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PROCEDURES FOR IDENTIFYING REASONABLY AVAILABLE CONTROL TECHNOLOGY FOR STATIONARY SOURCES OF PM-10

U.S. Environmental Protection Agency
Office of Air and Radiation
Office of Air Quality Planning and Standards
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ABSTRACT

This guidance document sets forth procedures and identifies sources of information that will assist state and local air pollution control agencies in determining RACT for PM-10 emissions from existing stationary sources on a case-by-case basis. It provides an annotated bibliography of documents to aid in identifying the activities that cause PM-10 emissions as well as applicable air pollution control measures and their effectiveness in reducing emissions for the industries and processes listed on Table 1-1. The most stringent state total particulate matter (PM) emission limits are identified for the stationary sources shown on Table 1-1 and compared to available emission test data. Finally, guidance is provided on procedures for estimating total capital investment and total annual cost of the control measures which are generally used to control PM-10 emissions.

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LIST OF ABBREVIATIONS AND SYMBOLS

ABBREVIATIONS

acfm	actual cubic feet per minute
AL	Alabama
AK	Alaska
AR	Arkansas
AOD	argon oxygen decarburization
AP-42	EPA publication entitled Compilation of Air Pollutant Emission Factors, Volume I
AZ	Arizona
BACT	Best Available Control Technology
BNA	Bureau of National Affairs
BOPF	Basic Oxygen Process Furnace
BOF	basic oxygen furnace
Btu/hr	British thermal unit per hour
CA	California
CRC	Capital Recovery Cost
CRF	Capital Recovery Factor
CO	Colorado
CT	Connecticut
days/yr	days per year
DE	Delaware
DC	District of Columbia
DC	Direct Cost
EAF	Electric arc furnaces
EPA	United States Environmental Protection Agency
ESP	Electrostatic precipitator
°F	degrees Fahrenheit
FCCU	fluidized catalytic cracking unit
FL	Florida
g/day	grams per day
g/hr	grams per hour
g/kg	grams per kilogram
g/m^3	grams per cubic meter
g/MJ	grams per megajoule
gr/acf	grams per actual cubic feet
gr/dscf	grains per dry standard cubic feet
gr lead/ dscf	grains of lead per dry standard cubic feet
gr/scf	grains per standard cubic feet
GA	Georgia
GJ/hr	Gigajoule per hour
hr/day	hours per day
hr/year	hours per year
HI	Hawaii
IA	Iowa
IC	Indirect annual cost
ID	Idaho

IL	Illinois
IN	Indiana
J/hr	Joules per hour
kg/hr	kilograms per hour
kg/kg	kilogram per kilogram
kg/1000m^2	kilograms per thousand meters squared
kg/Mg	kilograms per megagrams
kPa	kilopascals
kWh	kilowatt-hour
K	degrees Kelvin
KS	Kansas
KY	Kentucky
LA	Louisiana
LAER	Lowest achievable emission rate
lb/barrel	pounds per barrel
lb/1000ft^2	pounds per thousand feet squared
lb/hr	pounds per hour
lb/lb	pound per pound
lb/MMBtu	pounds per million Btu
lb/ton	pounds per ton
m^3	cubic meters
m^3/min	cubic meters per minute
m^3/hr	cubic meters per hour
MA	Massachusetts
MD	Maryland
ME	Maine
mg/scm	milligrams per standard cubic meter
mg/dscm	milligrams per dry standard cubic meter
MI	Michigan
min/hr	minutes per hour
mm H_2O	millimeters of water
Mg	megagrams
Mg/day	megagrams per day
Mg/hr	megagrams per hour
Mg/yr	megagrams per year
mg lead/ kg lead feed	milligrams of lead per kilograms of lead feed
mg lead/ scm	milagrams of lead per standard cubic meter
MN	Minnesota
MMBtu	Million British thermal units
MMBtu/hr	Million British thermal units per hour
MO	Missouri
MS	Mississippi
MT	Montana
ng/J	nanograms per Joule
NC	North Carolina
ND	North Dakota
NE	Nebraska
NH	New Hampshire

NJ	New Jersey
NM	New Mexico
NSPS	New Source Performance Standards
NTIS	National Technical Information Service
NV	Nevada
NY	New York
OAQPS	Office of Air Quality Planning and Standards (EPA)
OH	Ohio
OK	Oklahoma
PA	Pennsylvania
PM	Particulate matter
PM-10	Particulate matter that is less than or equal to 10 μm
RACT	Reasonably Available Control Technology
RACM	Reasonably Available Control Measures
RI	Rhode Island
SIPs	State Implementation Plans
SC	South Carolina
SD	South Dakota
ton/day	tons per day
ton/hr	tons per hour
ton/yr	tons per year
TN	Tennessee
TX	Texas
UK	United Kingdom
UT	Utah
VE	visible emissions
VT	Vermont
VA	Virginia
WA	Washington
WI	Wisconsin
WV	West Virginia
WY	Wyoming

Symbols

%	percent
μm	micrometers
$	dollars
$/hr	dollars per hour
$/kWh	dollars per kilowatt hour
$/Mg	dollars per Megagram
$/MWh	dollars per megawatt hour
$/ton	dollars per ton
H_2O	water
SO_2	sulfur dioxide

SECTION 1

INTRODUCTION

The U.S. Environmental Protection Agency (EPA) is issuing this document to assist states in identifying reasonably available control technology (RACT) for existing stationary sources of particulate matter having a nominal aerometric diameter of 10 microns or less (PM-10). The EPA has historically defined RACT as the lowest emission limitation that a particular source is capable of meeting by the application of control technology that is reasonably available considering technological and economic feasibility.[1]

Section 172(c)(1) of the Clean Air Act (Act) as amended November 15, 1990, requires that State implementation plans (SIPs) for nonattainment areas provide for the implementation of reasonably available control measures (RACM) including emission reductions obtained through the adoption of RACT. Section 189(2)(1)(C) of the Act requires that SIP's for moderate PM-10 nonattainment areas assure that RACM (including RACT) for PM-10 shall be implemented no later than four years after the area is designated nonattainment.

This guidance document sets forth procedures and identifies sources of information that will assist state and local air pollution control agencies in determining RACT for PM-10 emissions from existing stationary sources on a case-by-case basis. It provides an annotated bibliography of documents to aid in identifying the activities that cause PM-10 emissions as well as applicable air pollution control measures and their effectiveness in reducing emissions for the industries and processes listed on Table 1-1. The most stringent state total particulate matter (PM) emission limits are identified for the stationary sources shown on Table 1-1 and compared to available emission test data. Finally guidance is provided on procedures for estimating total capital investment and total annual cost of the control measures which are generally used to control PM-10 emissions.

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[1]See, for example, 44 FR 53762 (September 17, 1979) and footnote 3 of that notice.

TABLE 1-1. SOURCE CATEGORIES COVERED IN THIS DOCUMENT

Source category	Specific processes
Asphalt and asphaltic concrete plants	
Boilers	Utility - greater than 105 GJ/hr (100 MM Btu/hr) Industrial/commercial - greater than 0.5 GJ/hr (0.5 MMBtu/hr) and less than 105 GJ/hr (100 MM Btu/hr) Coal-fired Oil-fired Wood-fired
Brick manufacturing plants	Kiln
Calciners	
Charcoal plants	
Chemical manufacturing plants	Reactors Blenders Mixers
Coal preparation and cleaning plants	
Concrete batch plants	
Cotton seed milling plants	
Foundries	Aluminum Iron Secondary steel (shredders)
Glass manufacturing plants	
Grain milling operations	
Gypsum product manufacturing and processing plants	
Incinerators	Medical waste Agricultural waste Municipal waste

(Continued)

TABLE 1-1. (Continued)

Source category	Specific processes
Iron and steel facilities	Argon oxygen decarburization Electric arc furnaces Sinter plants Coke batteries Slag handling Blast furnaces Basic oxygen furnaces Scarfing Metal reladling
Lime plants	
Lumber mills	Planing Shaving Waste wood combustion
Marine grain terminals	Shipping - loadout Receiving - unloading Other grain handling
Metallic Minerals Processing Plants	Ore concentrators
Nonmetallic mineral processing plants	Conveyors Screens Quarrying Rock crushers Other materials handling
Paint manufacturing plants	
Petroleum refineries	Catalytic cracking units Boilers Heaters
Phosphate fertilizer plants	
Phosphate rock processing plants	
Plywood, particleboard and waferboard plants (including veneer dryers)	
Portland cement plants	
Primary aluminum reduction facilities	Vertical stud Soderberg Horizontal stud Soderberg Prebaked

(Continued)

TABLE 1-1. (Continued)

Source category	Specific processes
Pulp mills	Kraft Sulfite
Secondary aluminum reduction facilities	
Sugar production plants	Sugar beets
Surface mining operations	
Turbines (oil-fired)	

This document is organized as follows:

Section 2 - RACT Determination: Describes procedures for establishing an emission limit that would require the application of RACT.

Section 3 - Process Emissions and Emissions Control Bibliography: Provides an annotated bibliography of information sources that describe the processes listed on Table 1-1 and the magnitude of uncontrolled and controlled emissions and emission control measures from these processes.

Section 4 - Achievable Emission Limits: Identifies the most stringent state PM emission limits for the processes listed on Table 1-1 and presents available mass emissions test data.

Section 5 - Costs of Control: Describes procedures for estimating total capital investment and total annual cost of control measures.

A list of abbreviations and symbols used in this document is provided in the front of this document.

SECTION 2

DETERMINING REASONABLY AVAILABLE CONTROL TECHNOLOGY

INTRODUCTION

The EPA has defined reasonably available control technology (RACT) as:

> The lowest emission limitation that a particular source is capable of meeting by the application of control technology that is reasonably available considering technological and economic feasibility.

RACT is not limited to off-the-shelf control alternatives; it has a technology-forcing aspect to it, and it may vary among different facilities in the same source category depending on the feasibility of implementing particular control strategies at each location.

There are two key criteria that must be satisfied in the determination of RACT: (1) technological feasibility and 2) economic feasibility. This section describes guidelines for evaluating the technological and economic feasibility of control options and making a RACT determination. A case study is also presented.

DETERMINING TECHNOLOGICAL FEASIBILITY

The determination of technological feasibility should concentrate on factors specific to the source in question and should not be an evaluation of the feasibility of control measures for the entire source category. The evaluation should be restricted to the particular processes to be controlled by a single technology application.

For determining technological feasibility, the following steps are recommended:

Step 1. Determine the uncontrolled PM-10 and total particulate matter (PM) emission rates for the source and the nature of those emissions (solid or condensible).

Step 2. Identify a range of available PM-10 emission reduction and control options including process changes, facility redesign, and/or add-on air pollution control devices.

Step 3. Review performance data for the available control options.

Step 4. Identify the lowest PM-10 and/or total PM emission limitations achievable with the available control options and rank the options by performance.

Step 5. Identify the current lowest PM emission limitation that is placed on the source category by Federal, State, or local regulation; the regulation imposing that limit; and the method of determining compliance.

Each step will be discussed further in the subsections that follow.

Step 1. -- Determine Uncontrolled Emission Rates

The baseline emission rates should be determined for PM-10 and total PM from the source before process or operating changes are made or equipment is added to reduce emissions. Baseline emission rates can be determined using source test data, information from reports on the source category, such as those cited in Section 3, and/or emission factors derived from EPA's Compilation of Air Pollution Emission Factors (Office of Air Quality, Planning and Standards (OAQPS), 1985). Baseline emission rates should be calculated for the source operating at its maximum design capacity.

Step 2. -- Identify Available Control Options

In determining the technological feasibility of applying an emission reduction method to a particular source, consider the sources' process and operating procedures, raw materials, the physical plant layout, and any other environmental impacts that will result from controlling PM-10 emissions (i.e., water pollution, waste disposal, and energy requirements). Process changes or changes in raw materials should be investigated for their feasibility for reducing or eliminating emissions or simplifying the selection of an add-on control. Modifying processes or applying control equipment is also influenced by the physical layout of the particular plant. The space available in which to implement such changes may limit the choices and will also affect the costs of control.

Reducing air emissions may adversely affect other resources by increasing pollution of bodies of water, creating additional solid waste disposal problems, or substantially increasing energy demands. A PM-10 control technology may not be feasible if the resulting environmental impacts cannot be mitigated. In many instances, however, PM-10 control technologies have known energy penalties and adverse effects on other media, but such effects and the cost of their mitigation are also known and have been borne by owners of existing sources. Such well-established adverse effects and their costs are normal and assumed to be reasonable and should not, in most cases, justify not using the PM-10 control technology.

In selecting a control device, the size and nature of the particles to be collected must be considered. If the particles are sticky or large and abrasive, a fabric filter may not be suitable. If the emissions contain a significant fraction of particles less than 1 micron in diameter, a device capable of collecting fine particles must be chosen.

Alternative approaches to reducing emissions of particulate matter, including PM-10, are discussed in Control Techniques for Particulate Emissions From Stationary Sources Volumes I and II (EPA, 1982a; EPA, 1982b). The design, operation, and maintenance of general particulate matter control systems, such as mechanical collectors, electrostatic precipitators, fabric filters, and wet scrubbers, are discussed in Volume I. The collection efficiency of each system is discussed as a function of particle size. Information is also presented regarding energy and environmental considerations, and procedures for estimating costs of particulate matter control equipment. Volume II discusses the emission characteristics and control technologies applicable to specific source categories. Secondary environmental impacts are also discussed.

Additional sources of information on control technology are background information documents for new source performance standards, many of which are identified in section 2 of this document, and Identification, Assessment, and Control of Fugitive Particulate Emissions (EPA, 1986). The EPA's Control Technology Center (919/541-0800) and the RACT/BACT/LAER Clearinghouse are other possible sources of information. Information on the RACT/BACT/LAER Clearinghouse can be obtained from the following:

RACT/BACT/LAER Clearinghouse (MD-13)
U.S. Environmental Protection Agency
Emission Standards Division
Research Triangle Park, North Carolina 27711
Phone: (919) 541-2736

Step 3. -- Review Performance Data

Where available, performance data for emission control devices applied to the source categories listed in Table 1-1 is given in section 4. Section 3 provides an annotated bibliography of information sources that describe the processes listed in Table 1-1 and the magnitude of uncontrolled and controlled emissions and emission control measures. As mentioned above, Volume I of Control Techniques for Particulate Emissions From Stationary Sources (EPA, 1982a) contains information on collection efficiency as a function of particle size for control devices. Compilation of Air Pollutant Emission Factors (OAQPS, 1985) provides similar kinds of information.

Manufacturer's brochures are also a source of performance data and, for the numerous proprietary-design control devices, they may be the only source. General literature references such as section 20 in the Chemical Engineers Handbook (Perry, 1984) are an additional source of performance data.

Step 4. -- Identify the Lowest Emission Limitation Achievable

The available control options should be listed in a table designed for easy comparison of the attributes of each option. The lowest PM-10 and total PM emission rates achievable by each option should be listed in consistent units [such as milligrams per dry standard cubic meter (mg/dscm), kilograms per hour (kg/hr), kilograms per megagram of product (kg/Mg) or megagrams per year (Mg/yr).] The control effectiveness or percent reduction of emissions from the baseline levels determined in Step 1 should also be listed in the table for each control option.

The control effectiveness of add-on PM control devices varies with the size distribution of particles in the exhaust gases. Particle size distributions for many processes are included in the individual industry sections or Appendix C.1 of EPA's Compilation of Air Pollut Emission Factions (OAQPS, 1985). When the particle size distribution for a particular process is not available, Appendix C.2 (of OAQPS, 1985) includes guidelines and a worksheet for calculating the particle size distribution and size specific emissions from a control device (i.e., an achievable PM-10 emission rate).

Step 5. -- Identify the Current Lowest Emission Limitation

Emission limitations that currently apply to nearly every source category that emits PM are embodied in Federal and State air pollution control regulations. Several States have also delegated authority to local agencies for implementation of air pollution control programs. Furthermore, there may be consent agreements or permit conditions that place specific emission

standards on individual sources. Section 4 presents a discussion of the most stringent State standards and, when applicable, the Federal new source performance standards (NSPS) for selected source categories (see Table 1-1). Section 4 should be used as a starting point in determining the lowest emission limitation currently applicable to sources similar to the one for which RACT is being determined. The individual State and Federal regulations should be reviewed to determine their applicability or appropriateness to the type of source in question and the method of determining compliance.

Since most PM emission limits pertain to total PM as measured by a stack sampling method or visible emission observation method, it will also be necessary to estimate an equivalent PM-10 emission limit. An equivalent PM-10 emission limit can be established by determining the fraction of total PM that is PM-10 and applying the fraction, with a "safety factor" to allow for the variations in emissions, to the total PM emission limit. This procedure incorporates key information that was determined above in Steps 1 through 4, such as uncontrolled emission rates and achievable emission rates. A suggested procedure to calculate an equivalent PM-10 limit is outlined below. An example of the application of the procedure is included with the case study.

a. Determine the percent control that is required to meet the total PM allowable emission limit.

b. Select the most inefficient control technology that could achieve this emission reduction.

c. Determine the total PM emission rate that can be actually achieved by this control technology.

d. Calculate a "safety factor" to account for the difference between the total PM emission limit and the controlled total PM emissions. (Divide the total PM allowable emission limit by the actual achievable total PM emissions).

e. Determine the particle size distribution of the uncontrolled exhaust stream.

f. Determine the PM-10 emission rate that should be achieved by the control technology identified in Step b above.

g. Multiply the achievable PM-10 emission rate by the "safety factor" calculated from Step d. The product is a PM-10 emission limit that would require the same level of control.

DETERMINE ECONOMIC FEASIBILITY

Economic feasibility considers the cost of reducing emissions and the difference in costs between the particular source for which RACT is being determined and other similar sources that have implemented emission reductions. The EPA presumes that it is reasonable for similar sources to bear similar costs for emissions reduction. Economic feasibility rests very little on assertions of the ability of a particular source to "afford" to reduce emissions to the level of similar sources.

The following steps are recommended for evaluating the economic feasibility of the available control options.

Step 1. -- Develop Capital and Annual Costs

The capital costs and annualized costs of an emission reduction technology should be considered in determining its economic feasibility. Procedures for estimating total capital investment and total annual cost of control measures are described in section 5. These procedures are developed in greater detail in the OAQPS Control Cost Manual (OAQPS, 1990). Unless there are reasons not to, these estimating procedures should be followed to assure that all cost estimates are on the same basis and, therefore, can be compared.

The following should be considered when developing the capital and annual costs of a control option:

a. Costs should be determined for technologically efficient control systems. Only auxiliary systems and redundancies necessary to consistently achieve the desired collection efficiency should be included in the costs.

b. The evaluation should specify the control system "battery limits," i.e., the specific area or process segment to be controlled. Inadequate documentation of battery limits is a common reason for confusion in comparisons of costs of the same controls applied to similar sources.

c. Credits and debits associated with the control equipment should be valued consistently and accurately. Credits consist primarily of the value of recovered products. Debits include such items as fuel, labor, equipment, and interest on borrowed capital.

d. The evaluation should include a range of costs for each control option (reflecting the lowest and highest

likely cost); the assumptions behind each estimate should be explained.

Step 2. -- Compare Cost Impacts

The primary consideration of the economic impact analysis should be given to comparing the capital and annual costs and the relative cost effectiveness of implementing (e.g., purchasing, installing and operating) the available and technologically feasible control options. The costs of implementing the control options should also be compared with the costs incurred by similar sources that have implemented similarly effective controls measures. The capital and annual costs of each control option should be added to the table created during the analysis of technological feasibility to compare option attributes.

The relative cost effectiveness is another parameter that can be used in comparing control options. Cost effectiveness is calculated as the annual cost of the proposed control option divided by the baseline (i.e., uncontrolled) emissions minus the emission rate of the proposed control, as shown by the following formula:

$$\frac{\text{Control option annual cost}}{(\text{Baseline emissions rate} - \text{Control option emissions rate})}$$

Costs are calculated in dollars per year; emissions rates are calculated in megagrams (tons) per year. The result is a cost-effectiveness number in dollars per megagram (ton) of PM-10 removed. Baseline emissions are essentially uncontrolled emissions calculated using realistic upper boundary operating assumptions.

The cost-effectiveness ratio can be used to compare alternative controls for the same source, and to compare the costs of controlling sources of varying magnitude. However, EPA does not favor making any presumption that control options with cost effectiveness above or below some arbitrary level are reasonable or unreasonable.

Step 3. -- Affordability

The affordability of implementing a control option should generally not be considered in the economic impact analysis because affordability is highly subjective and depends upon the economic viability of a particular source. Consequently, control options should not be eliminated solely on the basis of economic parameters that indicate they are not affordable by the source.

If a company contends that it cannot afford RACT and/or may have to shut-down its operation if RACT controls are imposed, the economic impact analysis will then consist of weighing the

benefits (and costs) of the facility remaining open against those of closing. The following items should be considered in the analysis:

a. The extent to which the company will have to absorb the costs of control. (This should be demonstrated with data such as empirical data on supply and demand elasticities, as well as per-unit cost impacts, expected costs to be incurred by competitors, and available industry production capacity.)

b. The company should present data regarding its fixed and variable costs in producing the product affected.

c. If projected revenues exceed the sum of expected variable costs and annual costs of each available control option, closure would not be sufficient justification for concluding that control is economically infeasible.

d. Plant closure costs, including severance pay, relocation costs, demolition costs, and others.

IDENTIFYING RACT

The information gathered in determining the technological and economic feasibility of implementing alternative control options at the source in question can be delineated in a table similar to the example shown as Table 2-1. As a result of comparing the cost, energy and environmental impacts of the control options that achieve the lowest PM-10 emission rates, a reasonably available control technology will be revealed in most cases.

CASE STUDY

The following example is provided for illustration only. The example source is fictitious and has been created to highlight many of the aspects of RACT determination. The cost data and other numbers presented in the example are used only to illustrate the RACT decision making process. Cost data are used in a relative sense to compare costs among control devices. No absolute cost guidelines have been established above which costs are assumed to be too high or below which they are assumed to be reasonable. Determination of appropriate costs is made on a case-by-case basis.

The example source in this section is controlling PM-10 emissions from a boiler using pulverized coal. The purpose of the example is to illustrate points to be considered in developing RACT decision criteria for the source under review.

TABLE 2-1. EXAMPLE SUMMARY TABLE FOR RACT DETERMINATIONS

Parameter/ technology	Fabric filter	ESP	Venturi scrubber	Process change
Uncontrolled emissions, kg/Mg[a]				
a. Total PM				
b. PM-10				
Controlled emissions				
a. Total PM				
b. PM-10				
Control effectiveness, %				
a. Total PM				
b. PM-10				
Current allowable emissions				
a. Total PM, kg/Mg				
b. Opacity, %				
Equivalent PM-10 limit, kg/Mg				
Capital costs, $				
Annual costs, $/yr				
Cost effectiveness, $/Mg				
Energy requirement, kWh/yr				
Wastewater impact				
Solid waste impact				
Other impacts				

[a]Uncontrolled and controlled total PM and PM-10 emission rates and the current allowable rates should be expressed in the same units.

The example is intended to illustrate the process rather than provide universal guidance on what constitutes RACT for this particular source category. RACT must be determined on a case-by-case basis.

Source Description

A control device is required to collect flyash emissions from a coal-fired boiler (dry bottom) burning pulverized bituminous coal. Boiler operating parameters are given in Table 2-2.

Case Study -- Technological Feasibility

Step 1. Determine Uncontrolled Emission Rates --

Based on boiler operating parameters that are summarized on Table 2-2, the uncontrolled total PM and PM-10 emission rates are:

$$\frac{9.153\ g}{m^3} \times \frac{1{,}416\ m^3}{min} \times \frac{60\ min}{hr} \times \frac{kg}{1{,}000\ g}$$

$$= 777.6\ kg/hr\ total\ PM$$

$$777.6\ kg/hr \times 23/100 = 178.9\ kg/hr\ PM\text{-}10$$

If information on inlet PM concentrations were not available, uncontrolled emissions could also be estimated using emission factors in Compilation of Air Pollutant Emission Factors (OAQPS, 1985).

Step 2. Identify Available Control Options --

While many sources may be able to change their processes to reduce or eliminate PM-10 emissions, this is not always possible with a boiler. Changing the fuel from coal to oil or natural gas would reduce PM-10 emissions, but this case study assumes that the location of this boiler makes coal an economical fuel. The collected flyash is a waste product which must be disposed of in a properly permitted landfill. Such arrangements have been made.

Data in Compilation of Air Pollutant Emission Factors (OAQPS, 1985) indicates that emissions from pulverized coal-fired boilers range down to less than 0.6 μm (see size distribution data summarized on Table 2-2). Control Techniques for Particulate Emissions from Stationary Sources - Volume II (EPA,

TABLE 2-2. CASE STUDY:
BOILER OPERATING PARAMETERS

Coal feed rate, Mg/hr (ton/hr)	5.41 (5.97)
Heat input, GJ/hr (MMBtu/hr)	170.7 (162)
Flue gas rate, m^3/min (acfm)	1,416 (50,000)
Flue gas ash loading, g/m^3 (gr/acfm)	9.153 (4.0)
Flue gas temp, K (°F)	436 (325)
Operating hours/year	8,640
Uncontrolled particulate size distribution, % less than stated size (μm):	
15	32
10	23
6	17
2.5	6
1.25	2
1.00	2
0.625	1

[a]From Compilation of Air Pollutant Emission Factors (OAQPS, 1985).

1982b) indicates that electrostatic precipitators (ESPs), fabric filters (baghouses), and wet scrubbers are used to control boiler emissions.

Step 3. Review Performance Data --

Since 23 percent of the emissions from the coal-fired boiler in this case study are less than 10 μm, a control device capable of collecting such fine materials is required. ESPs can be designed to collect flyash particles between 0.1 and 1 μm at 99+ percent efficiency (EPA, 1982a). Baghouses also collect fine particulates at high efficiency. High energy wet scrubbers are capable of collecting particulates less than 1 μm in size (EPA, 1982a). Examples of mass emissions test data for coal-fired boilers equipped with ESPs, scrubbers and baghouses are presented in Section 4 (Figure 4-2). Other sources of mass emissions data are listed in Section 3.

Step 4. Identify the Lowest Emission Limitation Achievable --

The percent reduction from baseline emissions (see Step 1 above) for each control option identified in Step 2 is calculated next. Estimated control efficiencies for total PM for dry bottom boilers burning bituminous coal as listed on Table 1.1-3 of EPA's Compilation of Air Pollutant Emission Factors (OAQPS, 1985) are as follows: Scrubber - 94 percent, ESP - 99.2 percent, and baghouse - 99.8 percent. Appendix C.2 of EPA's Compilation of Air Pollutant Emission Factors (OAQPS, 1985) presents typical collection efficiencies of various particulate control device for PM-10 emissions. Using the size distribution for uncontrolled emissions and the size specific control efficiency information presented in Appendix C.2 (OAQPS, 1985), the estimated collection efficiencies for PM-10 emissions are as follows: venturi scrubber - 94.7 percent, ESP - 98.0 percent, and baghouse - 99.4 percent. Therefore, the estimated achievable PM-10 emissions for each control technology are:

Venturi scrubber	-	9.5 kg/hr
ESP	-	3.6 kg/hr
Baghouse	-	1.1 kg/hr

Step 5. Identify the Current Lowest Emission Limitation --

Section 4 presents a summary of the most stringent state total PM limits. From information on Table 4-1, the most stringent total PM emission limit applicable to this size and type of boiler is determined from the following equation:

$$A = 0.05 \times I$$

where:

A = Allowable total PM emission rate in lb/hr

I = Heat input in MMBtu/hr

Therefore, the allowable limit is 8.1 lb/hr or 3.7 kg/hr. A closer review of this state emission limit confirms that this limitation applies to combustion units with the primary purpose of steam generation. There is also an applicable Federal NSPS for this source category. Although NSPS does not apply to the boiler in this case study (because it is an existing source), the NSPS limitation is technologically achievable, however, the limit may not be reasonable to achieve in all situations for existing sources. The NSPS limitation for a boiler with a heat input of 170.7 GJ/hr is 22 ng/J (0.05 lb/MMBtu); for the case study boiler, this equates to an emission limit of 3.76 kg/hr.

An equivalent PM-10 emission limitation is estimated as follows:

a. Percent control required to meet total PM limit:

$$\frac{777.6 - 3.7}{777.6} \times 100 = 99.5\%$$

b. Control technology that achieves 99.5 percent: baghouse. This is based on available information in OAQPS, 1985. Other sources of information (such as data provided by manufacturer's) may indicate that other control technologies can also achieve the required level of control.

c. Total PM emission rate achieved by selected technology:

$$777.6 \times (1-0.998) = 1.6 \text{ kg/hr}$$

d. Calculate "safety factor"; total PM limit divided by achievable total PM emission rate:

$$3.7 \div 1.6 = 2.3$$

e. Particle size distribution of uncontrolled exhaust stream (from Table 2-2):

$\% \leq 10\mu m - 23$

$\% \leq 6\mu m - 17$

$\% \leq 2.5\mu m - 6$

f. Determine achievable PM-10 emission rate:

1.	Uncontrolled emission rates by size, kg/hr	$\leq 2.5\mu m$: 777.6 x 0.06 = 46.7	$\leq 6\mu m$: 777.6 x 0.17 = 132.2	$\leq 10\mu m$: 777.6 x 0.23 = 178.9
2.	Uncontrolled emission rates by size categories, kg/hr	0-2.5 μm: 46.7	2.5-6 μm: 85.5	6-10 μm: 46.7
3.	Control efficiencies of fabric filters by size category (from OAQPS, 1985, Appendix C.2), %	0-2.5 μm: 99	2.5-6 μm: 99.5	6-10 μm: 99.5
4.	Controlled emission rates by size category, kg/hr	0-2.5 μm: 46.7 x 0.01 = 0.47	2.5 = 6 μm: 85.5 x 0.005 = 0.43	6-10 μm: 46.7 x 0.005 = 0.23

Therefore, the achievable PM-10 emission rate:

$$0.47 + 0.43 + 0.23 = 1.1 \text{ kg/hr}$$

g. Multiply achievable PM-10 emission rate by "safety factor":

$$1.1 \times 2.3 = 2.5 \text{ kg/hr}$$

Therefore, 2.5 kg/hr is the equivalent PM-10 emission limit that requires 99.5 percent control (see step a above).

Case Study -- Economic Feasibility

Step 1. Develop Capital and Annual Costs --

The procedures used to develop capital and annual costs are described in detail in Section 5. Table 2-3 shows the capital cost calculations for a baghouse, the technologically feasible control technology that was identified above. Similarly, Table 2-4 shows the calculation of annual costs for the same baghouse.

Step 2. Calculate Cost Effectiveness --

Cost effectiveness is the annual cost of the control option divided by the quantity of PM-10 collected annually, expressed in dollars per Mg (ton). The cost effectiveness for the baghouse in the case study is determined as follows:

1. Quantity of PM-10 removed annually:

$$(178.9-1.1) \times 8{,}640 \times 10^{-3} = 1{,}536 \text{ Mg/yr}$$

where:

178.9 = Uncontrolled PM-10 emission rate, kg/hr

8,640 = Number of operating hours, hr/yr

10^{-3} = Converts kilograms to megagrams

2. Calculate cost effectiveness:

The cost effectiveness is calculated by dividing the annual cost, from Table 2-4 by the megagrams collected per year. Thus, for the baghouse:

$$\text{Cost effectiveness, \$/Mg} = \frac{400{,}800}{1{,}536} = 261$$

Step 3. Review of Economic Impacts/Affordability --

Should there be a claim that the RACT cannot be afforded for this source, the capital and annual costs and the cost effectiveness would be important considerations in evaluating the claim. Each non-affordability claim is unique and each must be evaluated individually using the guidelines presented under Step 3 -- Review of Affordability/Economic Impacts in the Economic Feasibility subsection.

TABLE 2-3. CASE STUDY: BAGHOUSE CAPITAL INVESTMENT

Cost Item	Cost, Thousand Dollars
DIRECT COSTS	
Purchased equipment[a]	
Baghouse and auxiliary equipment = A	186.9
Sales taxes = 0.03A	5.6
Freight = 0.05A	9.3
Instrumentation = 0.1 A	18.7
Purchased equipment cost = B	220.5
Installation costs[b]	
Foundation and supports = 0.04B	8.8
Handling and erection = 0.5B	110.3
Electrical = 0.08B	17.6
Piping = 0.01B	2.2
Insulation for duct work = 0.07B	15.4
Painting = 0.02B	4.4
Total direct cost	158.7
INDIRECT COSTS	
Engineering and supervision = 0.10B	22.1
Construction and field expenses = 0.20B	44.1
Contractor fees = 0.10B	22.1
Start=up = 0.01B	2.2
Performance test[c] = 0.01B	2.2
Contingencies[d] = 0.1B	22.1
Total indirect cost	114.8
TOTAL CAPITAL INVESTMENT	494.0

[a]Purchased equipment includes the baghouse plus auxiliaries such as fan, motor, starter, ductwork, dampers, screw conveyor, compressor, and stack.

[b]Site preparation and buildings would be included in the category if required.

[c]The performance test determines that all items of equipment are operating properly. It does not include the cost of determining that the control system emissions meet requirements; this is an operating expense.

[d]A contingency cost of 10 percent of purchased equipment was used since this is a retrofit installation.

TABLE 2-4. CASE STUDY: BAGHOUSE ANNUAL COSTS

Cost Item	Cost, Thousand Dollars
DIRECT ANNUAL COSTS	
Operating labor	
$\frac{2\text{ hr}}{\text{shift}} \times \frac{3\text{ shifts}}{\text{day}} \times \frac{360\text{ days}}{\text{yr}} \times \frac{\$14}{\text{hr}} =$	30.2
Operating supervision at 15 percent of operating labor	4.5
Maintenance labor	
$\frac{1\text{ hr}}{\text{shift}} \times \frac{3\text{ shifts}}{\text{day}} \times \frac{360\text{ days}}{\text{yr}} \times \frac{\$15.40}{\text{hr}} =$	16.6
Maintenance material at 100 percent of maintenance labor	16.6
Replacement bags[a]	
$[3{,}265 + (15{,}554 \times 1.08)]0.5762 =$	11.6
Utilities	
Electricity	
$0.00025164^{b} \times \frac{1{,}416\text{ m}^3}{\text{min}} \times 261.6\text{ mm } H_2O$ $\times \frac{8{,}640\text{ hr}}{\text{yr}} \times \frac{\$0.06}{\text{kWh}} =$	48.3
Compressed air (a pulse jet filter requires 25 $m^3/1{,}000\ m^3$ of gas filtered at a cost of \$5.65 per 1,000 sm^3)	
$\frac{25\text{m}^3}{1{,}000\text{ m}^3} \times \frac{1{,}146\text{ m}^3}{\text{min}} \times \frac{\$5.65}{1{,}000\text{ sm}^3} \times \frac{60\text{ min}}{\text{hr}} \times \frac{8{,}640\text{ hr}}{\text{yr}} =$	8.3
Waste disposal at \$22/Mg, disposed of on site, assuming 100 percent collection efficiency	
$\frac{9.2\text{ g}}{\text{m}^3} \times \frac{1{,}416\text{ m}^3}{\text{min}} \times \frac{60\text{ min}}{\text{hr}} \times \frac{8{,}640\text{ hr}}{\text{yr}} \times \frac{1\text{ Mg}}{10^6\text{ g}} \times \frac{\$22}{\text{Mg}} =$	148.6
Total direct annual costs	284.7

(continued)

TABLE 2-4. (CONTINUED)

Cost Item	Cost, Thousand Dollars
INDIRECT ANNUAL COSTS	
Overhead	
60 percent (labor and maintenance materials) = 0.6 (30.2 + 4.5 + 16.6 +16.6) =	40.7
Insurance	
1 percent of capital investment = 0.01 (494.0) =	4.9
Property tax	
1 percent of total capital investment = 0.01 (494.0) =	4.9
Administrative charges	
2 percent of total capital investment = 0.02 (494.0) =	9.9
Capital recovery[c] = 0.1175 (494.0 - 3.3 - 15.6 x 1.08)	55.7
Total indirect annual costs	116.1
TOTAL ANNUAL COST	400.8

[a]The cost of replacement bags is $15,554. The 1.08 factor is for freight and sales taxes. For bag replacement labor, 10 minutes per bag for each of 795 bags was estimated. At a maintenance labor rate of $24.64 (including 60% overhead) the labor cost is $3,265 for 133 hours. The replacement cost was calculated using equation 5.1. The CRF in equation 5.1 was calculated using equation 5.4 for a two year bag life and 10 percent interest:

$$CRF = \frac{0.1\ (1+0.1)^2}{(1+0.1)^2-1} = 0.5762$$

[b]See equation 5.2a.

[c]For a 20 year equipment life and a 10 percent interest rate, CRF = 0.1175. The total capital investment (from Table 2-3) is reduced by the total cost for replacing the bags to avoid double counting.

Case Study -- Identify RACT

The results of the technological and economic feasibility determinations for the case study are summarized on Table 2-5.

TABLE 2-5. SUMMARY OF RACT DETERMINATIONS FOR CASE STUDY[a]

Parameter/technology	Fabric filter	ESP	Venturi scrubber	Process change
Uncontrolled emissions, kg/hr				
a. Total PM	777.6	777.6	777.6	777.6
b. PM-10	178.9	178.9	178.9	178.9
Controlled emissions, kg/hr				
a. Total PM	1.6	6.2	46.7	NA
b. PM-10	1.1	3.6	9.5	NA
Control effectiveness, %				
a. Total PM	99.8	99.2	94	NA
b. PM-10	99.4	98.0	94.7	NA
Current allowable emissions				
a. Total PM, kg/hr	3.7	3.7	3.7	
b. Opacity, %	0%[b]			
Equivalent PM-10 limit, kg/Mg	2.5			
Capital costs, $	494,000			
Annual costs, $/yr	400,800			
Cost effectiveness, $/Mg				
a. Total PM	59.80			
b. PM-10	260.90			
Energy requirement, mWh/yr	805.2			
Wastewater impact	None			
Solid waste impact	On-site landfill			
Other impacts	None			

[a]There may be slight differences in numbers due to rounding.

[b]0 percent, with exceptions for start-up, soot blowing, etc. See Section 4 for a more detailed discussion.

REFERENCES

BNA Inc. 1991a. Bureau of National Affairs (BNA) Environmental Reporter State Air Laws. The Bureau of National Affairs, Inc. Washington, DC. October 25, 1991.

BNA Inc. 1991b. Bureau of National Affairs (BNA) Environmental Reporter Federal Regulations. The Bureau of National Affairs, Inc. Washington, DC. October 25, 1991.

EPA. 1982a. Control Techniques for Particulate Emissions from Stationary Sources; Volume I. EPA 450/3-81-005a, U.S. Environmental Protection Agency, Research Triangle Park, NC. September 1982.

EPA. 1982b. Control Techniques for Particulate Emissions from Stationary Sources; Volume II. EPA 450/3-81-005b, U.S. Environmental Protection Agency, Research Triangle Park, NC. September 1982.

EPA. 1986. Identification Assessment, and Control of Fugitive Particulate Emissions. EPA 600/8-86-023, U.S. Environmental Protection Agency, Research Triangle Park, NC. August 1986.

Office of Air Quality Planning and Standards, U.S. Environmental Protection Agency. 1985. Compilation of Air Pollutant Emission Factors; Fourth Edition, AP-42, September 1985, including Supplement A (October 1986), Supplement B (September 1988) Supplement C (September 1990) and Supplement D (September 1991).

Office of Air Quality Planning and Standards, U.S. Environmental Protection Agency. 1990. OAQPS Control Cost Manual; Fourth Edition. EPA 450/3-90-006, U.S. Environmental Protection Agency, Research Triangle Park, NC. January 1990.

Perry, R.H. and D.W. Green. 1984. Perry's Chemical Engineers Handbook; Sixth Edition. McGraw-Hill Book Co., New York, NY, 1984.

SECTION 3

PROCESS EMISSIONS AND EMISSIONS CONTROL BIBLIOGRAPHY

This Section presents an annotated bibliography of information sources that describe the processes in each source category that generate PM-10 emissions, the magnitude of uncontrolled and controlled emissions from these sources, and emission control measures. The list of source categories is shown in the previous Section on Table 1-1.

The bibliography first shows general information sources that cover multiple source categories. They are arranged chronologically. The remaining information sources are arranged alphabetically by source category.

Most of the reports listed in this Section are available through the National Technical Information Service (NTIS), 5285 Port Royal Road, Springfield, Virginia 22161; (703) 487-4650.

GENERAL INFORMATION SOURCES

Office of Air Quality Planning and Standards, U.S. Environmental Protection Agency. 1973. Background Information for Proposed New Source Performance Standards: Asphalt Concrete Plants, Petroleum Refineries, Storage Vessels, Secondary Lead Smelters and Refineries, Brass or Bronze Ingot Production Plants, Iron and Steel Plants, Sewage Treatment Plants; Volume 1 - Main Text. APTD-1352a, U.S. Environmental Protection Agency, Research Triangle Park, NC. 72 pp.

Provides background information on the derivation of the proposed second group of New Source Performance Standards and their economic impact on the construction and operation of the plants listed in the title. This document contains test results.

Office of Air Quality Planning and Standards, U.S. Environmental Protection Agency. 1973. Background Information for Proposed New Source Performance Standards: Asphalt Concrete Plants, Petroleum Refineries, Storage Vessels, Secondary Lead Smelters and Refineries, Brass or Bronze Ingot Production Plants, Iron and Steel Plants, Sewage Treatment Plants; Volume 2 - Appendix: Summaries of Test Data. APTD-1352b, PB229660, U.S. Environmental Protection Agency, Research Triangle Park, NC. 67 pp.

Volume 2 of previously described document.

Office of Air Quality Planning and Standards, U.S. Environmental Protection Agency. 1974. Background Information for New Source Performance Standards: Asphalt Concrete Plants, Petroleum Refineries, Storage Vessels, Secondary Lead Smelters and Refineries, Brass or Bronze Ingot Production Plants, Iron and Steel Plants, Sewage Treatment Plants. EPA 450/2-74-003, (APTD-1352c), U.S. Environmental Protection Agency, Research Triangle Park, NC. 151 pp.

Jutze, G.A., J.M. Zoller, T.A. Janszen, S. Amick, C.E. Zimmer, and R.W. Gerstle. 1977. Technical Guidance for Control of Industrial Process Fugitive Particulate Emissions. EPA-450-3-77-010, PB272288, U.S. Environmental Protection Agency, Research Triangle Park, NC. 522 pp.

Provides guidelines for evaluating industrial process fugitive particulate emission sources relative to revisions to State Implementation Plans. Document includes section on control technologies.

Office of Air Pollution Control, Ohio Environmental Protection Agency. 1980. Reasonably Available Control Measures for Fugitive Dust Sources. Ohio Environmental Protection Agency, Columbus, OH. 596 pp.

Presents guidelines for selection of reasonably available control measures for fugitive dust sources for major manufacturing categories. Document includes discussions of process operations, particle characterization, control methods, efficiencies, and costs.

Office of Air Quality Planning and Standards, U.S. Environmental Protection Agency. 1982. Control Techniques for Particulate Emissions from Stationary Sources; Volume 1, EPA-450/3-81-005a, PB83-127498, U.S. Environmental Protection Agency, Research Triangle Park, NC. 460 pp.

Presents information developments of control techniques which have become available since preparation of an earlier document entitled Control Techniques for Particulate Air Pollutants (AP-51). Includes sections on control technology and cost considerations.

Office of Air Quality Planning and Standards, U.S. Environmental Protection Agency. 1982. Control Techniques for Particulate Emissions from Stationary Sources; Volume 2, EPA-450/3-81-005b, PB83-127480, U.S. Environmental Protection Agency, Research Triangle Park, NC. 540 pp.

Volume 2 of a previously described document.

Cowherd, C. Jr., and J.S. Kinsey. 1986. Identification, Assessment, and Control of Fugitive Particulate Emissions. EPA-600/8-86-023, U.S. Environmental Protection Agency, Washington, D.C. 180 pp.

Designed to assist national, state, and local control agency personnel and industry personnel in evaluating fugitive emission control plans and in developing cost-effective control strategies. The document includes sections on control alternatives, estimation of control system performance for process and open sources, estimating control costs and cost effectiveness, and development of fugitive emissions control strategies.

Steigerwald, Joseph. 1990. BACT/LAER Clearinghouse: A Compilation of Control Technology Determinations; Volume 1, EPA 450/3-90-015a, PB90-259722; Volume II - Appendix H, Source Codes 1 to 3, EPA 450/3-90-015b, PB90-259730; Volume III - Appendix H, Source Codes 4 to 6, EPA - 450/3-90-015C, PB90-259748; Volume IV - Appendix H, Source Codes 7 to 12, EPA - 450/3-90-015d, PB90-259755, U.S. Environmental Protection Agency, Research Triangle Park, NC.

Provides State and local air pollution control agencies with current information on case-by-case control technology determinations that are made nationwide. The Clearinghouse is intended as a reference for State and local agencies in making BACT/LAER decisions.

Di Mauro, Desiree, Colleen Duffy. 1991. RACT/BACT/LAER Clearinghouse: A Compilation of Control Technology Determinations, First Supplement to 1990 Edition. EPA 450/3-91-015, PB91-231548, U.S. Environmental Protection Agency, Research Triangle Park, NC. 220 pp.

First Supplement to previously described document.

Office of Air Quality Planning and Standards, U.S. Environmental Protection Agency. 1991. Compilation of Air Pollution Emission Factors, AP-42, Supplements A, B, C and D. AP-42, U.S. Environmental Protection Agency, Research Triangle Park, NC.

Presents process and control system descriptions and uncontrolled and controlled emissions data for numerous source categories.

ASPHALT AND ASPHALTIC CONCRETE PLANTS

Khan, Z.S., and T.W. Hughes. 1977. Source Assessment Asphalt Hot Mix. EPA-600/2-77-107n, PB-276731, U.S. Environmental Protection Agency, Cincinnati, OH. 173 pp.

Summarizes data on air emissions from the asphalt hot mix industry. Sections on control technology and process description are also provided.

Brooks, K.J., E.L. Keitz, and J.W. Watson. 1979. A Review of Standards of Performance for New Stationary Sources - Asphalt Concrete Plants. EPA-450/3-79-014, PB-298-427, U.S. Environmental Protection Agency, Research Triangle Park, NC. 138 pp.

Reviews the current standards of performance for new stationary sources; Subpart I - Asphalt Concrete Plans. Emphasis is given to the state of control technology and economic cost.

Office of Air Quality Planning and Standards, U.S. Environmental Protection Agency. 1985. Second Review of New Source Performance Standards - Asphalt Concrete Plants. EPA 450/3-85-024, PB86-126448, U.S. Environmental Protection Agency, Research Triangle Park, NC. 135 pp.

Reviews the current New Source Performance Standards for asphalt concrete plants. Includes section on applicable control technology.

Kinsey, J.S. 1986. Asphaltic Concrete Industry Particulate Emissions. Source Category Report. EPA/600/7-86-038, PB87-119574, U.S. Environmental Protection Agency, Research Triangle Park, NC. 335 pp.

Describes the development of particulate emission factors based on cutoff size for inhalable particles for the asphaltic concrete industry. Process and control technology descriptions are also provided.

BOILERS

McKenna, J.D., J.C. Mycock, and W.O. Lipscomb. 1975. Applying Fabric Filtration to Coal Fired Industrial Boilers (A Pilot Scale Investigation). EPA-650/2-74-058a, PB-245186, U.S. Environmental Protection Agency, Research Triangle Park, NC. 203 pp.

Gives results of a pilot scale investigation to determine the technoeconomic feasibility of applying a fabric filter dust collector to coal-fired industrial boilers. Includes sections on process description, controlled emissions, control technology, and annualized cost.

Boubel, R.W. 1977. Control of Particulate Emissions from Wood-Fired Boilers. PB-278-483/3, U.S. Environmental Protection Agency, Washington, DC.

Intended primarily as a guide for control agency personnel and engineers who are not familiar with wood-fired boilers. Includes sections on control technology and cost of control.

Office of Air Quality Planning and Standards, U.S. Environmental Protection Agency. 1978. Electric Utility Steam Generating Units, Particulate Matter - Background Information for Proposed Emission Standards. EPA-450/2-78-006a, PB-286224, U.S. Environmental Protection Agency, Research Triangle Park, NC. 174 pp.

Revised standards of performance for the control of emissions of particulate matter from electric utility power plants proposed under the authority of Section 111 of the Clean Air Act. Includes process description and economic impact assessments.

Office of Air Quality Planning and Standards, U.S. Environmental Protection Agency. 1978. Wood Residue Fired Steam Generator Particulate Matter Control Technology Assessment. EPA-450/2-78-044, PB80-196843, U.S. Environmental Protection Agency, Research Triangle Park, NC.

This document discusses the control equipment and emission limits which represent Best Available Control Technology (BACT).

Leavitt, C., K. Arledge, C. Shih, R. Orsini, W. Hamersma, R. Maddalone, R. Beimer, G. Richard, and M. Yamada. 1978. Environmental Assessment of Coal- and Oil-firing in a Controlled Industrial Boiler; Volume III - Comprehensive Assessment and Appendices. EPA-600/7-78-164c, PB291236, U.S. Environmental Protection Agency, Research Triangle Park, NC. 328 pp.

Gives results of a comparative multimedia assessment of coal versus oil-firing in a controlled industrial boiler, to determine relative environmental, energy, economic and societal impacts.

Office of Air Quality Planning and Standards, U.S. Environmental Protection Agency. 1979. Electric Utility Steam Generating Units - Background Information for Promulgated Emission Standards. EPA-450/3-79-021, PB-298510, U.S. Environmental Protection Agency, Research Triangle Park, NC. 339 pp.

Standards of performance for the control of particulate matter, sulfur dioxide, and nitrogen oxides emissions from electric utility steam generating units adopted under the authority of Section 111 of the Clean Air Act. Includes section on process description.

Office of Air Quality Planning and Standards, U.S. Environmental Protection Agency. 1982. Fossil Fuel-Fired Industrial Boilers - Background Information. EPA-450/3-82-006a,b, PB82-202573, U.S. Environmental Protection Agency, Research Triangle Park, NC. 869 pp.

Provides background information for the fossil fuel-fired industrial boiler source category. Includes sections on uncontrolled emissions, control technologies, and cost impacts.

Office of Air Quality Planning and Standards, U.S. Environmental Protection Agency. 1982. Nonfossil Fuel Fired Industrial Boilers - Background Information. EPA-450/3-82-007, PB82-203209, U.S. Environmental Protection Agency, Research Triangle Park, NC. 789 pp.

Provides background information about air emissions and emission controls, for the nonfossil fuel fired boiler source category. This document includes uncontrolled emissions of particulate matter, sulfur dioxide and nitrogen oxides, also includes control technologies and cost impacts of applying these control technologies.

Office of Air Quality Planning and Standards, U.S. Environmental Protection Agency. 1985. Summary of Regulatory Analysis New Source Performance Standards for Industrial-Commercial-

Institutional Steam Generating Units of Greater than 100 Million Btu/hr Heat Input. EPA-450/3-86-005, PB86-212099. U.S. Environmental Protection Agency, Research Triangle Park, NC. 276 pp.

Summarizes the regulatory analysis of New Source Performance Standards for Industrial-Commercial-Institutional Steam Generating Units. Information on costs of controls and emission control technologies is included.

Energy and Environmental Analysis, Inc. 1989. Projected Impacts of Alternative New Source Performance Standards for Small Industrial-Commercial-Institutional Fossil Fuel-Fired Boilers. EPA-450/3-89-17, PB89-203723, U.S. Environmental Protection Agency, Research Triangle Park, NC. 139 pp.

Presents projected national environmental cost and energy impacts of alternative SO2 and particulate matter air emission standards for new small industrial-commercial-institutional steam generating units firing coal, oil, and natural gas. Includes sections on cost and cost effectiveness.

Office of Air Quality Planning and Standards, U.S. Environmental Protection Agency. 1989. Model Boiler Cost Analysis for Controlling Particulate Matter (PM) Emissions from Small Steam Generating Units. EPA-450/3-89-15, U.S. Environmental Protection Agency, Research Triangle Park, NC. 64 pp.

This report presents estimates of the cost and cost effectiveness associated with controlling particulate matter emissions from small coal-, oil-, and wood-fired industrial-commercial-institutional steam generating units.

Office of Air Quality Planning and Standards, U.S. Environmental Protection Agency. 1989. Projected Impacts of Alternative Particulate Matter New Source Performance Standards for Industrial-Commercial-Institutional Nonfossil Fuel-fired Steam Generating Units. EPA-450/3-89-18, U.S. Environmental Protection Agency, Research Triangle Park, NC. 13 pp.

Presents projected national environmental, cost and energy impacts of alternative particulate matter air emission standards for new small industrial-commercial-institutional steam generating units firing wood.

Office of Air Quality Planning and Standards, U.S. Environmental Protection Agency. 1989. Overview of the Regulatory Baseline, Technical Basis, and Alternative Control Levels for Particulate Matter (PM) Emission Standards for Small Generating Units. EPA-450/3-89-11, PB89-203715, U.S. Environmental Protection Agency, Research Triangle Park, NC. 31 pp.

Provides a summary of the technical data used in developing proposed New Source Performance Standards for small industrial-commercial-institutional steam generating units. Includes sections on emissions, process descriptions, and control technologies.

CALCINERS

Radian Corporation. 1980. Sodium Carbonate Industry-Background Information for Proposed Standards. EPA-450/3-80-029a, PB80-219678, U.S. Environmental Protection Agency, Research Triangle Park, NC. 358 pp.

Standards of performance to control emissions of particulate matter from new, modified, and reconstructed calciners, dryers and bleachers in natural process sodium carbonate plants as proposed under Section 111 of the Clean Air Act. Includes sections on emission control technology and economic impact analysis.

Office of Air Quality Planning and Standards, U.S. Environmental Protection Agency. 1985. Calciners and Dryers in Mineral Industries-Background Information for Proposed Standards. EPA-450/3-85-025a, PB86-196904, U.S. Environmental Protection Agency, Research Triangle Park, NC. 699 pp.

Standards of performance for the control of emissions from calciners and dryers in mineral industries proposed under the authority of Section 111 of the Clean Air Act. Contains section on economic impact assessments.

CHARCOAL PLANTS

Moscowitz, C.M. 1978. Source Assessment: Charcoal Manufacturing State of the Art. EPA-600/2-78-004Z, PB-290125, U.S. Environmental Protection Agency, Cincinnati, OH.

Document reviews the state of the art of air emissions from charcoal manufacture. Document includes process description, controlled emissions and control technology.

CHEMICAL MANUFACTURING PLANTS

Office of Air Quality Planning and Standards, U.S. Environmental Protection Agency. 1975. Engineering and Cost Study of Air Pollution Control for the Petrochemical Industry; Volume 7 - Phthalic Anhydride Manufacture from Ortho-xylene. EPA-450/3-73-006g, PB245277, Research Triangle Park, NC.

This document is one of a series. This volume covers the manufacture of phthalic anhydride from ortho-xylene. Includes sections on process description, control technology and cost analysis.

Gerstle, R.W., and J.R. Richards. 1977. Industrial Process Profiles for Environmental Use, Chapter 4: Carbon Black Industry. EPA-600-2-77-023d, U.S. Environmental Protection Agency, Cincinnati, OH.

The catalog of Industrial Process Profiles for Environmental Use was developed as an aid in defining the environmental impacts of industrial activity in the United States. The carbon black industry is a distinctive part of the chemical industry, which processes hydrocarbon feedstocks into finely divided carbon black particle for use largely in tires, pigments, cement and cosmetics. Sections on process description and atmosphere emissions are included.

Serth, R.W., and T.W. Huges. 1977. Source Assessment: Carbon Black Manufacture. EPA-600/2-77-107k, PB-273-068/7, U.S. Environmental Protection Agency, Research Triangle Park, NC.

The report summarizes the assessment of air emissions from the manufacture of carbon black. The document includes a section on process description.

Shreve, R.N., and J.A. Brink, Jr. 1977. Chemical Process Industries. Fourth Edition. McGraw Hill Book Company. 814 pp.

Provides an overview of the chemical process industry. Includes discussions on various industries, uses and economics, unit operations and raw materials.

Office of Air Quality Planning and Standards, U.S. Environmental Protection Agency. 1977. Final Guideline Document: Control of Fluoride Emissions from Existing Phosphate Fertilizer Plants. EPA-450/2-77-005, PB265062, Research Triangle Park, NC.

Document serves as a text to state agencies in development of their gaseous fluoride emission regulations from existing phosphate fertilizer plants. Document includes information on control technology, emissions, and economic impact.

Radian Corporation. 1980. Sodium Carbonate Industry - Background Information for Proposed Standards. EPA-450/3-80-029a, PB80-219678, U.S. Environmental Protection Agency, Research Triangle Park, NC. 358 pp.

Standards of performance to control emissions of particulate matter from new, modified, and reconstructed calciners, dryers, and bleachers in natural process sodium carbonate plants as proposed under Section 111 of the Clean Air Act. Includes sections on emission control technology and economic impact analysis.

U.S. Environmental Protection Agency. 1980. Source Category Survey: Detergent Industry. EPA-450/3-80-030, PB80219678, Research Triangle Park, NC. 1978.

Standards of performance to control emissions of particulate matter from new, modified, and reconstructed calciners, dryers, and bleachers in natural process sodium carbonate plants. This document includes emission control technology, emissions, and economic impacts.

Kirk-Othmer. Kirk-Othmer Encyclopedia of Chemical Technology. 1982. John Wiley & Sons, Inc., New York, NY.

Provides a detailed discussion of chemical process technology.

COAL PREPARATION AND CLEANING PLANTS

Office of Air Quality Planning and Standards, U.S. Environmental Protection Agency. 1974. Coal Preparation Plants - Background Information for Standards of Performance; Volume 1 - Proposed Standards. EPA-450/2-74-021a, PB237421, U.S. Environmental Protection Agency, Research Triangle Park, NC. 58 pp.

Presents the proposed standards and the rationale for the degree of control selected. The document includes analysis of costs and economic impact.

Office of Air Quality Planning and Standards, U.S. Environmental Protection Agency. 1974. Coal Preparation Plants - Background Information for Standards of Performance; Volume 2 - Test Data Summary. EPA-450/2-74-021b, PB237696, U.S. Environmental Protection Agency, Research Triangle Park, NC. 39 pp.

Presents the proposed standards and the rationale for the degree of control selected. Includes sections on sampling emissions and economic impact of standards.

Office of Air Quality Planning and Standards, U.S. Environmental Protection Agency. 1976. Coal Preparation Plants - Background Information for Standards of Performance; Volume 3 - Supplemental Information. EPA-450/2-74-021c, PB251618, U.S. Environmental Protection Agency, Research Triangle Park, NC. 62 pp.

Supplements information presented in two earlier background documents (EPA-450/2-74-021a and b) and is issued in connection with final promulgation of regulations for standards of performance for new and modified coal preparation plants. Document contains a summary of undated control costs.

TRW Energy Systems Group. 1980. A Review of Standards of Performance for New Stationary Sources for Coal Preparation Plants. EPA-450/3-80-022, PB82-193053, U.S. Environmental Protection Agency, Research Triangle Park, NC. 90 pp.

Reviews and assesses the need to revise the New Source Performance Standards for coal preparation plants. Includes sections on control technology and emissions.

Office of Air Quality Planning and Standards, U.S. Environmental Protection Agency. 1988. Second Review of New Source Performance Standards for Coal Preparation Plants. EPA-450/3-88-001, PB89-194237, U.S. Environmental Protection Agency, Research Triangle Park, NC. 73 pp.

The New Source Performance Standards for coal preparation plants were reviewed by the U.S. EPA for a second time. Includes section on control technology.

CONCRETE BATCH PLANTS

U.S. Environmental Protection Agency. 1975. Development Document for Effluent Limitations Guidelines and Standards of Performance, The Concrete Products Industries, Draft, Washington, DC.

COTTON SEED MILLING PLANTS

Monsanto Research Corporation. 1975. Source Assessment Document No. 27, Cotton Gins. EPA-600/2-78-004a, PB-280-024, U.S. Environmental Protection Agency, Research Triangle Park, NC.

This report describes a study of air pollutants from cotton gins. Document includes process description, emissions, and control technologies.

Enviro Control, Inc. 1980. Control Technology Assessment of Raw Cotton Processing Operations (Final Report). NIOSH-210-78-0001, PB82-186685, National Institute for Occupational Safety & Health, Cincinnati, OH. 367 pp.

Cotton dust control technology was assessed by conducting preliminary and detailed surveys of cotton ginning, cotton seed processing, yarn manufacturing, knitting, fabric weaving, and waste processing operations that use raw cotton.

Enviro Control, Inc. 1981. Use of Oil Additives (Liquid Oversprays) in Cotton Dust Control Technology (Final Report). PB82-177528, National Institute for Occupational Safety and Health, Cincinnati, OH. 68 pp.

Cotton dust control technology was assessed by conducting preliminary and detailed surveys of cotton ginning, cotton seed processing, yarn manufacturing, knitting, fabric weaving, and waste processing operations that use raw cotton.

FOUNDRIES

National Air Pollution Control Administration. 1970. Economic Impact of Air Pollution Controls on Gray Iron Foundry Industry. NAPCA publication-AP-74, NAPCA, Raleigh, NC. 124 pp.

Reviews the economic impact the four most common pollution devices (wet caps, multiple cyclones, wet scrubbers, fabric filters) have had on the Gray Iron Foundry Industry.

Fennelly, P., and P. Spawn. 1978. Air Pollution Control Techniques for Electric Arc Furnaces in the Iron and Steel Foundry Industry. EPA-450/2-78-024, PB283650, Research Triangle Park, NC.

This report provides guidance for evaluating air pollutant control technologies for EAF in the iron and steel foundry industry. Document contains sections of control technologies, emissions, and control technology cost.

Chmielewski, R.D., and S. Calvert. 1981. Flux Force/Condensation Scrubbing for Collecting Fine Particulate from Iron Melting Cupolas. EPA-600/7-81-148, PB82-196866, U.S. Environmental Protection Agency, Research Triangle Park, NC. 135 pp.

Gives results of a six month test, demonstrating the industrial feasibility of a flux/force condensation scrubbing system for controlling particulate emissions from an iron and steel melting cupola. Includes section on annual operating cost for scrubber system.

Office of Air Quality Planning and Standards, U.S. Environmental Protection Agency. 1981. Summary of Factors Affecting Compliance by Ferrous Foundries; Volume I - Text. EPA-340/1-80-021, Washington, DC.

Jeffrey, J., J. Fitzgerald, and P. Wolf. 1986. Gray Iron Foundry Industry Particulate Emissions: Source Category Report. EPA-600/7-86-054, PB87-145702, U.S. Environmental Protection Agency, Research Triangle Park, NC. 85 pp.

Gives the results of a study to develop particulate emission factors based on cutoff size for inhalable particles for the gray iron foundry industry.

Williams, R.L., and M. Duncan. 1986. Pilot Demonstration of the Air Curtain System for Fugitive Particle Control. EPA/600/7-86-041, PB87-132817, U.S. Environmental Protection Agency, Research Triangle Park, NC. 137 pp.

Gives results of the demonstration of the technical and economic feasibility of using an air curtain transport system to control buoyant fugitive particle emissions. Includes sections on control technology and controlled emissions.

GLASS MANUFACTURING PLANTS

Office of Air Quality Planning and Standards, U.S. Environmental Protection Agency. 1979. Glass Manufacturing Plants - Background Information for Standards of Performance. EPA-450/3-79-005a, U.S. Environmental Protection Agency, Research Triangle Park, NC. 278 pp.

A national emission standard for glass manufacturing plants as proposed under authority of Section 111 of the Clean Air Act. Document includes information on processes, control techniques, emissions and economic impacts.

Office of Air Quality Planning and Standards, U.S. Environmental Protection Agency. 1980. Glass Manufacturing Plants - Background Information for Promulgated Standards of Performance. EPA 450/3-79-005b, U.S. Environmental Protection Agency, Research Triangle Park, NC. 175 pp.

Standards of performance are being promulgated under Section 111 of the Clean Air Act to control particulate matter emissions from new, modified, and reconstructed glass manufacturing plants. Document covers public comments and testing data submitted during comment period.

Spinosa, E.D., and R.A. Holman. 1981. Chemical Analysis of Particle Size Fractions from Glass Melting Furnaces. EPA-600/2-81-015, PB81-160889, U.S. Environmental Protection Agency, Cincinnati, OH. 42 pp.

Identifies the size fraction distribution of the various chemical constituents of glass furnace emissions. Includes a section on control technology.

GRAIN MILLING OPERATIONS

Shannon, L.J., R.W. Gerstle, P.G. Gorman, D.M. Epp, T.W. Devitt, and R. Amick. 1973. Emissions Control in the Grain and Feed Industry; Volume I - Engineering and Cost Study. EPA-450/3-73-003a. U.S. Environmental Protection Agency, Research Triangle Park, NC. 544 pp.

Presents the results of a study of air pollution associated with the grain and feed industry.

Shannon, L.J., and P.G. Gorman. 1974. Emissions Control in the Grain and Feed Industry; Volume II - Emission Inventory. EPA-450/3-73-003b, PB241234, U.S. Environmental Protection Agency, Research Triangle Park, NC. 98 pp.

The emission information presented in "Volume I - Engineering and Cost Study" was used to calculate particulate emissions for each segment of the industry. This document includes a section on control technology.

Office of Air Quality Planning and Standards, U.S. Environmental Protection Agency. 1977. Standards Support and Environmental Impact Statement; Volume 1 - Proposed Standards of Performance for Grain Elevator Industry. EPA-450/2-77-001a, PB80-194152, U.S. Environmental Protection Agency, Research Triangle Park, NC. 348 pp.

Standards of performance to control particulate matter emissions from new and modified grain elevators in the U.S. as proposed under Section 111 of the Clean Air Act. Discussions on processes and emissions, control technologies, emission data, and economic impacts are included.

Office of Air Quality Planning and Standards, Emission Standards and Engineering Division, U.S. Environmental Protection Agency. 1978. Standards Support and Environmental Impact Statement; Volume 2 - Promulgated Standards of Performance for Grain Elevator Industry. EPA-450/2-77-001b, PB80-198435, U.S. Environmental Protection Agency, Research Triangle Park, NC. 92 pp.

Standards of performance for the control of particulate matter emissions from new, modified and reconstructed grain terminal elevators and certain storage elevators at grain processing plants promulgated under the authority of Section 111 of the Clean Air Act.

Midwest Research Institute. 1981. Source Category Survey: Animal Feed Dryers. EPA-450/3-81-017, PB82-151531, U.S. Environmental Protection Agency, Research Triangle Park, NC. 115 pp.

Presents the findings of a study to assess the need for New Source Performance Standards for animal feed dryers. Includes section on methods of air pollution control and their effectiveness.

Office of Air Quality Planning and Standards, U.S. Environmental Protection Agency. 1984. Review of New Source Performance Standards for Grain Elevators (Final Report). EPA-450/3-84-001, PB84-175744, U.S. Environmental Protection Agency, Research Triangle Park, NC. 105 pp.

Reviews the current standards of performance for new stationary sources: Subpart DD - Grain Elevators. Includes sections on control technology and economic costs.

GYPSUM PRODUCT MANUFACTURING AND PROCESSING PLANTS

Control Systems Division, U.S. Environmental Protection Agency. 1973. Screening Study for Background Information and Significant Emissions for Gypsum Product Manufacturing. EPA-RZ-73-286, PB-222736/1, Process Research, Inc., Cincinnati, OH. 52 pp.

The atmospheric emissions that are produced during the operation of calcining gypsum and production of gypsum board products are studied.

INCINERATORS

Helfand, R.M. 1979. A Review of Standards of Performance for New Stationary Sources for Incinerators. EPA-450/3-79-009, PB80-124787, U.S. Environmental Protection Agency, Research Triangle Park, NC. 64 pp.

Reviews the current Standards of Performance for New Stationary Sources: Subpart E - Incinerators. Includes information on the status of control technologies, processes, and emissions data.

Schindler, P. 1987. Municipal Waste Combustion Study: Emissions Database for Municipal Waste Combustors. EPA/530-SW-87-021b, PB87-206082, U.S. Environmental Protection Agency, Cary, NC.

This report describes an emission database compiled from tests conducted in U.S. and abroad. Results of controlled and uncontrolled testing programs are included.

Sedman, C.B., and T.G. Brna. 1987. Municipal Waste Combustion Study: Flue Gas Cleaning Technology. EPA/530-SW-87-021d, U.S. Environmental Protection Agency, Research Triangle Park, NC.

Radian Corporation. 1988. Hospital Waste Combustion Study Data Gathering Phase, Final Report, PB89-148308, U.S. Environmental Protection Agency, Research Triangle Park, NC.

Contains results of a study of air emissions from combustion of hospital waste. Document includes information on waste characterization, processes and equipment for combustion, control techniques, and air pollutants emitted.

Office of Air Quality Planning and Standards, U.S. Environmental Protection Agency. 1989. Municipal Waste Combustors - Background Information for Proposed Standards. 111(b) Model Plant Description and Cost Report. EPA-450/3-89-27b, PB90-154857, U.S. Environmental Protection Agency, Research Triangle Park, NC. 134 pp.

Twelve model plants are developed to represent the projected municipal waste combustor industry. Includes sections on operating and maintenance cost of control equipment, emission control options and control technology.

Office of Air Quality Planning and Standards, U.S. Environmental Protection Agency. 1989. Municipal Waste Combustors - Background Information for Proposed Standards. Post-Combustion Technology Performance. EPA-450/3-89-27c, PB90-154865, U.S. Environmental Protection Agency, Research Triangle Park, NC. 327 pp.

Evaluates the performance of various air pollution control devices applied to new and existing municipal waste combustors. Includes section on control technologies.

IRON AND STEEL FACILITIES

Office of Air Quality Planning and Standards, U.S. Environmental Protection Agency. 1974. Electric Arc Furnaces in the Steel Industry - Background Information for Standards of Performance; Volume 1 - Proposed Standards. EPA-450/2-74-017a, PB237-840, U.S. Environmental Protection Agency, Research Triangle Park, NC. 170 pp.

Provides background information and rationale used in the development of the proposed standard of performance. The economic and environmental impacts of the standard are discussed.

Office of Air Quality Planning and Standards, U.S. Environmental Protection Agency. 1974. Electric Arc Furnaces in the Steel Industry - Background Information for Standards of Performance; Volume 2 - Summary of Test Data. EPA-450/2-74-017b, PB237-841, U.S. Environmental Protection Agency, Research Triangle Park, NC. 39 pp.

Summarizes test data from electric arc furnaces in the steel industry.

Bohn, R., T. Cuscino Jr., and C. Cowherd Jr. 1978. Fugitive Emissions from Integrated Iron and Steel Plants. EPA-600/2-78-050, U.S. Environmental Protection Agency, Research Triangle Park, NC. 276 pp.

Presents results of an engineering investigation of fugitive emissions in the iron and steel industry. Includes sections on sources, quantification, and control technology are presented.

Drabkin, M., and R. Helfand. 1978. A Review of Standards of Performance for New Stationary Sources for Iron and Steel Plants/Basic Oxygen Furnaces. EPA-450/3-78-116, PB289877, U.S. Environmental Protection Agency, Research Triangle Park, NC. 65 pp.

Reviews the current standards of performance for new stationary sources: Subpart N - Iron and Steel Plants/Basic Oxygen Furnaces. Includes sections on control technology and emissions.

VanOsdell, D.W., D. Marsland, B.H. Carpenter, C. Sparacino, and R. Jablin. 1979. Environmental Assessment of Coke By-Product Recovery Plants. EPA-600/2-79-016. U.S. Environmental Protection Agency, Research Triangle Park, NC. 387 pp.

Gives results of a screening study, initiating a multimedia environmental assessment of coke by-product recovery plants in the U.S. Provides process descriptions of recovery processes.

Westbrook, C.W. 1979. Level 1 Assessment of Uncontrolled Sinter Plant Emissions. EPA 600/2-79-112, U.S. Environmental Protection Agency, Washington, DC. 83 pp.

Gives results of sampling and analysis of uncontrolled emissions from two sinter plants, to characterize and quantify the particulate, organic, and inorganic species present. Process descriptions of the two plants are provided.

Office of Air Quality Planning and Standards, U.S. Environmental Protection Agency. 1979. Review of Standards of Performance for Electric Arc Furnaces in Steel Industry. EPA-450/3-79-033, U.S. Environmental Protection Agency, Research Triangle Park, NC. 50 pp.

The purpose of the document is to review the current New Source Performance Standards for electric arc furnaces in the steel industry and to assess the need for revision on the basis of developments that either have occurred or are expected to occur in the near future. The document provides descriptions of control technologies and their effectiveness as well as a discussion of the furnaces and their emissions.

Office of Air Quality Planning and Standards, U.S. Environmental Protection Agency. 1982. Revised Standards for Basic Oxygen Process Furnaces - Background Information for Proposed Standards. EPA-450/3-82-005a, PB83166488, U.S. Environmental Protection Agency, Triangle Park, NC. 361 pp.

Discusses New Source Performance Standard for secondary emissions from basic oxygen process furnace steelmaking shops proposed under authority of Section 111 of the Clean Air Act. This document contains sections on emissions and control technology.

Spawn, P., and M. Jasinski. 1983. Envirotech/Chemico Pushing Emissions Control System Analysis. EPA-340/1-83-019, U.S. Environmental Protection Agency, Washington, DC. 103 pp.

Summarizes a study of the 21 Envirotech/Chemico one-spot, mobile pushing emissions control systems currently installed at coke plants operated by five domestic steel companies. System descriptions and emissions data are included.

Office of Air Quality Planning and Standards, U.S. Environmental Protection Agency. 1983. Electric Arc Furnaces and Argon-Oxygen Decarburization Vessels in Steel Industry - Background Information for Proposed Revisions to Standards. EPA-450/3-82-020a, U.S. Environmental Protection Agency, Research Triangle Park, NC. 398 pp.

Discussions of Standards of Performance for the control of emissions from electric arc furnaces and argon-oxygen decarburization vessels in the steel industry being proposed under authority of Section 111 of the Clean Air Act. Sections on processes, pollutants, costs, emission capture and control technologies are included.

Office of Air Quality Planning and Standards, U.S. Environmental Protection Agency. 1985. Revised Standards for Basic Oxygen Process Furnaces - Background Information for Promulgated Standards. EPA-450/3-82-005b, PB86-145083, U.S. Environmental Protection Agency, Research Triangle Park, NC. 58 pp.

Discusses New Source Performance Standard for secondary emissions of particulate matter from basic oxygen process

furnace (BOPF) steel-making shops being promulgated under authority of Section 111 of the Clean Air Act. This document contains sections on emissions and control technology.

United States Steel Corporation. The Making, Shaping and Treating of Steel, 10th Edition/Latest Technology. Association of Iron and Steel Engineers, Pittsburgh, PA. 1985. 1,511 pp.

Provides information relating to the latest technology and current practices used in making and processing steel.

Fitzgerald, J., J. Jeffery, and P. Wolf. 1986. Metallurgical Coke Industry Particulate Emissions: Source Category Report. EPA/600/7-85-050, PB87-140331, U.S. Environmental Protection Agency, Research Triangle Park, NC. 85 pp.

Presents results of a study to develop particulate emissions factors based on cutoff size for inhalable particles for the metallurgical coke industry. The report includes sections on a description of the industry and emission factors.

Jeffery, J., and J. Vay. 1986. Iron and Steel Industry Particulate Emissions: Source Category Report. EPA/600/7-86-036, PB87-119889, U.S. Environmental Protection Agency, Research Triangle Park, NC. 94 pp.

Presents results of a study to develop particulate emission factors based on cutoff size for inhalable particles for the iron and steel industry. Background information on the industry as well as emission factors are discussed.

LIME PLANTS

Industrial Gas and Cleaning Institute. 1973. Air Pollution Control Technology and Costs in Seven Selected Industries. EPA-450/3-73-010, PB-231757/6, U.S. Environmental Protection Agency, Research Triangle Park, NC. 724 pp.

Industrial Gas Cleaning Institute collected and formalized data on air pollution abatement in the following seven areas: Phosphate Fertilizer Manufacture, Feed & Grain Milling, Soap & Detergent Manufacture, Paint and Varnish Production, The Graphic Arts Industry, Lime Kiln Operation, and Gray Iron Foundry Cupola Operation. Includes process descriptions and information on pollutants, costs, and control technologies.

Office of Air Quality and Performance Standards, Emission Standards and Engineering Division, U.S. Environmental Protection Agency. 1977. Standards Support and Environmental Impact Statement; Volume 1 - Proposed Standards of Performance for Lime Manufacturing Plants. EPA-450/2-77-007a, U.S. Environmental Protection Agency, Research Triangle Park, NC. 328 pp.

Standards of performance for the control of particulate matter emissions from affected facilities at new and modified lime manufacturing plants as proposed under the authority of Sections 111, 114, and 301(a) of the Clean Air Act. Document includes process information, control technologies, costs and economic impacts and test data.

Office of Air Quality and Performance Standards, Emission Standards and Engineering Division, U.S. Environmental Protection Agency. 1977. Standards Support and Environmental Impact Statement; Volume II - Standards of Performance for Lime Manufacturing Plants. EPA-450/2-77-007b, U.S. Environmental Protection Agency, Research Triangle Park, NC. 20 pp.

Appendices for previously described document.

Office of Air Quality Planning and Standards, U.S. Environmental Protection Agency. 1984. Lime Manufacturing Plants - Background Information for Promulgated Standards of Performance. EPA-450/3-84-008, PB84-191543, U.S. Environmental Protection Agency, Research Triangle Park, NC. 45 pp.

Standards of performance for the control of particulate matter emissions from rotary lime kilns at new, modified, or reconstructed lime manufacturing plants promulgated under the authority of Sections 111, 114, and 301(a) of the Clean Air Act, as amended. This report contains an economic impact study.

Kinsey, J.S. 1986. Lime and Cement Industry. Particulate Emissions: Source Category Report; Volume I - Lime Industry. EPA/600/7-86/031, PB87-103628, U.S. Environmental Protection Agency, Research Triangle Park, NC. 284 pp.

Presents results of a study to develop particulate emission factors based on cutoff size for inhalable particles for the lime industry. Process and control technology descriptions are also provided.

MARINE GRAIN TERMINALS

Office of Air Quality Planning and Standards, U.S. Environmental Protection Agency. 1977. Standards Support and Environmental Impact Statement; Volume 1 - Proposed Standards of Performance for the Grain Elevator Industry. EPA-450/2-77-001a, PB80-194152, U.S. Environmental Protection Agency, Research Triangle Park, NC. 321 pp.

Standards of performance to control particulate matter emissions from new and modified grain elevators in the U.S. as proposed under Section 111 of the Clean Air Act. This document includes information on emission control technology and economic impacts.

GCA Corporation. 1984. Emission Factor Development for Ship and Barge Loading of Grain, U.S. Environmental Protection Agency, Research Triangle Park, NC.

METALLIC MINERALS PROCESSING PLANTS

Umlauf, G. & L.G. Wayne. 1977. Emission Factors and Emission Source Information for Primary and Secondary Copper Smelters. EPA-450/3-77-051, PB280377, U.S. Environmental Protection Agency, Research Triangle Park, NC.

Describes procedures and methodology used in obtaining relevant information regarding these industries and the operational characteristics of process equipment used therein. Includes section on process description.

U.S. Environmental Protection Agency. 1978. Environmental Assessment of the Domestic Primary Copper, Lead and Zinc Industries, EPA-600/2-82-066, PB82-230913, Cincinnati, OH.

The report discusses the design, laboratory scale tests, construction, and field test of an improved metal-to-metal seal for coke-oven doors. Includes section on cost study.

Office of Air Quality Planning and Standards, U.S. Environmental Protection Agency. 1982. Metallic Mineral Processing Plants -- Background Information for Proposed Standards; Volume 1: Chapters 1-9. EPA-450/3-81/009a, U.S. Environmental Protection Agency, Research Triangle Park, NC. 488 pp.

This document provides background information and environmental and economic impact assessments of the regulatory alternatives considered in developing the proposed standards of performance for the control of

particulate matter emissions from metallic mineral processing plants.

Office of Air Quality Planning and Standards, U.S. Environmental Protection Agency. 1984. Review of New Source Performance Standards for Primary Copper Smelters; Chapters 1-9. EPA-450/3-83-018a, U.S. Environmental Protection Agency, Research Triangle Park, NC. 579 pp.

Contains background information and environmental and economic assessments considered in arriving at the conclusion that no changes should be made to the existing standard. Discussions on process descriptions, emissions, and control technologies for process and fugitive emissions are included.

Office of Air Quality Planning and Standards, U.S. Environmental Protection Agency. 1984. Review of New Source Performance Standards for Primary Copper Smelters; Appendices. EPA-450/3-83-018b, U.S. Environmental Protection Agency, Research Triangle Park, NC. 150 pp.

Appendices for previously described document.

NONMETALLIC MINERAL PROCESSING PLANTS

Blackwood, T.R., P.K. Chalekode, and R.A. Wachter. 1978. Source Assessment: Crushed Stone. EPA-600/2-78-004L, PB-284-029, U.S. Environmental Protection Agency, Cincinnati, OH. 94 pp.

Describes a study of atmospheric emissions from the crushed stone industry. Includes sections on emissions and control technology.

Chalekode, P.K., J.A. Peters, T.R. Blackwood & S.R. Archer. 1978. Emissions from the Crushed Granite Industry State of the Art. EPA-600/2-78-021, PB-281043, U.S. Environmental Protection Agency, Cincinnati, OH. 68 pp.

Describes a study of atmospheric emissions from the crushed granite industry.

Office of Air Quality Planning and Standards, U.S. Environmental Protection Agency. 1982. Air Pollution Control Techniques for Nonmetallic Minerals Industry, EPA-450/3-82-014, PB83-105064, Research Triangle Park, NC.

Air pollution control technologies for the control of particulate emissions from non-metallic mineral processing plants are evaluated. Includes section on annualized emission control cost.

Office of Air Quality Planning and Standards, U.S. Environmental Protection Agency. 1983. Nonmetallic Mineral Processing Plants - Background Information for Proposed Standards. EPA-450/3-83-001a, U.S. Environmental Protection Agency, Research Triangle Park, NC. 469 pp.

Standards of performance for the control of emissions from non-metallic mineral processing plants as proposed under the authority of Section 111 of the Clean Air Act. Includes section on economic impact.

Office of Air Quality Planning and Standards, U.S. Environmental Protection Agency. 1985. Nonmetallic Mineral Processing Plants - Background Information for Promulgated Standards. EPA-450/3-83-001b, U.S. Environmental Protection Agency, Research Triangle Park, NC. 92 pp.

Standards of performance for the control of particulate matter emissions from nonmetallic mineral processing plants are being promulgated under the authority of Section 111 of the Clean Air Act.

PAINT MANUFACTURING PLANTS

Industrial Gas Cleaning Institute. 1973. Air Pollution Control Technology and Costs in Seven Selected Industries. EPA-450/3-73-010, PB-231757/6, U.S. Environmental Protection Agency, Research Triangle Park, NC. 724 pp.

Industrial Gas Cleaning Institute collected and formalized data on air pollution abatement in the following seven areas: Phosphate Fertilizer Manufacture, Feed & Grain Milling, Soap & Detergent Manufacture, Paint & Varnish Production, The Graphic Arts Industry, Lime Kiln Operation, & Gray Iron Foundry Cupola Operation. Includes process descriptions and information on pollutants, costs, and control technologies.

Dowd, E. 1974. Air Pollution Control Engineering and Cost Study of the Paint and Varnish Industry. EPA-45013-74-031, U.S. Environmental Protection Agency, Research Triangle Park, NC. 442 pp.

Cottrell, H., S. Patel, and N. Falla. 1985. Air Pollution Audits in Industrial Paint Finishing: A Survey of Paint Related Air Pollution Problems in the UK (United Kingdom) Together with Recommended Abatement Methods.

PAINTRA-85/02/XAB, Paint Research Association, Teddington, England. 154 pp.

Monitoring exercises were conducted to determine air pollution problems associated with the industrial paint finishing industry.

PETROLEUM REFINERIES

Burklin, C.E. 1977. Revision of Emission Factors for Petroleum Refining. EPA-450/3-77-030, PB275685, U.S. Environmental Protection Agency, Research Triangle Park, NC. 85 pp.

Presents the results of an in-depth study to revise and update the emission factors and process descriptions presented in AP-42 for the petroleum refining industry. Includes section on controlled emission testing.

Barrett, K., and A. Goldfarb. 1979. A Review of Standards of Performance for New Stationary Sources for Petroleum Refineries. EPA-450/3-79-008, U.S. Environmental Protection Agency, Research Triangle Park, NC. 83 pp.

Reviews the current Standards of Performance for New Stationary Sources: Subpart J - Petroleum Refineries. Includes process information, uncontrolled emission data, achievable emission limits and control technologies.

Wetherold, R.G., and C.D. Smith. 1980. Assessment of Atmospheric Emissions from Petroleum Refining; Volume 2 - Appendix A. EPA-600/2-80-075a-d, U.S. Environmental Protection Agency, Research Triangle Park, NC.

Gives results of a 3-year program to assess the environmental impact of petroleum refining atmospheric emissions.

Office of Air Quality Planning and Standards, U.S. Environmental Protection Agency. 1986. Review of New Source Performance Standards for Petroleum Refinery Fuel Gas. EPA-450/3-86-011, PB87-136966, U.S. Environmental Protection Agency, Research Triangle Park, NC. 87 pp.

As required by Section 111(b) of the Clean Air Act, as amended, a four year review of the New Source Performance Standards for petroleum refineries was conducted. No revisions are recommended. Includes section on control technology.

PHOSPHATE FERTILIZER PLANTS

Industrial Gas Cleaning Institute. 1973. Air Pollution Control Technology and Costs in Seven Selected Industries. EPA-450/3-73-010, PB-231858/6, U.S. Environmental Protection Agency, Research Triangle Park, NC. 724 pp.

Industrial Gas Cleaning Institute collected and formalized data on air pollution abatement in the following seven areas: Phosphate Fertilizer Manufacture, Feed and Grain Milling, Soap & Detergent Manufacture, Paint & Varnish Production, The Graphic Arts Industry, Lime Kiln Operation, and Gray Iron Foundry Cupola Operation. Includes section on cost of pollution control systems.

Office of Air Quality Planning and Standards, U.S. Environmental Protection Agency. 1974. Phosphate Fertilizer Industry - Background Information for Standards of Performance; Volume 1 - Proposed Standards. EPA-450/2-74-019a, PB237606, U.S. Environmental Protection Agency, Research Triangle Park, NC. 148 pp.

Provides background information on the derivation of the standards of performance for the phosphate fertilizer industry. Includes sections on control technology and economic impact.

Office of Air Quality Planning and Standards, U.S. Environmental Protection Agency. 1974. Phosphate Fertilizer Industry - Background Information for Standards of Performance; Volume 2 - Summary of Test Data. EPA-450/2-74-019b, PB237607, U.S. Environmental Protection Agency, Research Triangle Park, NC. 68 pp.

Provides background information on the derivation of the standards of performance for the phosphate fertilizer industry. Includes section on emissions.

Nyers, J.M., G.D. Rawlings, E.A. Mullen, C.M. Moscowitz, and R.B. Reznik. 1979. Source Assessment: Phosphate Fertilizer Industry. EPA/600/2-79/019C, PB-300681/4, Industrial Environmental Research Lab, Research Triangle Park, NC. 203 pp.

Describes a study of air emissions, water effluents, and solid residues resulting from the manufacture of phosphate fertilizers. Includes sections on emissions and control technology.

Office of Air Quality Planning and Standards, U.S. Environmental Protection Agency. 1980. Review of New Source Performance Standards for Phosphate Fertilizer Industry - Revised.

EPA-450/3-79-038R, PB81-122129, U.S. Environmental Protection Agency, Research Triangle Park, NC. 81 pp.

Determines that there is currently insufficient process experience and source test data to recommend New Source Performance Standards revisions at this time. Includes section on control technology.

PHOSPHATE ROCK PROCESSING PLANTS

Augenstein, D. M. 1978. Air Pollutant Control Techniques for Phosphate Rock Processing Industry. EPA-450/3-78-030, U.S. Environmental Protection Agency, Research Triangle Park, NC.

Provides information on the control of particulate emissions from phosphate rock processing plants, including the typical and best demonstrated control techniques, the cost and environmental impacts of several levels of emission control for phosphate rock dryers, calciners, grinders, and ground rock handling systems, regulatory options, and enforcement aspects of potential regulations.

Office of Air Quality Planning and Standards, U.S. Environmental Protection Agency. 1979. Phosphate Rock Plants - Background Information for Proposed Standards. EPA-450/3-79-017, U.S. Environmental Protection Agency, Research Triangle Park, NC.

Standards of Performance for phosphate rock plants are being proposed under the authority of Section 111 of the Clean Air Act. Emission Control Technologies, Environmental Impacts,and Economic Impacts are presented.

Office of Air Quality Planning and Standards, U.S. Environmental Protection Agency. 1979. Phosphate Rock Plants - Background Information; Volume 1 - Proposed Standards. EPA-450/3-79-017a, U.S. Environmental Protection Agency, Research Triangle Park, NC. 375 pp.

Standards of Performance for the control of emissions from phosphate rock plants as proposed under the authority of Section 111 of the Clean Air Act. Process descriptions, emission control technologies, economic impacts, and test data are presented.

Office of Air Quality Planning and Standards, U.S. Environmental Protection Agency. 1982. Phosphate Rock Plants - Background Information for Promulgated Standards. EPA-450/3-79-017b, PB82-200460, U.S. Environmental Protection Agency, Research Triangle Park, NC. 49 pp.

Standards of performance for the control of particulate and visible emissions from phosphate rock plants promulgated under the authority of Section 111 of the Clean Air Act.

PLYWOOD, PARTICLE BOARD AND WAFERBOARD PLANTS

Pullman College of Engineering, Washington State University. 1972. Investigation of Emissions from Plywood Veneer Dryers (Revised Final Report). APTD-1144, PB-210583, Washington State University, WA. 141 pp.

The emissions from thirteen plywood dryers drying ten different species types were studied. Includes section on emissions.

Office of Air Quality Planning and Standards, U.S. Environmental Protection Agency. 1983. Control Techniques for Organic Emissions from Plywood Veneer Dryers. EPA-450/3-83-012, PB83-228247, U.S. Environmental Protection Agency, Research Triangle Park, NC. 113 pp.

Summarizes information gathered by the U.S. Environmental Protection Agency on the control of emissions from softwood plywood manufacturing. Includes sections on control technology and costs of controls. The emissions from thirteen plywood dryers drying ten different species types were studied. Includes section on emissions.

PORTLAND CEMENT PLANTS

Barrett, K.W. 1978. A Review of Standards of Performance for New Stationary Sources for Portland Cement Industry. EPA-450/3-79-012, PB80-112084, U.S. Environmental Protection Agency, Research Triangle Park, NC. 83 pp.

Reviews the current Standards of Performance for New Stationary Sources: Subpart F - Portland Cement Plants. Includes sections on control technologies and emissions.

Office of Air Quality Planning and Standards, U.S. Environmental Protection Agency. 1985. Portland Cement Plants - Background Information for Proposed Revisions to Standards. EPA 450/3-85-003a, PB86-100476, U.S. Environmental Protection Agency, Research Triangle Park, NC. 125 pp.

Contains a summary of the information gathered during the review of this New Source Performance Standard.

Kinsey, J.S. 1987. Lime & Cement Industry Particulate Emissions: Source Category Report; Volume II - Cement Industry. EPA 600/7-87/007, PB87-168654, U.S. Environmental Protection Agency, Research Triangle Park, NC. 410 pp.

Gives results of the development of particulate emission factors based on cutoff size for inhalable particles for the cement industry. Includes a process description.

Office of Air Quality Planning and Standards, U.S. Environmental Protection Agency. 1988. Portland Cement Plants - Background Information for Promulgated Revisions to Standards. EPA-450/3-85-003b, PB89-135966, U.S. Environmental Protection Agency, Research Triangle Park, NC. 64 pp.

Contains revisions to the monitoring, recordkeeping, and reporting requirements associated with standards of performance for portland cement plants.

PRIMARY ALUMINUM REDUCTION FACILITIES

Office of Air Quality Planning and Standards, U.S. Environmental Protection Agency. 1974. Primary Aluminum Plants - Background Information for Standards of Performance; Volume 1 - Proposed Standards. EPA-450/2-74-020a, U.S. Environmental Protection Agency, Research Triangle Park, NC. 122 pp.

Presents the proposed standards and the rationale for the degree of control selected.

Office of Air Quality Planning and Standards, U.S. Environmental Protection Agency. 1974. Primary Aluminum Plants - Background Information for Standards of Performance; Volume 2 - Summary of Test Data. EPA-450/2-74-020b, U.S. Environmental Protection Agency, Research Triangle Park, NC. 48 pp.

Presents the proposed standards and the rationale for the degree of control selected. This document includes section on economic impact.

Office of Air Quality Planning and Standards, U.S. Environmental Protection Agency. 1976. Primary Aluminum Industry - Background Information for Standards of Performance; Volume 3 - Supplemental Information. EPA 450/2-74-020c, U.S. Environmental Protection Agency, Research Triangle Park, NC. 50 pp.

Includes comments in response to the proposed regulation and EPA responses to these comments, updated economic impact information, and a discussion of problems encountered with the analytical method for sampling emissions.

Emission Standards and Engineering Division, U.S. Environmental Protection Agency. 1978. Background Information for Proposed Amendments to the New Source Performance Standard for the Primary Aluminum Industry. EPA-450/2-78-025a, PB82-242611, U.S. Environmental Protection Agency, Research Triangle Park, NC. 65 pp.

Supplements information contained in the preamble to proposed amendments for the New Source Performance Standard for the primary aluminum industry. Includes sections on emissions and cost.

Office of Air Quality Planning and Standards, U.S. Environmental Protection Agency. 1980. Primary Aluminum - Background Information for Promulgated Amendments. EPA 450/3-79-026, PB80-192479, U.S. Environmental Protection Agency, Research Triangle Park, NC. 26 pp.

Summarizes and responds to comments submitted by the public on the proposed amendments to the standards of performance for new primary aluminum plants. Includes section on economic impact.

Office of Air Quality Planning and Standards, U.S. Environmental Protection Agency. 1986. Review of New Source Performance Standards for Primary Aluminum Reduction Plants. EPA 450/3-86-010, PB87-131637/AS, U.S. Environmental Protection Agency, Research Triangle Park, NC. 121 pp.

Presents a summary of the current standards, the status of current applicable control technology, and the ability of the plants to meet the standards.

PULP MILLS

Office of Air Quality Planning and Standards, U.S. Environmental Protection Agency. 1973. Atmospheric Emissions from the Pulp and Paper Manufacturing Industry. EPA-450/1-73-002, PB227181, U.S. Environmental Protection Agency, Research Triangle Park, NC. 120 pp.

Contains information on the nature and quantities of the atmospheric emissions from chemical pulping operations, principally the Kraft process. Includes sections on control techniques and emissions.

EKONO, Inc. 1976. Environmental Pollution Control in the Pulp and Paper Industry - Part I/Air. EPA-625/7-76-001, PB261708, U.S. Environmental Protection Agency, Cincinnati, OH.

Describes types, quantities, and sources of emissions presenting the latest control device alternatives, and estimates costs for implementing the air pollution control systems.

Office of Air Quality Planning and Standards, U.S. Environmental Protection Agency. 1976. Standard Support and Environmental Impact Statement; Volume 1 - Proposed Standards of Performance for Kraft Pulp Mills. EPA-450/2-76-014a. U.S. Environmental Protection Agency, Research Triangle Park, NC. 398 pp.

Standards of performance for the control of emissions of total reduced sulfur and particulate matter from new and modified kraft pulp mills as proposed under the authority of Section 111 of the Clean Air Act. Discussions on processes, control technologies, emission data, and economic impacts are included.

Office of Air Quality Planning and Standards, U.S. Environmental Protection Agency. 1977. Standard Support and Environmental Impact Statement; Volume II - Promulgated Standards of Performance for Kraft Pulp Mills. EPA-450/2-76-014b, PB278160, U.S. Environmental Protection Agency, Research Triangle Park, NC. 47 pp.

Standards of performance for the control of emissions of total reduced sulfur and particulate matter from new and modified kraft pulp mills promulgated under the authority of Section 111 of the Clean Air Act. Includes sections on emissions and economic effects.

Office of Air Quality Planning and Standards, U.S. Environmental Protection Agency. 1983. Review of New Source Performance Standards for Kraft Pulp Mills. EPA-450/3-83-017, PB84-154798, U.S. Environmental Protection Agency, Research Triangle Park, NC. 82 pp.

Reviews the current New Source Performance Standards for Kraft Pulp Mills. Includes section on control technology.

SECONDARY ALUMINUM REDUCTION FACILITIES

Brookman, E. T. 1978. Screening Study on Feasibility of Standards of Performance for Secondary Aluminum Manufacturing; Volume 1. EPA-450/3-79-037A, PB80-132954, U.S. Environmental Protection Agency, Washington, D.C. 156 pp.

The report contains background information on the secondary aluminum manufacturing industry. This report contains sections on production, processes and control techniques.

Brookman, E. T. 1978. Screening Study on Feasibility of Standards of Performance for Secondary Aluminum Manufacturing; Volume 2. EPA-450/3-79-037B, PB80-161284, U.S. Environmental Protection Agency, Washington, D.C. 214 pp.

Volume 2 of previously described document.

SUGAR PRODUCTION PLANTS

Cuscino, T. A., J. S. Kinsey, R. Hackney, R. Bohn, and R. M. Roberts. 1981. The Role of Agricultural Practices in Fugitive Dust Emissions. PB81-219073, ARB/R-81/138, Air Resources Board, State of California, Sacremento, CA. 264 pp.

The impact of agricultural operations on fugitive dust emissions were quantified for the San Joaquin Valley, the Sacramento Valley, and the Imperial Valley. Thirteen tests were performed to quantify emission factors from discing, land planning & vehicles traveling on unpaved farm roads. Also, six tests were performed to quantify emission factors from sugar beet harvesting.

Baker, R.A., and T. Lahre. 1977. Background Document Bagasse Combustion in Sugar Mills. EPA-450/3-77-007, U.S. Environmental Protection Agency, Research Triangle Park, NC. 45 pp.

Provides support for Section 1.8 of AP-2, Compilation of Air Pollution Emission Factors, Second Edition. It concerns the major criteria pollutants emitted during the combustion of baghouse in steam boilers.

SURFACE MINING OPERATIONS

Axetell, K., and C. Cowherd. 1981. Improved Emission Factors for Fugitive Dust from Western Surface Coal Mining Sources. OSM-242, PB90-177940, Office of Surface Mining Reclamation and Enforcement (DI), Washington, DC. 36 p.

The purpose of the study was to develop emission factors for significant surface coal mining operations that would be applicable to all Western mines and would be based on widely acceptable, state-of-the-art sampling and data analysis procedures.

Axetell, K. Jr., and C. Cowherd Jr. 1989. Improved Emission Factors for Fugitive Dust from Western Surface Coal Mining Sources; Volume 1 - Sampling Method/Test Results. PB90-179474, Office of Surface Mining Reclamation and Enforcement (DI), Washington, DC. 209 pp.

The primary purpose of the study was to develop emission factors for significant surface coal mining operations.

Axetell, K. Jr., and C. Cowherd Jr. 1989. Improved Emission Factors for Fugitive Dust from Western Surface Coal Mining Sources; Volume 2 - Emission Factors. PB90-179482, Office of Surface Mining Reclamation and Enforcement (DI), Washington, DC. 83 pp.

Volume 2 of previously described document.

Beyer, L.E., J.A. Diaper, and R.E. Nickel. 1989. Surface Mining and the Natural Environment: Technical Manual - Phase II. PB90-178856, Office of Surface Mining Reclamation and Enforcement (DI), Washington, DC. 327 pp.

Examines the process of surface mining: its potential impact on the natural environment, reclamation, and pollution control technologies used to minimize these impacts.

Office of Air Quality Planning and Standards, U.S. Environmental Protection Agency. 1989. Emission Factors and Control Technology for Fugitive Dust from Mining Sources/3rd Draft. PB90-177957, Office of Surface Mining Reclamation and Enforcement (DI), Washington, DC. 25 pp.

TURBINES (OIL-FIRED)

Shih, C.C., J.W. Hamersma, D.G. Ackerman, R.G. Beimer, M.L. Kraft, and M.M. Yamada. 1979. Emissions Assessment of Conventional Stationary Combustion Systems; Volume II - Internal Combustion Sources. EPA-600/7-79-029c, PB296390, U.S. Environmental Protection Agency, Research Triangle Park, NC. 239 pp.

Gives results of an assessment of emissions from gas - and oil-fueled gas turbines and reciprocating engines for electricity generation and industrial applications.

SECTION 4

ACHIEVABLE EMISSION LIMITS

INTRODUCTION

This Section discusses the most stringent mass and visible emission limits that can be routinely achieved for the source categories that are listed in Section 1. The most stringent achievable emission limits were determined by reviewing Federal and state regulations as well as available total particulate matter (PM) emissions test data. The achievable emission limits that are presented in this Section should be used as guidelines in determining RACT limit for particular sources.

Most states have not adopted limits specifically for PM-10. For this reason, the most stringent emission limits that are presented in the Section are for total PM. A suggested procedure to estimate an equivalent PM-10 emission limit is described in Section 2 (see page 2-5).

This Section is not intended to serve as a replacement for a review of applicable Federal and state regulations for a specific facility. The regulations cited here as the "most stringent" must be examined to determine their applicability to the particular facility being evaluated with respect to operating conditions, location, or other unique circumstances that may apply.

The format of the total PM emission limitations varies widely from state to state. The most common formats include:

- Concentration - mg/dscm (gr/dscf), which may also be corrected to a specific percent oxygen, carbon dioxide, or excess air.

- Emission rate - kg/hr (lb/hr), which is generally calculated by an equation or obtained from a table based on the production rate or, occasionally, air flow rate.

- Production based rate - kg/Mg (lb/ton) of product or, in the case of fuel burning equipment, ng/J (lb/MMBtu).

For most source categories, it was impossible to choose a single state with the most stringent total PM emission limitation because of the variety of regulatory formats. Therefore, a

discussion is included with each source category regarding the most stringent total PM emission limitation for each of the regulatory formats. However, the total PM emissions test data in this section are presented in mg/dscm (gr/dscf) or ng/J (lb/MMBtu) because most of the test data are presented in one of these two manners.

The format of visible emissions (VE) limitations also varies widely from state to state. Some states report the allowable limitation as an average, generally a 6-minute average, while other limitations are expressed in terms of an aggregate number of opacity readings that may exceed a specific value.

The state emission limits were determined by reviewing the state air regulations as printed in the Bureau of National Affairs (BNA) Environment Reporter (BNA, 1991a) as of October 25, 1991. Federal emission limits were determined by reviewing the New Source Performance Standards (NSPS) as they appear in the BNA Environment Reporter (BNA, 1991b), also as of October 25, 1991.

In many cases, the most stringent total PM and VE limitations only apply to new or modified sources or sources that are located in a certain area of the state, such as a nonattainment area or certain large metropolitan areas. For the purposes of determining the most stringent regulation, it was assumed that the emission source was located in the area of the state where the most stringent regulations apply.

The definition of new source varies from state to state and frequently even by source category within a state. Many states incorporate the Federal NSPSs into the state regulations, either by reference or by reiterating the emission limitations for the appropriate source categories. In these cases, the state "NSPS regulations" are described in the discussion for a given source category under the Federal NSPS regulations. Also, the time period for state classification of new sources ranges from the 1950's to the 1980's. In other words, a new source in one state may be considered an existing source in another state. Frequently an emission limit that applies to new sources in one state would apply to all sources in another state.

Although RACT, not NSPS, is required for existing sources, emission limits for new sources were included in the review because they are technologically achievable, however, the limits may not be reasonable to achieve in all situations for existing sources. As mentioned above, this section should not be seen as a replacement of a review of the regulations but should be used as a guideline to determine an achievable limit.

Several states have delegated authority to local agencies for implementing air pollution control programs. The most

notable state in this category is California. Local agencies may also have different emission limitations (more stringent) than the state agency emission limitations. Local agency emission limitations were not included in this review. There may also be air pollution operating permit conditions or consent agreements that place stricter standards on sources. It was beyond the scope of this project to review all of these sources of information to determine the most stringent limitation.

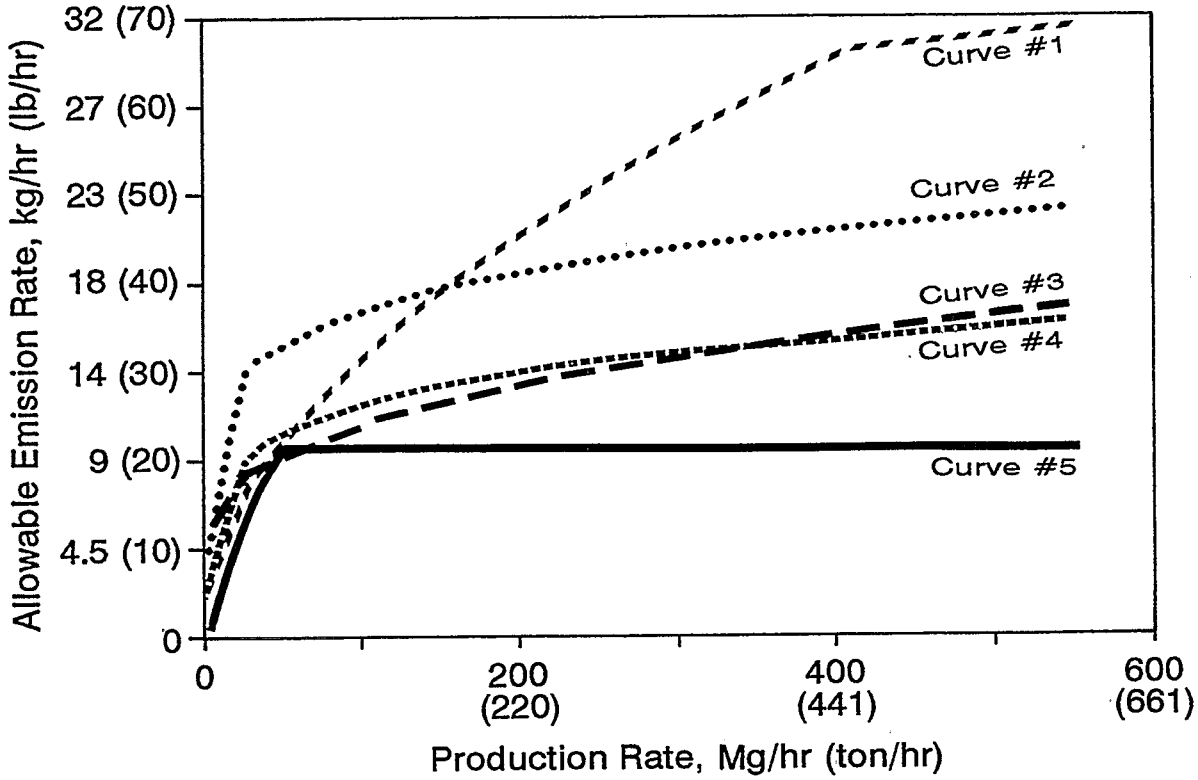
For most of the source categories, the strictest state total PM and VE limitations were determined by reviewing regulations for all fifty states. However, there are source categories that are not located in all fifty states, cotton milling, or iron and steel facilities, for example. For these types of source categories, the regulations were reviewed only for the states that were most likely to have these industries.

The total PM emissions test data for individual source categories were obtained from a variety of sources and are referenced with the discussion of the individual source category. Attempts were made to obtain total PM emissions test data from previous EPA data gathering projects or EPA published documents. The mass emission tests presented in this Section were generally conducted at existing, well-controlled facilities. The total PM emissions test data for an individual source category are by no means all inclusive; the test data are presented only to illustrate examples of emission rates achieved by existing well-controlled facilities.

The discussions in the remainder of this Section are arranged alphabetically by source category as shown on the list on Table 1-1 in Section 1. Each subsection has the following components: 1) most stringent state total PM limitations, 2) state VE limitations, 3) Federal NSPS requirements (if applicable) and 4) total PM emissions test data (if available). The state or states that have been identified as having the strictest regulations are shown in brackets. The discussion on individual source categories is preceded by a brief general discussion of emission rate limitations.

EMISSION RATE LIMITATIONS - GENERAL DISCUSSION

Many states use an equation related to process weight to determine the allowable total PM emission rate in kg/hr (lb/hr). This equation either applies to all industries within their state or to industries not otherwise explicitly regulated. The variable in the equation in almost all cases is the production rate. Figure 4-1 depicts the general curves that produce the most stringent total PM emission limitations. As shown on Figure 4-1, no one curve can be used to determine the most stringent



- - - Curve #1: $E = A(P)^B$; where E is the allowable rate (lb/hr), A is 2.54 for production rates up to 450 ton/hr and 24.8 for production rates > 450 ton/hr, P is production rate (ton/hr), and B is 0.534 for production rates up to 450 ton/hr and 0.16 for production rates > 450 ton/hr [IL].

••••• Curve #2: For production rates < 30 ton/hr: $E = 3.59\ P^{0.62}$; where E is the allowable rate (lb/hr) and P is production rate (ton/hr). For production rates > 30 ton/hr: $E = 17.31\ P^{0.16}$ [many states].

— — Curve #3: For production rates > 9,250 lb/hr: $E = 1.10(PW)^{0.25}$; where E is the allowable rate (lb/hr) and PW is production rate (lb/hr) [ID].

- - - - - Curve #4: For production rates > 30 ton/hr: $E = 0.5(55P^{0.11} - 40)$; where E is the allowable rate (lb/hr) and P is production rate (ton/hr). For production rates < 30 ton/hr: determined from table in state regulations [MA].

——— Curve #5: Applies only to certain operations which undergo a chemical change. Values are from a table in state regulations [WV].

Figure 4-1. Summary of most stringent state total PM emission rate equations.

emission rate limitation because of the change in the equation with production rate. Figure 4-1 is referenced as needed in the individual source category discussions that follow.

ASPHALT AND ASPHLATIC CONCRETE PLANTS

Total PM emission limitations for asphalt concrete plants for all fifty states were reviewed. There is also an applicable NSPS (Subpart I) emission limitation for this source category.

The following is a summary of the most stringent state total PM emissions limitations:

- Concentration - 69 mg/dscm (0.03 gr/dscf) [NY, IN, MD]. Another state [NJ] requires the least restrictive of the following: 1) an emission concentration of less than or equal to 46 mg/dscm (0.02 gr/dscf) with an upper cap of 14 kg/hr (30 lb/hr) or 2) a control efficiency of 99 percent.

- Emission rate - The most stringent emission rate results from the following equation: $A = 0.76(6W)^{0.42}$; where A is the allowable rate (lb/hr) and W is the production rate (ton/hr) [PA].

- Production based rate - 0.05 kg/Mg (0.1 lb/ton) of product [CT].

The most stringent state VE limitation is for certain areas of Maryland which are allowed no VE.

NSPS Subpart I applies to hot mix asphalt facilities that commenced construction or modification after June 11, 1973. Atmospheric total PM discharges can not contain more than 90 mg/dscm (0.04 gr/dscf) or exhibit 20 percent opacity or greater.

Examples of total PM emissions test data from well controlled facilities is summarized below (Fitzpatrick, *et al*, 1991; OAQPS, 1973; OAQPS, 1974a, OAQPS, 1985a):

	Cyclone/Baghouse	Cyclone/Scrubber
Number of tests	13	8
Number of facilities	13	8
Maximum, mg/dscm (gr/dscf)	98.8 (0.043)	94.2 (0.0410)
Minimum, mg/dscm (gr/dscf)	10.1 (0.0044)	28.0 (0.0122)
Average, mg/dscm (gr/dscf)	38.1 (0.0166)	56.9 (0.0248)

BOILERS

For the purposes of this document, utility boilers are defined as a unit with a heat input that is greater than 105 GJ/hr (100 MMBtu/hr), and industrial/commercial boilers as those units with a heat input that is greater than 0.5 GJ/hr (0.5 MMBtu/hr) and less than or equal to 105 GJ/hr (100 MMBtu/hr). Individual states and Federal NSPS regulations may define utility and industrial/commercial boilers differently.

Total PM regulations for all fifty states were reviewed for utility and industrial/commercial boilers burning coal, wood, and residual fuel oil. Many of the state regulations are calculated using an equation with the boiler's rated heat input as a variable. In order to determine the strictest state regulation, a boiler with a heat input of 270 GJ/hr (260 MMBtu/hr) was selected to represent a utility boiler and a boiler with a heat input of 105 GJ/hr (100 MMBtu/hr) was selected to represent an industrial/commercial boiler.

The strictest total PM emission limitations, by type of fuel, are summarized on Table 4-1.

The most stringent state VE limitations are as follows:

- No visible emissions, with exceptions for startup, soot blows, etc. [MD].
- If the emissions can be reasonably controlled, opacity shall not exceed 20% for more than 2 minutes per hour and shall not exceed 40 percent at any time [MA].
- Not greater than or equal to 40 percent at any time and not greater than or equal to 20 percent for 3 or more minutes per hour [NY].

NSPS Subparts D, Da, Db, and Dc apply to boilers. Subpart D applies to fossil fuel-fired units that are greater than 264 GJ/hr (250 MMBtu/hr) on which construction or modifications commenced after August 17, 1971. The total PM emission limitation is 43 ng/J (0.10 lb/MMBtu) and opacity can not exceed 20 percent except for one 6-minute period per hour when it can not exceed more than 27 percent.

Subpart Da applies to electric utility steam generating units that are greater than 264 GJ/hr (250 MMBtu/hr) that commenced construction or modification after September 18, 1978. The total PM emission limitation is 13 ng/J (0.03 lb/MMBtu). VE shall not exceed 20 percent except for one 6-minute period per hour which can not exceed 27 percent opacity.

TABLE 4-1. SUMMARY OF STRICTEST TOTAL PM EMISSIONS LIMITATIONS FOR BOILERS

	Utility[a] Boiler	Industrial/Commercial[b] Boiler
Coal		
Concentration	69 mg/dscm (0.03 gr/dscf) [MD]	114 mg/dscm[c] (0.05 gr/dscf) [AK, ID, MD]
Emission rate	Calculated using the following equation for steam generating units: A = 0.05 x I; where I is heat input in MMBtu/hr and A is the allowable rate in lb/hr [WV]	Calculated using the following equation for non-steam generating units: A = 0.09 x I; where I is heat input in MMBtu/hr and A is the allowable rate in lb/hr [WV]
Production-based rate	22 ng/J (0.05 lb/MMBtu) [ME, MA, NM]	43 ng/J (0.10 lb/MMBtu) [IL, MA, MI, MN, WY]
NSPS	13 ng/J (0.03 lb/MMBtu)	22 ng/J (0.05 lb/MMBtu)
Residual Oil		
Concentration	46 mg/dscm (0.020 gr/dscf) [MD]	46 mg/dscm (0.020 gr/dscf) [MD]
Emission rate	Calculated using the following equation for steam generating units: A = 0.05 x I; where I is heat input in MMBtu/hr and A is the allowable rate in lb/hr [WV]	Calculated using the following equation for non-steam generating units: A = 0.09 x I; where I is heat input in MMBtu/hr and A is the allowable rate in lb/hr [WV]
Production-based rate	13 ng/J (0.03 lb/MMBtu) [NM]	34 ng/J (0.08 lb/MMBtu) [ME]

(Continued)

TABLE 4-1. (CONTINUED)

		Utility[a] Boiler	Industrial/Commercial[b] Boiler
	NSPS	13 ng/J (0.03 lb/MMBtu)	43 ng/J (0.10 lb/MMBtu)
Wood			
	Concentration	69 mg/dscm (0.03 gr/dscf) [MD]	69 mg/dscm (0.05 gr/dscf) [AK, MD]
	Emission rate	Calculated using the following equation for steam generating units: A = 0.05 x I; where I is heat input in MMBtu/hr and A is the allowable rate in lb/hr [WV]	Calculated using the following equation for non-steam generating units: A = 0.09 x I; where I is heat input in MMBtu/hr and A is the allowable rate in lb/hr [WV]
	Production-based rate	26 ng/J (0.06 lb/MMBtu) [ME]	34 ng/J (0.08 lb/MMBtu) [ME]
	NSPS	13 ng/J (0.10 lb/MMBtu)	43 ng/J (0.10 lb/MMBtu)

[a]Utility boiler is represented by a unit with a rated heat input of 270 GJ/hr (260 MMBtu/hr).
[b]Industrial/commercial boiler is represented by a unit with a rated heat input of 105 GJ/hr (100 MMBtu/hr).
[c]Corrected to 8 percent oxygen in Idaho.

NSPS Subpart Db applies to industrial, commercial, and institutional steam generating units that are greater than 105 GJ/hr (100 MMBtu/hr) and commenced construction or modification after June 19, 1984. For facilities burning coal, the total PM emission limitation is 22 ng/J (0.05 lb/MMBtu). Oil-fired and wood-fired units are limited to 43 ng/J (0.10 lb/MMBtu). Visible emission shall not exceed 20 percent except for one 6-minute period per hour which shall not exceed 27 percent.

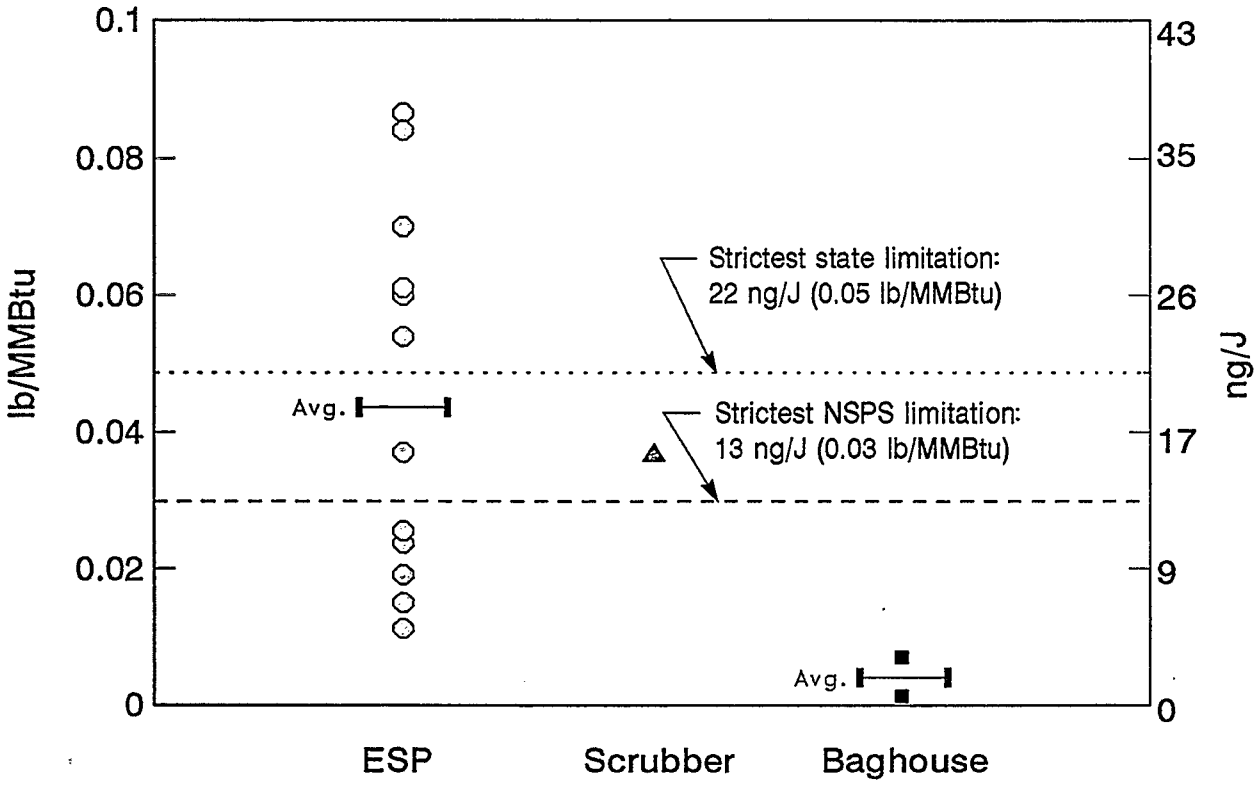
Subpart Dc applies to small industrial, commercial, and institutional steam generating units that commenced construction or modification after June 9, 1989. For coal-fired units that are greater than or equal to 32 GJ/hr (30 MMBtu/hr) and less than or equal to 105 GJ/hr (100 MMBtu/hr), the total PM emission limit is 22 ng/J (0.05 lb/MMBtu). The limit for wood-fired boilers in the same size range is 43 ng/J (0.10 lb/MMBtu). Opacity for coal oil, and wood-fired units shall not exceed 20 percent except for one 6-minute period per hour which shall not exceed 27 percent.

Examples of total PM emissions data for coal-fired utility boilers are depicted on Figure 4-2. (Fitzpatrick, *et al*, 1991). Data for wood-fired boilers is summarized below (Fitzpatrick, *et al*, 1991. All boilers are greater than 105 GJ/hr (100 MMBtu/hr).

	Wood-Fired Boilers		
	Multiclones/ electro-scrubber	Cyclone/ wet scrubber	Baghouse
Number of tests	1	5	1
Number of facilities	1	5	1
Maximum, ng/J (lb/MMBtu)	12.0 (0.028)	42 (0.098)	4.3 (0.01)
Minimum, ng/J (lb/MMBtu)	12.0 (0.028)	15.1 (0.035)	4.3 (0.01)
Average, ng/J (lb/MMBtu)	12 (0.028)	30.1 (0.07)	4.3 (0.01)

BRICK MANUFACTURING PLANTS

Regulations for all fifty states were reviewed to determine the strictest total PM and visible emissions limitations for brick kilns. The most stringent total PM emissions limitations for brick kilns are:



	ESP	Scrubber	Baghouse
Number of tests	12	1	2
Number of facilities	9	1	2
Maximum, ng/J (lb/MMBtu)	97.9 (0.0865)	84.7 (0.037)	16.0 (0.007)
Minimum, ng/J (lb/MMBtu)	25.6 (0.0112)	84.7 (0.037)	29.7 (0.013)
Average, ng/J (lb/MMBtu)	105.3 (0.046)	84.7 (0.037)	22.9 (0.010)

Figure 4-2. Examples of total PM emissions test data for coal-fired utility boilers.

- Concentration - 69 mg/dscm (0.03 gr/dscf) [FL, MD]. Another state [NJ] requires the least restrictive of the following: 1) an emission concentration of less than of equal to 46 mg/dscm (0.02 gr/dscf) with an upper cap of 14 kg/hr (30 lb/hr) or 2) a control efficiency of 99 percent.

- Emission rate - The emission limitation varies by production rate; refer to Figure 4-1.

The most stringent state VE limitation is for certain areas of Maryland which are allowed no VE.

CALCINERS

Regulations for all fifty states were reviewed to determine the most stringent total PM and VE limitations for calciners. The most stringent total PM regulations are as follows:

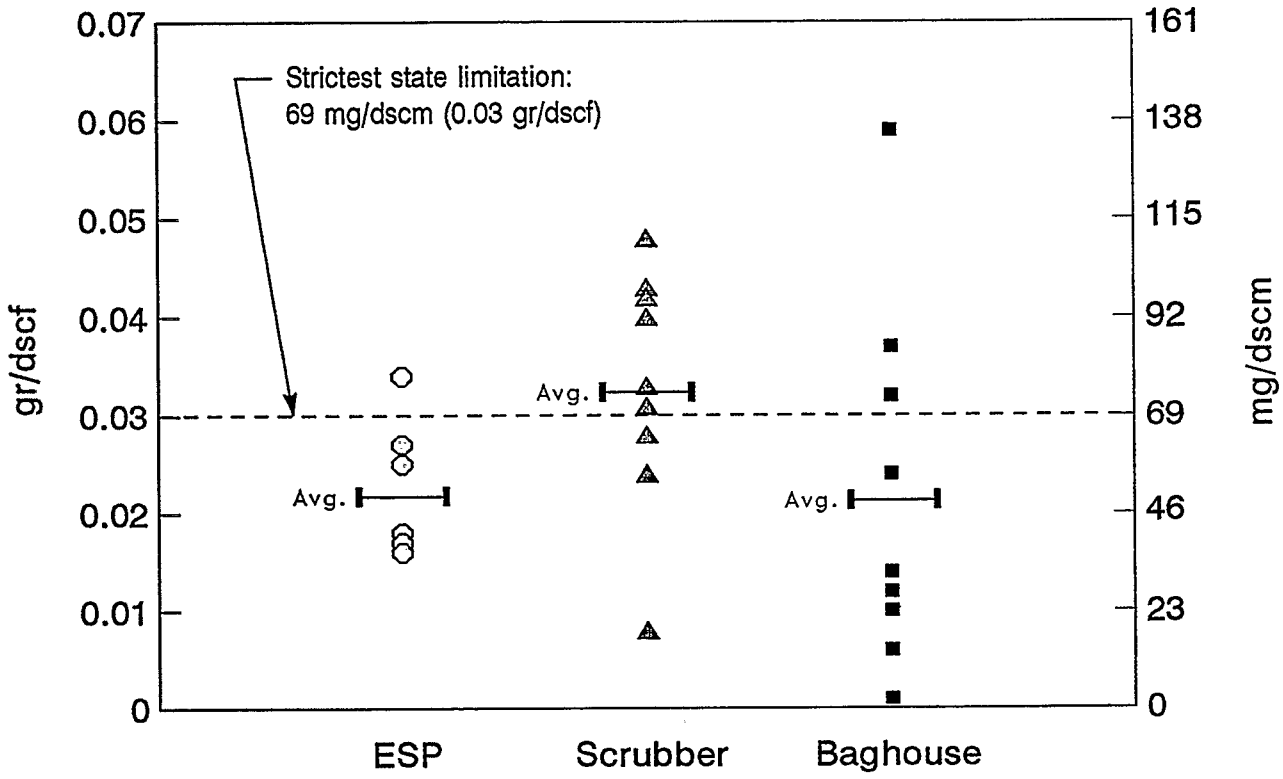
- Concentration - 69 mg/dscm (0.03 gr/dscf) [MD, FL]. Another state [NJ] requires the least restrictive of the following: 1) an emission concentration of less than of equal to 46 mg/dscm (0.02 gr/dscf) with an upper cap of 14 kg/hr (30 lb/hr) or 2) a control efficiency of 99 percent.

- Emission rate - The most stringent emission rate for a 18 Mg/hr (20 ton/hr) calciner is calculated by the following equation: A = 0.62 P; where A is the allowable rate in lb/hr and P is production rate in ton/hr [NV]. This regulation has a maximum allowable emission rate of 4.8 kg/hr (10.50 lb/hr). This regulation applies specifically to calciners at colemanite flotation processing plants. Refer to Figure 4-1 for the most stringent limitation for other calciners.

The most stringent state opacity standard is for certain areas of Maryland which are allowed no visible emissions.

NSPS Subpart NN applies to calciners at phosphate rock plants. The standards will be discussed in the subsection on phosphate rock processing plants.

Available total PM emissions test data for calciners is summarized on Figure 4-3 (Fitzpatrick, *et al*, 1991; OAQPS, 1985b).



	ESP	Scrubber	Baghouse
Number of tests	7	9	9
Number of facilities	5	9	8
Maximum, mg/dscm (gr/dscf)	77.8 (0.034)	109.8 (0.048)	135.0 (0.059)
Minimum, mg/dscm (gr/dscf)	36.6 (0.016)	18.3 (0.008)	2.3 (0.001)
Average, mg/dscm (gr/dscf)	50.3 (0.022)	75.5 (0.033)	50.3 (0.022)

Figure 4-3. Examples of total PM emissions test data for calciners.

CHARCOAL PLANTS

Regulations in all fifty states for charcoal plants were reviewed. The strictest total PM emissions standards are:

- Concentration - 69 mg/dscm (0.03 gr/dscf) [FL, MD]. Another state [NJ] requires the least restrictive of the following: 1) an emission concentration of less than of equal to 46 mg/dscm (0.02 gr/dscf) with an upper cap of 14 kg/hr (30 lb/hr) or 2) a control efficiency of 99 percent.

- Emission rate - Varies by production rate; refer to Figure 4-1.

The most stringent VE limitation is 0 percent [MD].

CHEMICAL MANUFACTURING PLANTS

Regulations were reviewed for all fifty states to determine the strictest total PM and opacity emission limitations for reactors, blenders, and mixers at chemical manufacturing plants. The most stringent general total PM emissions limitations are as follows:

- Concentration - 69 mg/dscm (0.03 gr/dscf)[FL, MD]. Another state [NJ] requires the least restrictive of the following: 1) an emission concentration of less than of equal to 46 mg/dscm (0.02 gr/dscf) with an upper cap of 14 kg/hr (30 lb/hr) or 2) a control efficiency of 99 percent.

- Emission rate - For an operation that results in a chemical change in the material of origin, the most stringent mass regulation is a value that varies by production rate that is determined from Curve 5 on Figure 4-1 [WV]. For a operation that involves a physical change in the material of origin, refer to Figure 4-1.

The most stringent VE limitation is 0 percent opacity [MD].

COAL PREPARATION AND CLEANING PLANTS

Regulations for all fifty states were reviewed to determine the most stringent total PM and opacity limitations for coal preparation and cleaning plants. A Federal NSPS also applies to this source category.

The most stringent state total PM emission limitations for thermal coal dryers are:

- Concentration - 69 mg/dscm (0.03 gr/dscf) [FL, MD]. Also, several states have a similar limitation of 70 mg/dscm (0.031 gr/dscf) [AZ, KY, and MN]. Another state [NJ] requires the least restrictive of the following: 1) an emission concentration of less than of equal to 46 mg/dscm (0.02 gr/dscf) with an upper cap of 14 kg/hr (30 lb/hr) or 2) a control efficiency of 99 percent.

- Emission rate - The most stringent emission rate is calculated using the following equation: $A = 0.76(2W)^{0.42}$; where A is the allowable emission rate (lb/hr) and W is production rate (ton/hr) [PA].

The most stringent state total PM regulations for pneumatic coal-cleaning equipment (air tables) are:

- Concentration - 40 mg/dscm (0.018 gr/dscf) [AZ, KY, MN].

- Emission rate - The most stringent emission rate is calculated using the following equation: $A = 0.76(2W)^{0.42}$; where A is the allowable emission rate (lb/hr) and W is production rate (ton/hr) [PA].

The most stringent state opacity limitation is 0 percent [MD]. Fugitive emissions are also limited to none [PA].

NSPS Subpart Y applies to coal preparation plants which process more than 181 Mg/day (200 ton/day) and were constructed or modified after October 24, 1974. The total PM limitation for thermal dryers shall not exceed 70 mg/dscm (0.031 gr/dscf) and 20 percent opacity or greater. Total PM emissions from pneumatic coal-cleaning equipment shall not exceed 40 mg/dscm (0.018 gr/dscf) and 10 percent opacity or greater. Coal processing and conveying equipment, coal storage systems, and coal transfer and loading systems shall not discharge 20 percent opacity or greater.

Total PM emissions data from three pneumatic coal-cleaning facilities equipped with baghouses ranges from 11 to 123 mg/dscm (0.005 to 0.0536 gr/dscf) with an average of 50 mg/dscm (0.022 gr/dscf. (Fitzpatrick, *et al* 1991; OAQPS, 1974b). Total PM emissions data from six facilities with thermal dryers controlled with multiclones and scrubbers ranged from 29 to 75 mg/dscm (0.0128 to 0.0327 gr/dscf) with an average concentration of 47 mg/dscm (0.0204 gr/dscf) (OAQPS, 1974b).

CONCRETE BATCH PLANTS

Total PM and visible emissions limitations for all fifty states were reviewed to determine the strictest limitations for concrete batch plants. The most stringent total PM emissions limitations are as follows:

- Concentration - 69 mg/dscm (0.03 gr/dscf) [FL, MD]. Another state [NJ] requires the least restrictive of the following: 1) an emission concentration of less than of equal to 46 mg/dscm (0.02 gr/dscf) with an upper cap of 14 kg/hr (30 lb/hr) or 2) a control efficiency of 99 percent.

- Emission rate - the most stringent standard depends on production rate; see Figure 4-1 for a graphical illustration of the standards.

- Production-based rate - 11.9 g/m^3 (0.021 lb/yd^3) concrete.

Visible emissions are limited to 0 percent [MD].

COTTON SEED MILLING PLANTS

State regulations for Alabama, Arizona, Arkansas, Georgia, Louisiana, Mississippi, Oklahoma, South Carolina, Tennessee, and Texas were reviewed to determine the most stringent total PM and opacity limitations for cotton seed milling.

State regulations are all expressed as an emission rate which varies by production rate. The strictest total PM emission rate limitations can be determined as follows.

- For operations less than 1.4 Mg/hr (3,000 lb/hr): $A = 3.12P^{0.985}$; where A is the allowable rate (lb/hr) and P is production rate (ton/hr) [AL, TX].

- For operations between 1.4 and 27 Mg/hr (3,000 and 60,000 lb/hr): $A = 3.59P^{0.62}$; where A is the allowable rate (lb/hr) and P is production rate (ton/hr) [TN].

- For operations between 27 and 36 Mg/hr (60,000 and 80,000 lb): $A = 17.31P^{0.16}$; where A is the allowable rate (lb/hr) and P is production rate (ton/hr) [TN]

- For operations above 36 Mg/hr (80,000 lb/hr): 14.6 kg/hr (31.2 lb/hr) [SC].

The strictest state VE standard states that opacity shall not be greater than equal to 20 percent after any manufacturing process [AR]. Another state stipulates the VE shall not exceed 20 percent for more than an aggregate of 5 minutes per hour and not more than 20 minutes per 24 hours [TN].

FOUNDRIES

Regulations for all fifty states were reviewed to determine the most stringent total PM and VE standards for grey iron foundries, aluminum foundries, and steel shredders.

The most stringent total emission standards for grey iron foundries are as follows:

- Concentration - 50 mg/dscm (0.022 gr/dscf) [NH]. Another state [NJ] requires the least restrictive of the following: 1) an emission concentration of less than of equal to 46 mg/dscm (0.02 gr/dscf) with an upper cap of 14 kg/hr (30 lb/hr) or 2) a control efficiency of 99 percent.

- Emission rate - For operations greater than 41 Mg/hr (45 ton/hr), the most stringent emission rate is calculated by the following equation: $A = 1.10(PW)^{0.25}$; where A is the allowable rate (lb/hr) and PW is production rate (lb/hr) [ID]. For operations less than 41 Mg/hr (45 ton/hr) the most stringent allowable rate is calculated as follows: $E = 2.54\ (P)^{0.534}$, where E is allowable rate (lb/hr) and P is production rate (ton/hr) [IL].

- Production-based rate - 0.85 kg/Mg (1.7 lb/ton) of iron or a 90 percent reduction.

Total PM emission test data is available for nine grey iron facilities equipped with baghouses. The average results are 14.9 mg/dscm (0.0065 gr/dscf) with a range of 5.5 to 58.8 mg/dscm (0.0024 to 0.0257 gr/dscf) (Fennelly, 1978; Fitzpatrick, *et al*, 1991).

The strictest total PM emission limitations for aluminum foundries and shredders are as follows:

- Concentration - 69 mg/dscm (0.03 gr/dscf) [FL, MD]. Another state [NJ] requires the least restrictive of the following: 1) an emission concentration of less than of equal to 46 mg/dscm (0.02 gr/dscf) with an

upper cap of 14 kg/hr (30 lb/hr) or 2) a control efficiency of 99 percent.

- Emission rate - Allowable rates varies by production rate; refer to Figure 4-1.

The most stringent state opacity standard for foundries is 0 percent [MD].

GLASS MANUFACTURING PLANTS

Regulations for all fifty states were reviewed to determine the most stringent total PM emissions and opacity regulations. A Federal NSPS also applies to this source category.

The most stringent state total PM emission regulations are as follows:

- Concentration - 69 mg/dscm (0.03 gr/dscf) for production rates greater than 45 Mg/hr (50 ton/hr) [NY].

- Emission rate - Allowable emission rates vary by production rate; refer to Figure 4-1.

- Process-based rate - 0.65 kg/Mg (1.3 lb/ton) of glass for gas-fired furnaces or 0.75 kg/Mg (1.5 lb/ton) of glass for oil-fired furnaces [FL]. For glass container furnaces, the standard is 1.0 g/2.0 Kg (1.0 lb/ton) of process material [IN].

The most stringent state opacity standard is 0 percent [FL, MD].

NSPS Subpart CC applies to glass melting furnaces that are designed to produce more than 4,550 kg/day (5 ton/day) of glass that commenced construction or modification after June 15, 1979. The standards are summarized on Table 4-2.

Figure 4-4 presents available total PM test data for controlled glass furnaces (Fitzpatrick, *et al*, 1991; OAQPS, 1980).

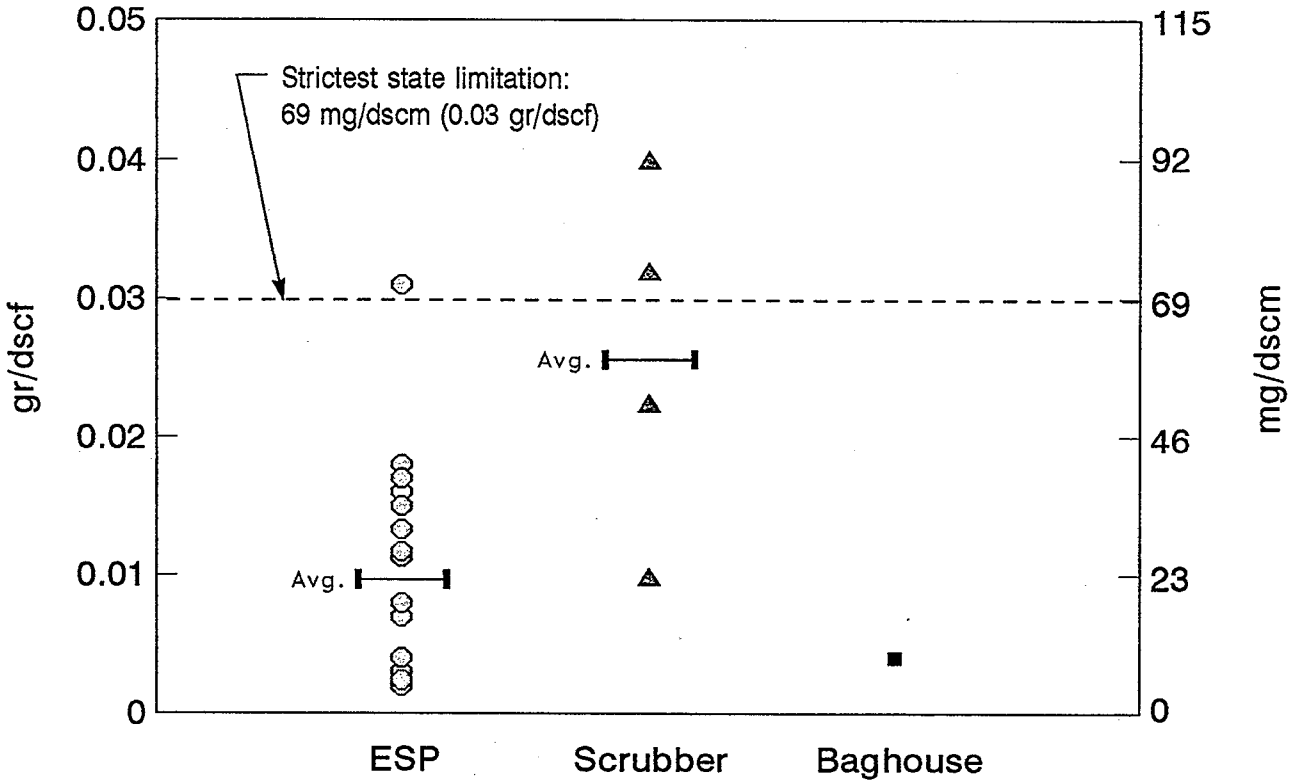
GRAIN MILLING OPERATIONS

Regulations for 45 states (Alaska, Nevada, New Hampshire, West Virginia and Wyoming were not included) were reviewed to determine the strictest standards for grain milling operations. Marine grain terminals are discussed in a later subsection.

TABLE 4-2. SUMMARY OF NSPS SUBPART CC TOTAL PM EMISSIONS LIMITATIONS FOR GLASS MELTING FURNACES IN g/kg (lb/ton) OF PRODUCT

Industry segment	Gaseous fuel-fired	Liquid fuel-fired	Furnaces w/modified processes[a]
Container Glass	0.1 (0.2)	0.13 (0.26)	0.5 (1.0)
Pressed and blown glass			
a) borosilicate recipes	0.5 (1.0)	0.65 (1.30)	1.0 (2.0)
b) soda-lime and lead recipes	0.1 (0.2)	0.13 (0.26)	0.5 (1.0)
c) other than borosilicate, soda-lime and lead recipes	0.25 (0.5)	0.325 (0.65)	- -
Wool fiberglass	0.25 (0.50)	0.325 (0.65)	0.5 (1.0)
Flat glass	0.225 (0.45)	0.225 (0.45)	0.5 (1.0)

[a]Modified processes are any technique that is designed to minimize emissions without add-on air pollution controls.



	ESP	Scrubber	Baghouse
Number of tests	16	4	1
Number of facilities	12	3	1
Maximum, mg/dscm (gr/dscf)	70.9 (0.031)	91.5 (0.040)	9.2 (0.004)
Minimum, mg/dscm (gr/dscf)	4.6 (0.002)	22.9 (0.010)	9.2 (0.004)
Average, mg/dscm (gr/dscf)	25.2 (0.011)	59.5 (0.026)	9.2 (0.004)

Figure 4-4. Examples of total PM emissions test data for glass furnaces.

The strictest state total PM emission standards are as follows:

- Concentration - 69 mg/dscm (0.03 gr/dscf) [FL]. Another state [NJ] requires the least restrictive of the following: 1) an emission concentration of less than of equal to 46 mg/dscm (0.02 gr/dscf) with an upper cap of 14 kg/hr (30 lb/hr) or 2) a control efficiency of 99 percent.

- Emission rate - Varies by production rate; refer to Figure 4-1. However, Curve 1 of this figure does not apply.

- Production-based rate - For rice mills: 0.75 kg/Mg (1.5 lb/ton) [AR].

- Other - Discharge gases from grain-drying installations must pass through a 707 μm (24 mesh) screen or equivalent.

The most stringent state opacity standard is 0 percent [FL, MD].

Total PM emissions test data from two grain milling operations equipped with baghouses show concentrations of 10.3 mg/dscm (0.0045 gr/dscf) and 15.3 mg/dscm (0.0067 gr/dscf) (Fitzpatrick *et al*, 1991; Shannon, 1974).

GYPSUM PRODUCT MANUFACTURING AND PROCESSING PLANTS

State regulations for all states except Alabama, Hawaii, Maine, Montana, North Dakota and South Dakota were reviewed to determine the strictest state emission limitations for gypsum operations. NSPS Subpart 000 (nonmetallic mineral processing plants) applies to this source category; a discussion of Subpart 000 appears under the Nonmetallic Mineral Plants subsection.

The most stringent state total PM emission limitations are as follows:

- Concentration - 69 mg/dscm (0.03 gr/dscf) [FL, MD, and NY for production rates greater than 45 Mg/hr (50 ton/hr)]. Another state [NJ] requires the least restrictive of the following: 1) an emission concentration of less than of equal to 46 mg/dscm (0.02 gr/dscf) with an upper cap of 14 kg/hr (30 lb/hr) or 2) a control efficiency of 99 percent.

- Emission rate - Refer to Figure 4-1; the allowable emission rate varies by production rate.

The most stringent state opacity standard is 0 percent [MD].

Examples of total PM test data for varies gypsum operations are summarized below (Fitzpatrick, *et al*, 1991):

Operation	Control device	mg/dscm	(gr/dscf)
Calcining	Baghouse	1.4	(0.0006)
		53.8	(0.0235)
		135	(0.059)
Rock dryer	Baghouse	48.5	(0.0212)
	Cyclone	10.1	(0.0044)
	Cyclone/baghouse	8.9	(0.0039)
Wallboard, sawing	Baghouse	10.5	(0.0046)
		23.8	(0.0104)

INCINERATORS

State regulations for medical waste, agricultural waste, and municipal waste incinerators were reviewed for all fifty states. There is also a NSPS for incinerators.

The most stringent total PM state regulations for medical waste incinerators are as follows:

- Concentration - 34 mg/dscm (0.015 gr/dscf) corrected to seven percent oxygen for facilities accepting waste that was generated off-site [NY]. Several other states have a similarly strict standard, however, the standards go into effect at varying production rates [CO, KY, NM].

- Emission rate - For units greater than or equal to 45 kg/hr (100 lb/hr) and less than 907 kg/hr (2,000 lb/hr) the most stringent limitation is 0.05 kg/100 kg charged (0.10 lb/100 lb charged) [OH]. For units greater than 907 kg/hr (2,000 lb/hr), the emission limit is calculated using the following equation: $E = 40.7 \times 10^{-5} C$ where E is the allowable rate (lb/hr) and C is the dry charge rate (lb/hr).

For municipal waste incinerators the most stringent total PM emission limitation expressed as a concentration is 23 mg/dscm (0.010 gr/dscf) at seven percent oxygen [NY]. The most stringent emission rate limitation is the same as the rates described above under medical waste.

The most stringent total PM concentration limit for agricultural waste incineration is 23 mg/dscm (0.010 gr/dscf) at seven percent oxygen for private solid waste disposal [NY]. There are other states have emission limitations for incineration of specific agricultural wastes, such as wood, peanut and cotton ginning wastes [AL] or manure [MI].

The most stringent state VE limit is zero percent [MD].

NSPS Subparts E and Ea apply to incinerators. Subpart E applies to incinerators with a capacity of more than 45 Mg/day (50 ton/day) that commenced construction or modification after August 17, 1971. The particulate standard for Subpart E is 180 mg/dscm (0.08 gr/dscf) corrected to 12 percent carbon dioxide. Subpart Ea applies to municipal waste combustors with a capacity of greater than 225 Mg/day (250 ton/day) that commenced construction or modification after December 20, 1989. The total PM limitation is 34 mg/dscm (0.015 gr/dscf) corrected to seven percent oxygen. VE cannot exceed 10 percent opacity for Subpart Ea sources.

Examples of total PM test data from medical waste incinerators include data from one facility with a baghouse and a concentration of 2.3 mg/dscm (0.001 gr/dscf) and two facilities with wet scrubbers with concentrations of 46 and 92 mg/dscm (0.020 and 0.040 gr/dscf) (Radian, 1988). Examples of total PM data from municipal waste incinerators are summarized below (Fitzpatrick *et al*, 1991; Helfand, 1979; OAQPS, 1989):

	ESP	Fabric filter
Number of facilities	34	6
Maximum, mg/dscm (gr/dscf)	92 (0.04)	73.2 (0.032)
Minimum, mg/dscm (gr/dscf)	4.6 (0.002)	9.2 (0.004)
Average, mg/dscf (gr/dscf)	31 (0.0137)	34 (0.0148)

IRON AND STEEL FACILITIES

The stack test data presented in this section is from the Listing of Iron and Steel Stack Test Reports (Fitzpatrick, 1986) and the Iron and Steel Stack Test Library (JACA, 1991) that is associated with this listing. The library contains approximately 800 stack test reports or summaries of reports and has been compiled under various EPA contracts over the past 12 years.

Argon Oxygen Decarburization and Electric Arc Furnaces

Emission limitations from 35 states for electric arc furnaces (EAF) and argon oxygen decarburization (AOD) vessels were reviewed. There are also applicable NSPSs (Subparts AA and AAa) emission limitations for this source category.

The following is a summary of the most stringent state total PM emissions limitations for EAFs:

- Concentration - 12 mg/dscm (0.0052 gr/dscf) [CO, DE, NY]

- Emission rate - The strictest limitation depends on the production rate and is determined by reviewing Figure 4-1 or the following equation: $A = 0.76(40W)^{0.42}$; where A is the allowable rate (lb/hr) and W is the production rate (ton/hr) [PA].

The most stringent state VE limitations for EAFs are as follows:

- Fugitive emissions - no fugitive emissions.

- Stack emissions - Two states have similarly stringent limitations. The limitations of the first state are: no VE greater than or equal to 20 percent except for an aggregate of not more than 3 min/hr of VE that are not greater than or equal to 60 percent opacity [PA]. The limitations of the second state are: no VE greater than or equal to 20 percent except for no more than 5 min/hr of VE that are not greater than or equal to 40 percent [CT].

The most stringent state total PM emission limitations for AOD vessels are as follows:

- Concentration - 69 mg/dscm (0.03 gr/dscf)[FL, MD]. Another state [NJ] requires the least restrictive of the following: 1) an emission concentration of less than of equal to 46 mg/dscm (0.02 gr/dscf) with an upper cap of 14 kg/hr (30 lb/hr) or 2) a control efficiency of 99 percent.

- Emission rate - The emission limit depends on the production rate as is determined by one of the curves in Figure 4-1 or the following equation: $A = 0.76 (40W)^{0.42}$; where A is the allowable rate (lb/hr) and W is production rate (ton/hr) [PA].

The most stringent state opacity standard is zero percent unless hoods and controls are in place [PA]. Another state allows five percent (6-minute average)[FL].

NSPS Subpart AA applies to EAFs and associated dust-handling equipment that commenced construction, modification or reconstruction after October 21, 1974 but before August 17, 1983. In these cases, total PM emissions from the control device stack are limited to 12 mg/dscm (0.0052 gr/dscf) and an opacity of less than three percent (6-minute average). Visible emissions from the shop that are due solely to the operation of the EAF vessels cannot exhibit greater than or equal to six percent opacity (6-minute average) except that VE less than 20 percent (6-minute average) may occur during charging periods and VE less than 40 percent (6-minute average) may occur during tapping periods. Opacity from dust-handling equipment is limited to less than 10 percent (6-minute average) opacity.

NSPS Subpart AAa applies to EAFs and AODs that were constructed or modified after August 7, 1983. Total PM emissions from an EAF or AOD vessels cannot exceed 12 mg/dscm (0.0052 gr/dscf). VE from a control device stack cannot equal or exceed 3 percent opacity. VE from a shop from EAF or AOD operations cannot exhibit 6 percent opacity or greater.

Figure 4-5 depicts available total PM test data for EAF control device stacks. There is also one stack test available for tapping and charging emissions controlled by a baghouse. The total PM test results are 0.89 mg/dscm (0.00039 gr/dscf).

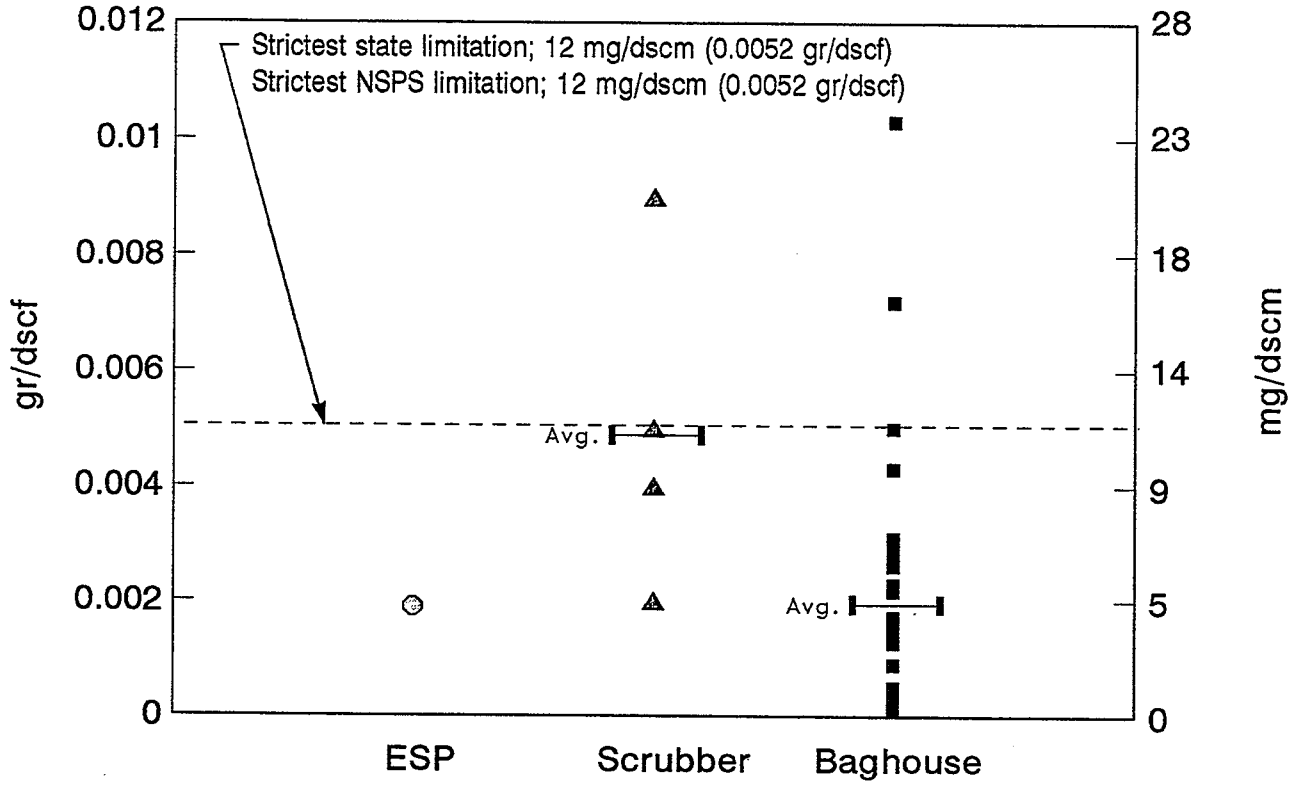
There are two total PM tests available for AOD vessels. One test was conducted at the exhaust at a baghouse and the results are 0.7 mg/dscm (0.0003 gr/dscf). The second test was conducted at the exhaust of a scrubber and the concentration is 27 mg/dscm (0.0118 gr/dscf).

Sinter Plants

To determine the most stringent state regulations for sinter plants, regulations were reviewed for the following states: Alabama, Colorado, Indiana, Illinois, Kentucky, Maryland, Michigan, New York, Ohio, Pennsylvania, Texas, Utah, and West Virginia.

The most stringent total PM emission regulations for sinter plant windboxes are:

- Concentration - 69 mg/dscm (0.03 gr/dscf) [AL, CO, MD, WV].



	ESP	Scrubber	Baghouse
Number of tests	1	4	24
Number of facilities	1	4	19
Maximum, mg/dscm (gr/dscf)	4.4 (0.0019)	20.6 (0.009)	23.6 (0.0103)
Minimum, (mg/dscm) (gr/dscf)	4.4 (0.0019)	4.6 (0.002)	0.05 (0.00002)
Average, (mg/dscm) (gr/dscf)	4.4 (0.0019)	11.5 (0.005)	5.0 (0.0022)

Figure 4-5. Examples of total PM emissions test data for primary emission control systems at electric arc furnaces at iron and steel facilities.

- Emission rate - The most stringent limit is calculated by the following equation: $A = 0.76(20W)^{0.42}$; where A is the allowable rate (lb/hr) and W is production rate (ton/hr)[PA].

The most stringent total PM limitations for other sinter plant operations are as follows:

- Sinter discharge end - 23 mg/dscm (0.01 gr/dscf)[CO].
- Sinter breaker - As calculated by the following equation: $E = 2.54P^{0.534}$; where E is the allowable rate (lb/hr) and P is production rate up to 408 Mg/hr (450 ton/hr)[IL].
- Hot and cold screens - 69 mg/dscm (0.03 gr/dscf)[IL, MD].
- Sinter cooler - 46 mg/dscm (0.02 gr/dscf)[WV].

The most stringent VE limitations are as follows:

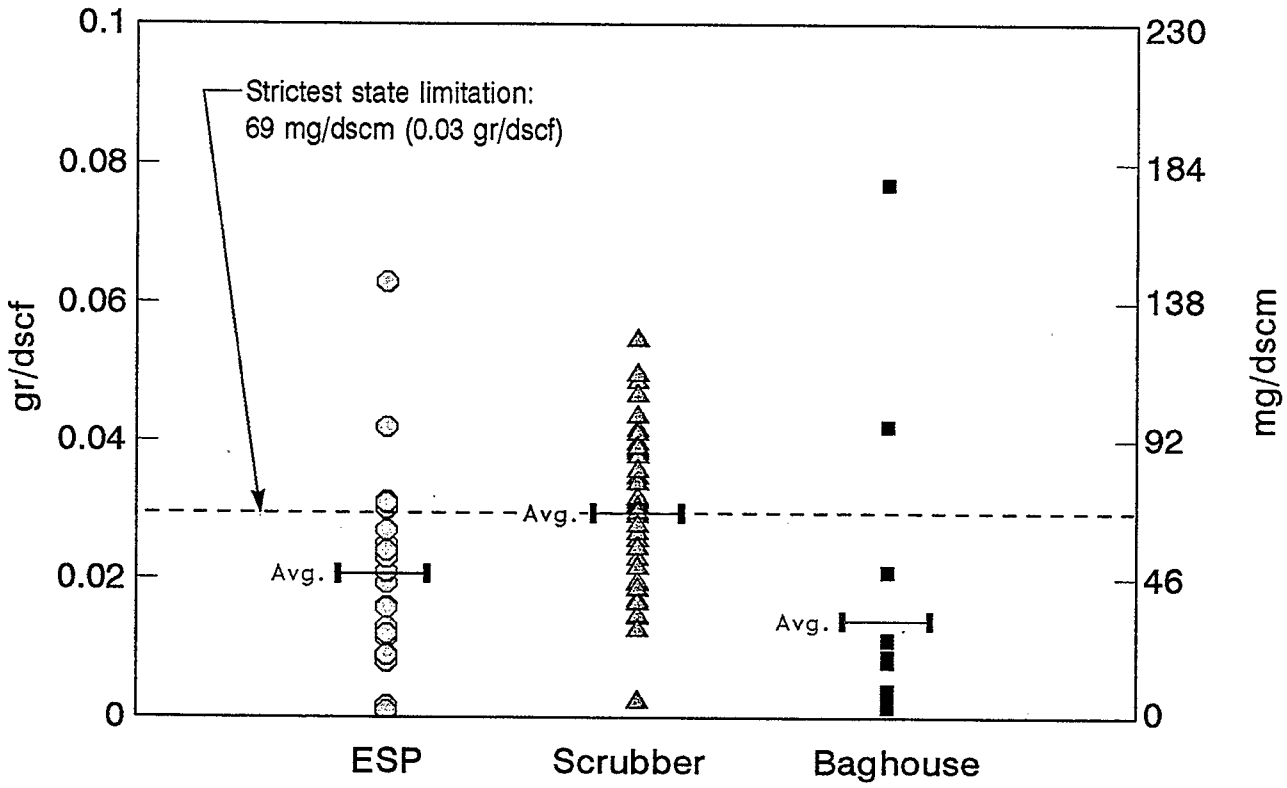
- Fugitive - no fugitive emissions [PA].
- Stack emissions - No VE greater than 10 percent [MD].

Examples of total PM emissions data for sinter plant windboxes is summarized on Figure 4-6. Examples of total PM test data for other sinter plant operations are summarized on Table 4-3.

Coke Batteries

State regulations were reviewed for by-product coke batteries for the following states: Alabama, Colorado, Indiana, Illinois, Kentucky, Maryland, Michigan, Missouri, New York, Ohio, Pennsylvania, Texas, Utah, Wisconsin and West Virginia. Coke pushing and coke underfire or combustion stack operations were included in the review. There are other emission sources at coke plants, such as door leaks, battery topside leaks, and quenching, however, there are generally no mass emission standards for these emission sources. (Opacity standards are generally specified for door leaks and battery topside leaks; water quality of the quench water may be specified for coke quenching.)

The most stringent total PM emission limitations for coke pushing are summarized as follows:



	ESP	Scrubber	Baghouse
Number of tests	26	46	13
Number of facilities	7	14	6
Maximum, mg/dscm (gr/dscf)	144.2 (0.063)	126.1 (0.0551)	176.2 (0.077)
Minimum, mg/dscm (gr/dscf)	18.3 (0.008)	6.2 (0.0027)	3.4 (0.0015)
Average, mg/dscm (gr/dscf)	50.3 (0.022)	68.6 (0.030)	36.8 (0.0161)

Figure 4-6. Examples of total PM emissions test data for sinter plant windboxes at iron and steel facilities.

TABLE 4-3. SUMMARY OF EXAMPLE TOTAL PM EMISSIONS TEST DATA FOR SINTER PLANT OPERATIONS (EXCLUDING SINTER PLANT WINDBOXES)[a]
mg/dscm (gr/dscf)

Sinter operation: control device	No. of tests	No. of facilities	Maximum	Minimum	Average
Raw materials transfer/handling:					
Scrubber	3	2	23 (0.01)	2 (0.0008)	10 (0.0044)
Baghouse	2	2	101 (0.044)	21 (0.009)	59 (0.026)
Sinter discharge end:					
Scrubber	3	2	76 (0.033)	37 (0.016)	55 (0.024)
Baghouse	8	7	101 (0.044)	5 (0.0023)	47 (0.0205)
Rotoclone	10	2	275 (0.12)	5 (0.002)	46 (0.0203)
Sinter breaker:					
Scrubber	3	2	203 (0.0888)	32 (0.0138)	103 (0.0452)
Baghouse	2	2	96 (0.0421)	14 (0.006)	55 (0.024)
Rotoclone	2	1	18 (0.008)	7 (0.003)	13 (0.0055)
Hot screening:					
Scrubber	5	3	203 (0.0888)	2 (0.0008)	65 (0.0282)
Baghouse	1	1	14 (0.006)	14 (0.006)	14 (0.006)
Rotoclone	9	3	46 (0.02)	7 (0.003)	23 (0.010)
Sinter cooler:					
Scrubber	1	1	34 (0.015)	34 (0.015)	34 (0.015)
Cyclone	1	1	14 (0.006)	14 (0.006)	14 (0.006)
Cold screening:					
Baghouse	1	1	7 (0.003)	7 (0.003)	7 (0.003)
Rotoclone	1	1	27 (0.012)	27 (0.012)	27 (0.012)

[a]Some control devices control emissions from multiple sources; test data may be listed under more than one operation.

- Concentration - 69 mg/dscm (0.03 gr/dscf)[MD].

- Emission rate - Emission rate varies by production rate and is determined by one of the following equations: 1) $A = 0.76(1W)^{0.42}$; where A is the allowable rate (lb/hr) and W is amount of coke pushed (ton/hr)[PA] or 2) $E = C^{0.09}$, where E the is allowable rate (lb/push) and C is coal charge rate (ton/oven)[WV].

- Production-based rate - 0.015 kg/Mg (0.03 lb/ton) of coke [CO, KY].

The most stringent opacity limit for coke pushing operations states that fugitive emissions from a coke pushing air cleaning device shall not exceed 20 percent opacity (any individual reading) during pushing unless the emissions are of minor significance as determined by the state agency and 10 percent during the transport of hot coke in the open atmosphere [PA].

Figure 4-7 illustrates examples of total PM emissions test data on coke pushing control systems.

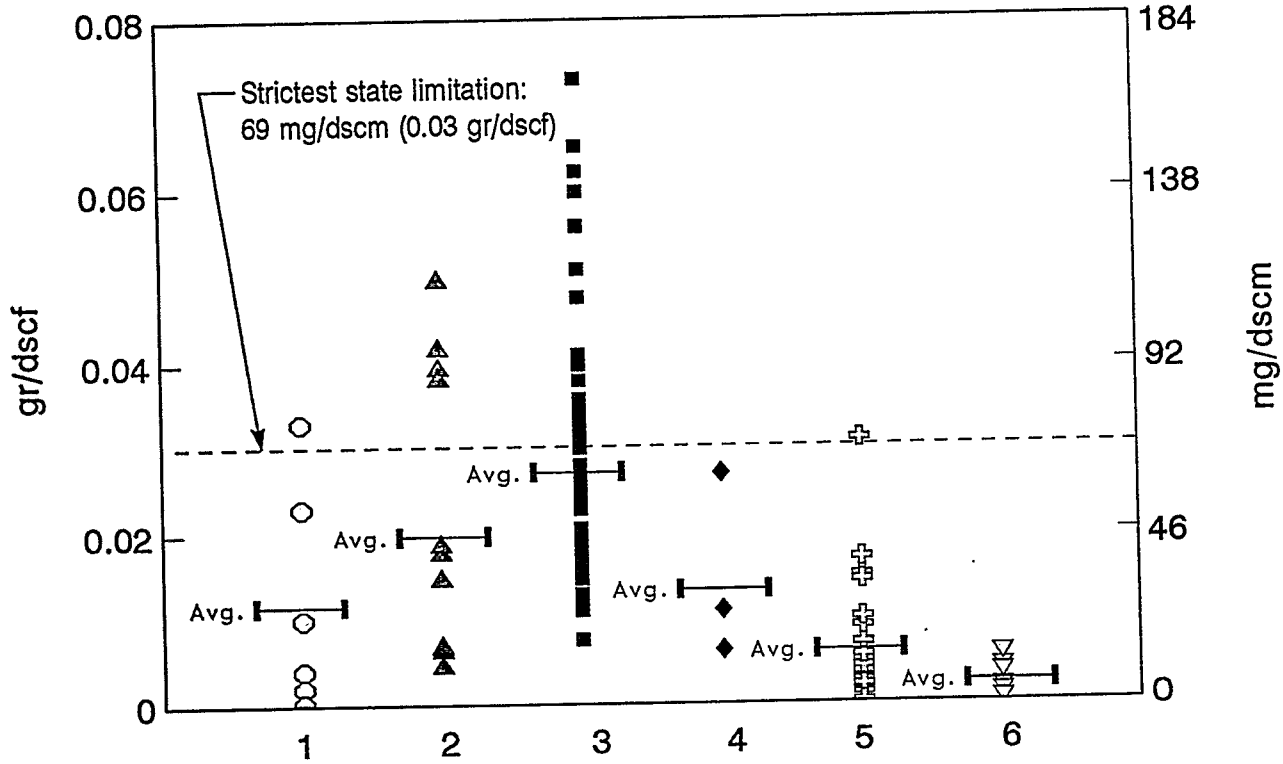
The most stringent state total PM emission limitations on coke oven underfire or combustion stacks is 57 mg/dscm (0.025 gr/dscf)[WV]. The most stringent VE limitation for combustion stacks is zero percent [MD].

Examples of total PM emissions test data from controlled combustion stacks are summarized below:

	ESP	Baghouse
Number of tests	14	10
Number of facilities	8	1
Maximum, mg/dscm (gr/dscf)	87 (0.038)	119 (0.052)
Minimum, mg/dscm (gr/dscf)	9 (0.004)	2 (0.001)
Average, mg/dscm (gr/dscf)	37 (0.016)	41 (0.018)

Slag Handling

Slag handling is a fugitive dust emission source. Fugitive dust regulations were reviewed for 35 states (the states with iron or steel making furnaces). The most stringent state limitation stipulates that there shall be no fugitive emissions



System configurations as follows:

1 - Shed with ESP
2 - Hood with land-based scrubber
3 - Mobile car with scrubber
4 - Shed with scrubber
5 - Hood with land-based baghouse
6 - Shed with baghouse

System configuration	1	2	3	4	5	6
Number of tests	6	12	51	3	18	6
Number of facilities	3	6	19	3	13	4
Maximum mg/dscm (gr/dscf)	75.5 (0.033)	114.4 (0.050)	167.3 (0.0731)	61.8 (0.027)	70.7 (0.0309)	12.8 (0.0056)
Minimum mg/dscm (gr/dscf)	0.5 (0.0002)	11.0 (0.0048)	17.4 (0.0076)	14.4 (0.0063)	0.5 (0.0002)	0.7 (0.0003)
Average mg/dscm (gr/dscf)	27.5 (0.0120)	50.1 (0.0219)	65.4 (0.0286)	33.9 (0.0148)	16.9 (0.0074)	6.2 (0.0027)

Figure 4-7. Examples of total PM emissions test data for coke pushing at iron and steel facilities.

[PA]. Many states specify reasonable precautions or measures shall be taken to reduce fugitive dust.

Blast Furnaces

State regulations for Alabama, Colorado, Illinois, Indiana, Kentucky, Maryland, Michigan, New York, Ohio, Pennsylvania, Texas, Utah, and West Virginia were reviewed to determine the most stringent mass and opacity limitations for blast furnace casthouses. The most stringent total PM emissions limitations are as follows:

- Concentration - 23 mg/dscm (0.01 gr/dscf) from air pollution control device stacks [KY, MI].

- Emission rate - As determined by the following equation for sources up to 408 Mg/hr (450 ton/hr): $E = 2.54P^{0.534}$; where E is the allowable rate (lb/hr) and P is the production rate (ton/hr).

- Production-based rate - 0.015 kg/Mg (0.03 lb/ton) of hot metal [IN - this emission rate is specific for a particular emission source].

The most stringent VE limitation for fugitive emissions is no fugitive emissions [PA]. The most stringent limitation for VE from the air pollution control device stack is zero percent [MD].

Six examples of total PM emission test data are available from six facilities using baghouses to control blast furnace casthouse emissions. The average results are 17 mg/dscm (0.0075 gr/dscf) with a range of 0.7 to 66 mg/dscm (0.0003 to 0.0287 gr/dscf). Another common control system that is employed at blast furnace casthouses is suppression technology. This type of control system uses technology to suppress the formation of the pollutants such as unevacuated hoods or covers and flame or nitrogen gas blankets. There are no exhaust stacks as there are with traditional air pollution control devices.

Basic Oxygen Furnaces

Emission limitations for basic oxygen furnaces (BOF) were reviewed for the following states: Alabama, Colorado, Illinois, Indiana, Kentucky, Maryland, Michigan, New York, Ohio, Pennsylvania, and West Virginia. There is also an applicable NSPS limitation (Subparts N and Na).

The most stringent state total PM emission limitations for BOF vessels are as follows:

- Concentration - 50 mg/dscm (0.0220 gr/dscf) during the oxygen blow and 23 mg/dscm (0.0100 gr/dscf) during scrap charging, hot metal transfer, tapping, and slagging (secondary emissions).

- Emission rate - One state specifies 2.27 kg/hr/furnace (5 lb/hr/furnace) as an emission rate [IN, specific to an individual furnace]. For emission rate limitations that vary by production rate the equation that yields the strictest emission limitations is: $A = 0.76 (40W)^{0.42}$; where A is the allowable emission rate (lb/hr) and W is the production rate (ton/hr).

- Production-based rate - 0.045 kg/Mg (0.09 lb/ton) steel for stack emissions and 0.1 kg/Mg (0.2 lb/ton) steel for the roof monitor [IN, specific to an individual facility].

The most stringent state VE limitation for emissions from the roof monitor is zero percent [PA]. The most stringent state limitation for stack VE is zero percent [MD].

NSPS Subparts N and Na apply to BOFs. Subpart N applies to BOFs that commenced construction or modification after June 11, 1973. This subpart states that atmospheric particulate emissions shall not exceed 50 mg/dscm (0.022 gr/dscf). VE from a control device cannot be greater than or equal to 10 percent except that an opacity greater than 10 percent but less than 20 percent may occur once per steel production cycle. For BOFs constructed or modified after January 20, 1983, total PM emissions from vessels that use open hooding as the method of controlling primary emissions are limited to 50 mg/dscm (0.022 gr/dscf) measured during the oxygen blow. Emissions from a control device not used solely for the collection of secondary emissions shall not be greater than or equal to 10 percent opacity except that an opacity greater than 10 percent and less than 20 percent may occur once per steel production cycle. Vessels that use closed hooding as the method for controlling total PM emissions are limited to 68 mg/dscm (0.030 gr/dscf) as measured during the oxygen below. The VE limit for closed hooding vessels is the same as the limit for open hooding vessels.

Subpart Na applies to secondary emissions from BOFs that were constructed or modified after January 20, 1983. Particulate emissions from a BOF shop roof monitor cannot be greater than or equal to 10 percent opacity during the steel production cycle of any top-blown vessel or during hot metal transfer or skimming operations for any bottom-blown BOF except that an opacity greater than 10 percent but less than 20 percent may occur once per steel production cycle. Control devices that are used only

for the collection of secondary emissions from a top-blown vessel or from hot metal transfer or skimming for a bottom-blown or top-blown vessel total PM emissions cannot exceed 23 mg/dscm (0.010 gr/dscf) and exhibit more than five percent opacity.

Table 4-4 presents examples of total PM test data from BOF vessels.

Scarfing

Regulations for Alabama, Colorado, Illinois, Indiana, Maryland, Michigan, Missouri, New York, Ohio, Pennsylvania, Texas and West Virginia were reviewed to determine the most stringent mass and opacity limitations for automatic scarfing operations.

The most stringent state total PM emission limitations are as follows:

- Concentration - 46 mg/dscm (0.02 gr/dscf) during scarfing [IN, for a specific facility]. 69 mg/dscm (0.03 gr/dscf) is the most stringent limitation that is not specific to an individual facility [IL, MD, MI, WV].

- Emission rate - Calculated using the following equation: $A = 0.76(20W)^{0.42}$; where A is the allowable rate (lb/hr) and W is the production rate (ton/hr) [PA].

The most stringent opacity limit is 0 percent [MD].

Examples of total PM emissions test data are summarized below.

	ESP	Scrubber
Number of tests	22	5
Number of facilities	13	4
Maximum, mg/dscf (gr/dscf)	110 (0.048)	108 (0.047)
Minimum, mg/dscm (gr/dscf)	0.7 (0.0003)	11 (0.0046)
Average, mg/dscm (gr/dscf)	17 (0.0074)	69 (0.0301)

TABLE 4-4. SUMMARY OF EXAMPLE TOTAL PM EMISSIONS TEST DATA FOR BOF VESSELS
mg/dscm (gr/dscf)

Type of vessel[a]: control device[b]	No. of tests	No. of facilities	Maximum	Minimum	Average
Bottom-blown; partial hood:					
Scrubber	12	3	82 (0.036)	12 (0.0051)	38 (0.0166)
Top-blown; full hood:					
ESP	58	16	208 (0.091)	7 (0.0031)	34 (0.015)
Scrubber	27	12	160 (0.07)	9 (0.004)	46 (0.020)
Top-blown; partial hood:					
Scrubber	13	6	44 (0.0192)	5 (0.0023)	19 (0.0083)
All types; secondary emissions[c] control:					
ESP	6	3	14 (0.0063)	4 (0.0017)	9 (0.0037)
Scrubber	1	1	21 (0.009)	21 (0.009)	21 (0.009)
Baghouse	5	3	44 (0.019)	0.1 (0.00003)	13 (0.0058)

[a]BOF vessels classified by oxygen blowing mechanism (either top-blown or bottom-blown) and by the type of combustion hood (either full or partial).

[b]Control devices are controlling primary emissions (emissions during the oxygen blow) unless otherwise indicated.

[c]Secondary emissions include vessel charging, tapping, slagging, and metal transfers. Tests shown above may include one or more of these operations.

Hot Metal Reladling

Emission limitations for hot metal reladling were reviewed for the following states: Alabama, Colorado, Illinois, Indiana, Kentucky, Maryland, Michigan, New York, Ohio, Pennsylvania, and West Virginia. The most stringent total PM emissions limitations are as follows:

- Concentration - 23 mg/dscm (0.0100 gr/dscf) [CO].
- Emission rate - Calculated using the following equation: $E = 17.31P^{0.16}$ for production rates greater than 27 Mg/hr (30 ton/hr); where E is the allowable rate (lb/hr) and P is the production rate (ton/hr).

The most stringent limitation for VE from the stack is 0 percent opacity [MD].

Examples of total PM emissions test data from hot metal reladling operations are:

	ESP	Baghouse
Number of tests	1	10
Number of facilities	1	7
Maximum, mg/dscm (gr/dscf)	6 (0.0024)	39 (0.0172)
Minimum, mg/dscm (gr/dscf)	6 (0.0024)	1 (0.0003)
Average, mg/dscm (gr/dscf)	6 (0.0024)	12 (0.0054)

LIME PLANTS

State regulations for rotary lime kilns at lime plants were reviewed for all states except Colorado, Delaware, Hawaii, Maine, Montana, Nebraska, North Dakota, and Wyoming. There is also an applicable NSPS emission limitation for this source category. The crushing, screening and material handling operations that may be associated with rotary lime kilns are discussing under the Nonmetallic Mineral Plants subsection.

The most stringent state total PM emission limitations for lime kilns are as follows:

- Concentration - 69 mg/dscm (0.03 gr/dscf) [FL, MD, NY - for kilns greater than 45 Mg/hr (50 ton/hr)].

Another state [NJ] requires the least restrictive of the following: 1) an emission concentration of less than of equal to 46 mg/dscm (0.02 gr/dscf) with an upper cap of 14 kg/hr (30 lb/hr) or 2) a control efficiency of 99 percent.

- Emission rate - The strictest limitation varies by production rate; see Figure 4-1.

- Production-based rate - 0.15 kg/Mg (0.30 lb/ton) of feed [NM].

The most stringent state opacity limit is zero percent [MD].

NSPS Subpart HH applies to rotary lime kilns at lime manufacturing plants that were constructed or modified after May 3, 1977. Total PM shall not exceed 0.30 kg/Mg (0.60 lb/ton) of stone feed. Opacity from a dry emission control device cannot exceed 15 percent.

Figure 4-8 summarizes examples of total PM emissions data for lime kilns (includes data for several lime kilns at pulp mills) (Fitzpatrick, *et al*, 1991; OAQPS, 1977; OAQPS, 1976; OAQPS, 1977; Kinsey, 1986).

LUMBER MILLS

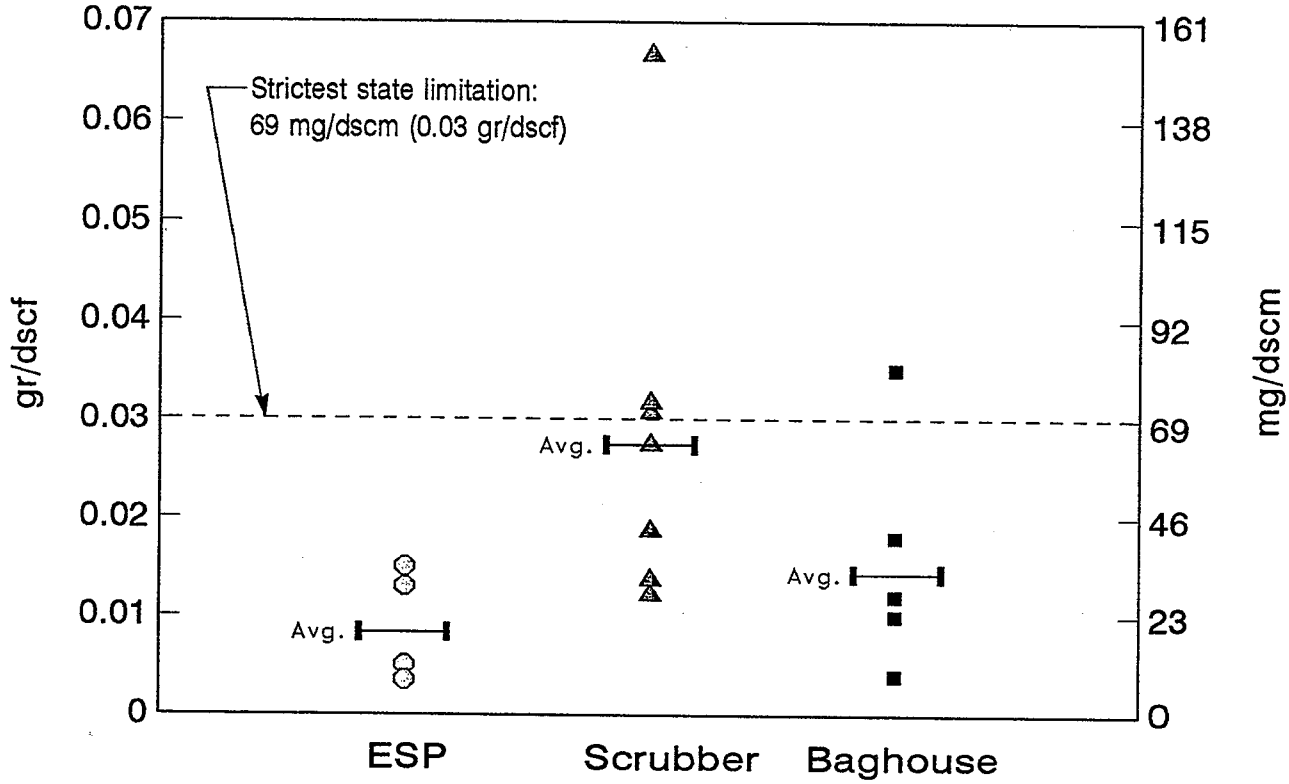
State regulations for all 50 states were reviewed to determine the most stringent total PM limitations for planning, shaving and combustion of wood waste at lumber mills.

The most stringent total PM emission limitations for planning and shaving operations that are exhausted through a stack are as follows:

- Concentration - 69 mg/dscm (0.03 gr/dscf) [MD, FL]. Another state [NJ] requires the least restrictive of the following: 1) an emission concentration of less than of equal to 46 mg/dscm (0.02 gr/dscf) with an upper cap of 14 kg/hr (30 lb/hr) or 2) a control efficiency of 99 percent.

- Emission rate - Varies by production rate; see Figure 4-1.

Emission limitations for combustion of wood waste in boilers are presented in the Boilers portion of this Section. Combustion of wood in wood waste burners is limited to 459 mg/dscm (0.2 gr/dscf) corrected to 12 percent carbon dioxide [AZ, IL].



	ESP	Scrubber	Baghouse
Number of tests	4	8	5
Number of facilities	4	6	5
Maximum, mg/dscm (gr/dscf)	34.3 (0.015)	153.3 (0.067)	80.1 (0.035)
Minimum, mg/dscm (gr/dscf)	8.0 (0.0035)	28.6 (0.0125)	9.2 (0.004)
Average, mg/dscm (gr/dscf)	20.8 (0.0091)	66.1 (0.0289)	36.6 (0.016)

Figure 4-8. Examples of total PM emissions test data for lime plants.

Operational and monitoring requirement on wood waste burners are imposed in some states [MT, OR, WA, WY]. Several states also have policies to encourage means, other than incineration, of wood waste disposal [MT, OR].

MARINE GRAIN TERMINALS

Regulations for 45 states (Alaska, Nevada, New Hampshire, West Virginia and Wyoming were not included) were reviewed to determine the most stringent limitations for shipping (load-out), receiving (unloading) and other grain handling operations. There is an applicable NSPS for this source category.

The most stringent total PM emissions regulations are summarized as follows:

- Concentration - 69 mg/dscm (0.03 gr/dscf) if a control device has been installed [FL]. Another state [NJ] requires the least restrictive of the following: 1) an emission concentration of less than of equal to 46 mg/dscm (0.02 gr/dscf) with an upper cap of 14 kg/hr (30 lb/hr) or 2) a control efficiency of 99 percent.

- Emission rate - Varies by production rate; see Figure 4-1. Pennsylvania has emission rates that vary by production rate specifically for grain elevators on grain screening/cleaning, however, the curves produce less stringent limits than those depicted on Figure 4-1.

- Other - Particulate matter cannot be larger than that which would pass through a 707 μm (24 mesh) screen.

The most stringent opacity standard limits VE to zero percent except 10 percent when loading to ship via a conveyor and the hatch is moved [FL].

NSPS Subpart DD applies to grain terminal elevators that were constructed or modified after August 3, 1978. Specifically this Subpart applies to barge and ship loading and unloading stations and other grain handling operations. Fugitive emissions from barge or ship loading stations cannot exhibit greater than 20 percent opacity. Fugitive emissions from any grain handling operations cannot exhibit greater than zero percent opacity. There are also operating requirements specified for ship unloading stations.

Total PM test data from grain loading from a barge equipped with a filter showed a concentration of 60 mg/dscm (0.0261 gr/dscf) (Fitzpatrick, *et al*, 1991).

METALLIC MINERAL PROCESSING PLANTS

State regulations were reviewed for all 46 states (Alaska, Delaware, North Dakota and South Dakota were not included) to determine the most stringent mass and opacity limitations for ore concentrators at nonferrous smelting facilities. There is an applicable NSPS for this source category.

The most stringent total PM emission regulations are as follows:

- Concentration - 69 mg/dscm (0.03 gr/dscf) [FL, MD]. Another state [NJ] requires the least restrictive of the following: 1) an emission concentration of less than of equal to 46 mg/dscm (0.02 gr/dscf) with an upper cap of 14 kg/hr (30 lb/hr) or 2) a control efficiency of 99 percent.

- Emission rate - Varies by production rate; refer to Figure 4-1.

The most stringent opacity limitation is zero percent [MD]. Fugitive emissions are limited to none [PA].

NSPS Subpart LL applies to metallic mineral processing plants that were installed or modified after August 24, 1982. Total PM emissions are limited to 50 mg/dscm (0.0218 gr/dscf). Opacity cannot exceed seven percent unless a wet scrubber is used as the control device. Process fugitive emissions cannot exceed 10 percent opacity.

Examples of total PM emissions test data are summarized on Table 4-5 (Fitzpatrick, *et al*, 1991).

NONMETALLIC MINERAL PLANTS

Mass and opacity regulations for all fifty states were reviewed to determine the most stringent limitations for conveyors and other material handling operations, screens, quarrying, and rock crushers at nonmetallic mineral plants. There is also an applicable NSPS for this source category.

The most stringent state total PM emission limitations are as follows:

- Concentration - 69 mg/dscm (0.03 gr/dscf) [FL, IN, MD]. Another state [NJ] requires the least restrictive of the following: 1) an emission concentration of less than of equal to 46 mg/dscm (0.02 gr/dscf) with an

TABLE 4-5. SUMMARY OF EXAMPLE TOTAL PM EMISSIONS TEST DATA FOR NONFERROUS ORE CONCENTRATORS

mg/dscm (gr/dscf)

Process operation: control device	No. of tests	No. of facilities	Maximum	Minimum	Average
Copper, truck loadout: Baghouse	3	2	36 (0.0156)	0.2 (0.0001)	18.4 (0.008)
Copper, primary crusher: Baghouse	1	1	12.9 (0.0056)	12.9 (0.0056)	12.9 (0.0056)
Fabric filter and chemical wet suppression	1	1	0.2 (0.0001)	0.2 (0.0001)	0.2 (0.0001)
Not specified	1	1	24.4 (0.0106)	24.4 (0.0106)	24.4 (0.0106)
Copper, secondary crusher: Not specified	1	1	41.1 (0.0179)	41.1 (0.0179)	41.1 (0.0179)
Molybdenum, primary crusher: Venturi scrubber and wet suppression	1	1	11.9 (0.0052)	11.9 (0.0052)	11.9 (0.0052)
Molybdenum, pebble screening and milling: Venturi scrubber	1	1	15.6 (0.0068)	15.6 (0.0068)	15.6 (0.0068)
Uranium, primary crusher: Centrifugal scrubber	1	1	84.1 (0.0366)	84.1 (0.0366)	84.1 (0.0366)

(Continued)

TABLE 4-5. (CONTINUED)

Process operation: control device	No. of tests	No. of facilities	Maximum	Minimum	Average
Uranium, ore bins:					
Centrifugal scrubber	1	1	53.5 (0.0233)	53.5 (0.0233)	53.5 (0.0233)
Zinc, ore processing:					
Baghouse	2	1	131.4 (0.0572)	88.4 (0.0385)	110.0 (0.0479)
Ore bins:					
Baghouse	2	2	6.9 (0.003)	0.2 (0.0001)	3.7 (0.0016)
Unloading:					
Scrubber	1	1	39 (0.017)	39 (0.017)	39 (0.017)

upper cap of 14 kg/hr (30 lb/hr) or 2) a control efficiency of 99 percent.

- o Emission rate - varies by production rate; refer to Figure 4-1.

The most stringent state opacity limitation is 0 percent for stacks [FL, MD] and fugitive sources [PA].

NSPS Subpart 000 applies to nonmetallic mineral processing plants that were installed or modified after August 31, 1983. Stack total PM emissions can not contain more than 50 mg/dscm (0.0218 gr/dscf) of particulate matter or exhibit greater than 7 percent opacity (unless emissions are controlled by a wet scrubber). Fugitive emissions from affected sources (except crushers which do not use a capture system, truck dumping, and sources enclosed by a building) are limited to 10 percent opacity. Fugitive emissions from crushers which do not use a capture system can not exceed 15 percent opacity. Sources that are enclosed by a building can meet the VE requirements of the individual sources or the building must not exhibit any visible fugitive emissions.

Examples of total PM emissions test data are summarized below (Fitzpatrick, *et al*, 1991):

Operation	Control	mg/dscm	(gr/dscf)
Kaolin, impact mill	Baghouse	17 37	(0.0073) (0.0160)
Roller and bowl mill	Cyclones and baghouse	7	(0.003)
Granite, secondary crushing	Wet suppres-sion	1	(0.0003)
Talc, pebble grinding	Baghouse	66	(0.0285)

PAINT MANUFACTURING PLANTS

State regulations for all 50 states were reviewed to determine the most stringent total PM and opacity limitations for paint manufacturing plants. The most stringent mass limitations are summarized as follows:

- o Concentration - 69 mg/dscm (0.03 gr/dscf) [FL, MD]. Another state [NJ] requires the least restrictive of

the following: 1) an emission concentration of less than of equal to 46 mg/dscm (0.02 gr/dscf) with an upper cap of 14 kg/hr (30 lb/hr) or 2) a control efficiency of 99 percent.

- Emission rate - The strictest limitation is calculated using the following equation: $A = 0.76(0.05W)^{0.42}$; where A is the allowable rate (lb/hr) and W is the amount of pigment handled (ton/hr).

PETROLEUM REFINERIES

State regulations for all states except Idaho, Maine, New Hampshire, and North Carolina were reviewed to determine the most stringent total PM and opacity limitations for petroleum refineries. There is applicable NSPS for this source category.

The most stringent state total PM emissions limitations are summarized below:

- Concentration - 62.0 mg/dscm (0.0270 gr/dscf) [UT, specific facility]. Another state [NJ] requires the least restrictive of the following: 1) an emission concentration of less than of equal to 46 mg/dscm (0.02 gr/dscf) with an upper cap of 14 kg/hr (30 lb/hr) or 2) a control efficiency of 99 percent.

- Emission rate - For catalytic cracking units, calculated from the following equation $A = 0.76 (40W)^{0.42}$; where A is the allowable rate (lb/hr) and W is liquid feed rate (ton) [PA].

- Production-based rate - For catalytic cracking units, 1.0 kg/1000 kg (1.0 lb/1,000 lb) of coke burnoff with an additional incremental rate of 43 g/MJ (0.10 lb/MMBtu) of heat input attributable to fuel if the gases pass through an incinerator or waste heat boiler in which auxiliary or supplemental liquid or solid fossil fuel is burned [AK, KY, MN, NM, NY, WI].

- Other - Recover 99.97 percent of catalyst or total gas-born particulate [IN].

Visible emissions are limited to zero percent opacity [FL, MD].

NSPS Subpart J applies to fluid catalytic unit catalyst regenerators (FCCU) which were installed or modified after June 11, 1973. Total PM in the exhaust gas cannot exceed 1.0 kg/1000

kg (1.0 lb/1000 lb) of coke burn-off in the catalyst regenerator. Opacity cannot be greater than 30 percent except for one six-minute period per hour. If gases from the FCCU pass through an incinerator or waste fuel boiler that burns auxiliary or supplemental liquid or solid fossil fuel, the incremental rate of total PM emissions shall not exceed 43 g/MJ (0.10 lb MMBtu) of heat input attributable to the liquid or solid fossil fuel.

PHOSPHATE FERTILIZER PLANTS

State regulations relative to phosphate fertilizer plants were reviewed for the following states: Alabama, Arizona, Arkansas, Florida, Georgia, Idaho, Iowa, Kansas, Kentucky, Louisiana, Maryland, Michigan, Minnesota, Mississippi, Missouri, North Carolina, North Dakota, Ohio, Oregon, Pennsylvania, South Carolina, South Dakota, Texas, Virginia, Wisconsin, and Wyoming. There are also several applicable NSPSs for this source category, however, the emission limitations pertain to fluorides.

The most stringent state total PM emission limitations are as follows:

- Concentration - 69 mg/dscm (0.03 gr/dscf) [MD].
- Emission rate - Calculated using the following equation: $E = 1.10(PW)^{0.25}$; where E is the allowable rate (lb/hr) for operations greater than 4.2 Mg/hr (9,250 lb/hr) and PW is production rate (lb/hr) [ID]. Concentrators at phosphate processing facilities are limited to 6.8 kg/hr (15 lb/hr) in Florida.
- Production-based rate - 0.15 kg/Mg (0.30 lb/ton) at phosphate processing facilities [FL].

Visible emissions are limited to zero percent opacity [MD].

PHOSPHATE ROCK PROCESSING PLANTS

State regulations for Florida, Idaho, Missouri, Montana, Nebraska, North Carolina, Tennessee, Utah and Wyoming were reviewed to determine the most stringent mass and opacity limitations for phosphate rock processing. There is also an applicable NSPS for this source category.

The most stringent total PM emission limitations are as follows:

- Emission rate - Calculated using the following equation for operations greater than 4.2 Mg/hr (9,250 lb/hr): $E = 1.10(PW)^{0.25}$; where E (lb/hr) is the allowable rate and PW is production weight (lb/hr) [ID]. Concentrators are limited to 6.8 kg/hr (15 lb/hr) [FL].

- Production-based rate - 0.1 kg/Mg (0.20 lb/ton) for dryers or grinders [FL].

There are several states with similarly strict opacity limits:

- VE cannot exceed 20 percent opacity for not more than an aggregate of 3 min/hr [ID].

- VE cannot exceed 20 percent opacity for not more than 5 min/hr or 20 minutes per 24 hr [IN].

- VE cannot equal or exceed 20 percent opacity (6-minute average) [MT, NE].

NSPS subpart NN applies to phosphate rock plants with a capacity greater than 3.6 Mg/hr (4 ton/hr) that were installed or modified after September 21, 1979. Total PM and opacity limitations are as follows:

	Mass limitation kg/Mg (lb/ton) of rock feed	Opacity limitation, %
Phosphate rock dryer	0.030 (0.06)	10
Phosphate rock calciner processing unbeneficiated rock	0.12 (0.23)	10
Phosphate rock calciner processing beneficiated rock	0.055 (0.11)	10
Phosphate rock grinder	0.006 (0.012)	0
Ground phosphate rock handling and storage system	-	0

Examples of total PM emissions test data are summarized in Table 4-6. (Fitzpatrick, *et al*, 1991; Kinsey, 1986).

TABLE 4-6. SUMMARY OF EXAMPLE TOTAL PM EMISSIONS TEST DATA FOR PHOSPHATE ROCK PROCESSING

mg/dscm (gr/dscf)

Process operation: control device	No. of tests	No. of facilities	Maximum	Minimum	Average
Grinders: Baghouse	6	5	21.8 (0.0095)	2.3 (0.001)	8.7 (0.0038)
Dryers: Scrubber and ESP	1	1	18.4 (0.008)	18.4 (0.008)	18.4 (0.008)
Venturi Scrubber	2	1	29.9 (0.013)	20.7 (0.009)	25.3 (0.011)
Calciners: Scrubber	5	2	62.0 (0.027)	0.7 (0.0003)	45.3 (0.0197)

PLYWOOD, PARTICLEBOARD, AND WAFERBOARD PLANTS

Mass and opacity limitations were reviewed for plywood, particleboard and waferboard plants (including veneer dryers) for all 50 states. The most stringent total PM emissions limitations are as follows:

- Concentration - 69 mg/dscm (0.03 gr/dscf) [FL, MD]. Another state [NJ] requires the least restrictive of the following: 1) an emission concentration of less than or equal to 46 mg/dscm (0.02 gr/dscf) with an upper cap of 14 kg/hr (30 lb/hr) or 2) a control efficiency of 99 percent.

- Emission rate - Varies by production rate; see Figure 4-1.

- Production-based rate - As listed below:

Plywood and veneer units using fuel with moisture content >20%	3.7 kg/1,000 m^2 (0.75 lb/1,000 ft^2)
Plywood and veneer units using fuel with moisture content <20%	7.3 kg/1,000 m^2 (1.50 lb/1,000 ft^2)
Plywood and veneer units; combustion	0.40 kg/1,000 kg (0.40 lb/1,000 lb steam)
Plywood and veneer, other operations	4.9 kg/1,000 m^2 (1.0 lb/1,000 ft^2)
Particleboard manufacturing truck dumping and storage	Enclose areas or equivalent alternative controls
Particleboard manufacturing, other sources (excluding truck dumping, storage, fuel or refuse burning equipment)	Total all sources: 14.7 kg/1,000 m^2 (3.0 lb/1,000 ft^2)
Hardboard manufacturing, truck dumping and storage	Enclose areas or equivalent alternative controls

Hardboard manufacturing, other sources (excluding truck dumping, storage, fuel or refuse burning equipment).	Total all sources: 4.9 kg/1,000 m^2 (1.0 lb/1,000 ft^2)

The most stringent state visible emission limitation is 0 percent [MD].

PORTLAND CEMENT PLANTS

State regulations were reviewed for all states except North Dakota and Rhode Island to determine the most stringent total PM and opacity limitations for portland cement plants. There is also an applicable NSPS for this source category.

The most stringent state total PM emission limitation for cement kilns are as follows:

- Concentration - 69 mg/dscm (0.03 gr/dscf) [MD]. Another state [NJ] requires the least restrictive of the following: 1) an emission concentration of less than of equal to 46 mg/dscm (0.02 gr/dscf) with an upper cap of 14 kg/hr (30 lb/hr) or 2) a control efficiency of 99 percent.

- Emission rate - Varies by production rate; refer to Curve 3 [ID] and Curve 4 [MA] on Figure 4-1.

- Production based rate - 0.15 kg/Mg (0.30 lb/ton) of feed [AL, FL, IL, MN, NH, NY, WI].

- Other - 99.7 control efficiency and not greater than 230 mg/dscm (0.1 gr/dscf) [IA] or not greater than 0.873 g/kg (0.327 lb/barrel) [NC].

The most stringent state total PM emission limitations for clinker coolers are as follows:

- Concentration - 69 mg/dscm (0.03 gr/dscf) [MD]. Another state [NJ] requires the least restrictive of the following: 1) an emission concentration of less than of equal to 46 mg/dscm (0.02 gr/dscf) with an upper cap of 14 kg/hr (30 lb/hr) or 2) a control efficiency of 99 percent.

- Emission rate - Varies by production rate; use Figure 4-1, Curves 3 and 4 [ID, MA] or the following equation:

$A = 0.76(50W)^{0.42}$; where A is the allowable rate (lb/hr) and W is production rate (ton/hr).

The most stringent state total PM emission limitations for other operations at portland cement plants are:

- Concentration - 69 mg/dscm (0.03 gr/dscf) [MD]. Another state [NJ] requires the least restrictive of the following: 1) an emission concentration of less than of equal to 46 mg/dscm (0.02 gr/dscf) with an upper cap of 14 kg/hr (30 lb/hr) or 2) a control efficiency of 99 percent.

- Emission rate - Varies by production rate; refer to Figure 4-1.

The most stringent opacity limitation is 0 percent [MD]. Fugitive emissions are limited to none [PA].

NSPS Subpart F applies to portland cement plants that were installed or modified after August 17, 1971. Total PM emission in the kiln exhaust gas can not exceed 0.15 kg/Mg (0.30 lb/ton) of feed and opacity cannot be greater than 20 percent. Clinker cooler total PM emissions are limited to 0.050 kg/Mg (0.10 lb/ton) of feed to the kiln and opacity cannot equal or exceed 10 percent. Other emission sources at portland cement plants cannot equal or exceed 10 percent opacity.

Examples of total PM emissions data from portland cement plants are summarized on Table 4-7 (Fitzpatrick, *et al*, 1991; Kinsey, 1987; Engineering-Science, Inc., 1978).

PRIMARY ALUMINUM REDUCTION FACILITIES

State regulations were reviewed for 27 states to determine the strictest total PM and opacity limits for prebaked, vertical stud Soderberg and horizontal stud Soderburg aluminum reduction cells at primary aluminum reduction facilities. There is an applicable NSPS for this source category.

The most stringent state total PM emissions regulations are as follows:

- Concentration - 69 mg/dscm (0.03 gr/dscf) [FL, MD, NY].

- Emission rate - Varies by production rate; see Curves 1 and 2 on Figure 4-1.

TABLE 4-7. SUMMARY OF EXAMPLE TOTAL PM EMISSIONS TEST DATA FOR PORTLAND CEMENT PLANTS

mg/dscm (gr/dscf)

Process operation: control device	No. of tests	No. of facilities	Maximum	Minimum	Average
Cement kiln:					
ESP	10	5	234 (0.102)	12 (0.005)	67 (0.029)
Scrubber	1	1	99 (0.043)	99 (0.043)	99 (0.043)
Baghouse	4	3	64 (0.028)	32 (0.014)	44 (0.019)
Clinker cooler:					
ESP	1	1	46 (0.02)	46 (0.02)	46 (0.02)
Baghouse	2	2	122 (0.053)	4.6 (0.002)	64 (0.028)
Various mills:					
Baghouse	10	3	53 (0.023)	4.6 (0.002)	18 (0.008)

- Production-based rate - Monthly average of 3.5 kg/Mg (7.0 lb/ton) of aluminum produced and annual average of 2.5 kg/Mg (5.0 lb/ton) of aluminum produced.

The most stringent state VE limitation is 0 percent opacity [MD].

NSPS Subpart S applies to primary aluminum reduction plants that were constructed or installed after October 23, 1974. The standard includes limits for fluorides and opacity. VE from potroom groups cannot equal or exceed 10 percent opacity. VE from an anode bake plant cannot exhibit greater than or equal to 20 percent opacity.

Examples of total PM emission test data from two potlines are summarized below (Fitzpatrick, *et al*, 1991):

- ESP control - 3.9 mg/dscm (0.0017 gr/dscf)
- Baghouse control - 0.9 mg/dscm (0.0004 gr/dscf)

PULP MILLS

State regulations were reviewed for 46 states (Nebraska, South Dakota, Vermont, and Wyoming were not included) to determine the most stringent total PM and opacity limitations for recovery furnaces, smelt dissolving tanks and lime kilns at kraft pulp mills, and blow pits and recovery systems at sulfite pulp mills. There is an applicable NSPS for kraft pulp mills.

The most stringent state total PM emissions limitations for recovery furnaces, smelt tanks and lime kilns at kraft pulp mills are summarized below:

	Recovery furnace	Smelt tank	Lime kiln
Concentration, mg/dscm (gr/dscf)	69 (0.03) [MD]	69 (0.03) [MD]	69 (0.03) [MD]
Emission rate	Curve 2 on Figure 4-1	Curve 2 on Figure 4-1	Curve 2 on Figure 4-1
Production-based rate	1.15 kg/Mg (2.3 lb/ton) equivalent unbleached dried pulp [KY]. 1.4 kg/1.4 Mg (3 lb/3,000 lb) of black liquor solids feed [FL].	0.25 kg/Mg (0.5 lb/ton) equivalent unbleached dried pulp [AL, ID, KY, LA, ME, NH, NM, OR, TN]. 0.1 kg/Mg (0.2 lb/ton black liquor solids [PA].	0.25 kg/Mg (0.5 lb/ton equivalent air dried pulp [NC].

The most stringent state opacity limitation is 0 percent [MD].

NSPS Subpart BB applies to kraft pulp mills that were installed or modified after September 24, 1976. The NSPS requirements are summarized as follows:

	Total PM	Opacity
Recovery furnace	100 mg/dscm (0.044 gr/dscf) corrected to 8% oxygen	Not $\geq$ 35%
Smelt dissolving tank	0.1 g/kg (0.2 lb/ton) black liquor solids (dry weight)	-
Lime kiln	150 mg/dscm (0.067 gr/dscf) corrected to 10% oxygen if gaseous fossil fuel is burned. 130 mg/dscm (0.13 gr/dscf) corrected to 10% oxygen if liquid fossil fuel is burned.	-

Examples of total PM emissions test data are summarized on Table 4-8 (OAQPS, 1976).

The most stringent state total PM emissions limitations for sulfite pulping are as follows:

- Concentration - 69 mg/dscm (0.03 gr/dscf [MD].
- Emission rate - 0.9 kg/24 hr (2 lb/24 hr) from blowpits, washer vents, storage tanks, digester relief and recovery operations [AK]. Also, refer to Curve 2 on Figure 4-1.
- Production-based rate - For recovery systems, 2 kg/Mg (4 lb/ton) of unbleached dried pulp [OR].

The most stringent state opacity limitation is 0 percent [MD].

SECONDARY ALUMINUM REDUCTION FACILITIES

Regulations for all 50 states were reviewed to determine the most stringent total PM and opacity limitations for secondary aluminum reduction facilities. The most stringent total PM emissions limitations are as follows:

- Concentration - 69 mg/dscm (0.03 gr/dscf) [FL, MD]. Another state [NJ] requires the least restrictive of the following: 1) an emission concentration of less than of equal to 46 mg/dscm (0.02 gr/dscf) with an upper cap of 14 kg/hr (30 lb/hr) or 2) a control efficiency of 99 percent.
- Emission rate - For melting and refining, as calculated by the following equation: $A = 0.76(10W)^{0.42}$; where A is the allowable rate (lb/hr) and W is the aluminum feed rate (ton/hr) [PA]. For other operations (sweating), allowable varies by production rate and is determined by the following equation: $A = 0.76(50W)^{0.42}$; where A is the allowable rate (lb/hr) and W is the production rate (ton/hr) [PA] or one of the curves on Figure 4-1.

The most stringent state opacity limit is 0 percent [MD].

Total PM emissions test data from a reverberatory furnace equipped with a scrubber are 37.9 mg/dscm (0.0165 gr/dscf) (Fitzpatrick, *et al*, 1991).

TABLE 4-8. SUMMARY OF EXAMPLE TOTAL PM EMISSIONS TEST DATA FOR KRAFT PULP MILLS

mg/dscm (gr/dscf)

Process operation: control device	No. of tests	No. of facilities	Maximum	Minimum	Average
Recovery furnace: ESP	9	4	120 (0.052)	7 (0.003)	53 (0.023)
Smelt dissolving tank: Scrubber	2	2	80 (0.035)	55 (0.024)	69 (0.030)
Lime kiln[a]: Scrubber	4	2	110 (0.048)	62 (0.027)	92 (0.040)

[a]Natural gas-fired.

SUGAR PRODUCTION PLANTS

State regulations were reviewed for California, Colorado, Idaho, Kansas, Michigan, Minnesota, Montana, Nebraska, North Dakota, Ohio, Oregon, Texas, Wisconsin and Wyoming to determine the most stringent total PM and opacity limitations for sugar production from sugar beets.

The most stringent total PM emission limitation is calculated from the following equations:

- $E = 0.045(PW)^{0.60}$ for production weights below 4.2 Mg/hr (9,250 lb/hr), or
- $E = 1.10\ (PW)^{0.25}$ for production weights greater than or equal to 4.2 Mg/hr (9,250 lb/hr); where E is the allowable rate (lb/hr) and PW is process weight (lb/hr) [ID].

There are two similarly strict opacity limitations:

- No more than an aggregate of 3 min/hr greater than or equal to 20 percent opacity [OR].
- Not greater than or equal to 20 percent opacity (6-minute) average [MT, NE].

SURFACE MINING OPERATIONS

State regulations for Arkansas, Arizona, Colorado, Illinois, Minnesota, Missouri, Montana, Nevada, New Mexico, North Carolina, North Dakota, South Dakota, Tennessee, Utah, Virginia, and Wyoming where reviewed to determine the most stringent limitations for surface mining. This source category includes such operations as scraping, grading and overburden removal. Ore concentrating is discussed under the Nonferrous Smelters portion of this Section. Nonmetallic mineral processing is discussed under the Nonmetallic Mineral Plants portion of this Section.

The emissions from this source category are fugitive dust. The most stringent fugitive dust limiations are as follows:

- Can not cause or permit handling, transporting or storing of any material in a manner which allows or may allow a controllable particulate to become airborne. Cannot use unpaved areas without reasonable precautions [NV].

- Fugitive emissions shall not be visible beyond property line. An operating program to minimize dust is required for certain sources [IL].

- Take reasonable precautions or measures to minimize fugitive emissions [CO, MN, ND, TN, VA, WY].

TURBINES (OIL-FIRED)

State regulations were reviewed for all fifty states to determine the most stringent total PM and opacity limitations for oil-fired turbines. The most stringent total emissions limitations are as follows:

- Concentration - 69 mg/dscm (0.03 gr/dscf) [MD, FL].

- Emission rate - Calculated from the following equation: $E = 1.02Q^{0.769}$; where E is the allowable rate (lb/hr) and Q is the heat input (MMBtu/hr) [AZ].

- Production-based rate - for units less than 53 GJ/hr (50 MMBtu/hr), 52 ng/J (0.12 lb/MMBtu). For units between 53 and 260 GJ/hr (50 and 250 MMBtu/hr), 34 ng/J (0.08 lb/MMBtu) [ME].

The most stringent opacity limitations states than there shall be no visible air contaminants, other than water, for longer than 10 consecutive seconds [MA].

Examples of total PM emissions test data for oil-fired turbines from 12 turbines ranges from 6.7 to 30.5 ng/J (0.02 to 0.07 lb/MMBtu) with an average of 15.5 ng/J (0.04 lb/MMBtu) (Shih, *et al*, 1979).

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SECTION 5

COSTS OF CONTROL

This Section describes procedures for estimating (1) total capital investment and (2) total annual costs of the control measures which are generally used to control PM-10 emissions. First it discusses the general sequence for preparing an estimate of total capital investment and total annual costs. The Section then defines the elements of total capital investment and of total annual costs in separate subsections. Each subsection also discusses estimating procedures and provides an example calculation. Sources of information needed to perform these estimating procedures are provided throughout the discussion, where appropriate.

GENERAL PROCEDURES

There are a number of different types of cost estimating procedures (Garrett, 1989) differing in the degree of detail required for preparation and the accuracy of the result. The procedures described here are for a "study" estimate, sometimes called a "factored" estimate. The accuracy should be within ± 30 percent (Garrett, 1989; Peters, 1980). The general sequence of steps for preparing a study estimate is:

1. Prepare a flowsheet for the control operation showing all the major control equipment and any auxiliary equipment required such as collection hoods, ductwork, fans, stacks, etc.

2. As necessary, calculate heat and material balances around each equipment item.

3. Size the equipment and determine the required material of construction. In some cases the equipment vendors or their representatives will size the equipment and specify the material of construction.

4. Estimate the cost of each equipment item either by obtaining vendor quotes or from published information.

5. Sum the cost of the equipment items plus the cost of instrumentation (if not already included in the

equipment cost), taxes, and freight to obtain the total purchased equipment cost.

6. The capital cost (total capital investment) estimate is then calculated from the total purchased equipment cost.

7. The total annual cost estimate is calculated based on information from the flowsheet and the capital cost estimate.

Flowsheet preparation, heat and material balance preparation, and equipment sizing procedures are beyond the scope of this document. For flowsheet preparation and heat and material balance preparation, consult basic chemical engineering texts such as Basic Principles and Calculations in Chemical Engineering (Himmelblau, 1982). Equipment sizing procedures can be found in the OAQPS Control Cost Manual (OAQPS, 1990) and the Chemical Engineers Handbook (Perry, 1984).

The remainder of this Section defines and discusses procedures that will allow you to arrive at total capital investment estimates and total annual cost estimates.

TOTAL CAPITAL INVESTMENT

Elements of Total Capital Investment

Total capital investment can be broadly broken into two categories, non-depreciable investment, which includes land and working capital, and depreciable investment, which includes all of the direct and indirect costs associated with the control system, including off-site facilities if applicable.

The non-depreciable investments (land and working capital) are not major factors. Working capital is the cost of raw materials and inventory, one month's accounts receivable and payable, and wages. It is rarely a factor for control equipment. Most control equipment does not occupy sufficient land for land to be a significant cost factor.

The depreciable investment (all of the direct and indirect costs) requires further explanation. Total direct costs comprise purchased equipment costs, direct installation costs, and related site preparation and building costs not already factored into the purchased equipment costs. Purchased equipment costs usually include:

- Primary control device
- Auxiliary equipment (including ductwork)
- Instrumentation

- Sales taxes
- Freight.

Direct installation costs include:

- Foundation and supports
- Handling and erection
- Electrical
- Piping
- Insulation
- Painting.

Total indirect costs comprise the following indirect installation costs:

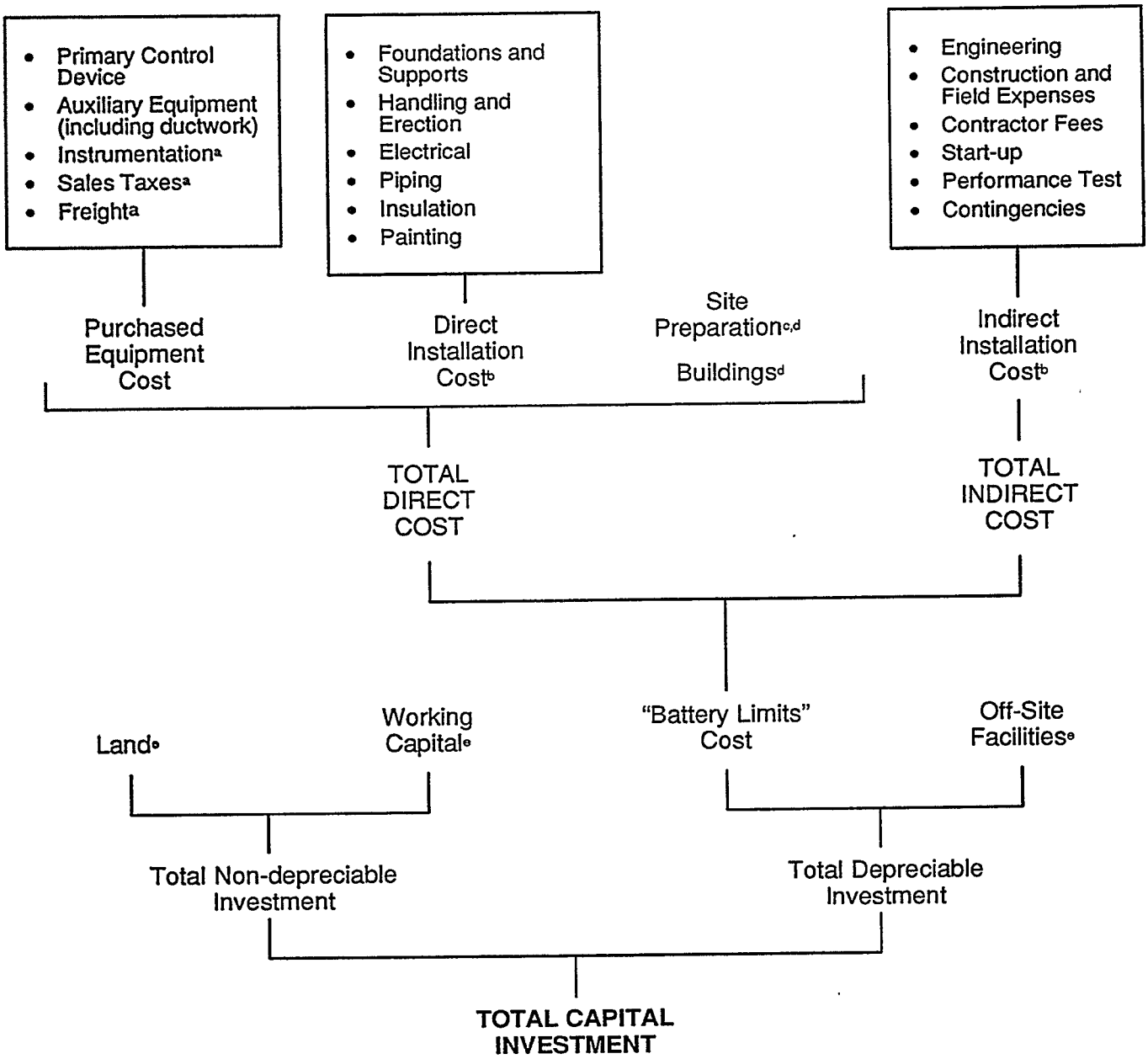
- Engineering
- Construction and field expenses
- Contractor fees
- Start-up
- Performance test
- Contingencies.

These elements of total capital investment are shown in Figure 5-1 and are taken from the OAQPS Control Cost Manual (OAQPS, 1990). Note on Figure 5-1 that the sum of the purchased equipment, total direct and indirect costs, site preparation, and buildings comprises the battery limits cost. The battery limits cost is an "estimate for a required investment for a specific job without regard to required supporting facilities which are assumed to exist already." (Humphreys, 1987). Examples of supporting facilities include an electrical substation or a cooling tower. It is valid to assume no supporting facilities when determining the cost of adding pollution control technology to an existing plant. It would also be valid for either new or existing plants unless such special supporting facilities are required specifically for the control device.

Estimating Total Capital Investment

"Of the many factors which contribute to poor estimates of capital investments, the most significant one is usually traceable to sizeable omissions of equipment, . . . or auxiliary facilities . . ." (Peters, 1991). Hence it is important that the entire control installation be thought through from the point where the pollutants are emitted to the point where the cleaned gas is discharged to the atmosphere to make sure all the required equipment is included.

There are a number of ways to calculate total capital investment. However, the procedure most commonly used in preparing study estimates begins by first obtaining the total



[a] Typically factored from the sum of the primary control device and auxilliary equipment costs.

[b] Typically factored from the purchased equipment cost.

[c] Usually required only at "grass roots" installations.

[d] Unlike the other direct and indirect costs, costs for these items usually are not factored from the purchased equipment cost. Rather, they are sized and costed separately.

[e] Normally not required with add-on control systems.

Figure 5-1. Elements of total capital investment.

purchased equipment cost. The remaining elements of the total capital investment are then calculated as percentages or "factors" of the total purchased equipment cost. This procedure is known as the "factored" approach to capital cost estimating.

Purchased Equipment Cost --

The costs of the individual equipment items which make up the control system can be obtained either from vendors' or fabricators' quotations or from published sources such as the OAQPS Control Cost Manual (OAQPS, 1990), the Chemical Engineers Handbook (Perry, 1984) or publications such as Chemical Engineering. Vendor's quotations will be in current dollars, but published cost data, will of necessity, be out of date. Cost indexes must be used to adjust these costs to current dollars. Cost indexes for equipment used in control systems can be found in Chemical Engineering which is published by McGraw-Hill Publications. These indexes are updated monthly. The current cost of the equipment item is obtained by multiplying the original cost of the equipment by the ratio of the cost index for the time the original cost was obtained to the current cost:

$$\text{current cost} = (\text{original cost}) \times \frac{\text{current index}}{\text{index at time original cost was obtained}}$$

If possible, cost data more than five years old should not be adjusted. If available, newer data should be used. The costs so obtained, and in most cases the vendors' quotations, will not include sales taxes, or the cost of transporting the equipment from the factory to the site where it is to be used. The cost of instrumentation must also be added if it is not already included in the cost of the control device. Without specific data, the cost of freight and taxes is estimated at 8 percent of the equipment cost (OAQPS, 1990). Instrumentation is usually a small part of the cost of the majority of control system installations. If no specific information is available, it can be estimated as 10 percent of the equipment cost (OAQPS, 1990). The total purchased equipment cost is then obtained by summing the equipment cost, taxes, freight, and instrumentation.

A contingency may also be included in calculating the total capital investment. A contingency "... is an estimate of the accuracy considering the development ... of the project" (Humphreys, 1987).

Total Capital Investment --

The components of the total capital investment are given in Table 5-1 for various control devices. The cost of each component of capital investment is obtained by multiplying the total purchased equipment cost by the factor for that component. The individual components are then summed to obtain the total capital investment.

The factors given in Table 5-1 (OAQPS, 1990; ORD, 1991) are for new construction, that is systems that are installed as the plant they are controlling is under construction. When the control system is sized for and installed on an existing process (i.e., retrofitted) the factors do not apply. Each retrofit installation is unique. Cost elements that can change in a retrofit installation are:

- Handling and erection - special care and time may be required if space for the installation is limited and the fit is tight.
- Piping, insulation, painting, and electrical may also increase. Retrofit installations may require longer than average pipe, duct and wire runs.
- Engineering and supervision - more than average may be required.
- Site preparation - this cost could go down, since most of the work would have been done when the plant was built.

For these reasons the contingency (i.e., uncertainty) factor should be increased when estimating retrofit installations. In the absence of specific information, 10 percent of the purchased equipment cost is suggested.

For illustration purposes, Table 5-2 is an example of the calculation of the total capital investment for a fabric filter using the factors given in Table 5-1. The fabric filter is designed to control fly ash emissions in a 1,416 m^3/min (50,000 acfm) flue gas stream at 436 K (325°F) from a new coal-fired boiler. The table is taken from the <u>OAQPS Control Cost Manual</u> (OAQPS, 1990).

TOTAL ANNUAL COST

<u>Elements of Total Annual Cost</u>

The total annual cost is generally broken down into direct and indirect costs. Direct costs are those which are

TABLE 5-1. CAPITAL INVESTMENT ELEMENTS AND FACTORS[a,b] FOR VARIOUS CONTROL DEVICES

Cost elements	Cost Factors		
	ESP	Venturi scrubbers	Fabric filters
DIRECT COSTS			
Purchased Equipment Cost[c]	1.00	1.00	1.00
Other Direct Costs[d]			
Foundation and supports	0.04	0.06	0.04
Erection and handling	0.50	0.40	0.50
Electrical	0.08	0.01	0.08
Piping	0.01	0.05	0.01
Insulation	0.02	0.03	0.07
Painting	0.02	0.01	0.02
Total Direct Cost	1.67	1.56	1.72
INDIRECT COSTS			
Engineering and supervision	0.20	0.10	0.10
Construction and field expenses	0.20	0.10	0.20
Contractor fees	0.10	0.10	0.10
Start-up	0.01	0.01	0.01
Performance test[e]	0.01	0.01	0.01
Model study	0.02	-	-
Contingencies[f]	0.03	0.03	0.03
Total Indirect Cost	0.57	0.35	0.45
TOTAL CAPITAL INVESTMENT	2.24	1.91	2.17

[a]Taken from Handbook, Control Technologies for Hazardous Air Pollutants for new source construction (ORD, 1991).

[b]As fractions of total purchased equipment cost. They must be applied to the total purchased equipment cost.

[c]Total of purchased costs of major equipment and auxiliary equipment and others, which include instrumentation and controls at 10%, taxes and freight at 8% of the equipment purchase cost. Note that instrumentation may be included in the cost of the control device and would therefore not need to be calculated separately.

[d]Site preparation and buildings would be included in this category if required.

[e]The performance test determines that all items of equipment operate properly. It does not include the cost of determining that the control system emissions meet requirements; this is an operating cost.

[f]Contingency costs are estimated to equal 3% of the purchased equipment cost (OAQPS, 1990). The contingency cost should be increased when estimating a retrofit installation. In the absence of specific information 10% of the purchased equipment cost is suggested.

TABLE 5-2. CAPITAL INVESTMENT FOR FABRIC FILTER SYSTEM -- EXAMPLE CALCULATION

Cost item			Cost
DIRECT COSTS			
Purchased equipment costs			
Fabric filter (with insulation)	$ 80,231		
Bags and cages	18,092		
Auxiliary equipment[a]	62,700		
Sum = A		$161,023	
Sales taxes, 0.03A		4,831	
Freight, 0.05A		8,051	
Instrumentation, 0.1A		16,102	
Purchased equipment cost= B			$190,007
Installation costs			
Foundation and supports, 0.04B		7,600	
Handling and erection, 0.50B		95,004	
Electrical, 0.08B		15,201	
Piping, 0.01B		1,900	
Insulation for ductwork, 0.07B		13,300	
Painting, 0.02B		3,800	
Installation cost			136,805
Site preparation		Not required	
Facilities and buildings		Not required	
Total Direct Cost			326,812
INDIRECT COSTS			
Engineering, 0.10B		19,001	
Construction and field expenses, 0.20B		38,001	
Contractor fees, 0.10B		19,001	
Start-up, 0.01B		1,900	
Performance test, 0.01B		1,900	
Contingencies, 0.03B		5,700	
Total Indirect Cost			85,503
TOTAL CAPITAL INVESTMENT			$412,315

[a]For the installation illustrated by this example, the auxiliary equipment is:

Ductwork	$14,000
Fan	14,000
Motor	7,000
Starter	3,500
Dampers	7,200
Compressor	6,000
Screw conveyor	4,000
Stack	7,000
Total	$62,700

proportional, or in some cases roughly so, to the plant operating rate. These costs include operating labor and supervision, maintenance labor and materials, parts that must be replaced on a routine basis (e.g., bags in a fabric filter), raw materials (if any), utilities, and any waste disposal costs. Indirect costs are plant overhead charges, taxes, insurance, administrative charges, and capital recovery. These costs are fixed and tend to be incurred whether or not the control system is operating.

If the control system recovers material or energy which can be used, recycled or sold, the value of the material or energy must be included as a recovery credit which will reduce the total annual costs. Figure 5-2 taken from the OAQPS Control Cost Manual (OAQPS, 1990) shows the elements of total annual cost.

Estimating Total Annual Cost

Direct Costs --

The procedures for estimating direct annual costs are discussed below.

Operating Labor -- Operating labor is dependent on the complexity of the control system, the degree of automation, and to a lessor extent on the size of the system, and is usually estimated based on the estimator's experience, considering the foregoing factors. Typical labor requirements can be found in the example problems in the OAQPS Control Cost Manual (OAQPS, 1990). Operating labor is usually stated on an hours-per-shift basis. The number of hours (or number of eight hour shifts) the equipment will operate annually is usually determined when the equipment is sized. Wage rates for operating labor are industry dependent. Employment and Earnings, a monthly publication of the U.S. Department of Labor, Bureau of Statistics, provides wage rates for most industries.

The cost of supervision must be added to the labor cost. Unless specific information is available, supervision is usually estimated as 15 percent of the cost of operating labor (OAQPS, 1990).

Maintenance -- Maintenance labor can be estimated and calculated in the same manner as operating labor. The maintenance labor rate is usually higher than the operating labor rate because greater skills are required. A 10 percent labor premium is typical (OAQPS, 1990). The number of maintenance hours will depend on the complexity of the control system, the composition of the emission stream (which will influence its corrosivity) and on the severity of the service environment. Maintenance materials are then usually estimated as equal to maintenance labor.

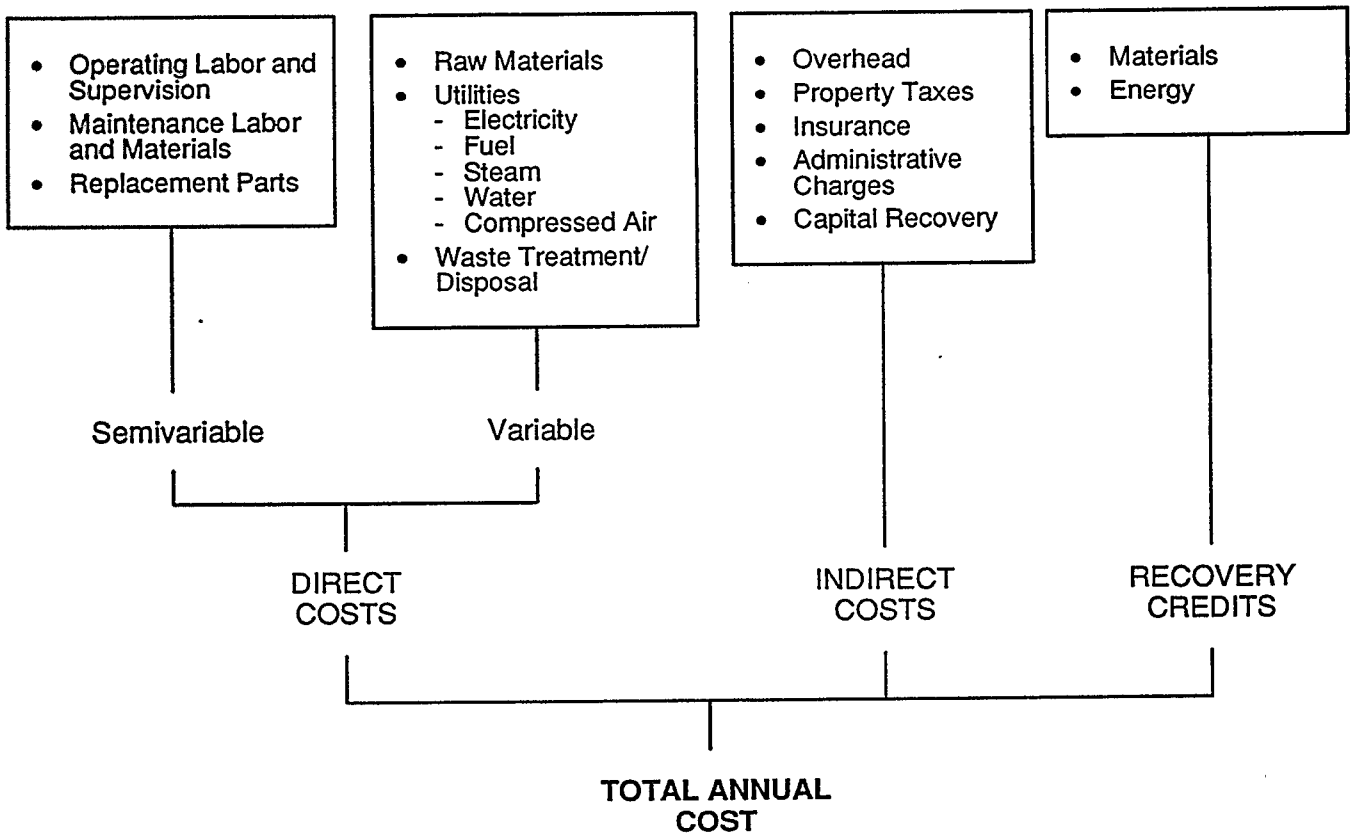


Figure 5-2. Elements of total annual cost.

An alternative way to estimate maintenance costs, if no data on actual hourly requirements is available, is as a fixed percentage of the total capital investment (Humphreys, 1987). The percentage varies from 3 to 5 percent for a simple system controlling a relatively non-corrosive emission stream to 12 percent for a complex system operating in a corrosive environment. Maintenance costs are usually distributed 50 percent to labor, 50 percent to materials.

Replacement Parts -- The cost of replacement parts, such as filter bags, that require replacement on a routine basis and are a significant expense is not included in the maintenance cost but is included in the direct costs as a separate item. The annual cost of replacement parts includes both the cost of the part and the cost of the labor to install it. In the OAQPS Control Cost Manual methodology (OAQPS, 1990) replacement parts are treated like any other investment in that they are considered an expenditure that must be amortized over the life of the part. The annual cost of the replacement part is then:

$$C = (R + L)CRF \qquad (5.1)$$

where:

C = annual cost of the replacement parts, $/year
R = initial cost of the part, including taxes and freight,$
L = part replacement labor, $
CRF = capital recovery factor whose value is a function of the annual interest rate and the useful life of the part. (See discussion of the capital recovery factor and equation 5.4 below.)

When the annual cost of replacement parts is calculated using equation 5.1 and included in the annual cost, double counting must be avoided. This is done by reducing the total capital investment (P in equation 5.3 below) by the sum of the cost of the parts, including taxes and freight and labor for installing them, when the annual capital recovery charge is calculated to avoid double counting.

Raw Materials -- Raw materials are generally not required. A possible exception would be an alkaline material added to the circulating water in a venturi scrubber to neutralize acidic gasses such as sulfur dioxide or hydrogen chloride in the emission stream. The quantity of raw material required is directly proportional to the quantity of material treated and is calculated by a material balance. The cost of chemicals can be obtained from the Chemical Marketing Reporter, published by the Schnell Publishing Company, Inc., New York, NY, or from chemical manufacturers or suppliers.

Utilities -- Electricity, fuel, steam, cooling water, and compressed air are included in this category. Consumption of these items is determined from energy and material balances calculated around the control device. These calculations are made during the design of the control system.

Because nearly every system requires an electric fan to move the process emission gas through the control device, a general expression for fan power requirements is provided (OAQPS, 1990):

$$K = 0.00025164Q\Delta P \qquad (5.2a)$$

where:

K = power required by the fan, kilowatts
Q = system flow rate, actual cubic meters per minute
ΔP= system pressure drop, in millimeters of water.

In English units the equation is:

$$K = 0.000181Q\Delta P \qquad (5.2b)$$

where:

K = power required by the fan, kilowatts
Q = system flow rate, actual cubic feet per minute
ΔP= system pressure drop, inches of water.

The equation assumes a combined fan/motor efficiency of 65 percent.

The cost of electricity and natural gas vary by region and are best obtained from the local supplier. The cost of utilities generated in-plant such as compressed air and steam should, if possible, be obtained from the plant.

Utilities are a direct cost. The utility usage rate (i.e., kilowatts for a fan) must be multiplied by the annual operating hours to obtain the annual consumption. The annual consumption is then multiplied by the cost per unit to obtain the annual cost.

Waste Disposal -- There can be a significant charge associated with the emitted material captured by a control system that can neither be sold or recycled. Some streams, such as the thin suspension from a venturi scrubber, may have to be processed to remove the solids before being discharged. Additional treatment such as pH adjustment may be required. If a liquid stream is discharged to a treatment works, there would be a charge. There would also be a charge for landfilling or possibly incinerating a solid stream.

Waste disposal charges can vary widely. Landfilling costs for non-hazardous solid waste can vary from $10 to over a $100 per ton depending on the area of the country (Siddens, 1990). Disposal costs for hazardous solid wastes are much higher. Waste water treatment costs range from $0.25 to $0.50/m^3 ($1.00 to $2.00/1,000 gallons) or more, depending on the degree of treatment required (OAQPS, 1990), plus the costs for disposing of any solids generated by the treatment.

Indirect Costs --

The procedures for estimating indirect annual costs are summarized below.

Overhead -- There are generally two categories of overhead: payroll and plant. Payroll overhead is comprised of expenses incurred as a result of operating, maintenance and supervisory labor and includes such items as Social Security fund payments, pension fund costs, workmen's compensation payments, and vacations.

Plant overhead accounts for the cost of plant protection services, plant lighting, parking lots, interplant communications, and shipping and receiving facilities. For study estimates these two types of overhead are combined. Peters and Timmerhaus (Peters, 1980) recommend a charge of 50 to 70 percent of the total cost for operating, maintenance and supervisory labor and maintenance materials. Sixty percent is recommended by the OAQPS Control Cost Manual (OAQPS, 1990).

Property Taxes, Insurance and Administrative Charges -- These three costs are proportional to the plant investment and are calculated at 1, 1 and 2 percent of the total capital investment, respectively. These values are standard in all OAQPS cost analyses (OAQPS, 1990).

Capital Recovery -- The capital recovery charge allows the owner/operator of the control equipment to recover the capital cost of the system plus interest over the useful life of the system as a series of uniform annual payments (Grant, 1982). The annual capital recovery cost is calculated as

$$CRC = CRF \times P \qquad (5.3)$$

where:

CRC = the capital recovery cost
CRF = the capital recovery factor
P = the total capital investment.

The capital recovery factor is:

$$CRF = \frac{i(1 + i)^n}{(1 + i)^n - 1} \qquad (5.4)$$

where:

i = the interest rate; it is usually set at 10 percent in keeping with the current Office of Management and Budget recommendations for use in regulatory analysis.

n = the economic life of the control system, typically 10 to 20 years for a system but may be much shorter for replacement parts.

Recovery Credit --

When there are recovery credits (e.g. raw material or product recovered by a fabric filter), they are included as a separate subheading following Total Indirect Annual Costs.

Total Annual Cost --

The total annual cost then is the sum of the direct costs (raw materials, utilities, labor, maintenance, and waste treatment/disposal) and the indirect costs (overhead, property taxes, insurance, administrative charges, and capital recovery) less any credits for material or energy recovery that will be achieved by the control system.

For illustration purposes, Table 5-3, taken from the OAQPS Control Cost Manual (OAQPS, 1990) shows the calculation of Total Annual Cost for a fabric filter system presented in Table 5-2, above. In this example, waste disposal is a major component of the annual cost, and there are no recovery credits.

TABLE 5-3. ANNUAL COSTS FOR FABRIC FILTER SYSTEM -- EXAMPLE CALCULATION

DIRECT ANNUAL COST	
Operating Labor	
Operator	
$\frac{2\ hr}{shift} \times \frac{3\ shifts}{day} \times \frac{360\ days}{yr} \times \frac{\$12}{hr} =$	$ 25,920
Supervisor	
15% of operator labor = .15 x 25,920 =	3,888
Maintenance	
Labor	
$\frac{3\ hr}{day} \times \frac{360\ days}{yr} \times \frac{\$13.20}{hr} =$	14,256
Material	
100% of maintenance labor =	14,256
Replacement parts, bags[a]	
[(13,220 x 1.08) + 2,809] x 0.5762 =	9,845
Raw materials	Not required
Utilities	
Electricity (fan only)	
$0.00025164 \times \frac{1,416\ m^3}{min} \times 261.6\ mm\ H_2O \times \frac{8,640\ hr}{yr} \times \frac{\$0.06}{kWh} =$	48,323
Compressed air (a pulse jet filter requires 2 $sm^3/1000m^3$ of gas filtered, at a cost of $5.65 per 1000 sm^3)	
$\frac{2\ sm^3}{1000\ m^3} \times \frac{1416\ m^3}{min} \times \frac{\$5.65}{1000sm^3} \times \frac{60\ min}{hr} \times \frac{8640\ hr}{yr} =$	8,295
Waste disposal (at $22/Mg, disposed of on-site, assuming 100% collection efficiency)	
$\frac{9.2\ g}{m^3} \times \frac{1416\ m^3}{min} \times \frac{60\ min}{hr} \times \frac{8640\ hr}{yr} \times \frac{1Mg}{10^6 g} \times \frac{\$22}{Mg} =$	148,573
Total Direct Annual Costs	$ 273,355

(continued)

TABLE 5-3. (Continued)

INDIRECT ANNUAL COSTS	
Overhead	
60% (labor and maintenance materials) = 0.6(25,920 + 3,888 + 14,256 + 14,256) =	$ 34,992
Property tax	
1% of Total Capital Investment = 0.01($412,000) =	4,120
Insurance	
1% of Total Capital Investment = 0.01($412,000) =	4,120
Administrative charges	
2% of Total Capital Investment = 0.02($412,000) =	8,240
Capital recovery[b]	
0.1175 (412,315 - 2,809 - 13,220 x 1.08) =	46,439
Total Indirect Annual Costs	97,911
RECOVERY CREDITS	Not applicable
TOTAL ANNUAL COST (ROUNDED)	$371,000

[a]The cost of the replacement bags is $13,220. The 1.08 factor is for freight and sales taxes. For bag replacement labor, 10 minutes per bag for each of 795 bags was assumed. At a maintenance labor rate of $21.12 (including 60% overhead), the labor cost is $2,809 for 133 hours. The replacement cost was] calculated using equation 5.1. The CRF, in equation 5.1 is calculated using equation 5.4 for a 2 year life and 10% interest:

$$CRF = \frac{0.1\ (1+0.1)^2}{(1+0.1)^2 - 1} = 0.5762$$

[b]For a 20 year equipment life and a 10% interest rate, CRF = 0.1175. The total capital investment (from Table 5-2) is reduced by the total cost of replacing the bags to avoid double counting.

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16. ABSTRACT

This guidance document sets forth procedures and identifies sources of information that will assist State and local air pollution control agencies in determining Reasonably Available Control Technology (RACT) for PM-10 (particulate matter having a nominal aerometri diameter of 10 microns or less) emission from existing stationary sources on a case-bycase basis. It provides an annotated bibliography of documents to aid in identifying the activities that cause PM-10 emissions as well as applicable air pollution control measures and their effectiveness in reducing emissions. The most stringent state total particulate matter (PM) emission limits are identified for several categories of PM-10 sources and compared to available emission test data. Finally, guidance is provided on procedures for estimating total capital investment and total annual cost of the control measures which are generally used to control PM-10 emissions.

17. KEY WORDS AND DOCUMENT ANALYSIS

a. DESCRIPTORS	b. IDENTIFIERS/OPEN ENDED TERMS	c. COSATI Field/Group
Particulate matter, PM-10, emission limits, control technology, cost of control		

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