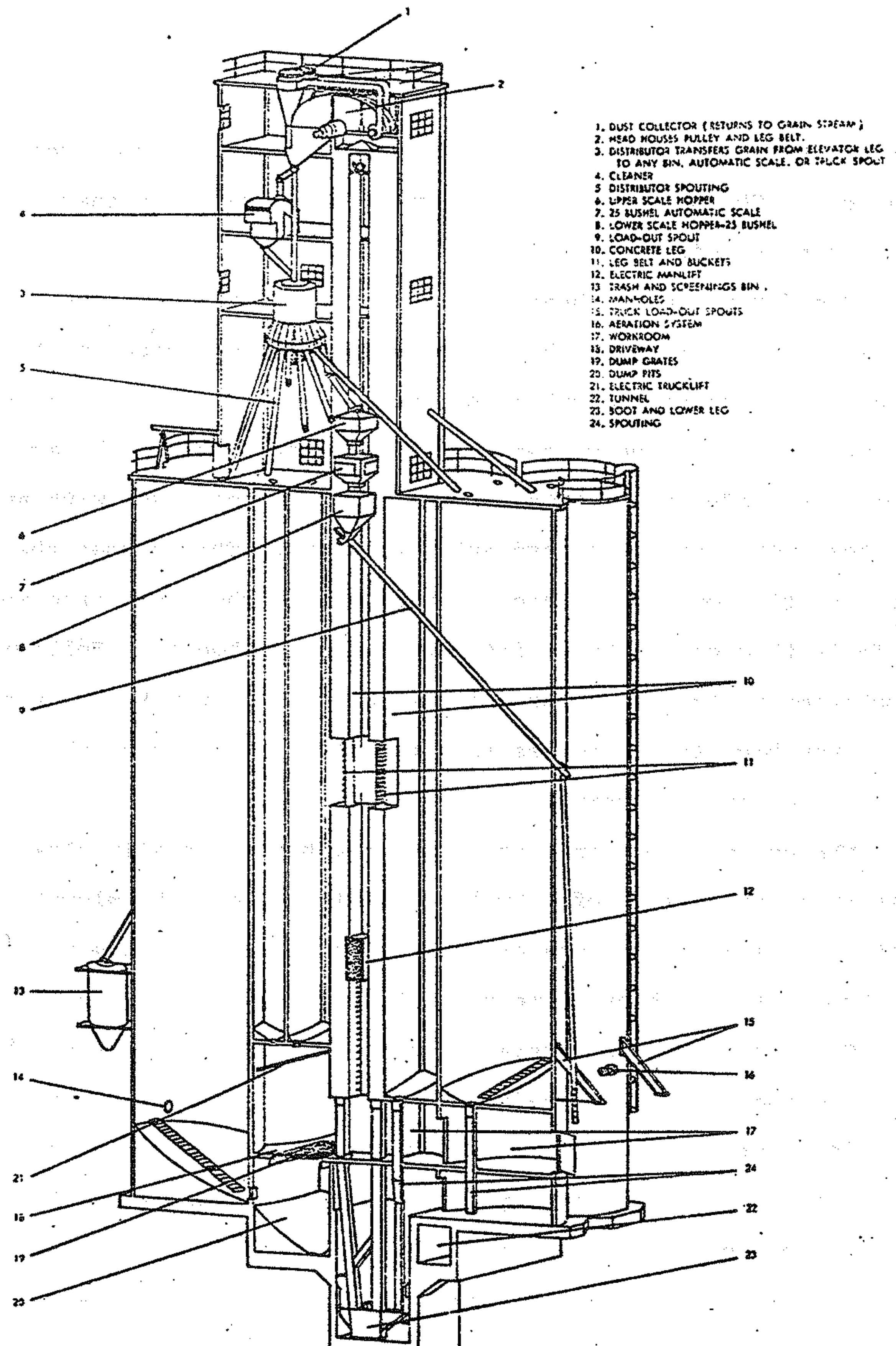

Figure 2.6-2. Diagram of an upright country grain elevator.[15]

then directed to the desired bin or into the scale for direct load-out. The section of the elevator which performs these functions is referred to as the "headhouse."

The first step in handling the grain after it arrives at the elevator is to weigh-in the loaded truck. After weigh-in, the truck is driven to the unloading station which is often a drive-through tunnel in the center of the elevator. The trucks are usually unloaded by lifting the front end of the truck with an overhead wench system or hydraulic platform. This causes the grain to flow out the opening in the back of the truck from which it falls through a grating into the receiving hopper. Following completion of the unloading and lowering of the truck, the truck is driven back to the scales and reweighed to determine the quantity of grain received.

The grain dumped into the receiving hopper usually flows by gravity to the bottom of a bucket elevator (i.e., the elevator boot). In some cases, the grain is transported from the receiving hopper to the boot by means of belt, drag or screw conveyors.

The receiving leg, averaging 5000-7500 bu/hr, elevates the grain to the top of the headhouse where it is discharged through the distributor head. The distributor head is positioned to direct the grain into the appropriate storage bins or to the cleaning equipment. Grain received from the farm usually contains a variety of impurities and a cleaning operation is sometimes performed prior to sending the grain to storage bins. Various types of screens and aspiration systems can be used to

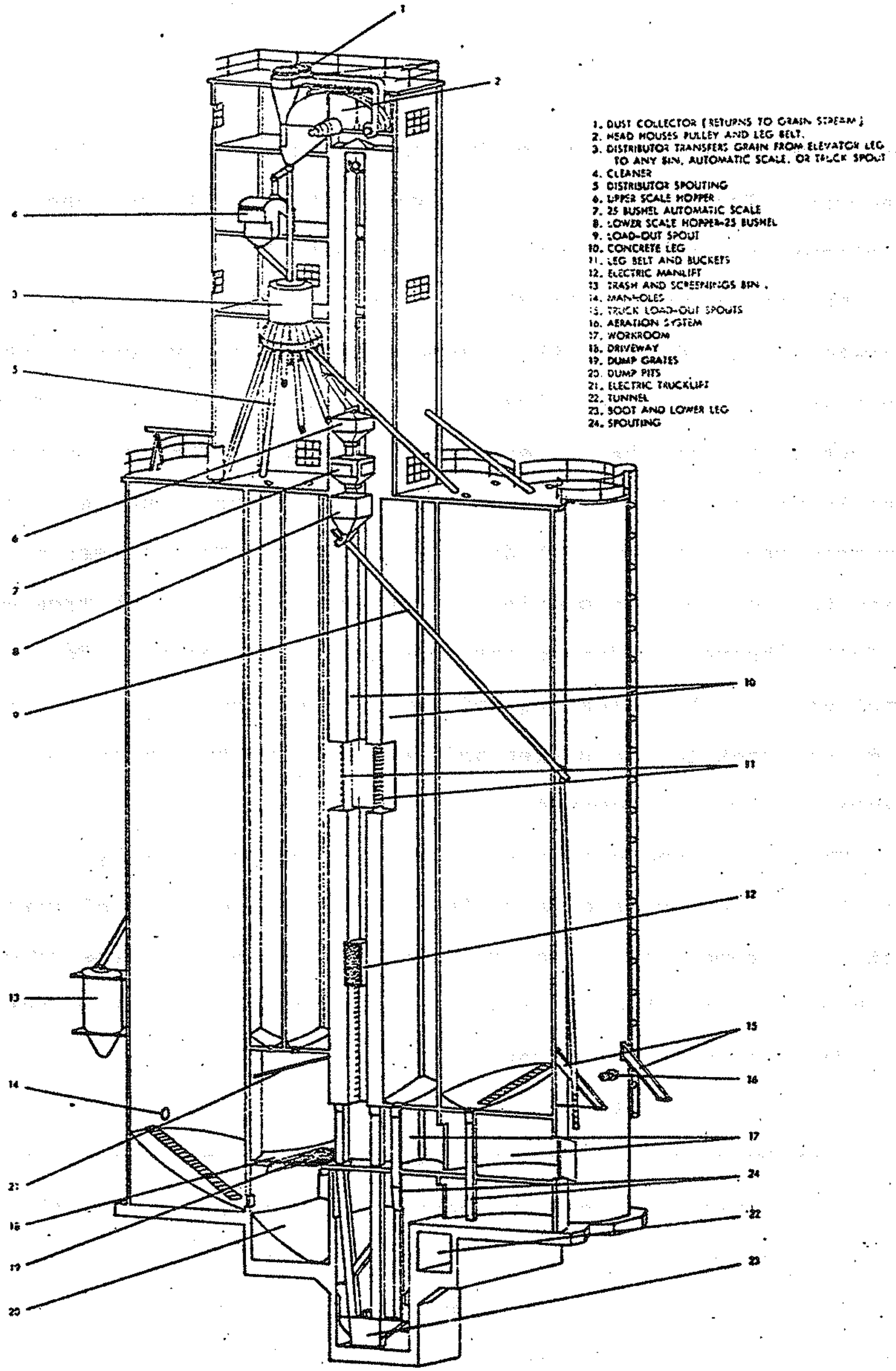

Figure 2.6-2. Diagram of an upright country grain elevator.[15]

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Certain grains, especially corn, must be dried before they are suitable for long-term storage. Elevators that receive these grains for long-term storage must be equipped with drying facilities. Certain dryers require an additional leg to elevate the wet grain from intermediate storage bins to the top of the dryer, and a means of conveying the dried grain from the dryer back to the primary leg for elevation to final storage. Grain dryers come in a wide range of capacities, and the size installed in country elevators is dependent upon the quantity of wet grain that is expected to be processed. The average drying operation would consist of a single dryer with a size capacity of 500-2000 bu/hr.

Fugitive emission sources at country grain elevators include grain receiving, transferring and conveying, screening and cleaning, drying and shipping. These sources are identified in Figure 2.6-1.

2.6.2 Fugitive Dust Emission Factors

Estimated fugitive emission factors for country grain elevators are summarized in Table 2.6-1. The emission factors are based upon a limited number of tests on grain elevators. It was found that the emission rates can vary greatly depending upon the types and characteristics of the grain being handled. Field

TABLE 2.6-1. FUGITIVE DUST EMISSION FACTORS FOR COUNTRY GRAIN ELEVATORS

Source	Emission factor, Average, (range)	Reliability rating	Reference
(1) Receiving Truck unloading	0.6 lb/ton unloaded (0.32 to 8.0 lb/ton)	D	2,3,4
(2) Transferring and conveying (total); Including:	2.5 lb/ton (2.0 to 4.0 lb/ton)	D	2,4,5,6
2a. Receiving, elevator leg and head	a		
2b. Garner and scale vents	a		
2c. Distributor, trippers, spouting	a		
2d. Storage bin vents	a		
(3) Screening and cleaning	3.0 lb/ton cleaned (0.19 to 10.1 lb/ton)	E	2,4,6
(4) Drying: Column	0.5 lb/ton dried (0.19 to 1.1 lb/ton)	D	2,3,4,7,8,9
Rack	4.0 lb/ton dried (1.8 to 8.0 lb/ton)	D	2,3,4,7,8,9
(5) Shipping Truck loading	0.3 lb/ton loaded (0.14 to 8.0 lb/ton)	D	2,3,4,5
Railcar loading	0.27 lb/ton loaded (0.015 to 8.0 lb/ton)	D	2,3,4,5

[a] Included in total estimate.

run grains such as soybeans, oats and sorghum are very dusty compared to wheat or corn. However, the data is insufficient for quantification of different emission factors by grain type. Therefore, the emission factors available cannot be considered accurate for any specific operation.

2.6.3 Particle Characterization

The fugitive particulate emissions from country grain elevators result from the unclean state in which grain is received at the elevators and from the generation of small particles by various physical handling operations. The grain may contain a small amount of spores of smuts and molds, insect parts, weed seeds, various pollens and siliceous dust from vegetation and soil in the vicinity of where it was grown. However, most of the dust is composed of bristles and other particles from the outer coats of the grain kernels. These particles are produced by the abrasion of the individual kernels of grain.

Grain dust has a specific gravity normally in the range 0.8 to 1.5 as compared to various other industrial dusts which usually have specific gravities between 2.0 and 2.5.[8] Grain dust is mostly in the range of 10 to 100 μm in size.[7]

Table 2.6-2 presents the results of size distribution tests of the material entering the inlet of a cyclone which vented an elevator leg.[6] These cyclone inlet emissions can be considered an approximation of the particle size distribution of the fugitive particulate emissions from an uncontrolled elevator leg vented to the atmosphere.

TABLE 2.6-2. PARTICULATE SIZE DISTRIBUTION FOR DUST FROM AN ELEVATOR LEG CYCLONE (INLET TEST)[6]

US Sieve mesh	Size opening (μm)	Cumulative weight, percent greater than
100	149	32.7
170	88	44.7
200	74	48.7
325	44	68.0
-	20	91.0
-	10	99.1
-	5	99.9
-	1	99.9

During corn drying, a material called "bees wings," which is the filmy outer skin of the corn kernel, is emitted into the air along with the grain dust. Essentially all bees wing emissions are over 50 μm in diamter, and the mass mean diameter is probably in the region of 150 μm.[8]

Additional information on toxicity and other health effects is presented in Section 2.5.3.

2.6.4 Control Methods

The control methods for country grain elevators are essentially identical to those for large grain terminals except on a smaller scale. A discussion of the available control techniques is presented in Section 2.5.4. Table 2.6-3 summarizes these techniques plus their efficiencies, estimated costs, and the RACM selections.

TABLE 2.6-3. A SUMMARY OF THE CONTROL ALTERNATIVES, EFFICIENCIES AND COSTS, AND THE RACM SELECTIONS FOR FUGITIVE DUST EMISSIONS FROM SOURCES AT COUNTRY GRAIN ELEVATORS

Fugitive dust sources	Control alternatives	Control efficiency, %	Control cost, Jan. 1980, $ Capital	Annualized	Cost benefit, $/lb	RACM selection
(1) Receiving: Truck unloading	Hopper vented to cyclone	90[a]	42,700[b,c]	8,700[b,c]	0.44	Enclosure vented to fabric filter (for capacities less than 700,000 bu/yr a 3-sided shed is recommended)
	Enclosure[d] vented to fabric filter	99+[e]	72,200[b,c]	14,900[b,c]	0.69	
	Enclosure (3-sided)	60[f]	27,700[g]	6,100[g]	0.59	
(2) Transferring and conveying Handling, weighing	Vent to cyclone	90[a]	14,100[b]	3,000[b]	0.05	Vent to fabric filter (for capacities less than 700,000 bu/yr, venting by a cyclone is recommended)
	Vent to fabric filter	99+[e]	22,100[b]	4,700[b]	0.07	
(3) Cleaning	Vent to cyclone	90[a]	16,100[h]	3,400[h]	0.54	Vent to fabric filter (for capacities less than 700,000 bu/yr, venting to a cyclone is recommended)
	Vent to fabric filter	99+[e]	23,900[h]	6,000[h]	0.86	
(4) Drying: Rack	Vent to cyclone	90[i]	79,000[j]	22,200[j]	2.13	50 mesh vacuum-cleaned screen
	Vacuum screen system (50 mesh)	93[k]	35,900[k]	7,300[k]	0.68	
Column	Limit perforation plate hole diameter to 0.084 in.	Unavailable	-	-	N.A.	0.084 in. perforation plate hole diameter
(5) Shipping: Truck loading	Adjustable chutes	75[l]	(See Section 2.1)			Enclosure vented to fabric filter (for capacities less than 700,000 bu/yr, adjustable chutes are recommended)
	Vent to cyclone	90[a]	42,700[b,c]	8,700[b,c]	2.22	
	Enclosure[d] vented to fabric filter	99+[e]	72,200[b,c]	14,900[b,c]	3.46	
Railcar loading	Adjustable chutes	75[j]	(See Section 2.1)			Enclosure vented to fabric filter (for capacities less than 700,000 bu/yr, adjustable chutes are recommended)
	Hood vented to cyclone	90[a]	27,000[h]	5,700[j]	1.62	
	Enclosure vented to fabric filter	99+[e]	62,700[j]	12,500[h]	3.23	

(continued)

TABLE 2.6-3 (continued)

[a] Reference 10. High efficiency cyclone.

[b] References 10 and 11. Terminal capacity-1,000,000 bushels annual throughput. Capital costs include purchase, auxiliaries, direct and indirect equipment installation. Annual costs include capitalization, electrical (@ $0.03/kWh), maintenance, property taxes/insurance/administrative costs at 4% total capital investment.

[c] Includes truck loading.

[d] Shed with one (1) quick closing door.

[e] Reference 12. Fabric filter.

[f] Estimated.

[g] Estimated as difference between options B anc C, Reference 12, upgraded country elevator handling 3,500,000 bu/yr.

[h] References 11 and 13. Based on an upgraded country facility with 3,500,000 bushels annual throughput capacity and retrofit penalty of 10 percent. Cleaning is not always conducted at country elevators.

[i] Assumed cyclone efficiency.

[j] References 11 and 14. Costs estimated for cyclone of 3/16 inch thick carbon steel @ 50,000 ACFM. Capital turnkey includes purchase price plus direct/indirect installation. Annual cost considers direct (at 11% turnkey) and indirect (overhead at 1% direct operating and capitalization at 17% turnkey) costs.

[k] References 11 and 13.

[l] Reference 15.

2.6.5 Recommended Reasonably Available Control Measures (RACM)

Table 2.6-3 presents RACM recommended for the control of country grain elevator fugitive emissions. Just as the control alternatives available to larger grain terminals are essentially identical for country grain elevators (yet on a smaller scale), so are the designated RACM selected.

However, it is recommended that a size be determined below which control is not required due to high relative cost. The U.S. EPA, in its economic analysis of the impacts of various regulatory options, has determined that control costs are essentially fixed for elevators smaller than 1 million bushels per year.[16] The U.S. EPA has determined that country elevators handling less than 700,000 bushels per year will not be governed by New Source Performance Standards.[16] Therefore, country elevators handling less than 700,000 bushels per year will be required to implement the alternative control options listed in Table 2.6-3.

REFERENCES FOR SECTION 2.6

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10. Op. cit. Reference 8. p. 8-17.

11. Ibid. pp. 6-26 through 6-31.

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14. Op. cit. Reference 8. p. 1-3.

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APPENDIX FOR SECTION 2.6

(1) Receiving

Emissions = (0.6 lb/ton)(1 x 10^6 bu/yr)(58 lb/bu)(t/2000 lbs)
= 17,400 lbs/yr

Hopper vented to cyclone

Captial cost = $42,700
Annual cost = 8,700

$$C/B = \frac{\$8,700/yr}{.9\ (17,400) + .9\ (4,350)} = \$0.44/lb$$

Enclosure vented to fabric filter

Capital cost = $72,200
Annual cost = 14,900

$$C/B = \frac{\$14,900}{.99\ (17,400) + .99\ (4,350)} = \$0.69/lb$$

Enclosure

Capital cost = $27,700
Annual cost = 6,100

$$C/B = \frac{\$6,100/yr}{.6\ (17,400)} = \$0.59/lb$$

(2) Transferring and conveying (Handling and weighing)

Emissions = (2.5 lb/ton)(27,000 tpy) = 72,500 lbs/yr

Vent to cyclone

Capital cost = $14,100
Annual cost = 3,000

$$C/B = \frac{\$3,000/yr}{.9\ (72,500)} = \$0.05/lb$$

Vent to fabric filter

Capital cost = $22,100
Annual cost = 4,700

$$C/B = \frac{\$4,700/yr}{.99\ (72,500)} = \$0.07/lb$$

(3) Cleaning (8% cleaned)

Emissions = (3 lb/ton)(29,000 tpy)(.08) = 7,000 lbs/yr

Vent to cyclone

Capital cost = $16,100
Annual cost = 3,400

$$C/B = \frac{\$3,400/yr}{.9\ (7,000)} = \$0.54/lb$$

Vent to fabric filter

Capital cost = $23,900
Annual cost = 6,000

$$C/B = \frac{\$6,000/yr}{.99\ (7,000)} = \$0.86/lb$$

(4) Drying

Rack (10% dried)

Emissions = (4 lbs/ton)(29,000 tpy)(0.1) = 11,600 lbs/yr

Vent to cyclone

Capital cost = $79,000
Annual cost = 22,200

$$C/B = \frac{\$22,200/yr}{.9\ (11,600)} = \$2.13/lb$$

Vacuum screen system (50 mesh)

Capital cost = $35,900
Annual cost = 7,300

$$C/B = \frac{\$7,300/yr}{.93\ (11,600)} = \$0.68/lb$$

Column

No data

(5) Shipping

Emissions = (.50)(0.3)(29,000 tpy) = 4,350 lbs/yr

Truck loading (50% by truck)

Adjustable chutes

See Section 2.1

Vent to cyclone

Capital cost = $42,700
Annual cost = 8,700

$$C/B = \frac{\$8,700/yr}{0.9\ (4,350)} = \$2.22/lb$$

Enclosure vented to fabric filter

Capital cost = $72,200
Annual cost = 14,900

$$C/B = \frac{\$14,900/yr}{.99\ (4,350)} = \$3.46/lb$$

Railcar loading

Emissions = (.50)(0.27)(29,000) = 3,915 lbs/yr

Adjustable chutes

See Section 2.1

Hooding vented to cyclone

Capital cost = $27,000
Annual cost = 5,700

$$C/B = \frac{\$5,700/yr}{.9\ (3,915)} = \$1.62/lb$$

Enclosure to fabric filter

Capital cost = $62,700
Annual cost = 12,500

$$C/B = \frac{\$12,500/yr}{.99\ (3,915)} = \$3.23/lb$$

2.7 IRON FOUNDRIES

2.7.1 Process Description[1-7]

Foundries produce castings for automotive parts, light and heavy machinery, pipe and a wide range of miscellaneous products. The process involves melting scrap metal and/or pig iron (crude iron in the form of blocks weighing about 100 pounds) and pouring the molten metal into prepared molds. The two major categories are "iron" foundries and "steel" foundries. Iron foundries may be further subdivided into "gray iron", "malleable iron" and "ductile iron" foundries. Both iron and steel consist primarily of elemental iron but with differing carbon content. Iron contains 2 to 4 percent carbon, and steel contains 1 percent or less. Iron formulations also incorporate various amounts of other elements. For example, silicon content is generally in the range of 2 to 3 percent in iron formulations.[8] Steel may also contain alloying elements.

Iron foundries may be further classified as either "captive" or "jobbing" foundries. A captive foundry is one that is a regular operating element of a manufacturing establishment and whose castings are generally made for the products of the parent company. In contrast, a jobbing foundry is one that manufactures a variety of castings which are not used in its own products, but are made for the products of other companies.

Figures 2.7-1 and 2.7-2 illustrate the process flow in a typical iron foundry. The basic process flow is essentially the same regardless of whether the foundry is captive or job shop. About 70 percent of the iron melted in the U.S. is produced in a cupola furnace.[9] Cupola capacities range from 1 to 100 tons of molten metal per hour. Over 60 percent operate in the range of 3 to 11 tons per hour. (Figure 2.7-3 illustrates a typical cupola furnace.) The other types of furnaces used in iron foundries are

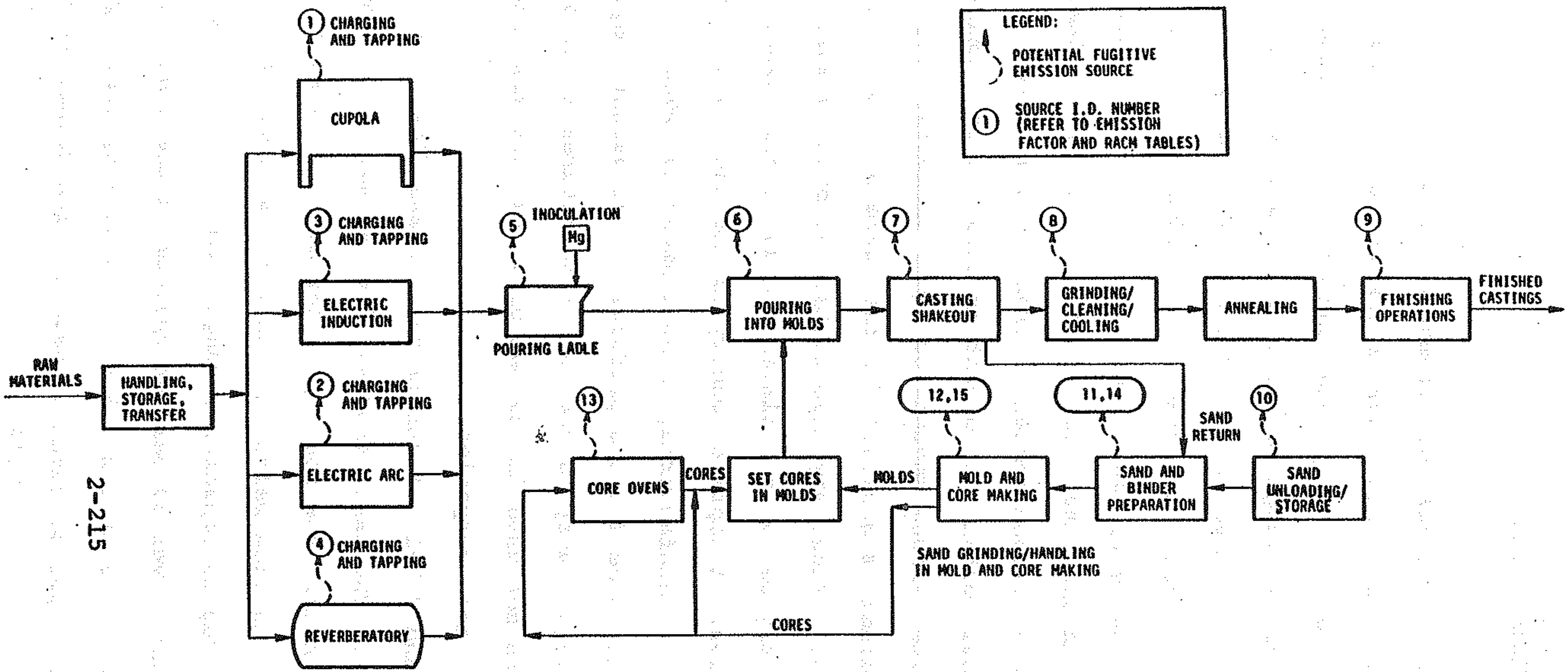


Figure 2.7-1. Simplified process flow diagram for iron foundries and associated fugitive particulate emission sources.

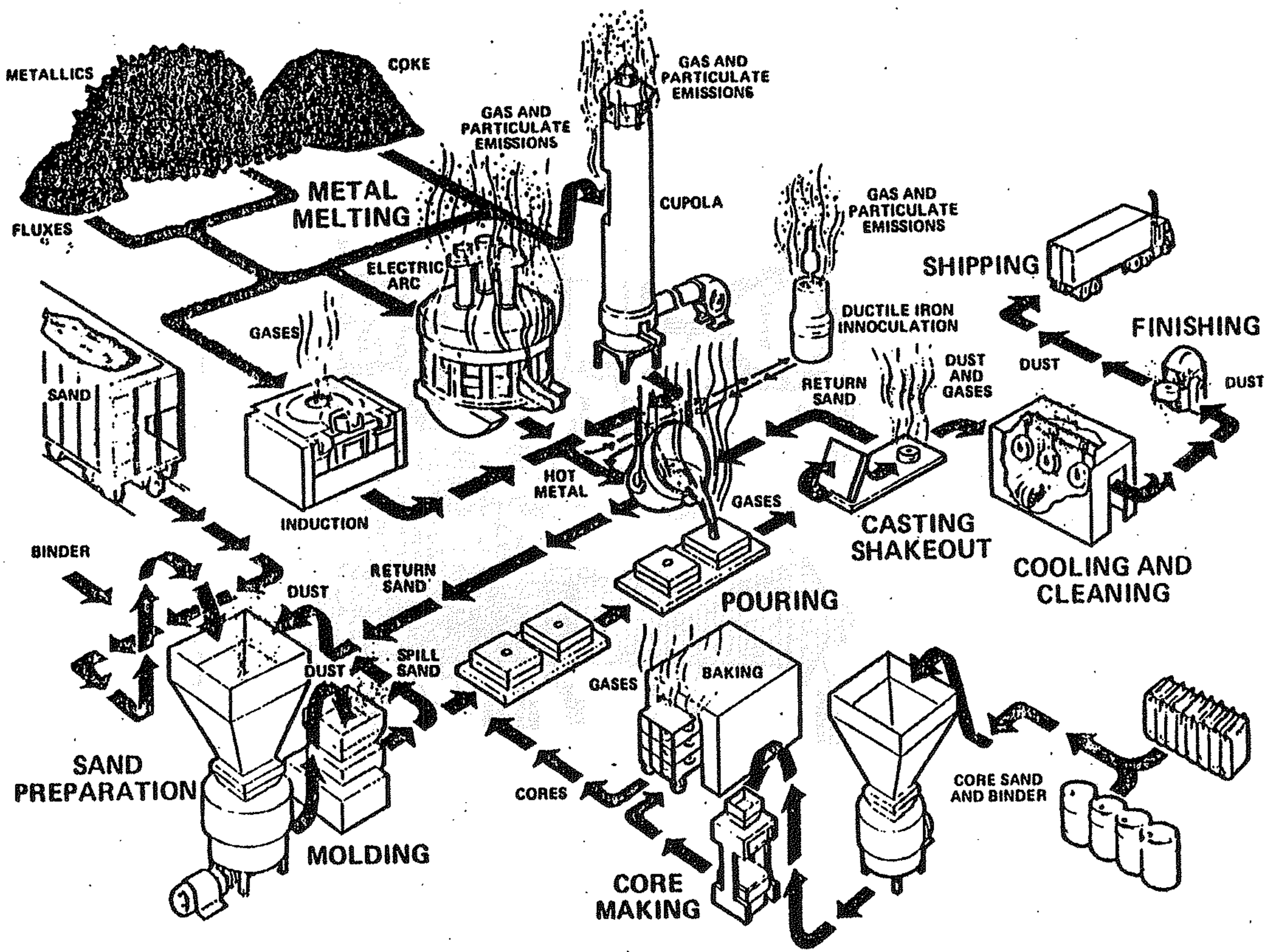


Figure 2.7-2. Iron foundry process flow diagram.[10]

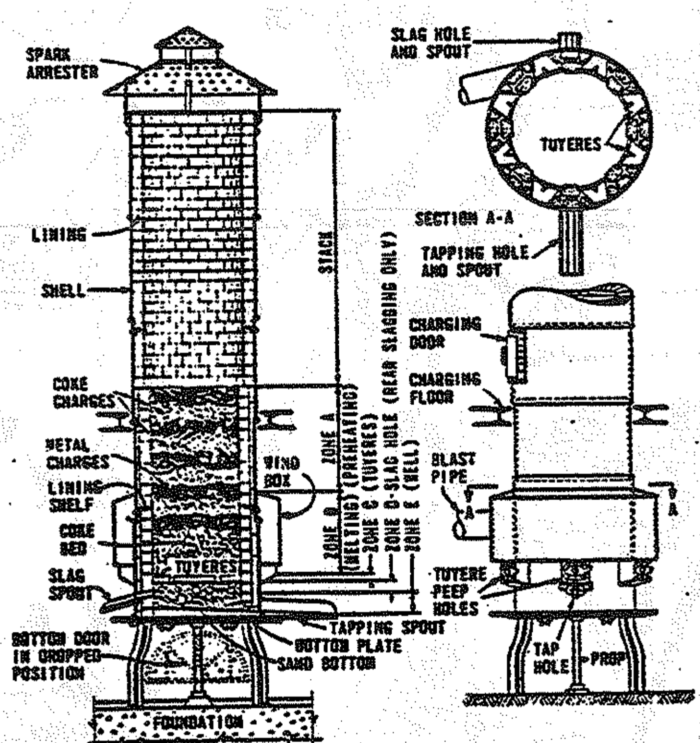


Figure 2.7-3. Cupola furnace.[11]

electric arc, electric induction and reverberatory. (These furnaces are shown in Figures 2.7-4 to 2.7-7.)

Raw materials are charged into the cupola through a door in the top of the furnace. The raw materials consist of iron and/or steel scrap, pig iron, flux materials, ferrosilicon and coke. Fluxes are limestone or similar minerals, that absorb impurities after the charge has melted. Coke is essentially pure carbon in lump form. The burning of the coke provides the heat to melt the raw materials. As the charge melts, it descends to the bottom of the furnace where the molten metal product is drained out periodically. Fresh raw materials are added to keep the furnace full. Operation of cupola furnaces can be done on a continuous basis.

The charge for electic arc, electric induction and reverberatory furnaces consists mainly of iron and/or steel scrap, pig iron and limestone. The reverberatory furnace is heated by firing gas or oil. These furnaces are operated on a batch basis.

The molten metal is tapped from the furnace at a temperature of about 2900°F into a ladle or into a holding furnace until it is ready to be drained into a ladle. The ladle is transported to the mold line, and molten metal is poured into prepared molds. The molds contain the molten iron within the mold form until it solidifies. In production of high strength ("ductile iron") castings, magnesium is added to the molten iron by a process called inoculation. (See Figure 2.7-8 for an illustration of the magnesium treatment methods used to produce ductile iron.) After solidification, the sand molds and castings are separated, and the sand is recycled to the mold making operation. Castings are shaken out of the molds, or the molds are broken away from the castings. When sufficiently

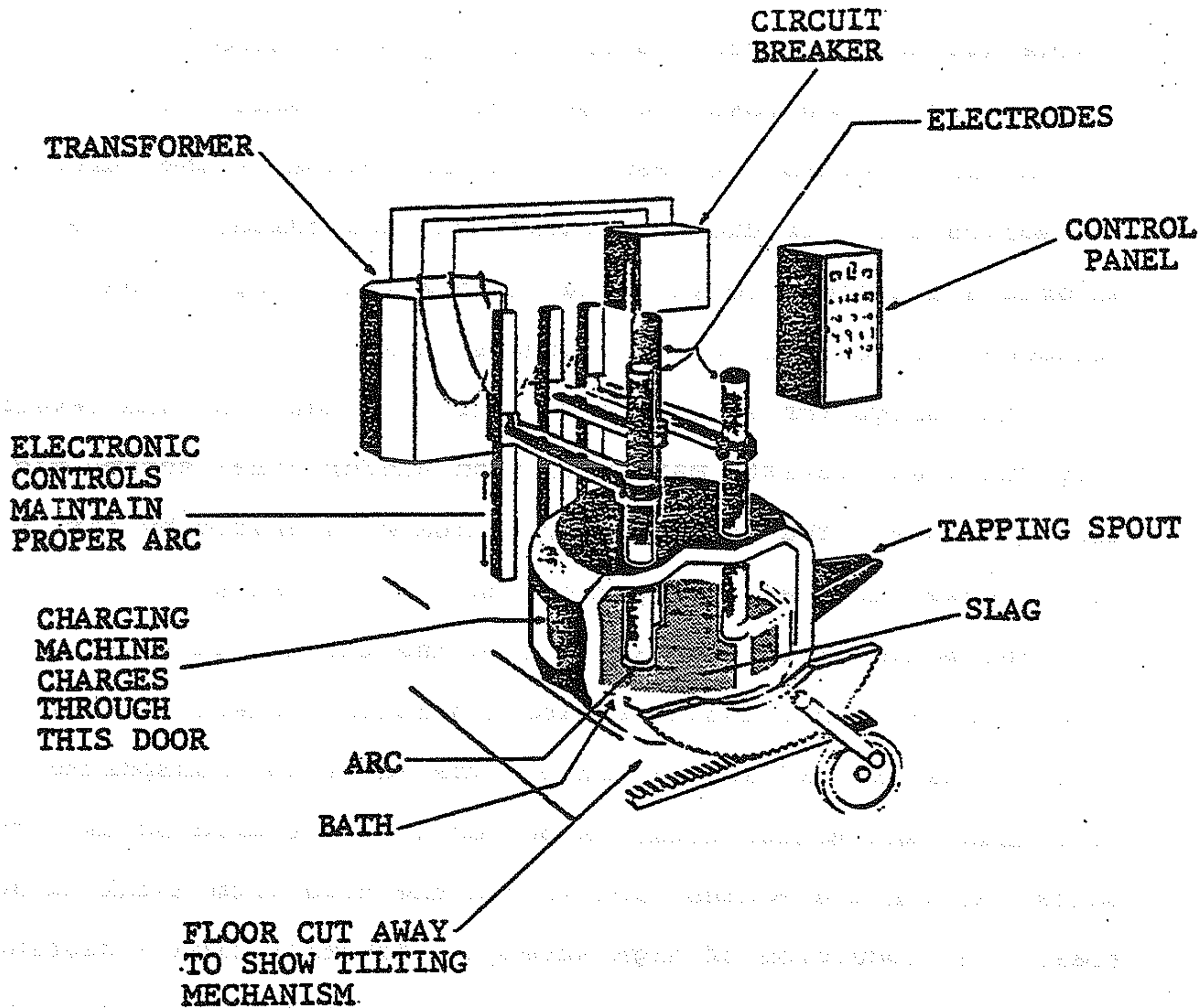


Figure 2.7-4. Electric arc furnace.[12]

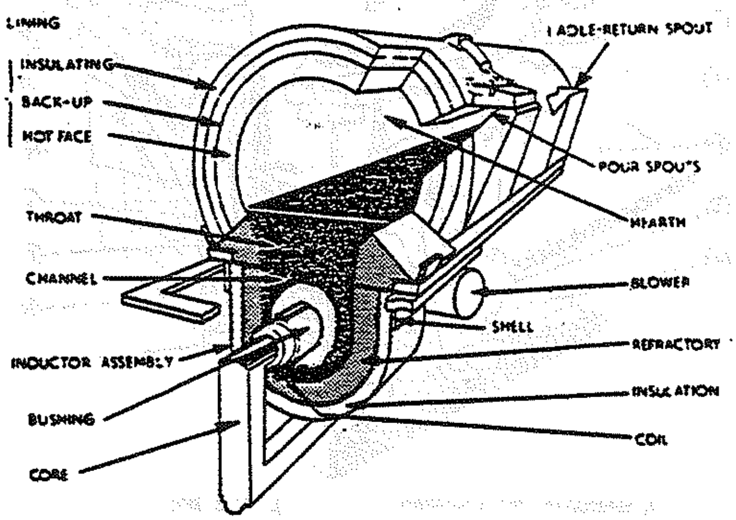
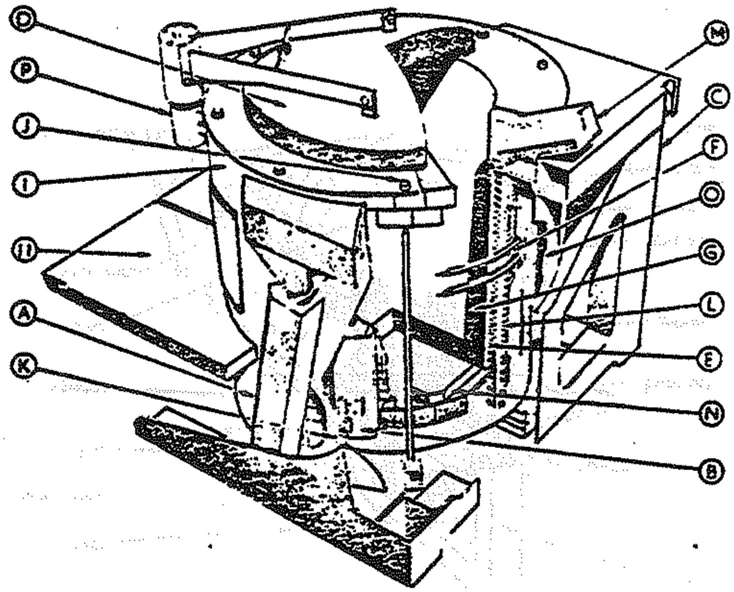


Figure 2.7-5. Channel electric induction furnace.[13]



A. HYDRAULIC TILT CYLINDERS
B. SHUNTS
C. STANCHION
D. COVER
E. COIL
F. LEADS
G. WORKING REFRACTORY
H. OPERATOR'S PLATFORM
I. STEEL SHELL
J. TIE RODS
K. CLAMPING BOLTS
L. COIL SUPPORT
M. SPOUT
N. REFRACTORY BRICK
O. ACCESS PORT
P. LID HOIST MECHANISM

Figure 2.7-6. Coreless electric induction furnace.[14]

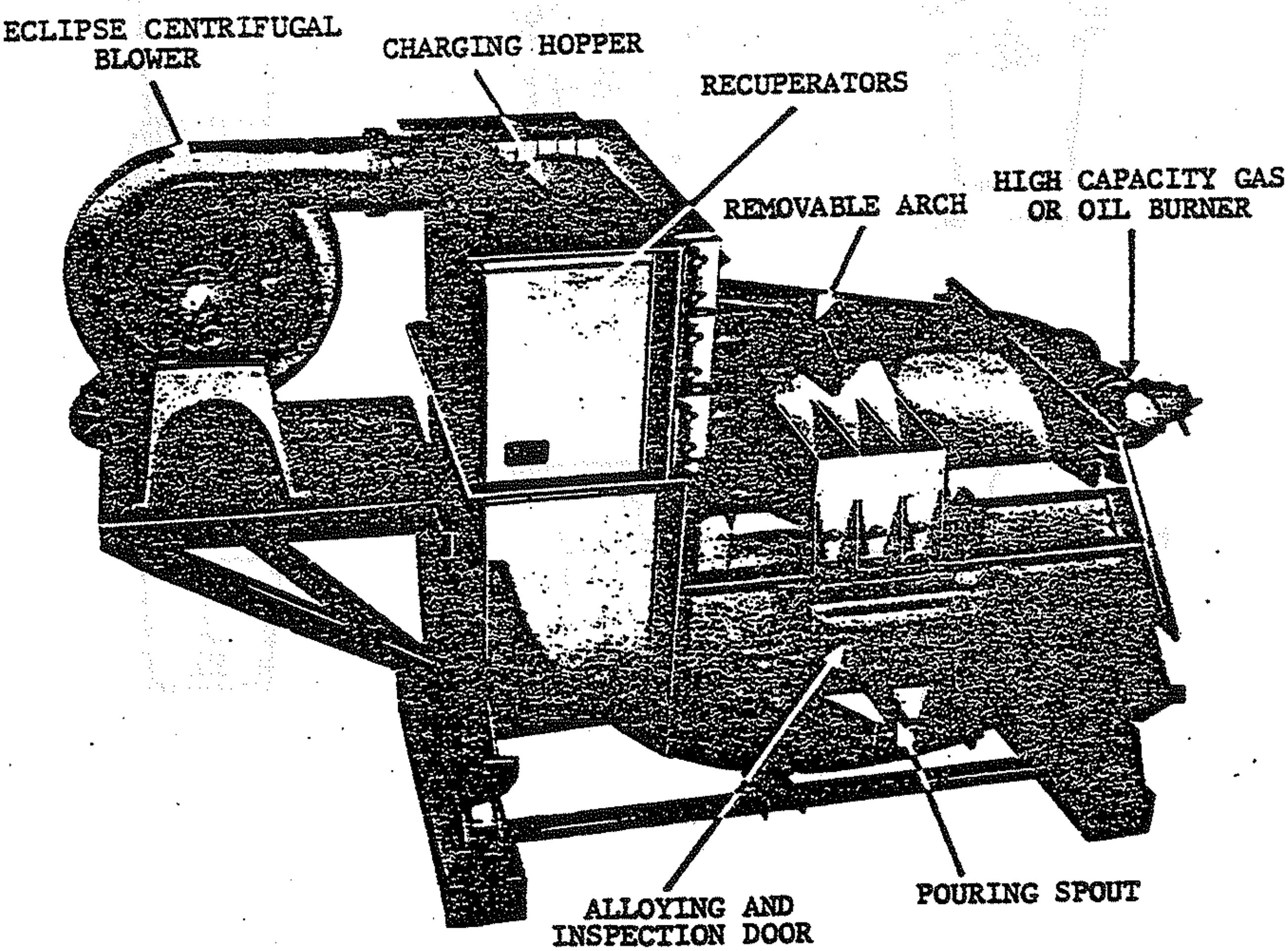


Figure 2.7-7. Reverberatory furnace.[15]

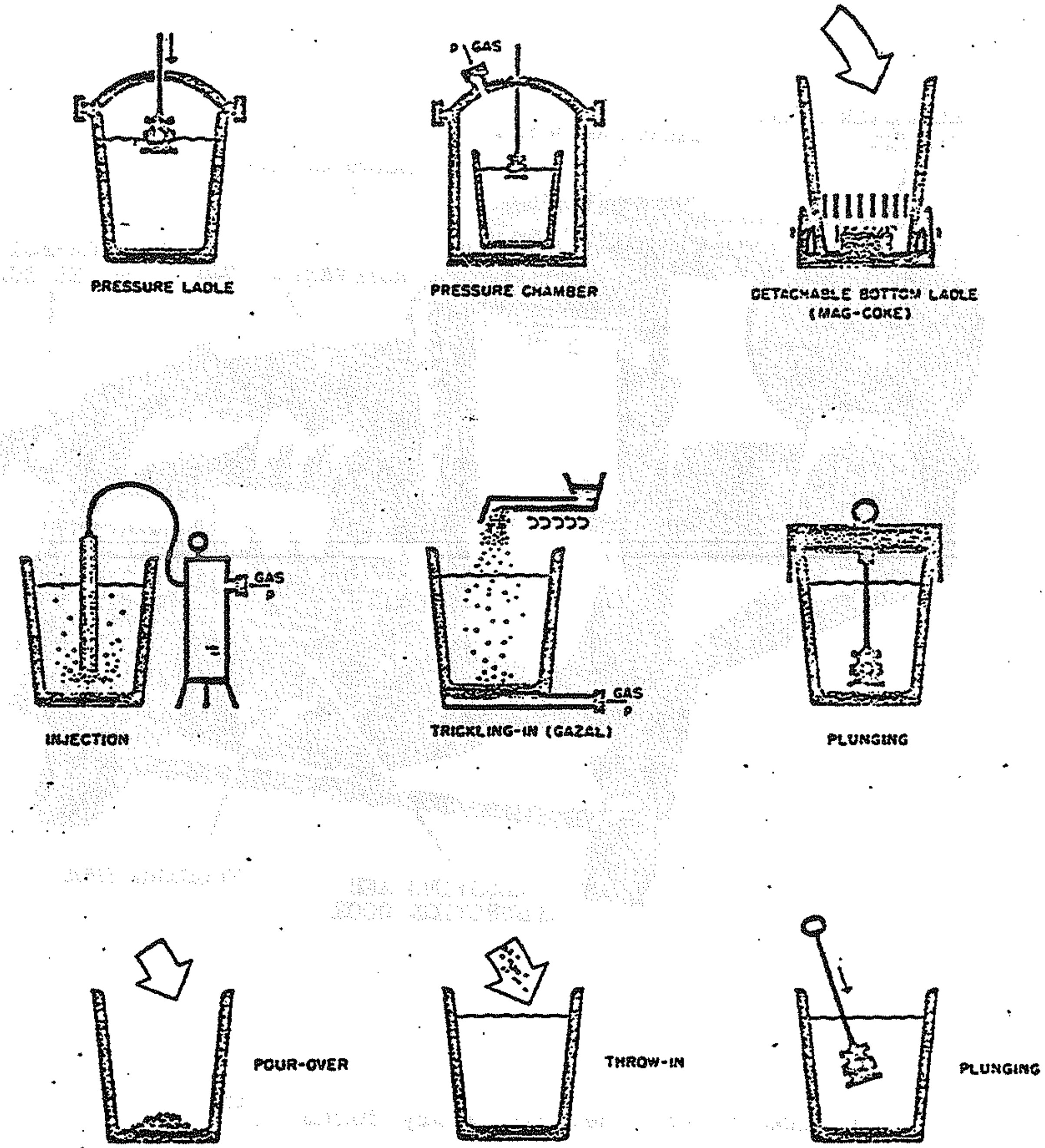


Figure 2.7-8. Magnesium treatment methods for producing ductile iron.[16]

cool, the castings are cleaned by shot blasting, and the remaining excess metal (gates, sprue, risers, flash, etc.) is removed by sawing, grinding, chipping, cutting, etc. These processes are generally housed in an enclosure.

Castings intended for certain uses may be annealed (heat treated) for several hours at temperatures of 1000 to 1600°F. Heat treating furnaces, fired by gas, oil or electricity, are referred to by such names as "annealing", "hardening", "car-bottom" and "traveling hearth" furnaces. Castings that have been annealed in the present of sufficient silicon are referred to as malleable iron castings. Some ductile iron castings, which are produced by inoculating the melt with a small amount of magnesium just prior to casting, are also often subjected to annealing. Finishing operations such as shot or sand blasting, grinding and surface coating may follow the heat treatment.

Production of molds and cores is an integral part of the foundry operation. A mold is made of sand mixed in a muller (see Figure 2.7-9) with water and binders, such as clay or resins. Pitch is sometimes added to the mold mixture primarily to prevent surface defects on the castings. A core is a separable part of the mold used to form a cavity in the casting. Cores are also made of sand and binders. Cores may be produced by any one of a number of processes including hot box, cold box, air set, shell and oil-sand methods.[17] In the oil-sand process, after the cores are formed in the desired shape, they are cured either in a baking oven (core oven) at 300-500°F or at room temperature. Curing evaporates moisture and hardens the sand mixture. Core ovens are fired with gas or oil.

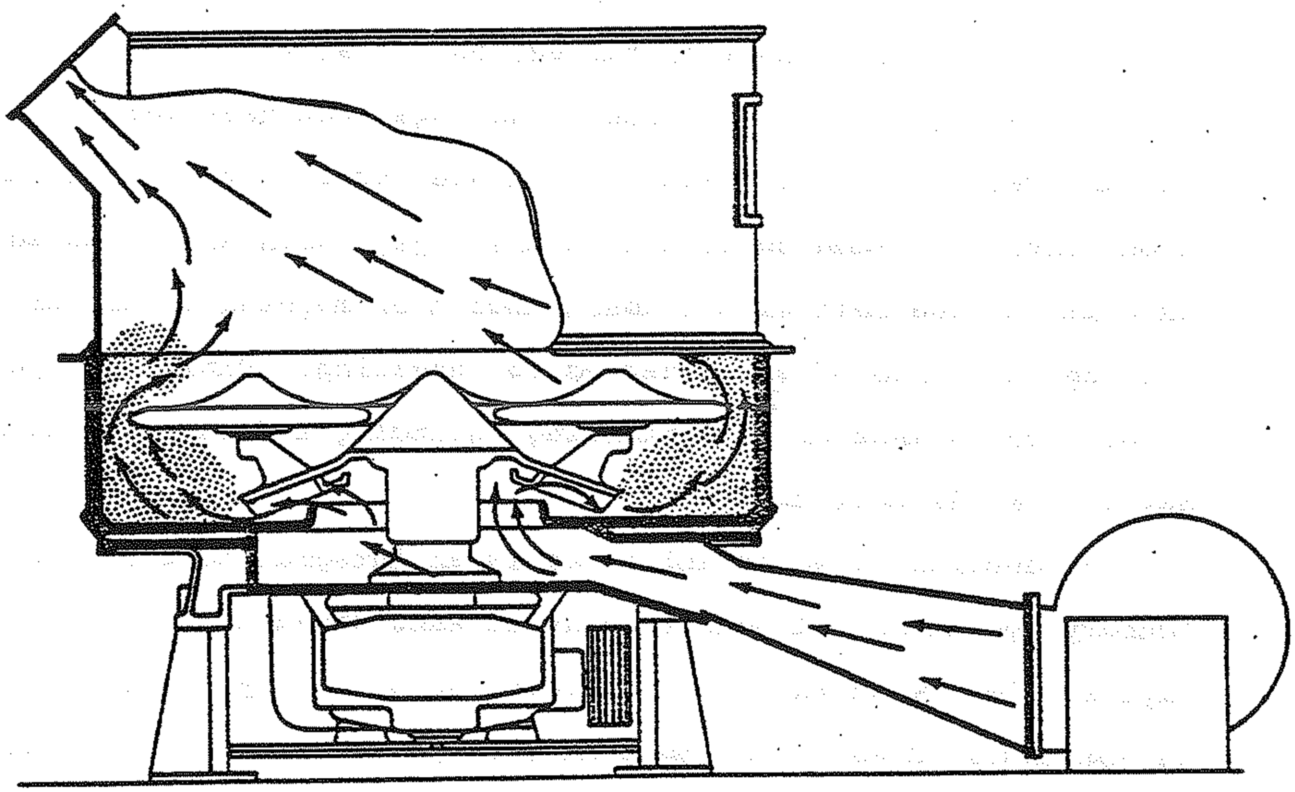


Figure 2.7-9. Sand muller.[18]

The potential sources of fugitive emissions in iron foundries include raw material receiving, storage and handling, melting furnace charging and tapping, iron inoculation, molten iron transporting and pouring, casting, shakeout, cooling, cleaning and finishing, and core and mold making. Each of these sources is identified in Figures 2.7-1 and 2.7-2.

2.7.2 Fugitive Dust Emission Factors

The estimated emission factors for iron foundry fugitive particulate sources are summarized in Table 2.7-1. Most of these emissions factors are based on "engineering judgment" (source's terminology) and very sparse test data. They should be considered of poor reliability. Emission factors were not included for coke handling and storage at iron foundries. These factors are discussed in Section 2.2.2-2. Factors are also not included for raw material handling, storage and transfer operations due to a lack of data. These sources are deemed to be insignificant as far as steel/iron scrap is concerned.

The emission factors for charging and tapping of the various furnace types, with the exception of electric induction furnaces, were derived by assuming a percentage of total furnace emissions. The emission factor for electric induction furnaces represents total furnace emissions including charging and tapping emissions. No test data were available; and, therefore, these factors are unconfirmed and have a very poor reliability rating.

The other emission factors are based upon very sparse test data and the source's engineering judgment. The reliability rating for these factors is also very poor.

TABLE 2.7-1. FUGITIVE DUST EMISSION FACTORS FOR IRON FOUNDRIES

Source	Emission factor	Reliability Rating	Reference
(1) Cupola furnace charging and tapping	0.1 to 2.0 lb/ton iron produced	E	1
(2) Electric arc furnace charging and tapping	0.7 lb/ton iron charged[a] 1.4 lbs/ton iron charged[b]	E	19
(3) Electric induction furnace melting, charging and tapping	1.5 lb/ton iron produced	E	1
(4) Reverberatory furnace charging and tapping	0.1 lb/ton iron produced	E	3
(5) Ductile iron inoculation	3.3 to 4.5 lb/ton iron produced	D	4,5
(6) Pouring molten metal into molds	0.1 to 4.13 lb/ton iron produced	D	4,6
(7) Casting shakeout	1.2 to 12.8 lb/ton iron produced	E	4,7
(8) Cooling and cleaning castings	0.16 to 0.8 lb/ton castings produced	D	4,7
(9) Finishing castings	0.01 lb/ton castings produced	E	7
(10) Core and mold sand unloading and storage:			
mechanical handling	0.03 lb/ton sand unloaded[c]	E	20
pneumatic handling	NA		
(11) Core sand and binder mixing	0.3 lb/ton sand mixed	E	2
	or		
	0.75 to 8.24 lb/ton iron produced	E	4,7
(12) Core making	0.35 lb/ton cores produced	E	2
(13) Core baking	0.03 to 5.4 lb/ton cores baked	E	7,9,20
(14) Mold sand preparation	1.3 lb/ton castings produced	E	4
(15) Mold making	0.04 lb/ton castings produced	E	7

NA = Not available
[a]With no alloying in the ladle.
[b]With alloying in the ladle.
[c]Sand unloading emission factor is assumed to be equivalent to the taconite pellets unloading emission factor as presented in Section 2.1.3. Fugitive dust emissions from storage are estimated to be negligible since sand is normally stored indoors.

2.7.2 Particle Characterization[21]

The composition and particle size of dusts from various foundry operations will vary considerably. For example, dusts from a casting shakeout are mostly very fine carbonaceous material. On the other hand, dust from the grinding of castings contains coarse, freshly fractured particles, along with elemental iron, iron oxide and sand particles. Table 2.7-2 indicates the characteristics and sources of emissions in various foundry operations.

Much of the information available on particle characteristics is for the stack (non-fugitive) emissions from cupola and electric arc furnaces. However, since such information may be of value in approximating the particle characteristics of fugitive dust emission sources such as furnace charging, tapping and leaks, it is presented in this section.

The range of chemical composition of stack emission components in cupola dust has been reported in the literature as shown in Table 2.7-3. Table 2.7-3 indicates that oxides of iron and silicon and combustible materials form a high proportion of cupola dust.

Particle size distribution studies have been performed for stack emissions from cupola furnaces. The data reported in two major studies is shown in Tables 2.7-4 and 2.7-5. There is very little information in the literature on whether or not a relationship exists between particle size distribution and chemical composition of cupola emissions. One source conjectures that a high percentage of less than 5 micron particles is generally observed with substantial percentages of metallic oxides. On the other hand, a high percentage of greater than 4.4 micron particles corresponds to significant amounts of silicon oxides from foundry returns, dirty scrap and combustible materials.[27]

TABLE 2.7-2. PARTICULATE EMISSION CHARACTERISTICS FOR VARIOUS FOUNDRY OPERATIONS[22]

FOUNDRY OPERATION	TYPE	PARTICLE SIZE (μm)
Raw material storage and charge makeup:		
Store metal scrap, coke, limestone, dolomite, fluorspar, silica sand	Coke dust Limestone and sand dust	Fine to coarse 30 to 1,000
Centrifuge or heat metal borings and turnings to remove cutting oil	Oil vapors Smoke Unburned hydro-carbons	.03 to 1 .01 to .4
Weigh charge materials	Coke dust Limestone dust	Fine to coarse 30 to 1,000
Melting:		
Cupola furnace	Fly ash Coke breeze Smoke Metallic oxides Oil Vapors	8 to 20 Fine to coarse .01 to .4 Up to .7 .03 to 1
Electric arc melting	Smoke Metallic oxides Oil vapors	.01 to .4 Up to .7 .03 to 1
Induction furnace	Oil vapors	
Reverberatory (air) furnace	Smoke Oil vapors Metallic oxides Fly ash	.01 to .4 .03 to 1 Up to .7 8 to 20
Furnace charge preheating or drying	Smoke Oil vapors Metallic oxides	.01 to .4 .03 to 1 75% - 5 to 60 (bottom fired)
	Metallic oxides	0 to 20 (top fired)
Holding furnaces	Iron oxide Oil vapor	Fine to medium .03 to 1
Duplexing furnaces	Oil vapor Metallic oxides	.03 to 1 Up to .7
Inoculation	Metal oxides	Up to .7
Molding, pouring and shakeout:		
Molding	Sand Dust	Coarse

TABLE 2.7-2. CONTINUED

FOUNDRY OPERATION	TYPE	PARTICLE SIZE (μm)
Pouring:		
Gray and ductile iron Malleable	Core gases Facing fumes Metallic oxides Fluoride fumes Magnesium oxide fumes Synthetic binder smoke and fumes	 Fine to medium 0.1 to .4
Shakeout	Sand fines Smoke Dust	50% - 2 to 15 .01 to .4 50% - 2 to 15
Cleaning and finishing:		
Abrasive cleaning	Dust	50% - 2 to 15
Grinding	Metal dust Sand fines Abrasives Wheel bond material Vitrified resins	Above 7 Fine to medium 50% - 2 to 7 Fine 50% - 2 to 15
Annealing and heat treating	Oil vapors	.03 to 1
Sand conditioning:		
New sand storage Sand handling system Screening	Fines Fines Fines	50% - 2 to 15 50% - 2 to 15 50% - 2 to 15
Mixing	Fines Flour Bentonites Sea coal Cellulose	50% - 2 to 15 Fine to medium Fine to medium Fine to medium Fine to medium
Drying and reclamation	Dust Oil vapors	50% - 7 to 15 .03 to 1
Sand storage	Sand fines Flour Binders	Fine 50% - 7 to 15
Core making	Sand fines Dust	Fine to medium Fine to medium
Baking	Vapors Smoke	

TABLE 2.7-3. CHEMICAL COMPOSITION OF CUPOLA DUST[23]

Component	% by Weight	
	Mean Range	Scatter Values
SiO_2	20-40	10-45
CaO	3-6	2-18
Al_2O_3	2-4	0.5-25
MgO	1-3	0.5-5
FeO (Fe_2O_3, FE)	12-16	5-26
MnO	1-2	0.5-9
Ignition Loss (C,S,CO_2)	20-50	10-64

TABLE 2.7-4. PARTICLE SIZE DISTRIBUTION OF DUST EMISSIONS FROM BOTH COLD AND HOT BLAST CUPOLA FURNACE STACKS[24]

Particle Size (µm)	Cumulative Percent by Weight for Indicated Particle Diameter	
	Cold Blast	Hot Blast (acid)[a]
< 1000	90-100	95-100
< 500	80-90	90-100
< 200	60-80	65-95
< 100	40-65	40-80
< 50	20-50	30-60
< 20	10-30	20-40
< 10	5-25	15-35
< 5	2-20	10-30
< 2	up to 15	5-20

[a] Cupola supplied with a preheated air blast and where slag is formed due to acid constituents originating from the furnace lining.

TABLE 2.7-5. SIZE DISTRIBUTION FOR PARTICULATE EMISSIONS FROM EIGHTEEN CUPOLA FURNACE INSTALLATIONS[25]

Particle Size (µm)	Cumulative Percent by Weight for Indicated Particle Diameter
< 2	14
< 5	24
< 10	34
< 20	44
< 50	61
< 100	78
< 200	93

Chemical composition or particulate emissions from electric arc furnaces at three iron foundries has been reported in one literature source and is shown in Table 2.7-6. The main components in these emissions were iron oxide and silicon dioxide, while substantial amounts of oxides of manganese, aluminum and magnesium were found. The emissions consist almost entirely of the oxides of various metals charged, with lesser amounts of furnace refractories and fluxing materials which were used.[28]

TABLE 2.7-6. CHEMICAL ANALYSIS OF PARTICULATE EMISSIONS FROM AN ELECTRIC ARC FURNACE[26]

Constituent	Proportion of Total Particulate, Weight Percent		
	Foundry A	Foundry B	Foundry C
Iron oxide	75-85	75-85	75-85
Silicon dioxide	10	10	10
Magnesium oxide	2	0.8	1
Manganese oxide	2	2	2
Lead oxide	1	2	0.5
Alumina	0.5	1	0.5
Calcium oxide	0.3	0.2	0.8
Zinc oxide	0.2	2	0.3
Copper oxide	0.04	0.03	0.01
Lithium oxide	0.03	0.03	0.03
Tin oxide	0.03	0.3	0.02
Nickel oxide	0.02	0.03	0.01
Chromium oxide	0.02	0.07	0.01
Barium oxide	0.02	0.07	0.01

Particle size distributions of particulate emissions have also been determined for electric arc furnaces at three foundries. These distributions are shown in Table 2.7-7. It is reported that particulate emissions from electric arc furnace melting and refining are quite small in diameter. Table 2.7-7, which indicates that 80 percent of the emissions have a particle diameter smaller than 5 microns, confirms this conclusion. A second literature reference indicates that 90 to 95 percent of the fumes from electric arc furnaces are below 0.5 microns in size.[29] Another literature source reports that 75 percent of the particulates are less than 5 microns in diameter with a mass median diameter between 2.27 and 2.33 μm.[30]

TABLE 2.7-7. PARTICLE-SIZE DISTRIBUTION FOR PARTICULATE EMISSIONS FROM THREE ELECTRIC-ARC-FURNACE INSTALLATIONS[31]

	Cumulative Percent by Weight for Indicated Particle Diameter		
Particle Size (μm)	Foundry A	Foundry B	Foundry C
< 1	5	8	18
< 2	15	54	61
< 5	28	80	84
< 10	41	89	91
< 15	55	93	94
< 20	68	96	96
< 50	98	99	99

The chemical composition and particle size distributions of particulate emissions from both cupolas and electric arc furnaces are highly variable and are dependent on a number of factors. One literature source concludes that the type of cupola emissions are more affected by the quantity and quality of charge materials, and that the nature and cleanliness of the charged materials are the most important factors in determining the type of emission from electric arc furnaces.[32]

2.7.4 Control Methods

Raw material handling, storage and transfer operations as such are not addressed here but are discussed in Section 2.2 for coke and limestone. These operations for the iron and steel scrap are assumed to be low emission sources, and no control is recommended.

Reduction of emissions from melting operations is enhanced when clean scrap is used in the raw charge. Clean materials that are essentially devoid of dirt, oil or grease carry no extraneous burden into and through the furnace. Use of clean scrap, or the pre-cleaning of dirty scrap before use, are useful and appropriate measures worthy of consideration and adjunctive to and supportive of other control measures. However, it has been reported that the pre-cleaning of dirty scrap is not economically feasible.[33]

Charging and tapping emissions from the cupola may be controlled by hooding the charging and tapping areas and venting the system to fabric filters or scrubbers. Another system that may be used is building evacuation and venting to a fabric filter. Proper sizing of the primary control system to maintain continuous draft through the charging door will help alleviate fugitive emissions.[13] Cupolas with above or below charge takeoffs can maintain a strong in-draft through the charge door and eliminate the escape of fugitive emissions.

Typical control devices used for electric arc or electric induction furnaces include a localized, fixed capture hood and a fabric filter or wet scrubber. The design air volume required to ventilate an electric arc furnace with an integral hood is approximately 2,500 cfm per ton of charge.[7,34] This level of ventilation should provide effective capture of charging and tapping emissions.

Newer furnaces can utilize the above system, canopy hoods (roof mounted hoods) or direct shell evacuation.[30] The latter two control measures may not be feasible on older furnaces due to space and design constraints.

Generally, control measures for charging, melting and tapping emissions from reverberatory furnaces have not been required because of their relatively low emission rates.[35] However, collection of charging and tapping emissions, as well as furnace emissions (if no stack discharge) is technically feasible thru the use of localized hooding or building evacuation with exhaust to a fabric filter or electrostatic precipitator. Such control measures may have to be implemented especially for reverberatory furnaces that are or will be using pulverized coal.

Technically feasible methods for capturing fugitive dusts from all furnace operations include building evacuation or local exhaust systems. (See Figures 2.7-10 and 2.7-11 for examples.) Building evacuation to a collection device can control emissions from all sources in a foundry such as casting shakeout, cooling, cleaning and finishing. (One source reports that the use of building evacuation or general dilution ventilation systems without separate primary emission capture is unlikely to provide a sufficient degree of control for airborne contaminants in most foundries to meet OSHA's permissible exposure limits for such contaminants.[33]) On the other hand, local exhaust control systems generally serve specific sources. Because of the large exhaust volumes and attendant high operating and capital costs for total building evacuation systems, the local exhaust methods are usually favored.

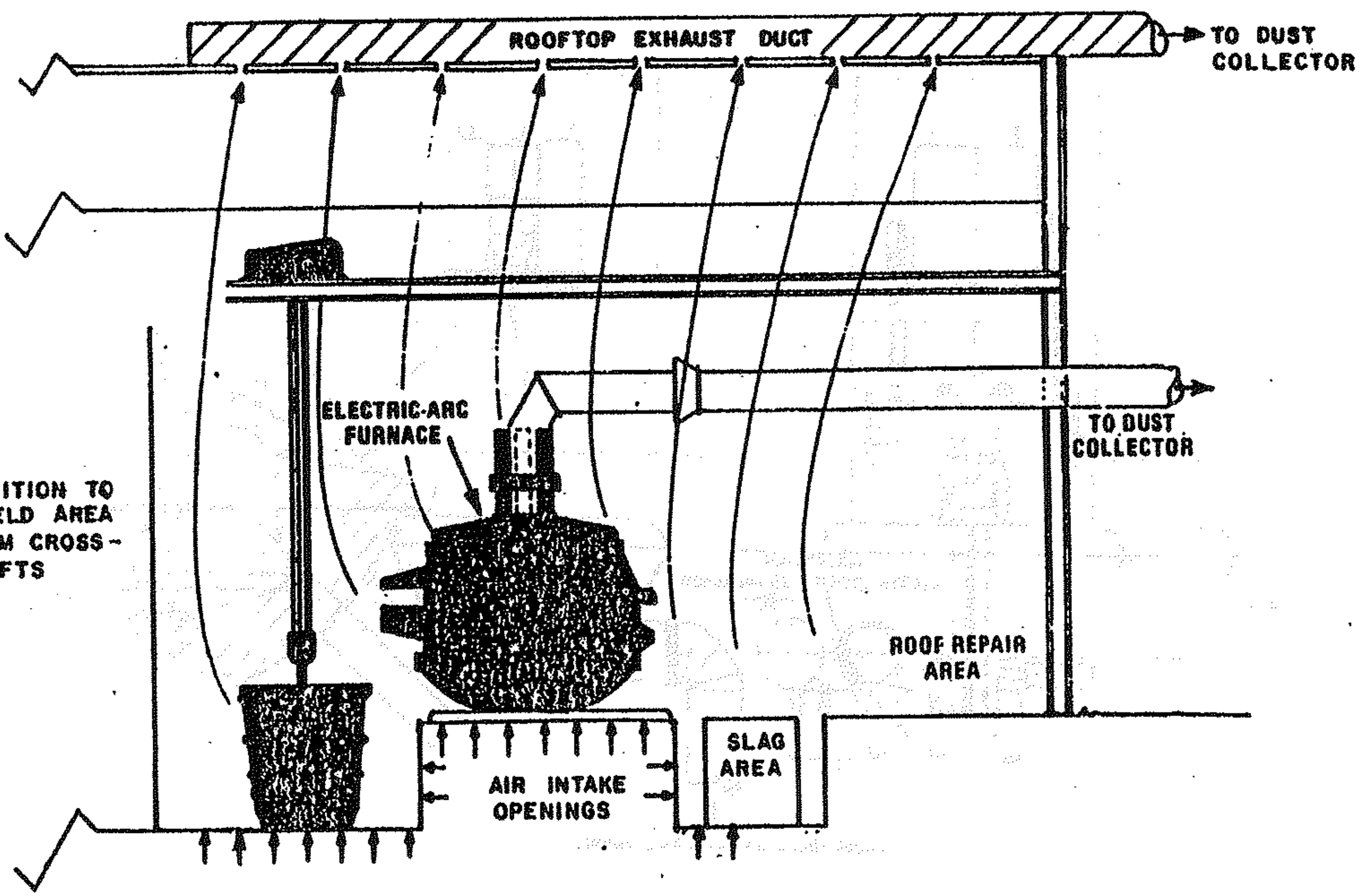


Figure 2.7-10. Building evacuation system.[36]

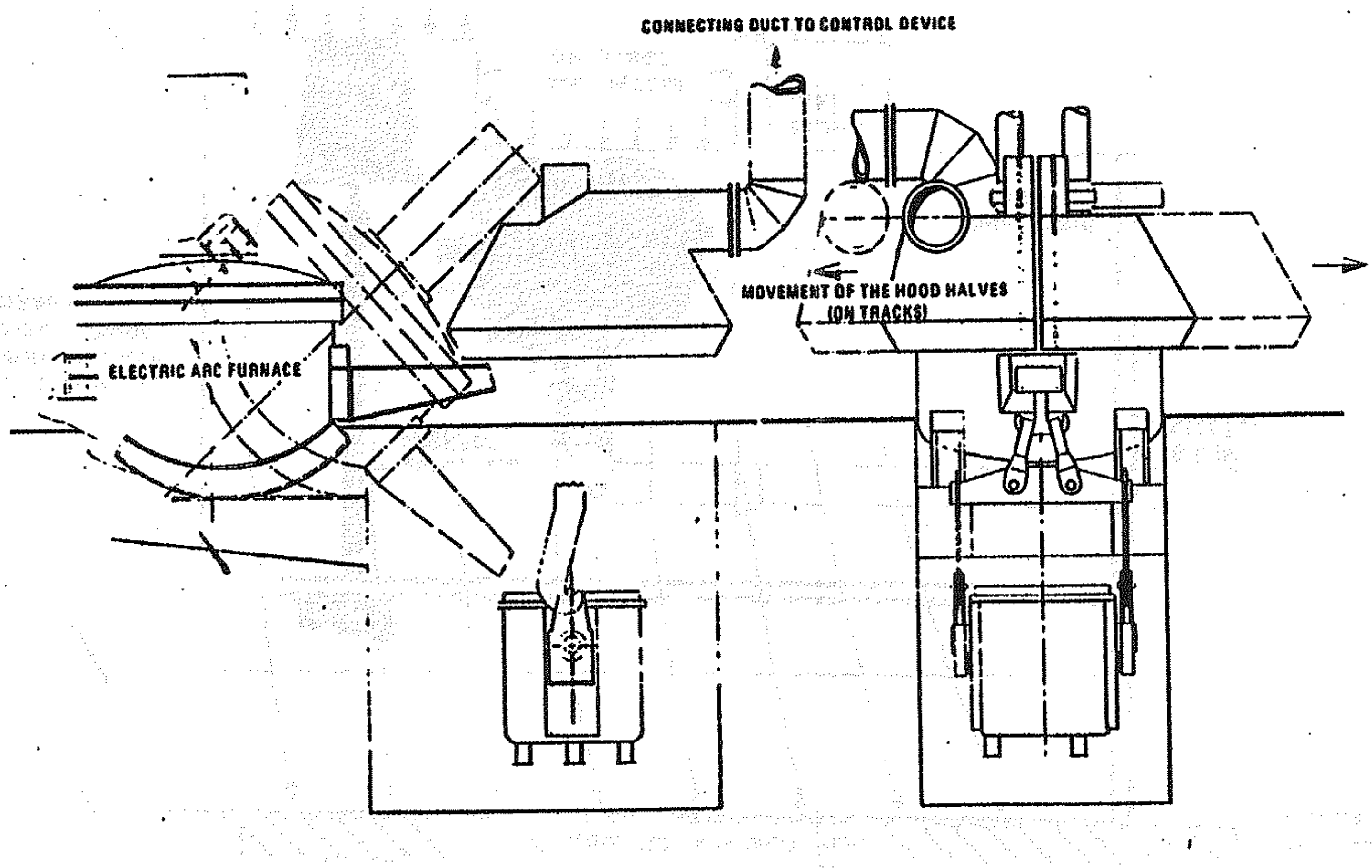


Figure 2.7-11. Mobile tapping hoods.[37]

In recent years, ductile iron inoculation stations have been equipped with collecting hoods or have been installed in enclosed rooms. The evolved gases are exhausted to a dust collection unit. Medium energy wet scrubbers and fabric filters have been used for dust collection.[38]

A side draft hood is often provided for the pouring area, and the mold cooling conveyor between the pouring and shakeout areas is often fully hooded with sheet metal. Also, the use of hooding as illustrated in Figure 2.7-12 is another successful system for capturing emissions from pouring and mold cooling. In this system, air is blown downward from the upper edge of the hood along with the pouring and mold cooling emissions. A variation of this system consists of utilizing an incoming draft from a floor grating rather than from the front edge of the hood. For smaller foundries, a movable pouring hood as shown in Figure 2.7-13 may be effective.[40] In practice, pouring and mold cooling emissions, especially for smaller production and jobbing foundries with non-fixed pouring and cooling locations, are usually exhausted directly to the atmosphere without control.[41] If control measures are deemed necessary, the hoods may be vented to wet scrubbers.

Fugitive dust emissions from the shakeout area are usually collected via a side or bottom draft hood or a partial enclosure. Duct systems from the shakeout usually lead to a single control device, frequently a wet scrubber or fabric filter. Figure 2.7-14 illustrates a shakeout with an enclosure vented to a wet scrubber.

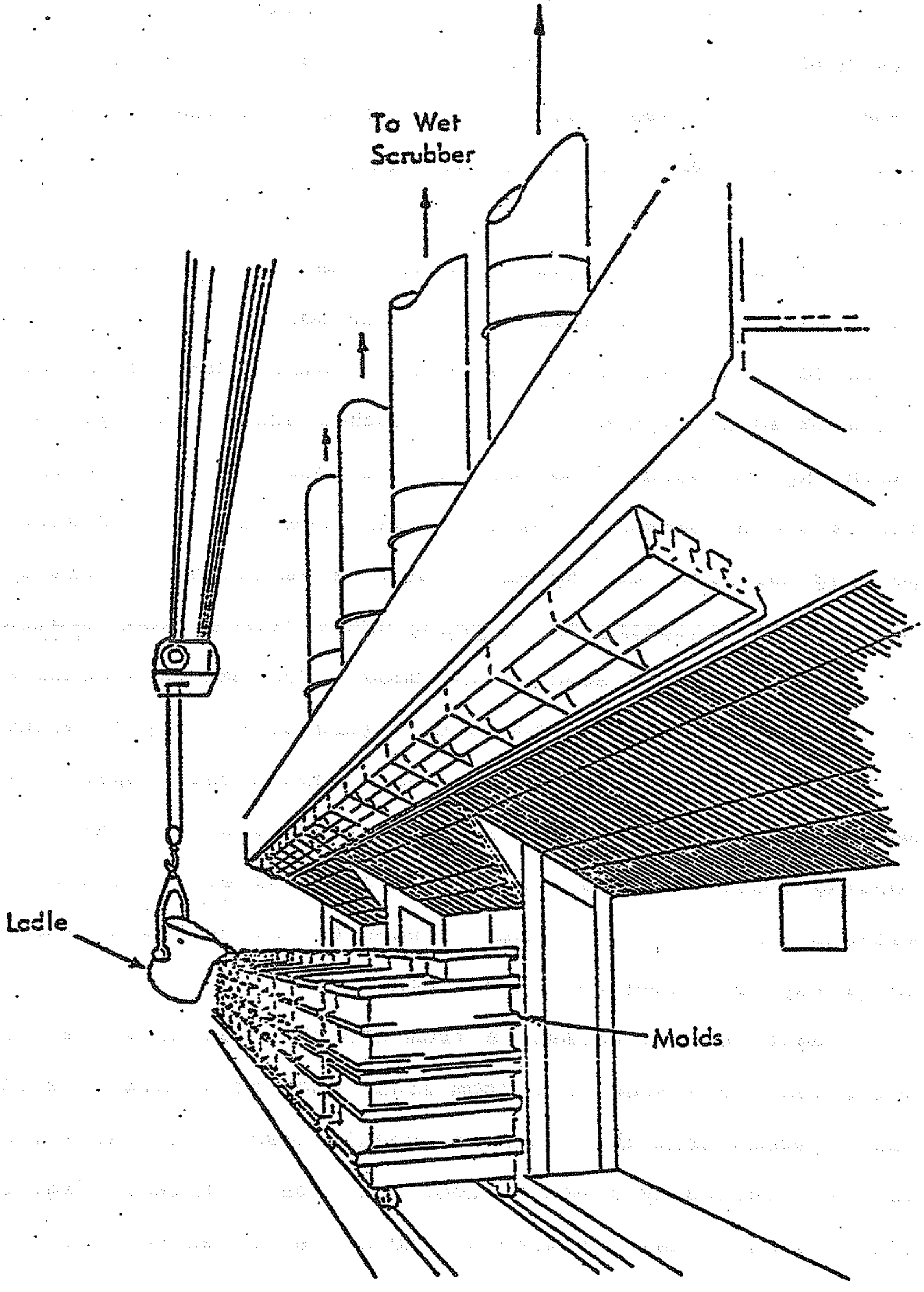


Figure 2.7-12. Hooded pouring station.[39]

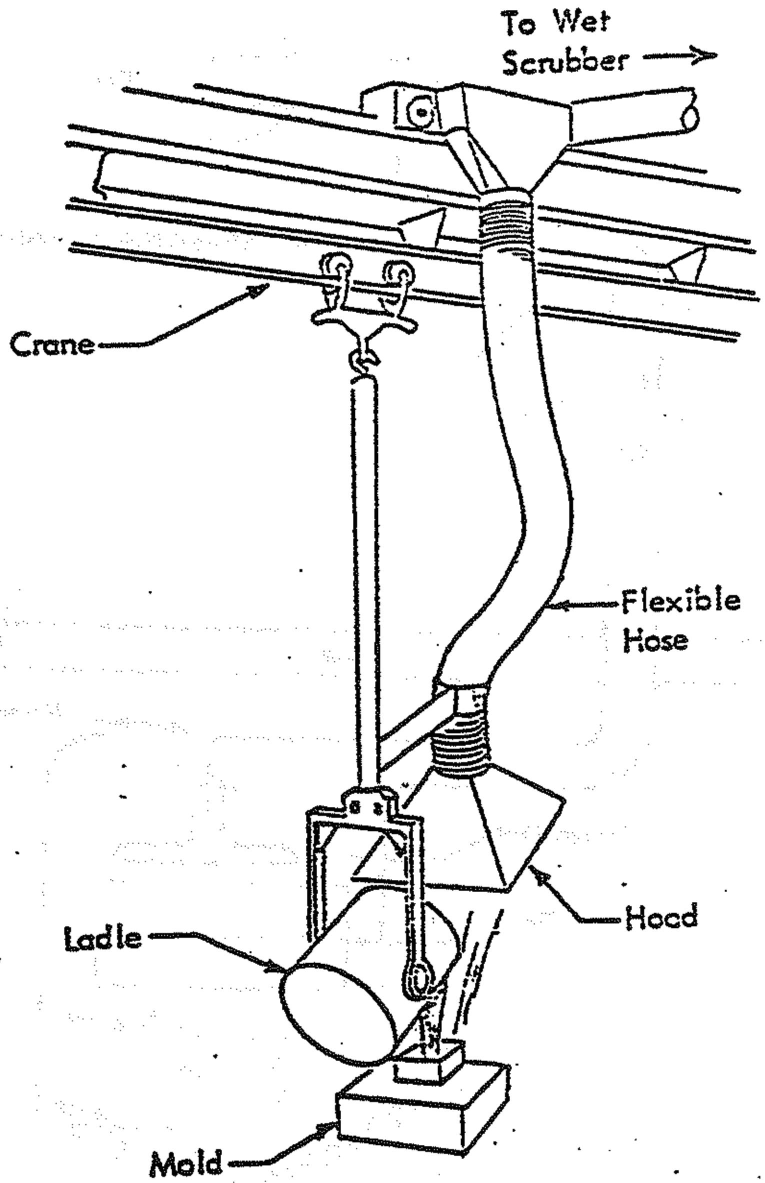


Figure 2.7-13. Movable pouring hood.[42]

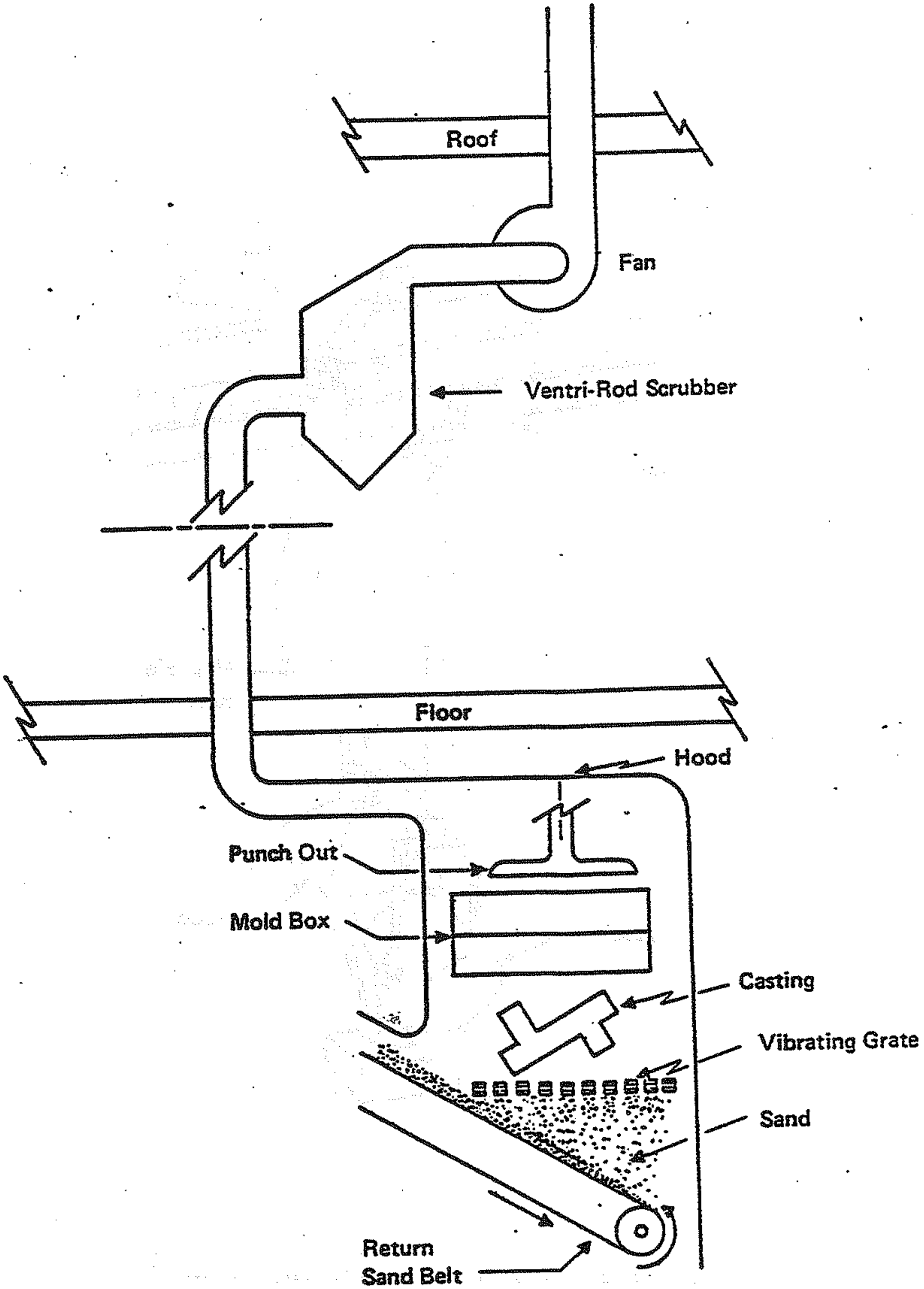


Figure 2.7-14. A casting shakeout control system.[43]

Particulate emissions from cleaning and finishing operations may be captured by local exhaust systems connected to either dry mechanical collectors (i.e., cyclones), fabric filters or wet collectors. Particulate emissions from abrasive shot blasting and tumble cleaners is commonly controlled by fabric filters or medium energy wet collectors. Dry mechanical collectors are also used at abrasive cleaning processes. Grinding operations are normally provided with local exhaust hoods connected to either high efficiency centrifugal collectors (multiple cyclones) or fabric filters.[44]

Coremaking effluents consist primarily of the gases emitted from the cold box, hot box, bake ovens and shell core machines and are usually exhausted to the atmosphere through a ventilation system or are passed through an odor scrubber before venting to the atmosphere.[44] Core ovens, when operated below 400°F and fired with natural gas, do not generally require air pollution control equipment and may be vented directly to the atmosphere. Emissions can be reduced by modifying the composition of the core binders and lowering the baking temperature.[45]

Medium energy wet collectors are best suited for moist sand preparation and handling. When dry sand conditions exist, fabric filters are occasionally used. Often some type of hood is used to capture emissions in sand conveyor systems especially at transfer points. As with many other processes, ductwork and exhaust fans are required in a complete collection system.[44] (Figure 2.7-15 illustrates the capture design on a typical sand-handling system.)

Table 2.7-8 summarizes the available control techniques, their effectiveness, estimated costs and RACM selections.

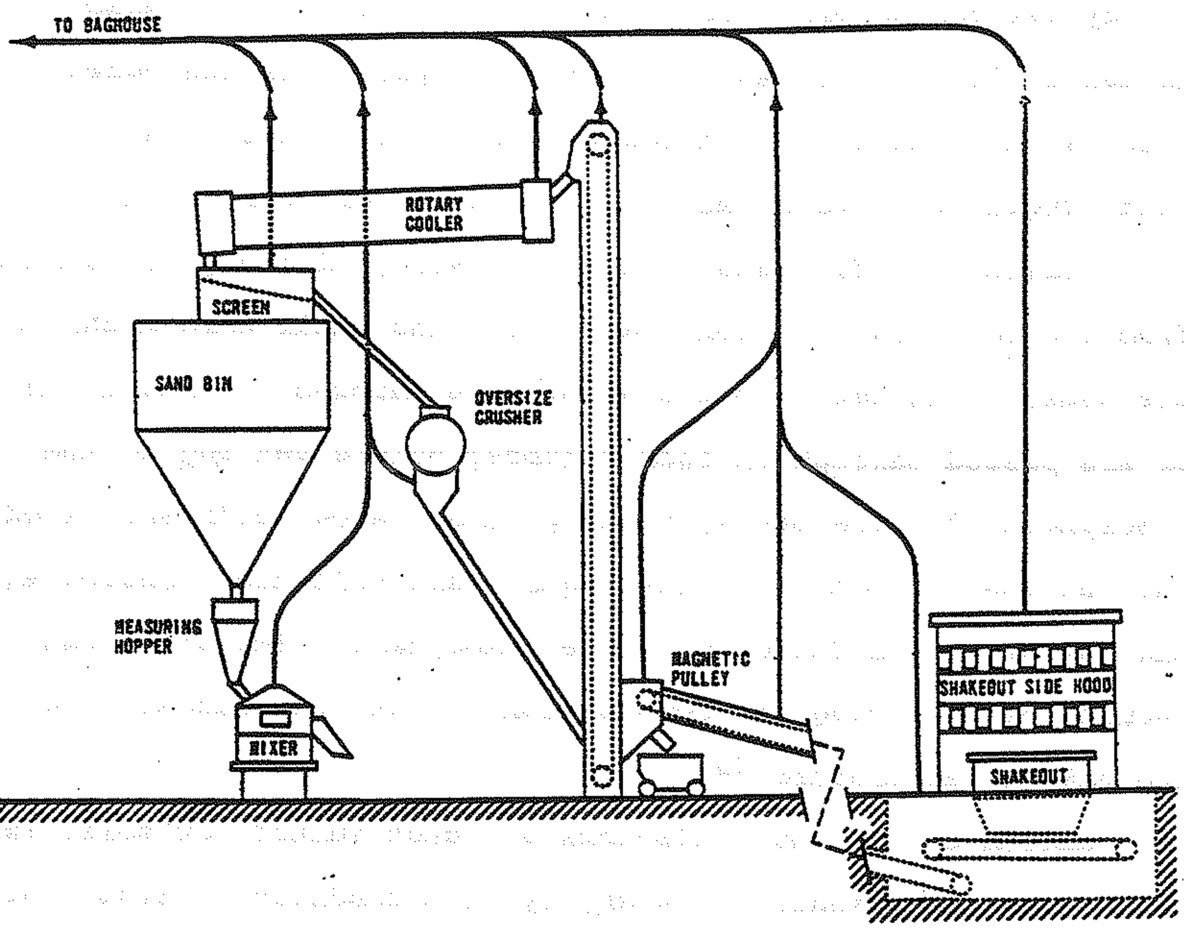


Figure 2.7-15. Capture design for a typical sand-handling system.[46]

2.7.2 Recommended Reasonably Available Control Measures (RACM)

The RACM selections for iron foundry fugitive sources are presented in Table 2.7-3.

The recommended control measure for cupola furnace charging emissions is the maintenance of sufficient draft through the charge door to effectively contain charging emissions and vent them to the existing primary control device. This is the most effective means of control that would not require a large capital outlay for cupolas having above-charge and below-charge take-offs. However, under this control measure, cupola furnace tapping emissions would be uncontrolled.

For control of electric arc and large electric induction furnaces which have primary controls, the selected RACM is maintenance of a continuous draft during the charging and tapping operations through the existing hooding for primary control. This technique could involve some modifications or extensions to the existing hoods to assure good capture. For furnaces which do not have primary controls, RACM consists of localized and canopy hooding which is vented to a fabric filter. For very small electric induction furnaces which have minimal visible emissions, no control is recommended.

No control is recommended for reverberatory furnaces since these are very low emitters of particulate matter and are not usually controlled.

The recommended RACM for ductile iron inoculation is hooding with exhaust to a fabric filter or wet scrubber. This system gives very good control and is commonly applied on existing foundries.

TABLE 2.7-8. A SUMMARY OF THE CONTROL ALTERNATIVES, EFFICIENCIES AND COSTS, AND THE RACM SELECTIONS FOR FUGITIVE DUST EMISSIONS FROM SOURCES AT IRON FOUNDRIES

Fugitive dust sources	Control alternatives	Control efficiency, %	Control costs, Jan. 1980, $		Cost benefit, $/lb	RACM selection
			Capital	Annualized		
(1) Cupola furnace charging and tapping	Hooding, vent to fabric filter	90[a]	336,000[a]	82,000[b]	2.60	Maintenance of continuous draft through charge door (if primary controls present); otherwise hooding, vent to fabric filter
	Building enclosure, evacuation to fabric filter	95[c]	d	d	NA	
	Maintenance of continuous draft through charge door	70[e]	150,000[f]	30,000[g]	1.22	
(2) Electric arc furnace charging and tapping	Hooding, vent to fabric filter	90[a]	336,000[a]	82,000[b]	3.94[r] 1.97[s]	Maintenance of continuous draft during charging and tapping operations (if primary controls present); otherwise hooding, vent to fabric filter
	Building enclosure, evacuation to fabric filter	95[c]	d	d	NA	
	Maintenance of continuous draft during charging and tapping	70[e]	20,000[h]	4,000[g]	0.25[r] 0.12[s]	
(3) Electric induction furnace melting, charging and tapping	Hooding, vent to fabric filter	90[a]	336,000[a]	82,000[b]	1.82	Maintenance of continuous draft during charging and tapping (if primary controls present); otherwise, hooding, vent to fabric filter
	Building enclosure, evacuation to fabric filter	95[c]	d	d	NA	
	Maintenance of continuous draft during charging and tapping	70[e]	20,000[h]	4,000[g]	0.11	
(4) Reverberatory furnace charging and tapping	Hooding, vent to fabric filter or ESP	90[a]	336,000[a]	82,000[b]	27.61	No control
	Building enclosure, evacuation to fabric filter or ESP	95[c]	d	d	NA	
(5) Ductile iron inoculation	Hooding, vent to fabric filter or scrubber	90[a]	153,000[a,i]	33,000[b]	0.28	Hooding, vent to fabric filter or scrubber
	Room enclosure, vent to filter or scrubber	95[c]	d	d	NA	
(6) Pouring molten metal	Hoods, vent to wet scrubber	95[c]	63,000[j]	17,000[b]	0.26	Hoods, vent to scrubber
(7) Casting shakeout	Hoods, vent to wet scrubber or fabric filter	95[c]	234,000[k]	82,000[b]	0.20	Hoods, vent to fabric filter or scrubber

(continued)

TABLE 2.7-8 (continued)

Fugitive dust sources	Control alternatives	Control efficiency, %	Control costs, Jan. 1980, $		Cost benefit, $/lb	RACM selection
			Capital	Annualized		
(8) Cooling and cleaning castings	Hooding, mechanical collector, fabric filter or scrubber	90[c]	1	1	0.20	m
(9) Finishing castings	Hooding, vent to mechanical collector, fabric filter or scrubber	90-99[a]	1	1	0.20	m
(10) Core and molding sand unloading and storage:						
mechanical handling	Hooding, vent to mechanical collector	80[c]	33,600[c]	12,000[c]	2.14	Wet suppression (chemical)
	Wet suppression (chemical)	85[c]	26,000[h]	7,000[o]	1.18	
	Enclosure	50[c]	15,000[p]	3,000[g]	0.85	
pneumatic handling	Vent storage hopper to fabric filter	99[c]	NA	NA	NA	Vent storage hopper to fabric filter
(11) Core sand and binder mixing	Hooding, vent to mechanical collector or fabric filter	90[c]	1	1	0.20	m
(12) Core making	Hooding, vent to fabric filter	90[c]	1	1	0.20	m
(13) Core baking	Afterburners	90[c]	35,000[q]	21,000[q]	2.59	No control
(14) Mold sand preparation	Hooding, vent to fabric filter or scrubber	90[c]	1	1	0.20	m
(15) Mold makeup	Hooding, vent to fabric filter or scrubber	90[c]	1	1	0.20	m

NA = Not available.

TABLE 2.7-8 (continued)

[a] Reference 47.
[b] Reference 48.
[c] Estimated.
[d] No cost data available.
[e] Based on control of 95% of charging emissions only. Reference 49.
[f] Reference 49.
[g] Includes only capital charges and maintenance estimated at 20% of capital investment.
[h] Estimated costs of movable ducting required.
[i] Assumed equivalent to control tapping emissions.
[j] Reference 50.
[k] Reference 50. Based on 50,000 acfm and control of sand handling, cooling, cleaning, mixing, core and mold mixing operations.
[l] Control costs included under the casting shakeout system.
[m] RACM is an integrated system ducting the casting shakeout, sand handling, cooling, cleaning, mixing, core and mold making operations to a single fabric filter or wet scrubber.
[n] Reference 51.
[o] Reference 52.
[p] Reference 53. Based on 20' x 20' x 30' enclosure.
[q] Reference 54.
r With no alloying in the ladle.
s With alloying in the ladle.

The RACM selected for hot metal pouring operations is hooding and local exhaust to a wet scrubber. This type of system provides very good control (95%).

The selected RACM for control of the casting shakeout fugitive emissions is a system of hoods ducted to a common fabric filter or wet scrubber. This system would be designed to handle exhaust gases from the cleaning and cooling of castings, finishing operations, sand and binder mixing, core and mold makeup, and sand preparation and handling operations. This system is very effective and is used in existing foundries.

The sand unloading operations (truck or railcar dumping into receiving hopper) can be effectively controlled by use of wet suppression. Other options offer inferior control at costs on the same order of magnitude. For the pneumatic unloading and storage of sand, the general industry practice is the use of a fabric filter to control emissions from the storage hopper vent.

No control was selected for the core baking operation since with proper operation this is a relatively minor source of particulate emissions.

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Assume furnace capacity = 11 tph or 33,000 tpy

(1) Cupola furnace charging and tapping
Emissions = (1.05 lb/ton)(33,000 tpy) = 35,000 lbs/yr

Hooding, vent to fabric filter

Capital cost = $336,000
Annual cost = 82,000

$$C/B = \frac{\$82,000/yr}{.9\ (35,000)} = \$2.60/lb$$

Building enclosure evacuation to fabric filter
No data

Maintenance of continuous draft through charge door

Capital cost = $150,000
Annual cost = 30,000

$$C/B = \frac{\$30,000/yr}{.70\ (35,000)} = \$1.22/lb$$

(2) Electric arc furnace charging and tapping
Emissions = (0.7 lb/ton)(33,000 tpy) = 23,100 lbs/yr (no alloying in ladle); (1.4 lbs/ton)(33,000 tpy) = 46,200 lbs/yr (with alloying in ladle)

Hooding, vent to fabric filter

Capital cost = $336,000
Annual cost = 82,000

$$C/B = \frac{\$82,000/yr}{.9\ (23,100)} = \$3.94/lb$$

$$C/B = \frac{\$82,000/yr}{.9\ (46,200)} = \$1.97/lb$$

Building enclosure, evacuation to fabric filter
No data

Maintenance of continuous draft during charging and tapping

Capital cost = $20,000
Annual cost = 4,000

$$C/B = \frac{\$4,000/yr}{.7\ (23,100)} = \$0.25/lb$$

$$C/B = \frac{\$4,000/yr}{.7\ (46,200)} = \$0.12/lb$$

(3) Electric induction furnace melting, charging and tapping
Emissions = (1.5 lb/ton)(33,000 tpy) = 50,000 lbs/yr

Hooding, vent to fabric filter

Capital cost = $336,000
Annual cost = 82,000

$$C/B = \frac{\$82,000/yr}{.9\ (50,000)} = \$1.82/lb$$

Building enclosure, evacuation to fabric filter
No data

Maintenance of continuous draft during charging and tapping

Capital cost = $20,000
Annual cost = 4,000

$$C/B = \frac{\$4,000/yr}{.7\ (50,000)} = \$0.11/lb$$

(4) Reverberatory furnace charging and tapping
Emissions = (0.1 lb/ton)(33,000 tpy) = 3,300 lbs/yr

Hooding, vent to fabric filter or ESP

Capital cost = $336,00
Annual cost = 82,000

$$C/B = \frac{\$82,000/yr}{.9\ (3,000)} = \$27.61$$

Building enclosure, evacuation to fabric or ESP
No data

(5) Ductile iron inoculation
Emissions = (3.9 lbs/ton)(33,000 tpy) = 129,000 lbs/yr

Hooding, vent to fabric filter or scrubber

Capital cost = $153,000
Annual cost = 33,000

$$C/B = \frac{\$33,000/yr}{0.9\ (129,000)} = \$0.28/lb$$

Room enclosure, vent to filter or scrubber
No data

(6) Pouring molten metal

Emissions = (2.115 lb/ton)(33,000 tpy) = 70,000 lbs/yr

<u>Hoods, vent to wet scrubber</u>

Capital cost = $63,000
Annual cost = 17,000

$$C/B = \frac{\$17,000/yr}{.95\ (70,000)} = \$0.26/lb$$

(7) Casting shakeout

Emissions = (7.0 lb/ton)(33,000) = 231,000 lbs/yr

<u>Hoods, vent to wet scrubber or fabric filter</u>

Capital cost = $234,000
Annual cost = 82,000

$$C/B = \frac{\$82,000/yr}{.95\ (231,000) + .9\ (16,000) + .95\ (330) + .9\ (148,500) + .9\ (1,000) + .9\ (43,000) + .9\ (1,300)}$$

$$= \$\ 0.20/lb$$

(8) Cooling and cleaning castings

Emissions = (0.48 lb/ton)(33,000 tpy) = 16,000 lbs/yr

<u>Hooding, mechanical collector, fabric filter or scrubber</u>

See (7)
C/B = $0.20/lb

(9) Finishing casting

Emissions = (0.01 lb/ton)(33,000 tpy) = 330 lbs/yr

<u>Hooding, vent to mechanical collector, fabric filter or scrubber</u>

See (7)
C/B = $0.20/lb

(10) Core and molding sand unloading and storage

Mechanical handling

Emissions = (.03 lb/ton)(33,000 tpy)(15)(.5) = 7,000 lbs/yr

Hooding, vent to mechanical collector

Capital cost = $33,600
Annual cost = 12,000

$$C/B = \frac{\$12,000/yr}{.8\ (7,000)} = \$2.14/lb$$

Wet suppression (chemical)

Capital cost = $26,000
Annual cost = 7,000

$$C/B = \frac{\$7,000/yr}{.85\ (7,000)} = \$1.18/lb$$

Enclosure

Capital cost = $15,000
Annual cost = 3,000

$$C/B = \frac{\$3,000/yr}{.5\ (7,000)} = \$0.85/lb$$

Pneumatic handling

Emissions = NA

Vent Storage hopper to fabric filter

No data

(11) Core sand and binder mixing

Emissions = (4.5 lb/ton)(33,000 tpy) = 148,500 lbs/yr

Hooding, vent to mechanical collector or fabric filter

See (7)

C/B = $0.20/lb

(12) Core making

Emissions = (0.35 lb/ton cores)(3,300 tpy) = ∿1,000 lbs/yr

Hooding, vent to fabric filter

See (7)

C/B = $0.20/lb

(13) Core baking
Emissions = (2.7 lb/ton core)(3,300 tpy) = 9,000 lbs/yr

Afterburners

Capital cost = $35,000
Annual cost = 21,000

$$C/B = \frac{\$21,000/yr}{.9\ (9,000)} = \$2.59/lb$$

(14) Mold sand preparation
Emissions = (1.3 lb/ton)(33,000 tpy) = 43,000 lbs/yr

Hooding, vent to fabric filter or scrubber

See (7)
C/B = $0.20/lb

(15) Mold makeup
Emissions = (0.04 lb/ton)(33,000 tpy) = 1,300 lbs/yr

Hooding, vent to fabric filter or scrubber

See (7)
C/B = $0.20/lb

2.8 STEEL FOUNDRIES

2.8.1 Process Description

Most steel foundries are operated independently from any integrated iron and steel mill. They produce low carbon content (1 percent or less) steel castings for use within the foundry to produce another product or by manufacturers of heavy equipment.

Several types of furnaces are used to melt the raw materials used to produce these steel castings: direct electric arc, electric induction, open hearth and crucible. The crucible furnace is not in widespread use. (See Sections 2.2.3 and 2.7 for illustrations of some of those types of furnaces.)

Figure 2.8-1 illustrates the process flow for a typical steel foundry operation. The melting furnace is charged through a door or opening with raw materials such as steel scrap, pig iron, ferroalloys and limestone. These materials melt as the furnace temperature is increased. When the temperature reaches about 3000°F, the furnace is tapped and molten metal flows to a holding ladle. The molten metal is transferred from the holding ladle to a pouring ladle and is then poured into prepared molds. The molten steel sets to form castings which are then shaken out of the mold and allowed to cool further. The castings are usually cleaned by shot blasting, and excess metal and surface defects are removed by localized melting and grinding. Finishing operations may include heat treatment in a soaking pit or furnace and surface painting.

Production of molds and cores is an integral part of the steel foundry operation. A mold is usually made of silica sand (although zircon and olivine sand are also used) mixed with water and binders such as clay, pitch or cereal. The mixture is transferred to a molding area, where it is either mechanically or hand packed into a flask.

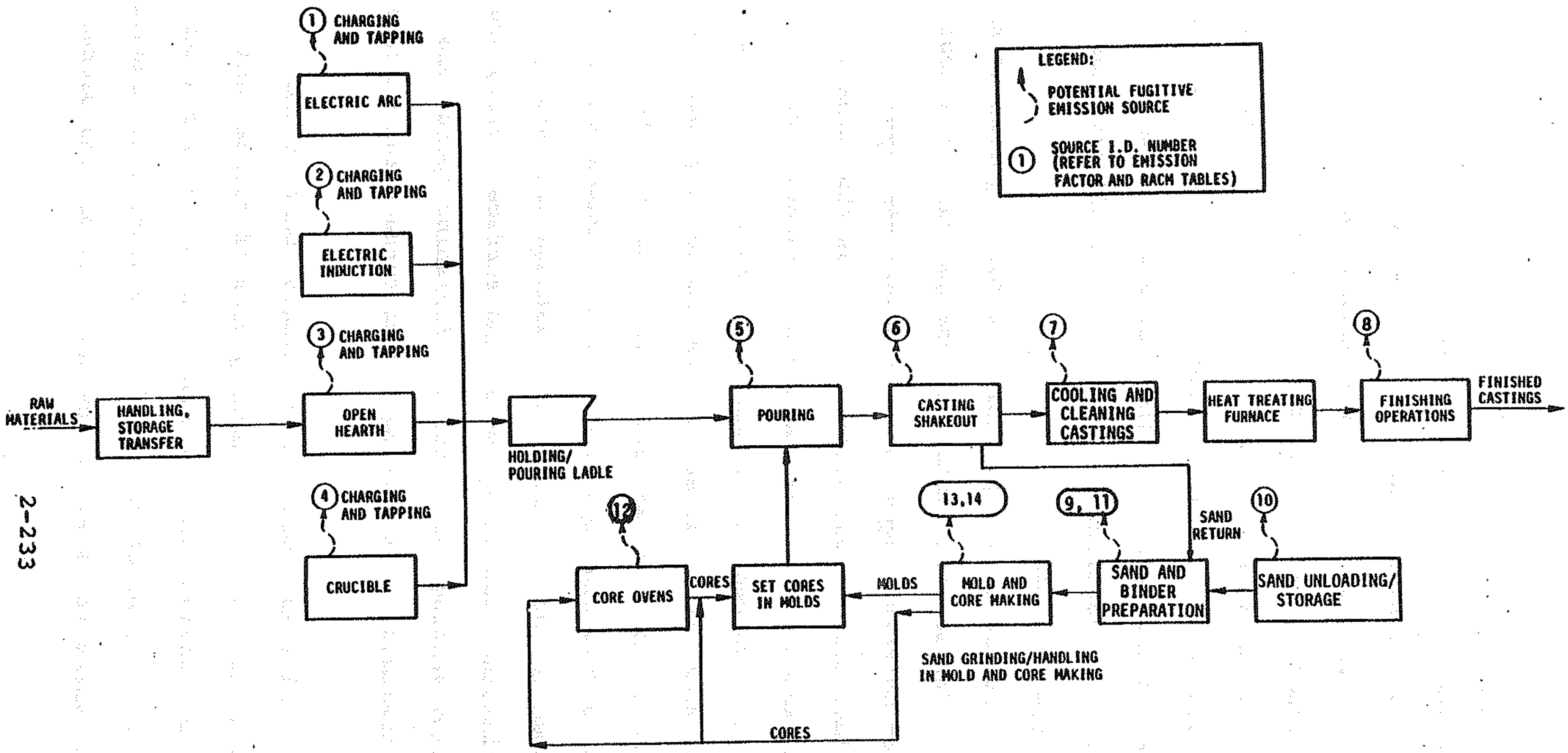

Figure 2.8-1. Simplified process flow diagram for steel foundries and associated fugitive particulate emission sources.

A core is a separate part of the mold that provides a cavity in the castings. Cores are usually made of sand and binders and are usually, but not always, bound to the mold with core paste. The core must be strong enough to withstand the temperature and pressure of the molten metal within the mold. Silicate, resin, oil and cereal binders are used to provide this strength. After the cores are formed, they may be baked in ovens or cured by carbon dioxide, air, a tertiary amine catalyst (Isocure process) or by using heated core boxes (shell and hotbox processes).

The potential fugitive emission sources associated with steel foundries are raw material handling, storage, and transfer operations, charging and tapping of the melting furnaces, pouring into molds, casting shakeout, cleaning operations, finishing operations, sand preparation, and mold and core making.

Large steel foundries operate continuously, 24 hours a day, 7 days a week, while smaller foundries operate only 8 hours a day. The capacity of a foundry depends upon the number and size of furnaces, but typically ranges from 25 to 240 tons of steel produced per day.

2.8.2 Fugitive Dust Emission Factors

The estimated emission factors for steel foundry fugitive particulate sources are summarized in Table 2.8-1. There is practically no data availabl on fugitive emission rates from steel foundries; and, therefore, it is suggested that emission factors for iron foundries (Section 2.7) be used for steel foundries. These are also included in Table 2.8-1 for informational purposes.

It should be noted that use of the iron foundry emission factors for mold sand preparation, core sand and binder mixing and mold making may not be directly applicable to such operations at steel foundries due to differenc in yields and possibly in sand to metal ratios between steel and iron casting production. Such differences should be evaluated and, if necessary, adjustme made to such emission factors to reflect any differences.

TABLE 2.8-1. FUGITIVE DUST EMISSION FACTORS FOR STEEL FOUNDRIES[a]

Source	Emission factor	Reliability rating	References
(1) Electric arc furnace charging and tapping	1.05 to 3.48 lb/ton steel	E	1,2
(2) Electric induction furnace melting, charging and tapping	0.1 lb/ton metal charged	E	3
(3) Open hearth furnace charging and tapping	0.1 to 0.9 lb/ton metal charged	E	4,5
(4) Crucible furnace charging and tapping	0.1 to 0.6 lb/ton metal	E	6
(5) Hot metal pouring	0.55 to 4.13 lb/ton metal	D	7,8
(6) Shakeout of castings[b]	1.2 to 12.8 lb/ton steel	E	1,9
(7) Cooling and cleaning castings[b]	0.16 to 0.8 lb/ton castings	E	9
(8) Finishing castings[b]	0.01 lb/ton castings	E	9
(9) Mold sand preparation[b]	1.3 lb/ton castings	E	1
(10) Core and mold sand unloading and storage:			
mechanical handling	0.03 lb/ton sand unloaded[c]	E	6
pneumatic handling	NA		
(11) Mixing of core sand and binder[b]	0.3 lb/ton sand, or 0.75 to 8.24 lb/ton	E E	10 1,9
(12) Core baking	0.03 to 5.4 lb/ton cores baked	E	6,9,10
(13) Core making[b]	0.35 lb/ton cores	E	10
(14) Mold making[b]	0.04 lb/ton castings	E	9

NA = Not available.

[a] Where ranges are given, use average unless more accurate data is available.

[b] Emission factor given is for iron foundries.

[c] Sand unloading emission factor is assumed to be equivalent to the taconite pellets unloading emission factor as presented in Section 2.1.3. Fugitive dust emissions from storage are estimated to be negligible since sand is normally stored indoors.

2.8.3 Particle Characterization

Data on particle characteristics specific for steel foundries were not found in the literature. Data were available for iron foundries. The available data are presented similar for steel foundries. The available data are presented in Section 2.7.3.

2.8.4 Control Methods

Control techniques available for steel foundries are essentially the same as those for iron foundries. Section 2.7.4 presents a discussion of available control options.

Available control techniques, their effectiveness, estimated costs and RACM selections are listed in Table 2.8-2. Where data were unavailable, it was assumed that control characteristics would be the same as those for control of iron foundries (See Section 2.7.4).

2.8.5 Recommended Reasonably Available Control Measures (RACM)

The RACM selections for steel foundry fugitive sources are presented in Table 2.8-2. It is noted that the reduction of emission from melting operations is enhanced when clean scrap is used in the raw charge. Clean materials that are essentially devoid of dirt, oil or grease carry no extraneous burden into and through the furnace. Use of clean scrap, or the pre-cleaning of dirty scrap before use, are useful and appropriate measures worthy of consideration as adjunctive to and supportive of other control measures.

TABLE 2.8-2. A SUMMARY OF THE CONTROL ALTERNATIVES, EFFICIENCIES AND COSTS, AND THE RACM SELECTIONS FOR FUGITIVE DUST EMISSIONS FROM SOURCES AT STEEL FOUNDRIES

Fugitive dust sources	Control alternatives	Control efficiency, %	Control cost, Jan. 1980, $ Capital	Annualized	Cost benefit, $/lb	RACM selection
(1) Electric arc furnace charging and tapping	Hooding, vent to fabric filter	90[a]	336,000[a]	82,000[b]	1.09	Maintenance of continuous draft during charging and tapping operations (if primary controls present); otherwise hooding, vent to fabric filter
	Building enclosure, evacuation to fabric filter	95[c]	d	d	d	
	Maintenance of continuous draft during charging and tapping	70[e]	20,000[h]	4,000[g]	0.07	
(2) Electric induction furnace, charging and tapping	Hooding, vent to fabric filter	90[a]	336,000[a]	82,000[b]	23.11	Maintenance of continuous draft during charging and tapping (if primary controls present); otherwise, no control
	Building enclosure, evacuation to fabric filter	95[c]	d	d	d	
	Maintenance of continuous draft during charging and tapping	70[e]	20,000[f]	4,000[g]	1.45	
(3) Open hearth furnace charging and tapping	Hooding, vent to fabric filter	90[a]	336,000[a]	82,000[b]	4.62	Maintenance of continuous draft during charging and tapping operations (if primary controls present); otherwise hooding, vent to fabric filter
	Building enclosure, evacuation to fabric filter	95[c]	d	d	d	
	Maintenance of continuous draft during charging and tapping	70[e]	20,000[f]	4,000[g]	0.29	
(4) Crucible furnace charging and tapping	Hooding, vent to fabric filter	90[a]	336,000[a]	82,000[b]	8.32	No control
	Building enclosure, evacuation to fabric filter	95[c]	d	d	d	
	Maintenance of continuous draft during charging and tapping	70[e]	20,000[f]	4,000[g]	0.52	

(continued)

TABLE 2.8-2 (continued)

Fugitive dust sources	Control alternatives	Control efficiency, %	Control cost, Jan. 1980, $ Capital	Annualized	Cost benefit, $/lb	RACM selection
(5) Hot metal pouring	Hoods, vent to wet scrubber or fabric filter	95[c]	63,000[h]	18,000[b]	0.22	Hoods, vent to fabric filter
(6) Casting shakeout	Hoods, vent to wet scrubber or fabric filter	95[c]	234,000[i]	82,000[b]	0.18	Hoods, vent to fabric filter
(7) Cooling and cleaning castings	Hooding, mechanical collector, fabric filter or scrubber	90[c]	j	j	j	k
(8) Finishing castings	Hooding, vent to mechanical collector, fabric filter or scrubber	90-99[e]	j	j	j	k
(9) Mold sand preparation	Hooding, vent to fabric filter or scrubber	90[c]	j	j	j	k
(10) Core and mold sand unloading and storage:						
mechanical handling	Wet suppression (chemical)	85[c]	26,000	7,000	1.00	Wet suppression (chemical)
	Enclosure	50[c]	15,000	3,000	0.73	
	Hooding, vent to mechanical collectors	80[c]	33,600	12,000	1.83	
pneumatic handling	Vent to storage hopper to fabric filter	99[c]	NA	NA	NA	Vent to storage hopper to fabric filter
(11) Core sand and binder mixing	Hooding, vent to mechanical collector or fabric filter	90[c]	j	j	j	k
(12) Core baking	Afterburners	90[c]	35,000	21,000	2.37	No control
(13) Core making	Hooding, vent to fabric filter	90[c]	j	j	j	k
(14) Mold makeup	Hooding, vent to fabric filter or scrubber	90[c]	j	j	j	k

[a] Reference 11.

[b] Reference 12.

[c] Estimated.

[d] No cost data available.

[e] Based on control of 95% of charging emissions only. Reference 13.

[f] Estimated costs of movable ducting required.

[g] Includes only capital charges and maintenance estimated as 20% of capital investment.

[h] Reference 14.

[i] Reference 14. Based on 50,000 acfm and control of sand handling, cooling, cleaning, mixing, screening, core and mold making operations.

[j] Control costs included under casting shakeout system.

[k] RACM is an integrated system ducting the casting shakeout, sand handling, cooling, cleaning, mixing, screening, core and mold making operations to a single fabric filter.

The selected RACM for control of electric arc, electric induction and open hearth furnaces is predicated upon utilization of an existing capture and control system to effect emission control at charging and tapping operations. The RACM technique may necessitate modification of the existing hood(s) and duct system(s) and may require the addition of control device capacity. For electric arc and open hearth furnaces with no primary controls, RACM consists of localized and canopy hooding vented to a fabric filter. For electric induction furnaces with no primary controls, RACM is no control.

No control is recommended for crucible furnaces since these are fairly low emitters of particulate matter, are not usually controlled, and are being phased out of the industry.

The RACM selected for hot metal pouring operations is hooding and local exhaust to a fabric filter. This type of system gives an estimated 95 percent control and has typically been employed at foundries.

The selected RACM for control of the casting shakeout fugitive emission is a local exhaust system comprised of hood(s), ductwork and a fabric filter. Combination systems can be designed to handle exhaust gases from the cleaning and cooling castings, finishing operations, sand and binder mixing, core and mold make up, sand preparation and handling operations. Such systems are very effective and are used in existing foundries.

For illustrations of some of the above control methods, see Section 2.7.

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APPENDIX FOR SECTION 2.8

Assume 100 tpd steel production, 93% yield and 108 tpd input

(1) Electric arc furnace

Emissions = (2.3 lb/ton)(100 tpd)(365 d/y)
= 83,950 lbs/yr

<u>Hooding, vent to fabric filter</u>

$$\text{Capital cost} = \$275{,}000 \frac{(249.6)}{(204.1)} = \$336{,}000$$

$$\text{Annual cost} = \$67{,}100 \frac{(249.6)}{(204.1)} = \$82{,}000$$

$$C/B = \frac{\$82{,}000/\text{yr}}{.9\ (83{,}950)} = \$1.09/\text{lb}$$

<u>Building enclosure, evacuation to fabric filter</u>

No data

<u>Maintenance of continuous draft during charging and tapping</u>

$$\text{Capital cost} = \$16{,}800 \frac{(249.6)}{(204.1)} = \$20{,}000$$

Annual cost = $4,000

$$C/B = \frac{\$4{,}000/\text{yr}}{.7\ (83{,}950)} = \$0.07/\text{lb}$$

(2) Electric induction furnace, charging and tapping

Emissions = (0.1 lb/ton)(108)(365) = 3,942 lbs/yr

<u>Hooding, vent to fabric filter</u>

See (1)

$$C/B = \frac{\$82{,}000/\text{yr}}{.9\ (3{,}942)}\ \$23.11/\text{lb}$$

<u>Building enclosure, evacuation to fabric filter</u>

No data

<u>Maintenance of continuous draft during charging and tapping</u>

See (1)

$$C/B = \frac{\$4{,}000/\text{yr}}{.7\ (3{,}942)} = \$1.45/\text{lb}$$

(3) Open hearth furnace charging and tapping
Emissions = (0.5 lb/ton)(108)(365) = 19,719 lbs/yr

Hooding, vent to fabric filter

See (1)

$$C/B = \frac{\$82,000/yr}{.9\ (19,710)} = \$4.62/lb$$

Building enclosure, evacuation to fabric filter
No data

Maintenance of continuous draft during charging and tapping

See (1)

$$C/B = \frac{\$4,000/yr}{.7\ (19,710)} = \$0.29/lb$$

(4) Crucible furnace charging and tapping
Emissions = (0.3 lb/ton)(100)(365) = 10,950 lbs/yr

Hooding, vent to fabric filter

See (1)

$$C/B = \frac{\$82,000/yr}{.9\ (10,950)} = \$8.32/lb$$

Building enclosure, evacuation to fabric filter
No data

Maintenance of continuous draft during charging and tapping

See (1)

$$C/B = \frac{\$4,000/yr}{.7\ (10,950)} = \$0.52/lb$$

(5) Hot metal pouring
Emissions = (2.34 lbs/ton)(36,500 tpy) = 85,410 lbs/yr

Hoods, vent to wet scrubber or fabric filter

$$\text{Capital cost} = 51,500\ \frac{(249.6)}{(204.1)} = \$63,000$$

$$\text{Annual cost} = 15,000\ \frac{(249.6)}{(204.1)} = \$18,000$$

$$C/B = \frac{\$18,000/yr}{.95\ (85,410)} = \$0.22/lb$$

(6) Casting shakeout

Emissions = (7.0 lbs/ton) x (100)(365) = 255,500 lbs/yr

Hoods, vent to wet scrubber or fabric filter (Includes control of source #'s 7, 8, 9, 11, 13, 14)

$$\text{Capital cost} = 190,000 \frac{(249.6)}{(204.1)} = \$234,000$$

$$\text{Annual cost} = 67,000 \frac{(249.6)}{(204.1)} = \$82,000$$

$$C/B = \frac{\$82,000/yr}{.95(255,500) + 0.9(17,520) + .95(365) + .9(47,450) + .9(164,250) + .9(1,278) + .9(1,460)} = \$0.18/lb$$

(7) Cooling and cleaning castings

Emission = (0.48 lb/ton)(36,500 tpy) = 17,520 lbs/yr

Hooding, mechanical collector, fabric filter or scrubber

See (7)
C/B = $0.18/lb

(8) Finishing castings

Emissions = (0.01 lb/ton)(36,500 tpy) = 365 lbs/yr

Hooding, vent to mechanical collector, fabric filter or scrubber

See (7)
C/B = $0.18/lb

(9) Mold sand preparation

Emissions = (1.3 lbs/ton)(36,500 tpy) = 47,450 lbs/yr

Hooding, vent to fabric filter or scrubber

See (7)
C/B = $0.18/lb

(10) Core and mold sand unloading and storage

Mechanical handling

Emissions = (0.03 lb/ton)(36,500 tpy)(15)(.5) = 8,213 lbs/yr

Hooding, vent to mechanical collectors

Capital cost = $33,600
Annual cost = 12,000

$$C/B = \frac{\$12,000/yr}{.8\ (8,213)} = \$1.83/lb$$

Wet suppression (chemical)

Capital cost = $26,000
Annual cost = 7,000

$$C/B = \frac{\$7,000/yr}{.85\ (8,213)} = \$1.00/lb$$

Enclosure

Capital cost = $15,000
Annual cost = $3,000

$$C/B = \frac{\$3,000/yr}{.5\ (8,213)} = \$0.73/lb$$

Pneumatic handling
Emissions = NA

Vent storage hopper to fabric filter
No data

(11) Core sand and binder mixing
Emissions = (4.5 lbs/ton)(36,500 tpy) = 164,250 lbs/yr

Hooding, vent to mechanical collector or fabric filter

See (7)
C/B = $0.18/lb

(12) Core baking
Emissions = (2.7 lbs/ton)(0.1)(36,500 tpy) = 9,855 lbs/yr

Afterburners

Capital cost = $35,000
Annual cost = $21,000

$$C/B = \frac{\$21,000/yr}{.9\ (9,855)} = \$2.37/lb$$

(13) Core making
Emissions = (.35 lb/ton cores)(.1)(36,500 tpy) = 1,278 lbs/yr

Hooding, vent to fabric filter

See (7)
C/B = $0.18/lb

(14) Mold makeup
Emissions = (0.04 lb/ton)(36,500 tpy) = 1,460 lbs/yr

Hooding, vent to fabric filter or scrubber

See (7)
C/B = $0.18/lb

2.9 GLASS MANUFACTURING PLANTS

2.9.1 Process Description

Glass is defined as an amorphous, multicomponent mixture of inorganic oxides. As commercially produced, there are several recognized classifications that are named on the basis of composition or feed materials, such as soda-lime, fused silica, borosilicate or 96 percent silica. Of these classifications, soda-lime glass, comprising 90 percent[1] of total glass production, has been selected for description. The processes involved in making other types of glasses are basically the same. Soda-lime glass consists of sand, limestone, soda ash, cullet (broken, recycled glass) and small amounts of conditioners such as sulfates. Typical product composition is:[2]

70 to 74 wt. percent SiO_2,

10 to 13 wt. percent CaO, and

13 to 16 wt. percent Na_2O.

A flow diagram of the manufacturing process is shown in Figure 2.9-1.

The part of the process dealing with feed material storage and handling is normally housed separately and is referred to as the batch plant. The materials are individually received by rail or truck and are dumped into a receiving hopper. After passing through a crusher, it is transferred via screw conveyor and bucket elevator to elevated feed material storage hoppers. Cullet is handled in similar fashion from a surge hopper. The major and minor ingredients are gravity fed from the storage

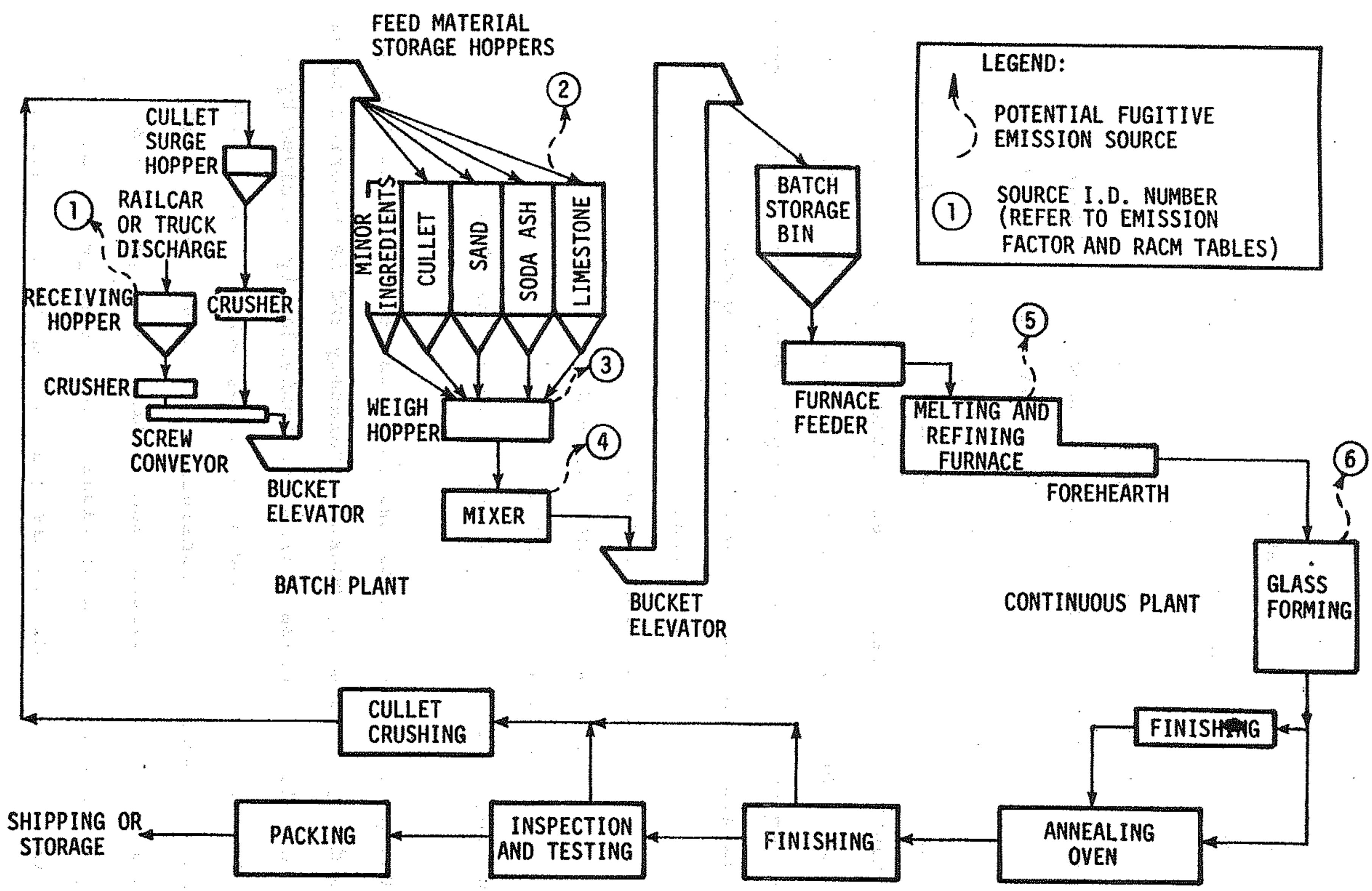

Figure 2.9-1. Simplified process flow diagram for manufacture of soda-lime glass and associated fugitive particulate emission sources.

hoppers to a weigh hopper where proper batch proportions of the ingredients are regulated. The batch is then dropped by gravity into a mixer from which it is taken by bucket elevator to a batch storage bin. The mixed material is charged as needed to the melting furnace through a furnace feeder which regulates the rate of charging.

The feed materials charged to the furnace are melted and maintained at 2700 to 3100°F to promote chemical reaction of the materials and to produce a mass of uniform consistency.[3] A process known as fining, which is the removal of gas bubbles, also takes place at this temperature where the melt viscosity is minimal. The melt thereafter passes to the conditioning section of the furnace where the temperature is slowly lowered to 2400°F to increase melt viscosity and forming characteristics.[4]

The furnace most commonly utilized is a continuous, gas-fired, regenerative furnace with a glass production capacity of 50 to 300 tons per day.[5] As shown in Figures 2.9-2 and 2.9-3, the furnace may have either side or end ports connecting brick checker-work to the interior of the furnace. The purpose of the checker-work is to conserve fuel by utilization of the heat in the combustion products to preheat the combustion air to the furnace. To accomplish this economy, the paths of the combustion air and furnace exhaust gases are periodically reversed from one end of the furnace to the other.

Furnaces may also be oil-fired and use an alternative heat transfer system known as recuperative heat recovery. Also,

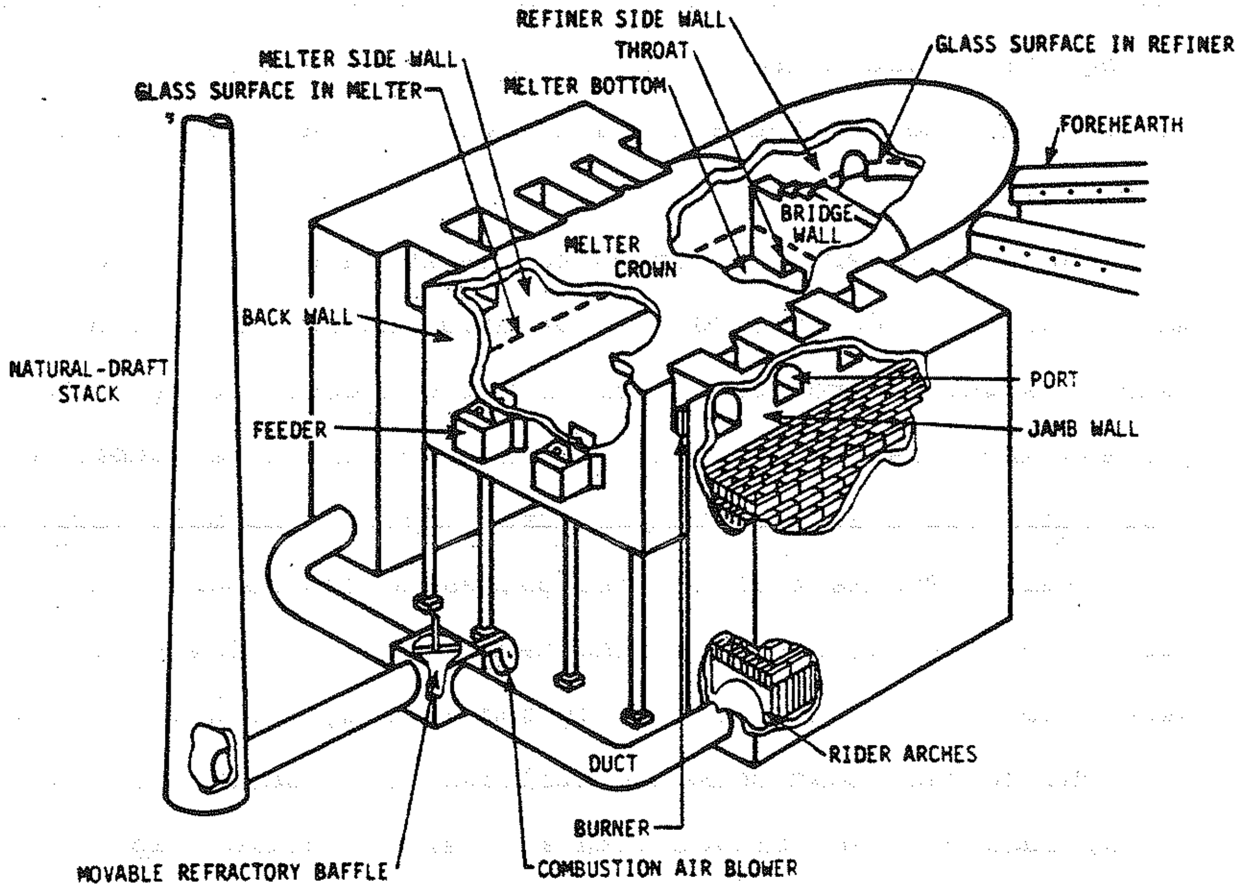

Figure 2.9-2. Side-port continuous regenerative furnace.[1]

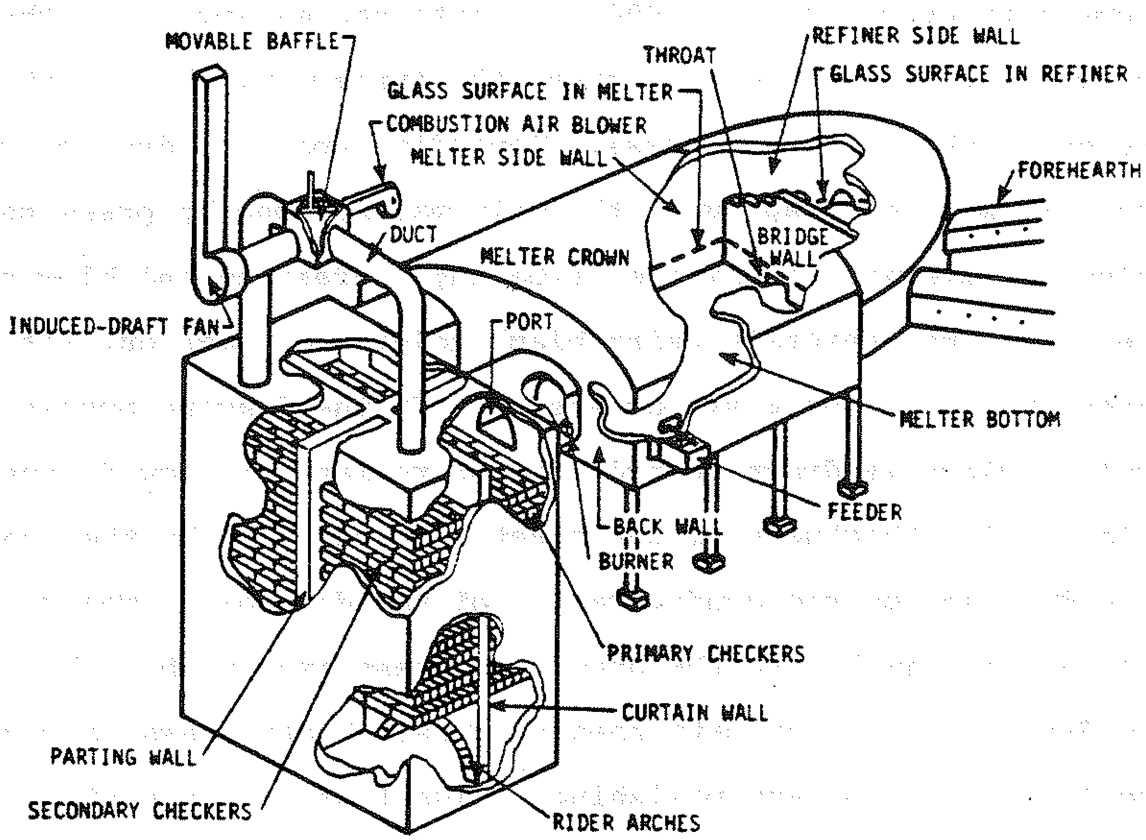

Figure 2.9-3. End-port continuous regenerative furnace.[1]

electric induction systems may be used to provide a boost in production rates. Electric induction can also be used exclusively for melting the glass.

After the melt has been refined, it is ready to be formed at temperatures of 1500 to 2000°F.[6] With the exception of the float process, the molten glass leaves the furnace via the forehearths to go to the forming process. Depending upon the desired product, forming or shaping of the melt may be done by pressing, blowing, drawing, rolling or floating. Pressing and blowing are performed mechanically using blank molds and glass cut into sections (gobs) by a set of shears. In the drawing process, molten glass is drawn upward through rollers that guide the sheet glass. The thickness of the sheet is determined by the speed of the draw and by the configuration of the draw bar. The rolling process is similar to the drawing process except that the glass is drawn by plain or patterned rollers. Plate glass so produced requires grinding and polishing.[1] The float process utilizes a molten tin bath over which glass from the melt furnace is drawn and formed into a finely finished surface requiring no grinding or polishing.[1]

The shaped product may be finished (decorated or coated) before being annealed,or it may proceed directly to annealing. Annealing is required to remove stresses incurred in the forming process. Upon subsequent finishing operations such as cutting or trimming, the product is cooled to room temperature, inspected and tested prior to packaging and shipment. Rejected product material is crushed to form coarse cullet that is recycled to the cullet surge hopper preparatory to recharging it to the melt furnace.

The potential sources of fugitive particulate emissions from the process area are:

1. discharge of materials from railcar or truck,
2. storage hoppers,
3. feed materials weigh hopper,
4. feed materials mixer,
5. melting and refining furnace, and
6. glass forming area.

2.9.2 Fugitive Dust Emission Factors

The fugitive emission factors for the various manufacturing operations are presented in Table 2.9-1. Although there is recognition of such emissions within the industry, the literature surveyed contained no data concerning fugitive emissions. The factors shown were derived from analogous operations in other industries. The melting furnace itself is a point source having a stack to vent combustion and reaction gases from the furnace. This exhaust stream is usually routed through a control device for particulate removal. In the event of furnace leakage, however, fugitive emissions would occur in the melt building and escape to the atmosphere via the roof vents. The emission factor shown is an estimated portion of the uncontrolled stack emissions.

TABLE 2.9-1. FUGITIVE DUST EMISSION FACTORS FOR GLASS MANUFACTURING PLANTS

Source	Uncontrolled fugitive emission factor		
	lb/ton of glass produced	Reference	Reliability rating
(1) Feed materials receiving	1.0[a]	1,5	E
(2) Feed materials transfer to storage	0.5[b]	4	E
(3) Materials batch weighing	0.02[c]	4	E
(4) Materials mixing	0.04[c]	4	E
(5) Melting and refining furnace	0.15[d]	6,8	E
(6) Glass forming	Neg.[e]	1,6,8	E

[a] Estimated emission factor from reference 7 for soda ash and reference 8 for alumina unloading.

[b] Estimated average factor based upon analogous cement industry operating factors from reference 9.

[c] Factors taken from analogous cement industry operations in reference 10.

[d] Engineering estimate that fugitive emissions from the furnace equal 5 percent of the uncontrolled stack emissions. Stack emissions for soda-lime glass manufacture were obtained from references 11 and 12.

[e] Per references 13 and 14, emissions from this source are vapors, not particulate.

2.9.3 Particle Characterization

The particles emanating from the feed materials handling section of the plant are relatively large in size, 10 to 100 μm diameter,[15] and reflect the feed materials being handled (i.e., sand, soda ash and limestone).

Particulate coming from the melting furnace, however, is smaller in size and has a composition high in sodium, silicon and calcium. The literature[16,17] cites particle sizes less than 1 micron in diameter for the furnace effluent.

Toxicity of emissions, either gaseous or particulate, has not been established in the literature surveyed. There are analytical data, however, which show the presence of fluorides in the particulate emission from the melting furnace when a fluoride flux or feed material is employed.[18] These data also show the presence of gaseous fluoride, arsenic and hydrocarbons in furnace and forming effluent gases.

2.9.4 Control Methods

A summary of the fugitive emission control alternatives is presented in Table 2.9-2. As can be seen from the table, a variety of methods are applicable for control of fugitive emissions from feed materials handling. Emissions generated when feed materials are discharged from rail cars or trucks may be controlled by enclosing the site of discharge, by using pneumatic conveying removal of received material, by employing choke-feeding to prevent flooding of materials from the carrying vehicle or by wetting of the material with a small amount of water.

TABLE 2.9-2. A SUMMARY OF THE CONTROL ALTERNATIVES, EFFICIENCIES AND COSTS, AND THE RACM SELECTIONS FOR FUGITIVE DUST EMISSIONS FROM SOURCES AT GLASS MANUFACTURING PLANTS

Fugitive dust sources	Control alternatives	Control efficiency, %	Control costs $ (Jan. 1980) Capital	Control costs $ (Jan. 1980) Annualized	Cost benefit, $/lb	RACM selection
(1) Feed materials receiving	Closure	50[a]	28,000[b]	9,000[c]	0.33	Closure, fabric filter
	Closure, fabric filter	90[a]	93,000[b,n]	30,000[c,d]	0.62	
	Choke-feeding	70[d]	33,000[e]	11,000[c]	0.29	
	Wet suppression	50[f]	23,000[g]	7,000[h]	0.26	
	Pneumatic unloading	90[d]	53,000[i]	22,000[j]	0.45	
(2) Feed materials transfer to storage	Wet suppression	50[f]	23,000[g]	7,000[h]	0.52	Wet suppression
	Area ventilation to fabric filter	90[k]	136,000[l]	49,000[m]	2.02	
(3) Feed materials batch weighing	Fabric filter	90[k]	65,000[n]	21,000[o]	21.60	Fabric filter
(4) Feed materials mixing	Fabric filter	90[k]	65,000[n]	21,000[o]	10.80	Fabric filter
(5) Melting and refining furnace	Preventive maintenance of furnace and control device	90[d]	Neg.[p]	25,000[q]	3.43	Furnace and control device preventive maintenance
(6) Glass forming	None					

[a] Estimated for partial closure based upon data in reference 19.
[b] Estimated per reference 20.
[c] Reflects enclosure maintenance estimated at 15% of investment cost and indirect costs estimated at 17% of investment cost.
[d] Estimated effectiveness based on engineering experience and judgment.
[e] Estimated per reference 21.
[f] Per reference 22. Method cited in reference 23.
[g] Estimated per reference 24 for one site of spray application and a rate of 50 tons per hour.
[h] Estimated per reference 25.
[i] Estimated for 500 cfm system.
[j] Estimated cost based upon engineering judgment.
[k] Combined efficiency of hood capture and fabric filter control.
[l] Per reference 26 for 20,000 cfm air flow.
[m] Per reference 27 for 20,000 cfm air flow.
[n] Per reference 26 for 10,000 cfm estimated air flow.
[o] Per reference 27 for 10,000 cfm estimated air flow.
[p] Increase of maintenance will not incur capital charges.
[q] Estimated costs for increased maintenance labor and materials.

Choke-feeding regulates solids feed flow by use of a flow control device such as an intermediate hopper fitted with a motor drive rotary valve. This prevents flooding, the action when finely divided solids flow from a container at an extremely high rate.

Fugitive emissions from transfer of feed materials to storage may be controlled by wet suppression or by enclosure and ventilation to a fabric filter.

Particulate emissions from batch weighing and mixing of feed materials can be controlled by the installation of hoods over these operations to capture the emissions. The hoods are vented via duct work to fabric filters to remove the particulate.

The melting and refining furnace is the major point source of emissions for glass manufacture. Even though a furnace may be equipped with a particulate control device, fugitive emissions may result from leakage of gases through furnace openings, deteriorated furnace walls or from badly operated or maintained control devices. Therefore, fugitive emission prevention consists of preventive maintenance of the furnace and the particulate control system.

Preventive maintenance means the making of repairs to equipment before the need for them becomes apparent. In this instance, it would involve rebricking melting furnace walls before the furnace lining shows evidence of deterioration. For a control device, it would mean the regular periodic servicing of associated equipment to prevent leaks or failure during operation. Examples would be the greasing of air blowers, periodic examination of blower blades for deterioration or solids build-up, bag replacement for a fabric filter and removal of solids build-up from the walls of a scrubber.

Particulate emissions are considered negligible from glass forming operations; and, thus, no fugitive emissions would be experienced. Gaseous emissions do occur but they are not in the venue of this report.

Depending upon the specific glass manufacturing facility, fugitive particulate emissions can also come from plant roadways and from outside storage piles. The control of such emissions is addressed in Section 2.1.

2.9.5 Recommended Reasonably Available Control Measures (RACM)

The recommended RACM for the control of each fugitive emission is listed in Table 2.9-2. The RACM's were selected on the basis of the degree of controls needed to meet state emission control regulations, practice of the industry, ease of application or installation and economics.

For raw materials receiving, enclosure with ventilation to a fabric filter is recommended on the basis of removal efficiency on the largest source of fugitive emissions.

Of the control alternatives for emissions control from feed materials transfer, wet suppression is selected on the basis of industrial practice, ease of application and expense.

Fabric filter installations are the only listed alternatives for feed materials weighing and mixing. Such installations are reasonable because they are practical for the process location, permit the captured emissions to be recycled and are reasonable in cost.

For the melting and refining furnace, preventive maintenance of the furnace and associated emissions control device, if any, is the only viable alternative. Such maintenance, as explained earlier, is designed to prevent breakdown of the equipment during production time. By servicing of the equipment at scheduled periodic intervals of production downtime, not only are fugitive emissions avoided but higher production may be realized due to a decrease of downtime caused by equipment failure.

REFERENCES FOR SECTION 2.9

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13. Op. cit. Reference 11. p. 39.

14. Op. cit. Reference 12. p. 3-22.

15. Op. cit. Reference 9.

16. Op. cit. Reference 11.

17. Op. cit. Reference 12.

18. Op. cit. Reference 11.

19. Op. cit. Reference 9. p. 2-38.

20. Op. cit. Reference 8. p. 2-87.

21. Op. cit. Reference 9. p. 2-294.

22. Ibid. p. 2-39.

23. Op. cit. Reference 11. p. 20.

24. Nonmetallic Minerals Industries Control Equipment Costs, Industrial Gas Cleaning Institute for U.S. EPA under Contract No. 68-02-1473, Task No. 19, February 1977. p. 4-9.

25. Ibid. p. 4-11.

26. Ibid. p. 3-3.

27. Ibid. p. 3-6.

APPENDIX FOR SECTION 2.9

Assume an average size plant = 150 tpd or 54,000 tpy glass

(1) Feed materials receiving

Emissions = (1.0 lb/ton)(54,000) = 54,000 lbs/yr

Closure

Capital cost = \$28,000
Annual cost = 9,000

$$C/B = \frac{\$9,000/yr}{.5\ (54,000)} = \$0.33/lb$$

Closure, fabric filter

Capital cost = \$93,000
Annual cost = 30,000

$$C/B = \frac{\$30,000/yr}{.9\ (54,000)} = \$0.62/lb$$

Choke-feeding

Capital cost = \$33,000
Annual cost = \$11,000

$$C/B = \frac{\$11,000/yr}{.7\ (54,000)} = \$0.29/lb$$

Wet suppression

Capital cost = \$23,000
Annual cost = 7,000

$$C/B = \frac{\$7,000/yr}{.5\ (54,000)} = \$0.26/lb$$

Pneumatic unloading

Capital cost = \$53,000
Annual cost = 22,000

$$C/B = \frac{\$22,000/yr}{.9\ (54,000)} = \$0.45$$

(2) Feed materials transfer to storage

Emissions = (0.5 lb/ton)(54,000) = 27,000 lbs/yr

Wet suppression

Capital cost = \$23,000
Annual cost = \$7,000

$$C/B = \frac{\$7,000/lb}{.5\ (27,000)} = \$0.52/lb$$

Area ventilation to fabric filter

Capital cost = $136,000
Annual cost = 49,000

$$C/B = \frac{\$49,000/yr}{.9\ (27,000)} = \$2.02/lb$$

(3) Feed material batch weighing
Emissions = (0.02 lb/ton)(54,000) = 1,080 lbs/yr

Fabric filter

Capital cost = $65,000
Annual cost = 21,000

$$C/B = \frac{\$21,000/yr}{.9\ (1,080)} = \$21.60/lb$$

(4) Feed materials mixing
Emissions = (0.04 lb/ton)(54,000) = 2,160 lbs/yr

Fabric filter

Capital cost = $65,000
Annual cost = 21,000

$$C/B = \frac{\$21,000/yr}{.9\ (2,160)} = \$10.80/lb$$

(5) Melting and refining furnace
Emissions = (0.15 lb/ton)(54,000) = 8,100 lbs/yr

Preventive maintenance of furnace and control device

Capital cost = Negligible
Annual cost = $25,000

$$C/B = \frac{\$25,000/yr}{.9\ (8,100)} = \$3.43/lb$$

(6) Glass forming
No control

2.10 FIBERGLASS MANUFACTURING

2.10.1 Process Description

The steps of manufacture employed to produce various forms of fiberglass are shown in Figure 2.10-1. Feed materials such as glass sand, alumina, borate and alkaline earths are delivered by truck or rail and are transferred to separate storage bins. The materials are metered from the bins to batch weigh hoppers in accordance with the following typical proportions:[1]

silicon dioxide	52 to 56 weight percent,
aluminum oxide	12 to 16 weight percent,
boron oxide	8 to 13 weight percent,
calcium oxide	16 to 25 weight percent,
sodium and potassium oxides	0 to 1 weight percent, and
magnesium oxide	0 to 6 weight percent.

After discharge into a revolving drum mixer, the materials are mixed for about 5 minutes and sent via conveyor and elevator to furnace feed hoppers where the batch mix is held until charged to the melting and refining furnace. The borosilicate glass mix is melted and maintained at about 2800°F[2] to lower viscosity and to enhance refining. The furnace normally used is the regenerative type described in Section 2.9.1; however, other furnaces used include recuperative and electric induction furnaces.

Furnace capacity varies from 50 to 200 tons per day.[3] The remaining steps of manufacture are dictated by the type of product which is desired. If textile fibers, staple yarns or mat products are wanted, glass melt from the refining furnace is formed into marbles which are melted in a small electric furnace and fed through a set of platinum bushings located at the furnace

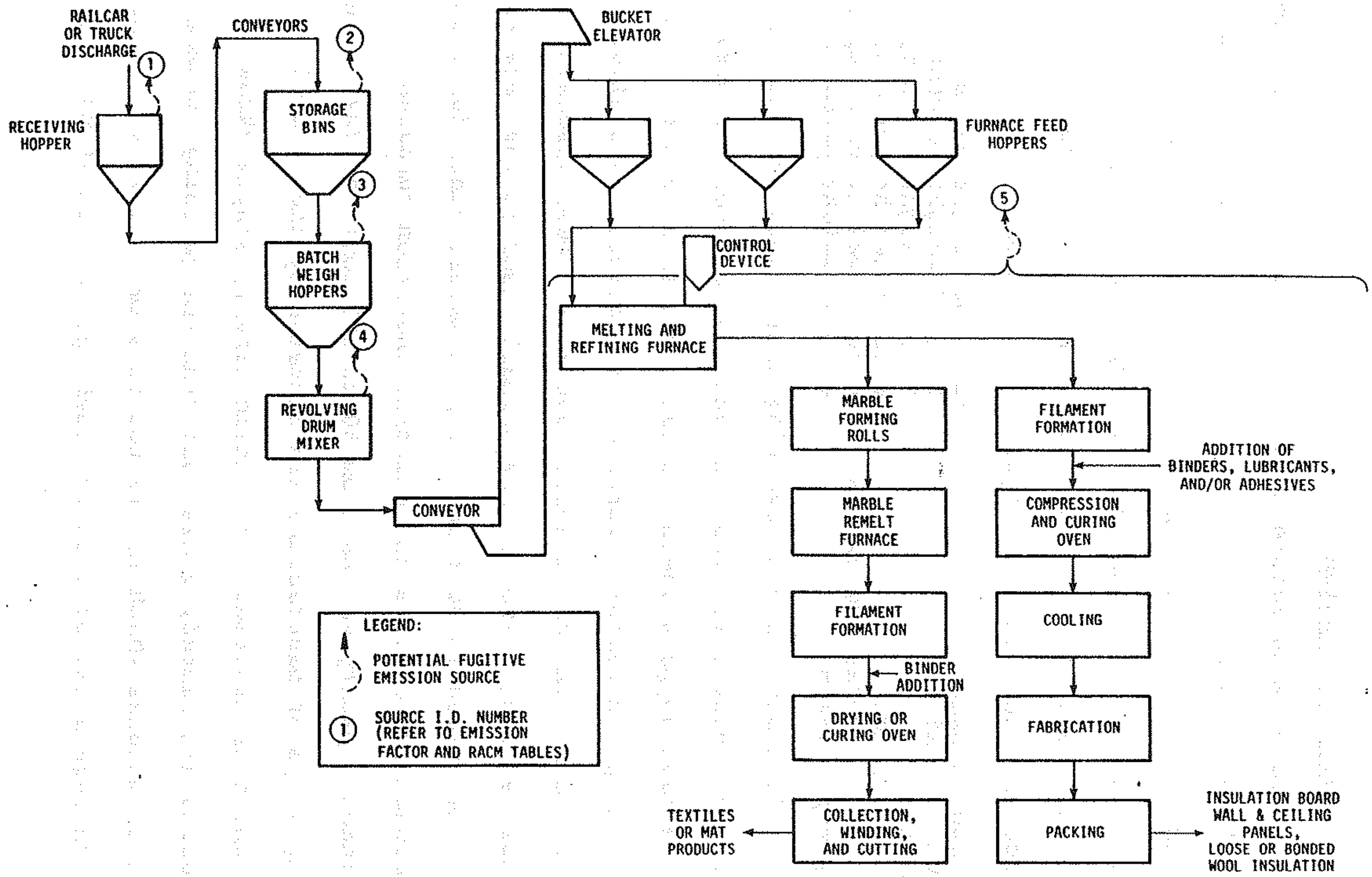

Figure 2.10-1. Simplified process flow diagram of fiberglass manufacture and associated fugitive particulate emission sources.

forehearth. Alternately, an air blower may be used to force the molten glass through small openings to form glass filaments which are drawn and collected by high speed winders. For manufacture of mat products, the filaments are made to form a mat which is conveyed through an oven prior to being slit or chopped to specified dimensions. The mat thus produced is rolled and packaged for shipment.

Should glass wool products be desired, the melt from the refining furnace is blown by air or steam jets through small holes in a platinum bushing located at one end of the furnace. The filaments so formed are caught by high-speed gas jets, pulled into fibers and collected on a moving belt. The resulting woolly mass is impregnated with organic binder material before being cured and formed into bats for use as insulation or set into frames for use as air filters.

Potential sources of fugitive particulate emissions from the plant include the following:

1. receipt of feed materials,
2. the transfer of received feed materials to storage bins,
3. weighing of materials,
4. the mixing of materials in a revolving drum, and
5. melting, refining and forming.

2.10.2 Fugitive Dust Emission Factors

Estimated fugitive emission factors for the operations associated with fiberglass manufacture are presented in Table 2.10-1. The literature surveyed contained no data for fugitive

TABLE 2.10-1. FUGITIVE DUST EMISSION FACTORS FOR FIBERGLASS MANUFACTURING

Source	Uncontrolled fugitive emission factor		
	lb/ton of glass produced	Reference	Reliability rating
(1) Feed materials receiving	1.0[a]	4, 5	E
(2) Feed materials transfer to storage	0.5[b]	6	E
(3) Materials batch weighing	0.02[c]	7	E
(4) Feed materials mixing	0.04[c]	7	E
(5) Melting, refining and forming	1.0[d]	8	E

[a] Estimated average emission factor based upon similar materials, reference 4 for alumina (aluminum oxide) unloading; reference 5 for soda ash unloading.

[b] Estimated average factor based upon cement industry analogy from reference 6.

[c] Factors taken from cement industry in reference 7.

[d] Engineering estimate that fugitive emissions are 5 percent of uncontrolled emissions from furnace. Stack emissions per reference 8.

emissions. Therefore, the factors shown were either derived from analogous operations in other industries or estimated on the basis of engineering experience and judgment.

2.10.3 Particle Characterization

The particulate emitted from the feed materials handling portion of the plant is relatively large in size, 10 to 100 μm diameter,[9] and reflects in its composite the feed materials handled, i.e., sand, borate and boric acid.

Particulate from the melting furnace, however, is much smaller in size and is reported[10] to be primarily boric acid and alkali borates. Particle sizes are less than 1 μm in diameter.[11]

Particulate emissions from either glass filament or wool formation are fiberlike in nature, i.e., they are thin and elongated with a diameter of 0.05 to 3 μm.[12] They are identical in composition to the borosilicate glass being produced.

The toxicity of the emissions, whether gaseous or particulate, from any of the operations has not been established in the literature surveyed.

2.10.4 Control Methods

A summary of the fugitive emission control alternatives is given in Table 2.10-2. As can be noted from the table, fugitive emissions from feed materials handling may be controlled by a variety of methods. These methods are the same as those for glass manufacturing and are described in detail in Section 2.9.4.

TABLE 2.10-2. A SUMMARY OF THE CONTROL ALTERNATIVES, EFFICIENCIES AND COSTS, AND THE RACM SELECTIONS FOR FUGITIVE DUST EMISSIONS FROM SOURCES AT FIBERGLASS MANUFACTURING PLANTS

Fugitive dust sources	Control Alternatives	Control efficiency, %	Control costs $ (Jan. 1980)		Cost benefit, $/lb	RACM selection
			Capital	Annualized		
(1) Feed materials receiving	Closure	50[a]	28,000[b]	9,000[c]	0.33	Closure, fabric filter
	Closure, fabric filter	90[a]	93,000[b,n]	30,000[c,o]	0.62	
	Choke-feeding	70[d]	33,000[e]	11,000[c]	0.29	
	Wet Suppression	50[f]	23,000[g]	7,000[h]	0.26	
	Pneumatic unloading	90[d]	53,000[i]	22,000[j]	0.45	
(2) Feed materials transfer to storage	Wet suppression	50[f]	23,000[g]	7,000[h]	0.52	Wet suppression
	Area ventilation to fabric filter	90[k]	136,000[l]	49,000[m]	2.02	
(3) Feed materials batch weighing	Fabric filter	90[k]	65,000[n]	21,000[o]	21.60	Fabric filter
(4) Feed materials mixing	Fabric filter	90[k]	65,000[n]	21,000[o]	10.80	Fabric filter
(5) Melting and refining furnace, forming line	Preventive maintenance of furnace and control device	90[d]	Neg.[p]	25,000[q]	3.43	Furnace and control device preventive maintenance

[a] Estimated for partial closure based upon data in reference 13.
[b] Estimated per reference 14.
[c] Reflects enclosure maintenance estimated at 15 percent of investment cost and indirect costs estimated at 17 percent of investment.
[d] Estimated effectiveness based on engineering experience and judgment.
[e] Estimated per reference 15.
[f] Per reference 16. Method cited in reference 17.
[g] Estimated per reference 18 for one site of spray application and a rate of 50 tons per hour.
[h] Estimated per reference 19.
[i] Estimated for 500 cfm system.
[j] Estimated cost based upon engineering judgment.
[k] Combined efficiency of hood capture and fabric filter control.
[l] Per reference 20 for 20,000 cfm air flow.
[m] Per reference 21 for 20,000 cfm air flow.
[n] Per reference 20 for 10,000 cfm estimated air flow.
[o] Per reference 21 for 10,000 cfm estimated air flow.
[p] Increase of maintenance will not incur capital charges.
[q] Estimated costs for increased maintenance labor and materials.

2.10.5 Recommended Reasonably Available Control Measures (RACM)

The RACM recommended for the control of each fugitive particulate emission are shown in Table 2.10-2. The measures were selected after consideration of the various criteria to be satisfied, i.e., compliance with state emission control standards, ease of application or installation, and industrial practice.

For receipt of raw materials, an enclosure vented to a fabric filter is the selected RACM due to its effectiveness on the largest fugitive emission source.

Wet suppression is selected as RACM for feed materials transfer to storage. This control is presently employed in the industry[22,23] and is easy to apply at reasonable expense.

Fabric filter installations for emissions control at the feed materials weighing and mixing steps are recommended RACM since they are reasonable in cost, are suitable for the process location and permit recycle of the captured emissions to the process.

For the melting furnace and the filament formation and treating facilities, the maintenance of the equipment and their associated emission control devices to prevent emission leakage is the recommended RACM. Such maintenance on a regular scheduled basis will not only prevent fugitive emissions, but will extend the useful life of the equipment and permit higher equipment productivity due to avoidance of equipment failure.

REFERENCES FOR SECTION 2.10

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3. Glass Manufacturing Plants-Background Information: Proposed Standards of Performance, Draft EIS, U.S. EPA, Report EPA-450/3-79-005a, June 1979, p. 6-14.
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5. Op. cit. Reference 2, p. 5.16-1.
6. Technical Guidance for Control of Industrial Process Fugitive Particulate Emissions, EPA-450/3-77-010, March 1977, p. 2-283.
7. Ibid. p. 2-314.
8. Op. cit. Reference 2, p. 8.11-3.
9. Op. cit. Reference 6, pp. 2-7, 2-38, 2-221.
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11. Op. cit. Reference 3, p. 3-20.
12. Evaluation of the Applicability and Feasibility of Control Measures for Particulate Emission Reduction from Microfiber Operations at Johns-Manville Corporation, Waterville, Ohio, by PEDCo Environmental, Inc., PN 5060-A, July 1979, p. 2-1.
13. Op. cit. Reference 6, p. 2-38.
14. Op. cit. Reference 4, p. 2-87.

15. Op. cit. Reference 6, p. 2-294.

16. Ibid., p. 2-39.

17. Summary Report on Emissions from the Glass Manufacturing Industry. U.S. Environmental Protection Agency, Cincinnati, Ohio, EPA-600/2-79-010. April 1979. p. 20.

18. Nonmetallic Minerals Industries Control Equipment Costs, Industrial Gas Cleaning Institute for U.S. EPA under Contract No. 68-02-1473, Task No. 19. February 1977. p. 4-9.

19. Ibid, p. 4-11.

20. Ibid, p. 3-3.

21. Ibid, p. 3-6.

22. Op. cit, Reference 6.

23. Op. cit. Reference 17, p. 28.

APPENDIX FOR SECTION 2.10

Assume an average size plant = 150 tpd or 54,000 tpy glass

(1) Feed materials receiving
Emissions = (1.0 lb/ton)(54,000) = 54,000 lbs/yr

Closure

Capital cost = $28,000
Annual cost = 9,000

$$C/B = \frac{\$9{,}000/yr}{.5\ (54{,}000)} = \$0.33/lb$$

Closure, fabric filter

Capital cost = $93,000
Annual cost = 30,000

$$C/B = \frac{\$30{,}000/yr}{.9\ (54{,}000)} = \$0.62/lb$$

Choke-feeding

Capital cost = $33,000
Annual cost = 11,000

$$C/B = \frac{\$11{,}000/yr}{.7\ (54{,}000)} = \$0.29/lb$$

Wet suppression

Capital cost = $23,000
Annual cost = 7,000

$$C/B = \frac{\$7{,}000/yr}{.5\ (54{,}000)} = \$0.26/lb$$

Pneumatic unloading

Capital cost = $53,000
Annual cost = 22,000

$$C/B = \frac{\$22{,}000/yr}{.9\ (54{,}000)} = \$0.45$$

(2) Feed materials transfer to storage
Emissions = (0.5 lb/ton)(54,000) = 27,000 lbs/yr

Wet suppression

Capital cost = $23,000
Annual cost = 7,000

$$C/B = \frac{\$7{,}000/lb}{.5\ (27{,}000)} = \$0.52/lb$$

Area ventilation to fabric filter

Capital cost = \$136,000
Annual cost = 49,000

$$C/B = \frac{\$49,000/yr}{.9\ (27,000)} = \$2.02/lb$$

(3) Feed materials batch weighing
Emissions = (0.02 lb/ton)(54,000) = 1,080 lbs/hr

Fabric filter

Capital cost = \$65,000
Annual cost = 21,000

$$C/B = \frac{\$21,000/yr}{.9\ (1,080)} = \$21.60/lb$$

(4) Feed materials mixing
Emissions = (0.04 lb/ton)(54,000) = 2,160 lbs/yr

Fabric filter

Capital cost = \$65,000
Annual cost = \$21,000

$$C/B = \frac{\$21,000/yr}{.9\ (2,160)} = \$10.80/lb$$

(5) Melting and refining furnace
Emissions = (0.15 lb/ton)(54,000) = 8,100 lbs/yr

Preventive maintenance of furnace and control device

Capital cost = Negligible
Annual cost = \$25,000

$$C/B = \frac{\$25,000/yr}{.9\ (8,100)} = \$3.43/lb$$

2.11 SECONDARY ALUMINUM PROCESSING PLANTS

2.11.1 Process Description[1]

In secondary aluminum operations, aluminum scrap is melted and mixed with other metals to produce lightweight alloys for industrial castings. Copper, magnesium and silicon are the most common alloying constituents.

The raw materials for secondary aluminum plants come from three main sources:

1. Aluminum pigs. These may be primary metal or may be secondary aluminum produced by a large secondary smelter to meet more restrictive alloy specifications.

2. Foundry returns. These include rejected castings and mold components such as gates, risers, runners and sprues.

3. Miscellaneous scrap. This category includes aluminum borings and turnings; other items that may be contaminated with oil, grease, paint, rubber and plastics; and aluminum mixed with metals such as iron, magnesium, zinc and brass.

Figure 2.11-1 is a process flow diagram of secondary aluminum operations. The raw materials are sometimes pretreated to prepare them for smelting by removal of impurities such as oxides. Used castings and other foundry returns may be crushed or screened to facilitate the mechanical or magnetic removal of iron and the mechanical separation of dirt and loose aluminum oxide. Borings and turnings are heated in direct-fired rotary kilns to remove cutting oils, grease and moisture.

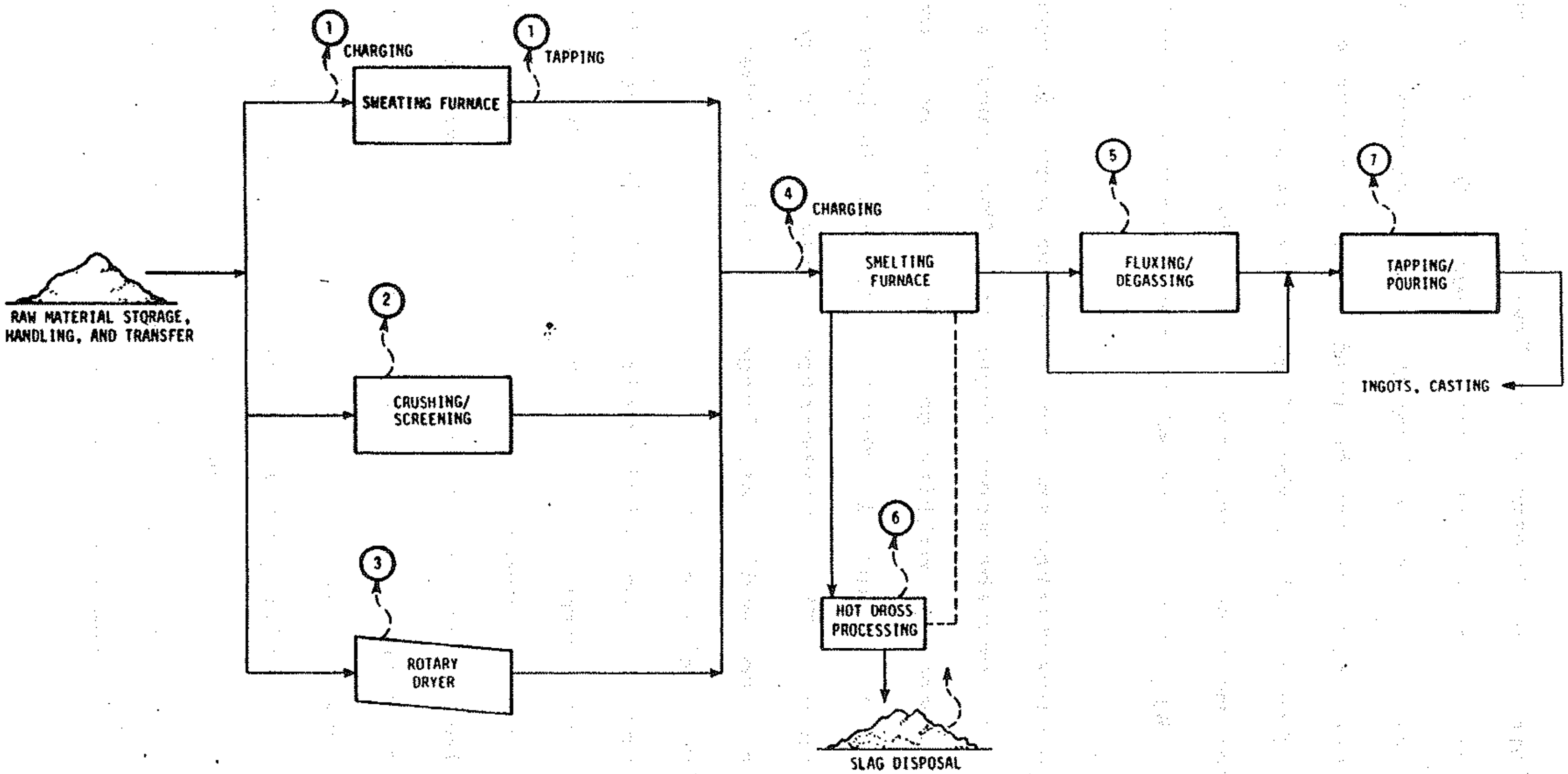

Figure 2.11-1. Simplified process flow diagram for secondary aluminum processing plants and associated fugitive particulate emission sources.

Another form of pretreatment is "sweating" to recover aluminum from scrap having a high iron content. Open-flame reverberatory furnaces with sloping hearths are in general use; although, grate-type furnaces may be used. The aluminum scrap is charged to the furnace where the aluminum melts and is collected while the higher melting iron, brass and other materials remain in solid form. Aluminum recovered by this process is referred to as "sweated" pig.

Smelting of pretreated and raw aluminum scrap is done in either crucible or reverberatory furnaces. The crucible or pot-type furnace is used for melting small quantities of aluminum (up to 1000 pounds) and is usually charged (loaded) by hand with pigs and foundry returns. The reverberatory furnace, with mechanical charging, is used for medium and large capacity batches. Both gas and oil-fired units are used.

After a batch is completely melted, alloying ingredients are added to adjust the composition of the product. The melt is then treated or "fluxed" to remove trapped gases and metals such as magnesium. Chlorine gas or other materials are used as fluxing agents. This process is carried out either in the smelting furnace, in a separate well in the furnace, or in a different unit. Often the fluxing process is referred to as degassing or demagging, depending upon its purpose. Degassing reduces dissolved gases. Demagging reduces the magnesium content of the melt. Chlorine can function as a fluxing agent to demag and also to degas molten aluminum, depending on the nature of the chlorine material and the amount added.

Chlorine and fluoride fluxing are accomplished by introducing chlorine or fluoride through the molten metal to float the magnesium to the surface where it is removed with the dross or slag. The melt can also be degassed by bubbling chlorine through the molten metal bath.

Degassing can be accomplished by other methods, such as bubbling dry nitrogen through the melt, mechanical vibration or application of a vacuum.

After these operations, the metal is poured either into ingot molds for shipping or into preheated crucibles for product manufacturing and shipping.

The dross from the smelting furnace contains enough aluminum metal to justify its recovery. The two methods for recovering the metal are wet or dry milling (mechanical) or hot dross processing (pyrometallurgical). In wet milling, the cooled dross is ground, screened and magnetically separated. In dry milling the cooled dross is ground, screened and separated by air classification. In hot dross processing, materials that solubilize impurities are added to the molten dross. The insoluble aluminum metal is tapped off the bottom and returned to the smelting furnace.

A typical plant will have four or five furnaces and produce 100,000 to 1,000,000 pounds of aluminum per day.

Fugitive emissions are generated by several sources in secondary aluminum operations as indicated in Figure 2.11-1. They include raw material receiving and handling operations, the sweating furnace, scrap metal crushing and screening, scrap metal drying, smelting operations, hot dross handling and cooling, fluxing/degassing, hot metal pouring and slag disposal.

2.11.2 Fugitive Dust Emission Factors

The estimated emission factors for secondary aluminum processing plants are summarized in Table 2.11-1. According to the literature sources, these emission factors are all based on assumptions regarding the percentage of total process emissions that escape as fugitive particulates. No details were given regarding these assumptions. Therefore, the reliability of these estimates should be considered as very poor.

2.11.3 Particle Characterization

Particulates from the secondary aluminum smelting furnace are less than 2 μm in size. The particulates may have toxic properties because of fluoride and chloride content. Table 2.11-2 shows the effluent characteristics from secondary aluminum production.

TABLE 2.11-2. EFFLUENT CHARACTERISTICS FROM SECONDARY ALUMINUM PRODUCTION[4]

Source	Maximum particle size, μm	Chemical composition	Toxicity
Fluxing/degassing	2.0	Highly variable, may contain Al_2O_3, $AlCl_3$, NaCl, fluorides, oxides of alkali metals	Toxic due to fluorides and chlorides
Chlorination	1.0		

TABLE 2.11-1. FUGITIVE DUST EMISSION FACTORS FOR SECONDARY ALUMINUM PROCESSING PLANTS

	Source	Emission factor	Reliability Rating	Reference
(1)	Sweating furnace charging and tapping	0.72 lb/ton metal processed	E	2
(2)	Crushing and screening scrap metal	Negligible	E	2
(3)	Rotary chip dryer	0.72 lb/ton metal dried	E	2
(4)	Smelting furnaces, charging and tapping			
	4a. Reverberatory	0.22 lb/ton metal processed	E	2
	4b. Crucible	0.09 lb/ton metal processed	E	2
	4c. Induction	0.09 lb/ton metal processed	E	2
(5)	Fluxing (chlorination)	50 lb/ton chlorine used	E	2
(6)	Hot dross handling and cooling	0.22 lb/ton metal processed	E	2
(7)	Pouring hot metal into molds or crucible	Negligible	E	3
(8)	Slag disposal	Unknown	-	-

One study found that the major constituent in the fumes from salt-cryolite fluxing in a furnace was sodium chloride with considerable, but smaller, quantities of aluminum and magnesium compounds. The particles were all under 2 μm. The fumes were somewhat corrosive when dry, and when wet, formed a highly corrosive sludge that tended to set up and harden.[5]

Another study of fumes from degassing revealed that 100 percent of the fumes were smaller than 2 μm, and 90 to 95 percent were smaller than 1 μm. Microscopic examination indicated the mean particle size to be about 0.7 μm.[5]

Particle size data from an aluminum sweating furnace with a capacity of 760 lb/hr indicate that 95 percent of the particles are less than 39 μm.[6]

2.11.4 Control Methods[7]

Raw materials in the form of sheet castings, clippings and borings are normally received and stored inside a building. Therefore, the fugitive dust, if any, is confined; and no control is necessary.

In the dry milling process, dust generated at the crusher, the shaker screens and at the points of transfer can be controlled by hooding these operations and providing ductwork connections to a fabric filter.[2]

Emissions from the rotary dryer are usually vented to a scrubber system. Fugitive emissions could result from process leaks and may be controlled by improved maintenance and/or increased exhaust rate to the primary control device.

Emissions from sweating and smelting furnaces may be controlled by canopy hood capture and exhaust to the primary control device or a fabric filter or wet scrubber. Another system that may be used is building enclosure and evacuation to a control device. A total building evacuation system controls emissions from all operations within the building.

The emissions from fluxing operations can be captured by installing a hood above the fluxing operation and exhausting the hood to a baghouse or wet scrubber.[3,4]

Hot dross handling and cooling emissions can also be controlled by hood capture and venting to a fabric filter.[3] Slag disposal operations can be controlled by wet suppression.

Table 2.11-3 summarizes the available control techniques, their effectiveness, estimated costs and RACM selections.

2.11.5 Recommended Reasonably Available Control Measures (RACM)

The RACM selections for secondary aluminum processing plant fugitive emissions are presented in Table 2.11-3.

The RACM selection for the sweating and smelting furnaces is an extension or modification of the existing hoods to provide capture of charging and tapping emissions together with ductwork connections to the existing primary control device. Most furnaces are already controlled, and these measures would provide good control of the fugitive emissions at a relatively low cost. As an alternative, building enclosure with ventilation to a fabric filter is also selected as RACM.

TABLE 2.11-3. A SUMMARY OF THE CONTROL ALTERNATIVES, EFFICIENCIES AND COSTS, AND THE RACM SELECTIONS FOR FUGITIVE DUST EMISSIONS FROM SOURCES AT SECONDARY ALUMINUM PROCESSING PLANTS

Fugitive dust sources	Control alternatives	Control efficiency, %	Control costs, Jan. 1980 $		Cost benefit, $/lb	RACM selection
			Capital	Annualized		
(1) Sweating furnace charging and tapping	Hooding, vent to primary control device	95[a]	20,000[b]	5,000[c]	0.07	Hooding, vent to primary control device or new control device
	Building enclosure, vent to fabric filter	99[a]	600,000[d]	162,000[e]	0.87	
(2) Crushing and screening scrap metal	Hooding, vent to fabric filter	95[a]	63,000[d]	17,000[e]	NA	Hooding, vent to fabric filter
	Building enclosure, vent to fabric filter	99[a]	f	f	0.87	
(3) Rotary dryer	Hooding, vent to scrubber	95[a]	63,000[g]	30,000[g]	0.44	Afterburner
	Afterburner	90[a]	35,000[h]	21,000[h]	0.32	
(4) Smelting furnaces, charging and tapping						
4a Reverberatory furnace charging and tapping	Hooding, vent to primary control device	95[a]	20,000[b]	5,000[c]	0.24	Hooding, vent to primary control device or building enclosure, vent to fabric filter
	Building enclosure, vent to fabric filter	99[a]	f	f	0.87	
	Hooding, vent to scrubber or fabric filter	90[j]	336,000[j]	82,000[g]	4.13	
4b Crucible furnace charging and tapping	Hooding, vent to primary control device	95[a]	20,000[b]	5,000[c]	0.58	Hooding, vent to primary control device or building enclosure, vent to fabric filter
	Building enclosure, vent to fabric filter	99[a]	f	f	0.87	
	Hooding, vent to scrubber or fabric filter	90[j]	336,000[j]	82,000[g]	10.09	
4c Induction furnace charging and tapping	Hooding, vent to primary control device	95[a]	20,000[b]	5,000[c]	0.58	Hooding, vent to primary control device or building enclosure, vent to fabric filter
	Building enclosure, vent to fabric filter	99[a]	f	f	0.87	
	Hooding, vent to scrubber or fabric filter	90[j]	336,000[j]	82,000[g]	10.09	

(continued)

TABLE 2.11-3 (continued)

Fugitive dust sources	Control alternatives	Control efficiency, %	Control costs, Jan. 1980 $		Cost benefit, $/lb	RACM selection
			Capital	Annualized		
(5) Fluxing	Hooding, vent to scrubber or fabric filter	99[a]	175,000[g]	62,000[g]	1.37	Use of low emission fluxes or hoods, vent to scrubber or fabric filter
	Use of low emission fluxes	Unknown	i	i	NA	
(6) Hot dross handling and cooling	Hooding, vent to scrubber or fabric filter	95[a]	60,000[g]	27,000[g]	1.29	No control
	Building enclosure, vent to fabric filter	99[a]	f	f	0.87	
(7) Pouring hot metal into molds or crucible	Negligible source					No control
(8) Slag disposal	Wet suppression	Unknown	i	i	NA	No control

[a] Engineering estimate.
[b] Estimated costs of additional hooding and modifications.
[c] Estimated capital and maintenance charges at 20% of installed capital.
[d] Reference 8. Includes control of the sweating furnace, crushing and screening, scrap metal, furnace charging and tapping emissions, fluxing emissions, and hot dross handling and cooling emissions.
[e] Reference 9.
[f] Costs of this control technique are presented under the sweating furnace control costs.
[g] Reference 10.
[h] Reference 11.
[i] No cost data available.
[j] Reference 12. Based on control cost for comparable steel foundry furnace charging and tapping.

The control recommended for the crushing and screening of scrap metal is hooding and control of the captured emissions by a fabric filter. This has been demonstrated as being effective on existing operations.

An afterburner is the RACM selection for the rotary dryer. It is commonly used to thermally destroy both the condensible and hydrocarbon emissions in the dryer exhaust.

Fluxing emissions will usually be controlled along with the furnace emissions by the primary control device. However, where the fluxing station is separate from the furnace, the recommended RACM is adequate hooding with control by a wet scrubber or fabric filter. Use of fluxes that do not result in significant emissions is an alternate, acceptable control option.

No control is recommended for the hot dross processing or the hot metal pouring operations. These are very minor emission sources and are not normally controlled in the industry. Also, slag handling operations are minor and no control is recommended.

REFERENCES FOR SECTION 2.11

1. Technical Guidance for Control of Industrial Process Fugitive Particulate Emissions. PEDCo Environmental, Inc., Cincinnati, Ohio: prepared for EPA, Research Triangle Park, North Carolina, March 1977. pp. 2-164, 2-165.

2. Ibid. pp. 2-167, 2-168.

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4. Particle Pollutant Systems Study. Vol. III. Handbook of Emissions Properties. Midwest Research Institute. Prepared for U.S. Environmental Protection Agency. Contract No. CPA 22-69-104. Durham, North Carolina. May 1971.

5. Op. cit. Reference 2. p. 289.

6. Multimedia Environmental Assessment of the Secondary Nonferrous Metal Industry. Vol. II. Final Draft. Radian Corporation. Austin. June 1976.

7. Op. cit. Reference 1. p. 2-270 through 2-172.

8. GARD, Inc. Capital and Operating Costs of Selected Air Pollution Control Systems. EPA-450/3-76-014, May 1976, pp. 4-24 to 4-28, 4-34 to 4-36, 4-89.

9. Ibid p. 4-89.

10. Industrial Gas Cleaning Institute. Air Pollution Control Technology and Cost in Seven Selected Areas. Prepared for the U.S. Environmental Protection Agency, Research Triangle Park, North Carolina. EPA 450/3-73-010. December 1973. pp. 586-599.

11. Op. cit. Reference 8. pp. 4-17, 4-89, 4-90.

12. PEDCo Environmental, Inc. Source Evaluation in Region IV Non-Attainment Areas to Determine TSP Emission Reduction Capabilities. Prepared for U.S. Environmental Protection Agency. Contract No. 68-02-2603, Task No. 2. Research Triangle Park, North Carolina. June 1978. p. 2-7.

APPENDIX FOR SECTION 2.11

Assume 550,000 lbs of metal processed per day, 365 dpy

(1) Sweating furnace charging and tapping

Emissions = (0.72 lb/ton)(550,000)(.005)(365)

= 72,270 lbs/yr

Hooding, vent to primary control device

Capital cost = $20,000
Annual cost = $6,000

$$C/B = \frac{\$5,000/yr}{.95\ (72,270)} = \$0.07/lb$$

Building enclosure, vent to fabric filter

Capital cost = $600,000
Annual cost = $162,000

$$C/B = \frac{\$162,000/yr}{.99\ (72,270 + 72,270 + 22,082 + 22,082)}$$

$$= \$0.87/lb$$

(2) Crushing and screening scrap metal

Emissions = Negligible

Hooding, vent to fabric filter

Capital cost = $63,000
Annual cost = $17,000
C/B = NA

Building enclosure, vent to fabric filter

See (1)
C/B = $0.87/lb

(3) Rotary dryer

Emissions = (0.72 lb/ton)(550,000)(365)(.0005) = 72,270 lbs/yr

Hooding, vent to scrubber

Capital cost = $63,000
Annual cost = $30,000

$$C/B = \frac{\$30,000/yr}{.95\ (72,270)} = \$0.44/lb$$

Afterburner

Capital cost = \$35,000
Annual cost = \$21,000

$$C/B = \frac{\$21,000/yr}{.9\ (72,270)} = \$0.32/lb$$

(4) Smelting furnaces, charging and tapping

Reverberatory furnace charging and tapping
Emissions = (0.22 lb/ton)(550,000)(365)(.0005) = 22,082 lbs/yr

Hooding, vent to primary control device

See (1)

$$C/B = \frac{\$5,000/yr}{.95\ (22,082)} = \$0.24/lb$$

Building enclosure, vent to fabric filter

See (1)
C/B = \$0.87/lb

Hooding, vent to scrubber or fabric filter

Capital cost = \$336,000
Annual cost = \$82,000

$$C/B = \frac{\$82,000/yr}{.9\ (22,082)} = \$4.13/lb$$

Crucible furnace charging and tapping
Emissions = (0.09 lb/ton)(550,000)(365)(.0005) = 9,034 lbs/yr

Hooding, vent to primary control device

See (1)

$$C/B = \frac{\$5,000/yr}{.95\ (9,034)} = \$0.58/lb$$

Building enclosure, vent to fabric filter

See (1)
C/B = \$0.87/lb

Hooding, vent to scrubber or fabric filter

Capital cost = \$336,000
Annual cost = \$82,000

$$C/B = \frac{\$82,000/yr}{.9\ (9,034)} = \$10.09/lb$$

Induction furnace charging and tapping

Emissions = (0.09)(550,000)(365)(.0005) = 9,034 lbs/yr

Hooding, vent to primary control device

See (1)

$$C/B = \frac{\$5,000/yr}{.95\ (9,034)} = \$0.58/lb$$

Building enclosure, vent to fabric filter

See (1)

C/B = $0.87/lb

Hooding, vent to scrubber or fabric filter

Capital cost = $336,000
Annual cost = $82,000

$$C/B = \frac{\$82,000/yr}{.9\ (9,034)} = \$10.09/lb$$

(5) Fluxing

Assume 5,000 lbs/day chlorine
Emissions = (50 lbs/ton)(5,000)(365)(.0005) = 45,625 lbs/yr

Hoods, vent to scrubber or fabric filter

Capital cost = $175,000
Annual cost = $62,000

$$C/B = \frac{\$62,000/yr}{.99\ (45,625)} = \$1.37/lb$$

Use of low emission fluxes

No data

(6) Hot dross handling and cooling

Emissions = (0.22 lb/ton)(550,000)(365)(.0005) = 22,082 lbs/yr

Hooding, vent to scrubber or fabric filter

Capital cost = $60,000
Annual cost = $27,000

$$C/B = \frac{\$27,000/yr}{.95\ (22,082)} = \$1.29/lb$$

Building enclosure, vent to fabric filter

See (1)

C/B = $0.87/lb

(7) Pouring hot metal into molds or crucible

Emissions = Negligible
No control

(8) Slag disposal

Emissions = Unknown

<u>Wet suppression</u>
No data