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BACKGROUND INFORMATION FOR STANDARDS OF PERFORMANCE: ELECTRIC SUBMERGED ARC FURNACES FOR PRODUCTION OF FERROALLOYS

VOLUME 1: PROPOSED STANDARDS

Emission Standards and Engineering Division

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PREFACE

A. Purpose of this Report

Standards of performance under section 111 of the Clean Air Act[1/] are proposed only after a very detailed investigation of air pollution control methods available to the affected industry and the impact of their costs on the industry. This report summarizes the information obtained from such a study of the ferroalloy industry. It is being distributed in connection with formal proposal of standards for that industry in the *Federal Register*. Its purpose is to explain the background and basis of the proposal in greater detail than could be included in the *Federal Register*, and to facilitate analysis of the proposal by interested persons, including those who may not be familiar with the many technical aspects of the industry. For additional information, for copies of documents (other than published literature) cited in the Background Information Document, or to comment on the proposed standards, contact Mr. Don R. Goodwin, Director, Emission Standards and Engineering Division, United States Environmental Protection Agency, Research Triangle Park, North Carolina 27711 [(919)688-8146].

B. Authority for the Standards

Standards of performance for new stationary sources are promulgated in accordance with section 111 of the Clean Air Act (42 USC 1857c-6), as amended in 1970. Section 111 requires

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1/ Sometimes referred to as "new source performance standards" (NSPS).

the establishment of standards of performance for new stationary sources of air pollution which "... may contribute significantly to air pollution which causes or contributes to the endangerment of public health or welfare." The Act requires that standards of performance for such sources reflect "... the degree of emission limitation achievable through the application of the best system of emission reduction which (taking into account the cost of achieving such reduction) the Administrator determines has been adequately demonstrated." The standards apply only to stationary sources, the construction or modification of which commences after regulations are proposed by publication in the Federal Register.

Section 111 prescribes three steps to follow in establishing standards of performance.

1. The Administrator must identify those categories of stationary sources for which standards of performance will ultimately be promulgated by listing them in the Federal Register.
2. The regulations applicable to a category so listed must be proposed by publication in the Federal Register within 120 days of its listing. This proposal provides interested persons an opportunity for comment.
3. Within 90 days after the proposal, the Administrator must promulgate standards with any alterations he deems appropriate.

It is important to realize that standards of performance, by themselves, do not guarantee protection of health or welfare; that is, they are not designed to achieve any specific air quality levels. Rather, they are designed to reflect best demonstrated technology (taking into account costs) for the affected sources. The overriding purpose of the collective body of standards is to maintain existing air quality and to prevent new pollution problems from developing.

Previous legal challenges to standards of performance for portland cement plants, steam generators, and sulfuric acid plants have resulted in several court decisions[2/] of importance in developing future standards. In those cases, the principal issues were whether EPA: (1) made reasoned decisions and fully explained the basis of the standards, (2) made available to interested parties the information on which the standards were based, and (3) adequately considered significant comments from interested parties.

Among other things, the court decisions established: (1) that preparation of environmental impact statements is not necessary for standards developed under section 111 of the Clean Air Act because, under that section, EPA must consider any counter-productive environmental effects of a standard in determining what system of control is "best;" (2) in considering costs it is not necessary to provide a cost-benefit analysis;

2/ Portlant Cement Association v Ruckelshaus, 486 F. 2nd 375 (D.C. Cir. 1973); Essex Chemical Corp. v Ruckelshaus, 486 F. 2nd 427 (D.C. Cir. 1973).

(3) EPA is not required to justify standards that require different levels of control in different industries unless such different standards may be unfairly discriminatory; and (4) it is sufficient for EPA to show that a standard can be achieved rather than that it has been achieved by existing sources.

Promulgation of standards of performance does not prevent State or local agencies from adopting more stringent emission limitations for the same sources. On the contrary section 116 of the Act (42 USC 1857-D-1) makes clear that States and other political subdivisions may enact more restrictive standards. Furthermore, for heavily polluted areas, more stringent standards may be required under section 110 of the Act (42 USC 1857c-5) in order to attain or maintain national ambient air quality standards prescribed under section 109 (42 USC 1857c-4). Finally, section 116 makes clear that a State may not adopt or enforce less stringent standards than those adopted by EPA under section 111.

Although it is clear that standards of performance should be in terms of limits on emissions where feasible,[3/] an alternative method of requiring control of air pollution is sometimes necessary. In some cases physical measurement of emissions from a new source may be impractical or exorbitantly expensive.

3/ "'Standards of performance,' ... refers to the degree of emission control which can be achieved through process changes, operation changes, direct emission control, or other methods. The Secretary [Administrator] should not make a technical judgment as to how the standard should be implemented. He should determine the achievable limits and let the owner or operator determine the most economical technique to apply." Senate Report 91-1196.

For example, emissions of hydrocarbons from storage vessels for petroleum liquids are greatest during storage and tank filling. The nature of the emissions (high concentrations for short periods during filling and low concentrations for longer periods during storage) and the configuration of storage tanks make direct emission measurement highly impractical. Therefore, a more practical approach to standards of performance for storage vessels has been equipment specification.

C. Selection of Categories of Stationary Sources

Section 111 directs the Administrator to publish and from time to time revise a list of categories of sources for which standards of performance are to be proposed. A category is to be selected "... if [the Administrator] determines it may contribute significantly to air pollution which causes or contributes to the endangerment of public health or welfare."

Since passage of the Clean Air Amendments of 1970, considerable attention has been given to the development of a system for assigning priorities to various source categories. In brief, the approach that has evolved is as follows.

First, we assess any areas of emphasis by considering the broad EPA strategy for implementing the Clean Air Act. Often, these "areas" are actually pollutants which are primarily emitted by stationary sources. Source categories which emit these pollutants are then evaluated and ranked by a process involving such factors as (1) the level of emission control (if any) already required by State regulations; (2) estimated levels of control that might result from standards of performance for the source category; (3) projections of growth and replacement of existing facilities for the source category; and (4) the estimated incremental amount of air pollution that could be prevented, in a preselected future year, by standards of performance for the source category.

After the relative ranking is complete, an estimate must be made of a schedule of activities required to develop a standard. In some cases, it may not be feasible to immediately develop a standard for a source category with a very high priority. This might occur because a program of research and development is needed or because techniques for sampling and measuring emissions may require refinement before study of the industry can be initiated. The schedule of activities must also consider differences in the time required to complete the necessary investigation for different source categores. Substantially more time may be necessary, for example, if a number of pollutants must be investigated in a single source category. Even late in the development process the schedule for completion of a standard may change. For example, inability to obtain emission data from well-controlled sources in time to pursue the development process in a systematic fashion may force a change in scheduling.

Selection of the source category leads to another major decision: determination of the types of sources or facilities to which the standard will apply. A source category often has several facilities that cause air pollution. Emissions from some of these facilities may be insignificant and, at the same time, very expensive to control. An investigation of economics may show that, within the costs that an owner could reasonably afford, air pollution control is better served by applying standards to the more severe pollution problems. For this reason (or perhaps because there may be no adequately demonstrated system for controlling emissions from certain facilities), standards often do not apply to all sources within a category. For similar reasons, the standards may not apply to all air pollutants emitted by such sources. Consequently, although a source category may be selected to be covered by a standard of performance, treatment of some of the pollutants or facilities within that source category may be deferred.

D. Procedure for Development of Standards of Performance

Congress mandated that sources regulated under section 111 of the Clean Air Act be required to utilize the best practicable air pollution control technology that has been adequately demonstrated at the time of their design and construction. In so doing, Congress sought to:

1. maintain existing high-quality air,
2. prevent new air pollution problems, and
3. ensure uniform national standards for new facilities.

The selection of standards of performance to achieve the intent of Congress has been surprisingly difficult. In general, the standards must (1) realistically reflect best demonstrated control practice; (2) adequately consider the cost of such control; (3) be applicable to existing sources that are modified as well as new installations; and (4) meet these conditions for all variations of operating conditions being considered anywhere in the country.

A major portion of the program for development of standards is spent identifying the best system of emission reduction which "has been adequately demonstrated" and quantifying the emission rates achievable with the system. The legislative history of section 111 and the court decisions referred to above make clear that the Administrator's judgment of what is adequately demonstrated is not limited to systems that are in actual routine use. Consequently, the search may include a technical assessment of control systems which have been adequately demonstrated but for which there is limited operational experience. To date, determination of the "degree of emission limitation achievable" has been commonly based on (but not restricted to) results of tests of emissions from existing sources. This has required worldwide investigation and measurement of emissions from control systems. Other countries with heavily populated, industrialized areas have sometimes developed more effective systems of control than those used in the United States.

Because the best demonstrated systems of emission reduction may not be in widespread use, the data base upon which the standards are established will necessarily be somewhat limited. Test data on existing well-controlled sources are an obvious starting point in developing emission limits for new sources. However, since the control of existing sources generally represents retrofit technology or was originally designed to meet an existing State or local regulation, new sources may be able to meet more stringent emission standards. Accordingly, other information must be considered and judgment is necessarily involved in setting proposed standards.

Since passage of the Clean Air Amendments of 1970, a process for the development of a standard has evolved. In general, it follows the guidelines below.

1. Emissions from existing well-controlled sources are measured.
2. Data on emissions from such sources are assessed with consideration of such factors as: (a) the representativeness

of the source tested (feedstock, operation, size, age, etc.); (b) the age and maintenance of the control equipment tested (and possible degradation in the efficiency of control of similar new equipment even with good maintenance procedures); (c) the design uncertainties for the type of control equipment being considered; and (d) the degree of uncertainty affecting the judgment that new sources will be able to achieve similar levels of control.

3. During development of the standards, information from pilot and prototype installations, guarantees by vendors of control equipment, contracted (but not yet constructed) projects, foreign technology, and published literature are considered, especially for sources where "emerging" technology appears significant.
4. Where possible, standards are set at a level that is achievable with more than one control technique or licensed process.
5. Where possible, standards are set to encourage (or at least permit) the use of process modifications or new processes as a method of control rather than "add-on" systems of air pollution control.
6. Where possible, standards are set to permit use of

systems capable of controlling more than one pollutant (for example, a scrubber can remove both gaseous and particulate matter emissions, whereas an electrostatic precipitator is specific to particulate matter).

7. Where appropriate, standards for visible emissions are established in conjunction with mass emission standards. In such cases, the standards are set in such a way that a source meeting the mass emission standard will be able to meet the visible emission standard without additional controls. (In some cases, such as fugitive dust, there is no mass standard).

Finally, when all pertinent data are available, judgment is again required. Numerical tests may not be transposed directly into regulations. The design and operating conditions of those sources from which emissions were actually measured cannot be reproduced exactly by each new source to which the standard of performance will apply.

E. How Costs are Considered

Section 111 of the Clean Air Act requires that cost be considered in setting standards of performance. To do this requires an assessment of the possible economic effects of implementing various levels of control technology in new plants within a given industry. The first step in this analysis requires the generation of estimates of installed capital costs and annual operating costs for various demonstrated control systems, each control system alternative having a different overall control capability. The final step in the analysis is to determine the economic impact of the various control alternatives upon a new plant in the industry. The fundamental question to be addressed in this step is whether or not a new plant would be constructed given that a certain level of control costs would be incurred. Other issues that would be analyzed in this step would be the effects of control costs upon product prices and the effects on product and raw material supplies and producer profitability.

The economic impact upon an industry of a proposed standard is usually addressed both in absolute terms and by comparison with the control costs that would be incurred as a result of compliance with typical existing State control regulations. This incremental approach is taken since a new plant would be required to comply with State regulations in the absence of a Federal standard of performance. This approach requires a detailed analysis of the impact upon the industry resulting from the cost differential that usually exists between the standard of performance and the typical State standard.

It should be noted that the costs for control of air pollutants are not the only control costs considered. Total environmental costs for control of water pollutants as well as air pollutants are analyzed wherever possible.

A thorough study of the profitability and price-setting mechanisms of the industry is essential to the analysis so that an accurate estimate of potential adverse economic impacts can be made. It is also essential to know the capital requirements placed on plants in the absence of Federal standards of performance so that the additional capital requirements necessitated by these standards can be placed in the proper perspective. Finally, it is necessary to recognize any constraints on capital availability within an industry as this factor also influences the ability of new plants to generate the capital required for installation of the additional control equipment needed to meet the standards of performance.

The end result of the analysis is a presentation of costs and potential economic impacts for a series of control alternatives. This information is then a major factor which the Administrator considers in selecting a standard.

F. Impact on Existing Sources

Proposal of standards of performance may affect an existing source in either of two ways. First, if modified after proposal of the standards, with a subsequent increase in air pollution, it is subject to standards of performance as if it were a new source. (Section 111 of the Act defines a new source as "any stationary source, the construction or modification of which is commenced after the regulations are proposed.")4/

Second, promulgation of a standard of performance requires States to establish standards of performance for the same pollutant for existing sources in the same industry under section 111(d) of the Act; unless the pollutant limited by the standard for new sources is one listed under section 108 (requiring promulgation of national ambient air quality standards) or one listed as a hazardous pollutant under section 112. If a State does not act, EPA must establish such standards. Regulations prescribing procedures for control of existing sources under section 111(d) will be proposed as Subpart B of 40 CFR Part 60.

G. Revision of Standards of Performance

Congress was aware that the level of air pollution control achievable by any industry may improve with technological advances. Accordingly, section 111 of the Act provides that the Administrator may revise such standards from time to time. Although standards proposed and promulgated by EPA under section 111 are designed to require installation of the "... best system of emission reduction ... (taking into account the cost)..." the standards will be reviewed periodically. Revisions will be proposed and promulgated as necessary to assure that the standards

4/ Specific provisions dealing with modifications to existing facilities are being proposed by the Administrator under the General Provisions of 40 CFR Part 60.

continue to reflect the best systems that become available in the future. Such revisions will not be retroactive but will apply to stationary sources constructed or modified after proposal of the revised standards.

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I. THE FERROALLOY INDUSTRY

A. General

A ferroalloy is "a crude alloy of iron with one or more other elements (as metals) used for deoxidizing molten steels and making alloy steels."(1) A list of the major ferroalloys and their manufacturing processes is shown in Table I-1. Calcium carbide, although not a ferroalloy, is produced at ferroalloy plants by a process similar to that for ferroalloys. For purposes of this report, "ferroalloys" will include calcium carbide unless otherwise specified.

The United States is the world's largest producer and user of ferroalloys. In 1971, about 2,331,000 tons of ferroalloys valued at about 558 million dollars were produced by the United States ferroalloy industry.(2) Another 400,000 tons of high-carbon ferromanganese were manufactured by the iron and steel industry in blast furnaces. An additional 380,000 tons of ferroalloys were imported. During the 10 years prior to 1972, the United States' consumption of ferroalloys increased at an average annual rate of 2 percent while average production increases were 1.5 percent per year.(3) Table I-2 shows the companies, plant locations, plant sizes, products, furnace types and number of furnaces for each domestic producer for the year 1971. In 1971 the industry employment was about 10,100 persons.(4)

Section 111(b)(1) of the Clean Air Act, as amended, requires that the Environmental Protection Agency develop standards of performance for sources which "cause or contribute to the endangerment of public health

Table I-1

Major Ferroalloys and Their Manufacturing Processes

Process	Ferroalloys
Submerged-arc furnace process -	Silvery iron 50% Ferrosilicon 65-75% Ferrosilicon Silicon metal Calcium silicon Silicomanganese zirconium (SMZ) High-carbon (HC) ferromanganese Silicomanganese Ferromanganese silicon Charge chrome and HC ferrochrome Ferrochrome silicon Calcium carbide
Exothermic process -	Low-carbon (LC) ferrochrome LC ferromanganese Medium-carbon (MC) ferromanganese Chromium metal, FeTi, FeV and FeCb
Electrolytic process -	Chromium metal Manganese metal
Vacuum furnace process -	LC ferrochrome
Induction furnace process -	Ferrotitanium

TABLE I-2. TYPES, SIZES, AND LOCATIONS OF FERROALLOY PRODUCING PLANTS IN THE UNITED STATES, AUGUST 1971[1/]

	Producers	Plant Size[2/]	Locations	Products	Type of Furnace	No. Furnaces Alloy	No. Furnaces Carbide
1	Air Reduction Co., Inc.	L	Calvert City, Ky.		Electric	11	3
2	Airco Alloys Div.	M	Charleston, S.C.	FeCr, FeMn, FeSi, FeCrSi, CaC_2	Electric	2	
3		M	Niagara Falls, N. Y.		Electric	1	
4		S	Theodore, Ala.		Electric	1	
5		M	Louisville, Ky.	CaC_2	Electric		1
6	American Potash Co.	S	Aberdeen, Miss.	Mn	Electrolytic		
7	Chromium Mining and Smelting Co.	M	Woodstock, Tenn.	FeMn, SiMn, FeSi, FeCr, FeCrSi	Electric	5	
8	Climax Molybdenum Co.	S	Langeloth, Pa.	FeMo	Aluminothermic		
9	Foote Mineral Co.	S	Cambridge, Ohio	FeB, FeCb, FeTi, FeV, other	Electric	2	
10		L	Graham, W. Va.	FeCr, FeCrSi, FeSi, other	Electric	9	
11		M	Keokuk, Iowa	FeSi, Silvery Iron	Electric	5	
12		S	N. Johnsonville, Tenn.	Mn	Electrolytic		
13		M	Steubenville, Ohio	FeCr, FeCrSi	Electric	6	
14		M	Wenatchee, Wash.	FeSi, Si	Electric	4	
15	Hanna Nickel Smelting Co.	S	Riddle, Oreg.	FeSi	Electric	4	
16	Interlake Steel Corp.	L	Beverly, Ohio	FeCr, FeSi, SiMn	Electric	7	
17	Kawecki Berylco Industries	S	Springfield, Oreg.	Si	Electric	2	
18	Kawecki Chemical Co.	S	Easton, Pa.	FeCb	Aluminothermic		
19	Luckenby	S	Selma, Ala.	FeSi	Electric	1	
20	Manganese Chemicals Co., Diamond Shamrock	S	Kingwood, W. Va.	FeMn	Electric		
21	Midwest Carbide Co.	S	Keocuk, Iowa	CaC_2	Electric		1
22		S	Muskogee, Okla.	CaC_2	Electric		1
23	Molybdenum Corporation of America	S	Washington, Pa.	FeMo	Electric & aluminothermic		
24	National Lead Co.	S	Niagara Falls, N. Y.	FeCbTi, FeTi, other	Electric	3	
25	New Jersey Zinc Co.	S	Palmerton, Pa.	Spiegeleisen	Electric	1	
26	Ohio Ferro Alloy Corp.	M	Brilliant, Ohio	FeCr, FeSi, Si, FeCrSi	Electric	4	
27		L	Philo, Ohio	FeB, FeMn, FeSi, SiMn, Si	Electric	10	
28		M	Powhaton, Ohio	FeSi, Si	Electric	4	
29		S	Tacoma, Wash.	FeCr, FeSi	Electric	2	
30	Pacific Carbide Co.	S	Portland, Oreg.	CaC_2	Electric		1
31	Reynolds Metals Co.	S	Lister Hill, Ala.	Si	Electric	1	
32	Reading Alloys	S	Robesonia, Pa.	FeB, FeCb, FeV, NiCb, FeMo	Aluminothermic		
33	Sandgate Corp.	S	Houston, Tex.	FeMn, SiMn	Electric	3	
34	Shieldalloy Corp.	S	Newfield, N. J.	FeV, FeTi, FeB, FeMo, FeCb, FeCbTa	Aluminothermic		
35	Tennessee Alloys Corp.	S	Bridgeport, Ala.	FeSi	Electric	3	
36	Tennessee Metallurgical Co.	S	Kimball, Tenn.	FeSi	Electric	2	
37	Union Carbide Corp.	L	Alloy, W. Va.	FeB, FeCr, FeCrSi, FeCb, FeSi, FeMn	Electric	16	
38	Ferroalloys Div.	L	Ashtabula, Ohio		Electric	8	5
39		L	Marietta, Ohio		Electric, electrolytic, vacuum	11	
40	Mining & Metals Div.	S	Niagara Falls, N. Y.	FeTi, FeW, FeV, SiMn, other	Electric & aluminothermic	2	
41	Ferroalloys Div.	S	Portland, Oreg.		Electric	2	1
42		M	Sheffield, Ala.		Electric	5	
43	Woodward Co.	M	Rockwood, Tenn.	FeMn, SiMn	Electric	7	
44	Div. Mead Corp.	S	Woodward, Ala.	FeSi	Electric	1	
					Total	145	13

1/ Minerals Yearbooks, U. S. Bureau of Mines, 1963-1971

2/ Plant size classification:

S - Up to 25,000 KW
M - 25,000 to 75,000 KW
L - Over 75,000 KW

or welfare." The major pollutant from ferroalloy plants is particulate matter, a pollutant for which ambient air quality standards were promulgated in 40 CFR 50. The health effects data necessary to issue air quality criteria are based on non-specific particulate matter. In addition, particulate matter emissions result in the deleterious effects of soiling, nuisance properties, reduction of visibility and modification of atmospheric conditions. Ferroalloy plants were specifically mentioned in a Report of the Committee on Public Works, United States Senate, as a source category to which standards of performance for new sources could be expected to apply.[5]

The rate of particulate matter emissions from the United States ferroalloy industry in 1967 is estimated to have been 160,000 tons per year.[6] This total consists of 1,000 tons from blast furnaces, 150,000 tons from electric submerged-arc (ESA) furnaces, and 9,000 tons from handling of materials. The estimate of 150,000 tons of emissions from ESA furnaces assumes an average control efficiency of about 40 percent. It has been estimated that in 1970 about 50 percent of the existing ESA furnace capacity operating in the United States was equipped with particulate matter emission control systems which had efficiencies ranging from 75 to 99 percent (including capture and treatment of tap fumes).[7] Obviously the major source of ferroalloy plant particulate matter emissions is the ESA furnace. It is therefore the primary candidate for standards of performance for new sources.

There are several processes, which are minor sources of emissions compared to the ESA furnace, for which standards are not now being recommended. These processes, listed below, are candidates for standards which may be developed in the future:

- The electrolytic process
- Vacuum and induction furnaces
- Product sizing
- Raw materials handling and preparation

There are only six electrolytic process operations in the United States ferroalloy industry. These produce chromium, manganese, and manganese dioxide. The electrolytic process results in emissions of ammonia and sulfur oxides.[8]

Vacuum and induction furnaces are used to produce ferroalloys at fewer than five locations in the United States.

The final ferroalloy products are marketed in sizes ranging from 75-pound pieces to fine powders. Several types of crushers and screens are used for sizing the products. Although the amount of particulate matter emitted from crushing and screening operations has not been quantified, it is substantially less than particulate matter emissions from ESA furnaces. About half of the existing ferroalloy plants have air pollution abatement equipment for these operations.[9] No measurements of emissions from ferroalloy crushing and sizing operations have been made by EPA.

Raw materials such as ores, quartz or quartzite, limestone, scrap steel, coke, and coal are delivered to ferroalloy plants by ship, railroad cars, or trucks and then are normally transferred to outdoor storage piles. These materials range in size from 5 inches to 1/4 inch, but contain significant quantities of dust. Entrainment of the dust by wind may be minimized by sheltering the storage piles with block walls, snow fences, or plastic covers, or by spraying with water.

Additional dust may be generated during loading, unloading, transferring, and pretreatment of this raw material. Pretreatment may include operations such as crushing, sizing, drying, mixing, pelletizing, and sintering. Standards of performance for these operations are not recommended at this time but may be considered in the future.

B. Processes or Facilities and Their Emissions

1. The electric submerged-arc furnace production process.

A typical flow diagram of ferroalloy production is shown in Figure I-1. As discussed previously, the major source of pollution is the electric submerged-arc furnace which performs the smelting operation. The furnace (Figure I-2) consists of a hearth lined with a high-temperature refractory which has holes to permit tapping (or draining) of metal and slag. The furnace shell and its hood or cover components are fabricated from steel. These are water cooled to protect them from the heat of the process. Above the hearth are three carbon electrodes vertically suspended in a triangular formation. Although these electrodes may be prebaked or of the self-baking, *in situ* Soderberg type, the trend is to use the Soderberg electrodes.

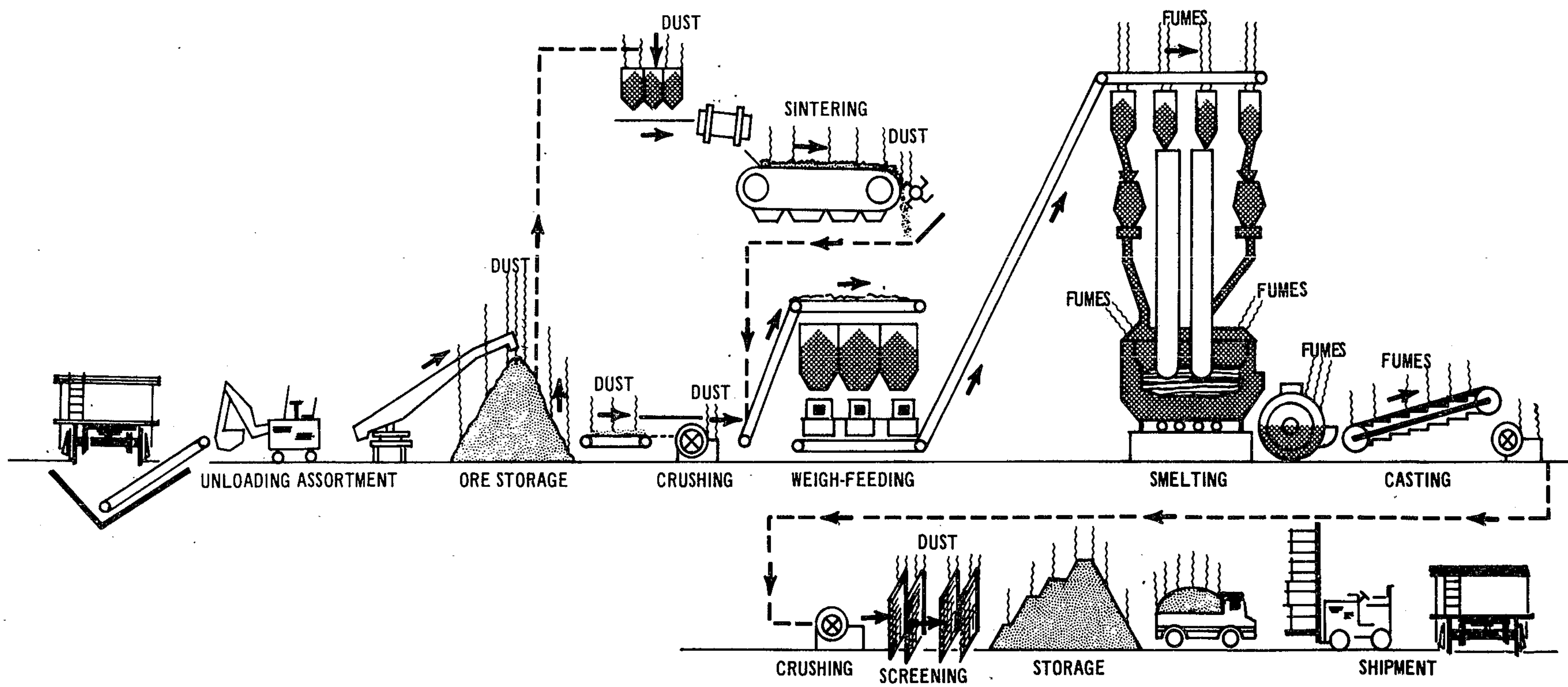


Figure I-1. Ferroalloy production process.

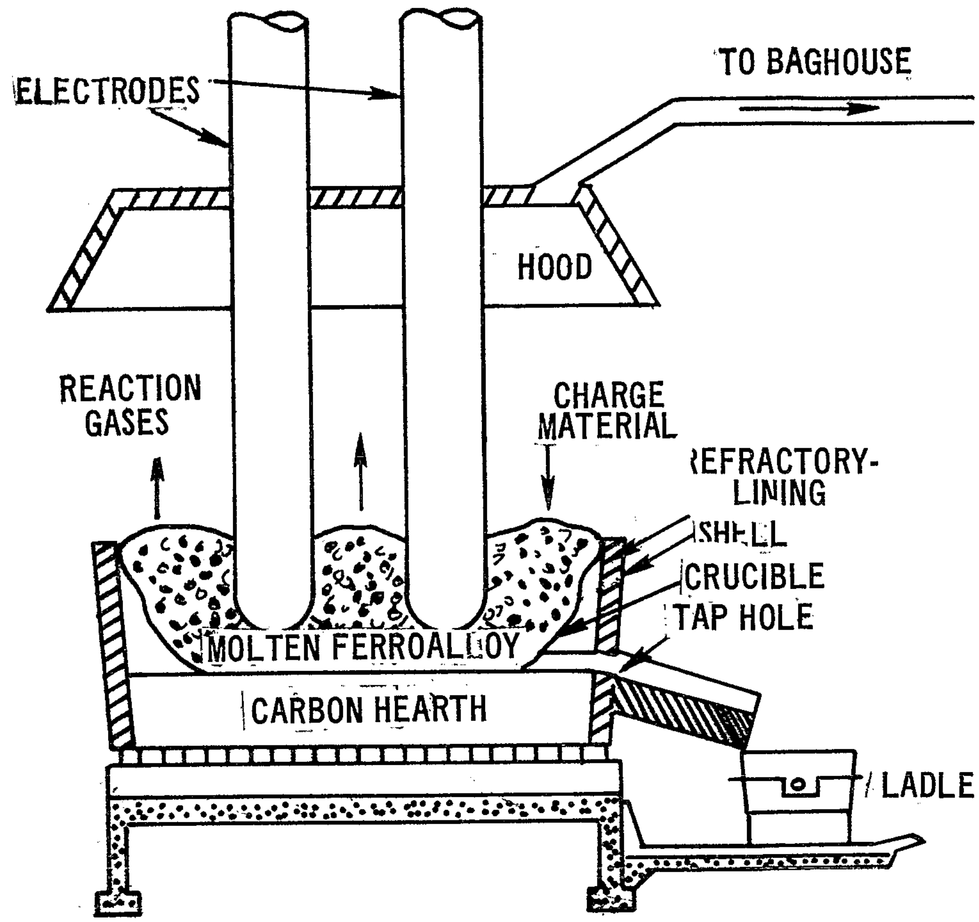


Figure I-2. Submerged-arc furnace for ferroalloy production.

Electrodes extend three to five feet into the charge materials. Three-phase current arcs through the charge material from electrode to electrode. The charge melts as the electrical energy is converted to heat. Coke added to the furnace chemically reacts with the oxygen in the metal oxides to form carbon monoxide and reduce the ores to base metal. Large quantities of by-product carbon monoxide are formed. These reaction gases entrain particulate matter and carry them from the furnace.

Power is applied continuously to the ESA furnace. Feed materials may be charged continuously or intermittently. Molten ferroalloy and slag are intermittently tapped into ladles from ports in the lower furnace wall. (Furnaces producing calcium carbide may be intermittently or continuously tapped.) From the ladles, the melt is poured into molds or casting machines. After the product cools and solidifies, it is crushed, sized, loaded and shipped to customers.

2. Emissions from ESA furnaces.

A study of emissions from the United States ferroalloy industry by EPA and The Ferroalloys Association was completed in 1973. During this study, which began before promulgation of the Clean Air Act Amendments of 1970, EPA measured emissions from several ferroalloy furnaces and collected samples of emissions for chemical analysis from open furnaces producing ferrochrome-silicon, silicomanganese, and high-carbon ferrochrome. (Open, semi-enclosed, and sealed furnaces are described in

Chapter III of this document.) In addition, metals analyses were performed on samples of manganese ore, chrome ore, and ferromanganese slag used as charge material for a silicomanganese furnace.

No significant concentrations of sulfur dioxide were found in the exhaust gases from five furnaces tested by EPA. SO_2 concentrations ranged from 1 to 17 ppm and emissions did not exceed 7 pounds per hour.[10]

A significant amount of carbon monoxide gas is formed as a by-product of the ESA reduction process. Depending on the type of furnace, this gas is either burned at the surface of the charge material or captured by the emission control system. If the latter, it may be flared at the stack of the collection device or used for fuel or other chemical processes.

No nitrogen oxides are formed during the carbon reduction of oxidic ores.

Particulate matter emissions, the major pollutant in this industry, may vary from 150 to 2,000 pounds per hour from an uncontrolled ESA furnace. The actual rate depends on:[11]

- The type of alloy produced.
- Choice and size of raw materials.
- Operating techniques.
- Existence of a furnace shutdown or start-up condition.

Chemical analyses of samples of particulate emissions revealed no significant amounts of heavy metals such as mercury, beryllium, cadmium, or arsenic.[12] The physical properties and quantities of particulate matter emitted generally depend upon the alloy being produced, but the particle size is usually below 2 microns. The mass median diameter (the diameter at which 50 percent of the particles by weight are smaller and 50 percent are larger) of emissions from open furnaces producing ferrochrome silicon, silicomanganese, and high-carbon ferrochrome has been measured by EPA as between 0.66 to 1.7 micron.[13]

The type of alloy produced affects the quantity of uncontrolled emissions. Uncontrolled particulate matter emissions from open furnaces tested by EPA (excluding tap fumes) varied from 25 to 144 pounds per megawatt-hour of power consumption for furnaces producing ferrochrome silicon and silicon metal. The uncontrolled particulate matter emission rate will also vary for different grades of a given product. For instance, the rate of uncontrolled emissions will increase with increasing silicon content of the product, so that a furnace will emit more particulate matter when producing 75 percent than when producing 50 percent ferrosilicon.

The type and size of raw material also affects the emission rate. A porous charge promotes uniform gas distribution and furnace operating stability. Very fine materials may promote channelization of gas flow through the furnace charge, and bridging and nonuniform descent of charge materials. Collapse of a bridged area causes a momentary surge of gas which results in unstable furnace operation. Another factor which influences furnace operation and emissions is the volatile content of the charge material, including moisture and undesirable chemicals.

The design of the furnace and its power consumption affect the rate of uncontrolled emissions. A covered or sealed furnace without control is reported to generate less emissions than an equivalent open furnace without control.(14) Uncontrolled emissions from a furnace producing a given alloy are related to furnace production which is a function of power consumption.(15), (16)

Differences in operating techniques can also significantly affect the uncontrolled emissions from a furnace.(16) Operation at higher voltages requires the electrodes to be positioned higher, resulting in increased emissions. Poor placement of mix or insufficient feed rate of the mix increases emissions through the open, annular areas around the electrodes of a semi-enclosed furnace. Manufacture of silicon metal requires stoking of the charge to break up crust, permitting uniform evolution of reaction gases, and preventing violent jets of gas emanating from the furnace reaction zone. Emissions can vary depending upon the frequency and adequacy of stoking.

Furnace shutdowns may be caused by broken electrodes, water leaks, tap hole problems, utility failures, and many other reasons. Upon start up after short shutdown periods, uncontrolled emissions return to normal levels in a time period approximately equal to the length of interruption. When starting up a new furnace or one which has been shut down for a long time period, heavier-than-normal uncontrolled emissions may occur for a period varying from a few days to several weeks.

Emissions from existing ferroalloy furnaces are restricted by State regulations. These are all of the process weight type and most are the result of State implementation plans developed pursuant to section 110 of the Clean Air Act, as amended. Since production rate is a function of the product being manufactured, allowable emissions must be calculated for the particular alloy being produced. For example, allowable emissions from a 30-megawatt furnace located in Ohio producing calcium carbide, silicomanganese, and ferromanganese are about 29, 32, and 46 pounds per hour respectively (0.97 to 1.5 pounds per megawatt-hour furnace power consumption).[17] It is doubtful that these regulations can be attained without control of tapping fumes. Consequently, it would appear that with proper enforcement, the State regulations will require installation of control systems which will minimize emissions during the tapping operation.

II. PROPOSED STANDARDS OF PERFORMANCE

A. Standards of Performance as Proposed

The proposed standards of performance for ferroalloy plants limit the discharge of particulate matter as follows:

No owner or operator shall cause to be discharged to the atmosphere from any affected facility any gases which:

1. Contain particulate matter in excess of 0.45 kg/Mw-hr (0.99 lb/Mw-hr) while that facility produces silicon metal, ferrosilicon (50 percent silicon and above), calcium silicon, or silicomanganese zirconium.
2. Contain particulate matter in excess of 0.23 kg/Mw-hr (0.51 lb/Mw-hr) while that facility produces high-carbon ferrochrome, charge chrome, standard ferromanganese, silicomanganese, calcium carbide, ferrochrome silicon, ferromanganese silicon, or silvery iron.
3. Exhibit 20 percent opacity or greater. This opacity requirement shall apply to all gas streams from the affected facility except as follows:
   - (i) Any emissions which escape the furnace hood or cover shall not be visually detectable without the aid of instruments.
   - (ii) Any emissions which escape the control device at the tapping station shall not be visually detectable without the aid of instruments for more than 40 percent of each tapping period.

This requirement applies to fumes which may escape the device (required by the standard) used to capture tapping fumes.

(iii) Any emissions from the dust handling equipment shall not exhibit 10 percent opacity or greater.

The proposed standards limit the discharge of carbon monoxide as follows:

No owner or operator shall discharge or cause the discharge into the atmosphere from any affected facility any gases which contain 20 or greater volume percent of carbon monoxide, dry basis.

Combustion of carbon monoxide under conditions acceptable to the Administrator shall constitute compliance with this paragraph. Acceptable conditions include but are not limited to flaring of gases or use of gases as fuel for other processes such as plant boilers or raw material dryers.

B. Discussion of Proposed Mass Standards

The proposed standards for particulate matter and visible emissions can be achieved with open, semi-enclosed and sealed furnaces with appropriate hooding and air pollution control devices (i.e. venturi scrubbers, venturi scrubbers in series with electrostatic precipitators, or fabric filters). As pointed out in Chapter VIII, a standard was considered which would encourage the use of sealed furnaces for those ferroalloy products that can be produced in sealed furnaces; however, such a standard has a major disadvantage in that it would restrict the flexibility of new furnaces to respond to fluctuating market demands. A specific sealed furnace can be used to produce only one family of products. The sealed furnace cannot be adapted to the production of other ferroalloys without changing the electrode spacings (which are determined by the product family). To do this on a sealed furnace also requires replacing the furnace cover. Thus, modification of sealed furnaces to produce other products is prohibitively expensive. Product flexibility is possible at minimum cost with open furnaces which have multiple transformer taps and adjustable electrodes.

The industry has alleged that a standard requiring sealed furnaces (with their attendant limited product flexibility) would severely handicap the small domestic producers: (1) It would eliminate his ability to respond to a rapidly changing world market. (2) Only large companies with adequate capital and marketing capabilities could commit a large furnace to one product line. (3) Since a few large sealed furnaces could supply the entire United States market for select materials, a large company could install several and drive the small producer from the market, thereby eliminating domestic competition.

EPA attempted to determine the need for furnace flexibility. Data were obtained on various products made in each furnace over a 5 to 10-year period from several United States ferroalloy producers, both large and small. Some furnaces were reported to have been changed from one product to another quite frequently while other furnaces produced the same product for the entire period reported. This was true of both large and small companies. Market conditions can fluctuate rapidly in the ferroalloy industry, however, so it is understandable why product flexibility is advantageous. For these reasons, we are proposing a standard which will allow open furnaces to be used in conjunction with the best available control equipment for open furnaces. The standard is also readily achievable by using sealed furnaces with adequate control equipment.

EPA's Control Systems Laboratory has contracted for a long-term study to further investigate the issue of product flexibility. That study could ultimately result in standards of performance based on sealed furnaces.

C. Discussion of Proposed Opacity Standard

The visible emission regulations on emissions from the furnace hood or cover and the tapping station were established to make enforcement simpler. The revised regulations no longer require discerning opacities in order to determine compliance. The proposed standard specifies no visually detectable emissions without the aid of instruments. This proposal does not require a distinction to be made between different opacity levels because the observations are made inside the shop and the criteria of Reference Method 9 for determining the opacity of emissions cannot be followed. The distinction between no visible emissions and the existence of visible emissions can be made however. The emission from the furnace hood or cover and the tapping station are a significant portion of the furnace's total emissions. The no visible emissions limitation is intended to require very good capture of these emissions.

In the case of hoods or covers used to capture fumes generated within the furnaces, the standard requires that fumes which escape capture by the furnace hood or cover be invisible at all times. This requirement is supported by observations at four open furnaces and several sealed furnaces. (See Chapter VI.)

The visible emission limitation on fumes from the tapping station is based on observations of one tap hood during two tapping periods. These data are summarized in Chapter VI. During these two tapping periods, no visible emissions were observed escaping the hood for 71.4 percent of the time during the first tapping period, and 73 percent of the time during the second tapping period. The remainder of the time, emissions of various opacities escaped capture by the hood. The proposed standard was established to require no visible emissions for at least 60 percent of the time because the best system observed had some fumes escaping the collector system at the tapping station, and to allow a margin of safety between the data base (71.4 to 73 percent of the tapping with no visible emissions) and the proposed standard. The proposed standard still requires very good collection and control of tapping fumes.

The proposed standard limits the opacity of fugitive emissions from the dust handling system at or near the control device to less than 10 percent to be consistent with the observed levels of 0 percent opacity and allow a small margin of safety. This proposed limitation is based on observations of dust handling equipment in the steel and asphalt concrete industries.

III. EMISSION CONTROL TECHNOLOGY

Air pollution from the electric submerged-arc furnace is minimized by good capture of fumes at the furnace and use of an appropriate particulate matter collection device. The three different furnace configurations--open, semi-enclosed, and sealed--strongly affect the efficiency of air pollution control. In each type, the hood or cover above the furnace not only collects emissions but also protects the furnace superstructure and electrode column components. The three types of furnaces and common control devices are discussed below. Emissions from controlled furnaces of each of three types are discussed and compared in Chapter VI, Data to Substantiate a Standard.

A. Open Furnace

The open furnace (Figure III-1) has a water-cooled canopy hood, normally located 6 to 8 feet above the furnace crucible rim. This large opening between the furnace crucible and hood permits large quantities of ambient air to be drawn into the air pollution control system diluting the furnace off-gas by as much as 50 to 1.[18] As the air combines with the hot furnace gases, it combusts the carbon monoxide generated in the furnace. Gas volumes from this type of system range from 100,000 to 400,000 standard cubic feet per minute (scfm).[19] Gas volume can be reduced by decreasing the opening between the furnace and hood. This may be done by adding a skirt to the hood or with chain curtains (lengths of chain hung in close proximity around the perimeter of the hood).

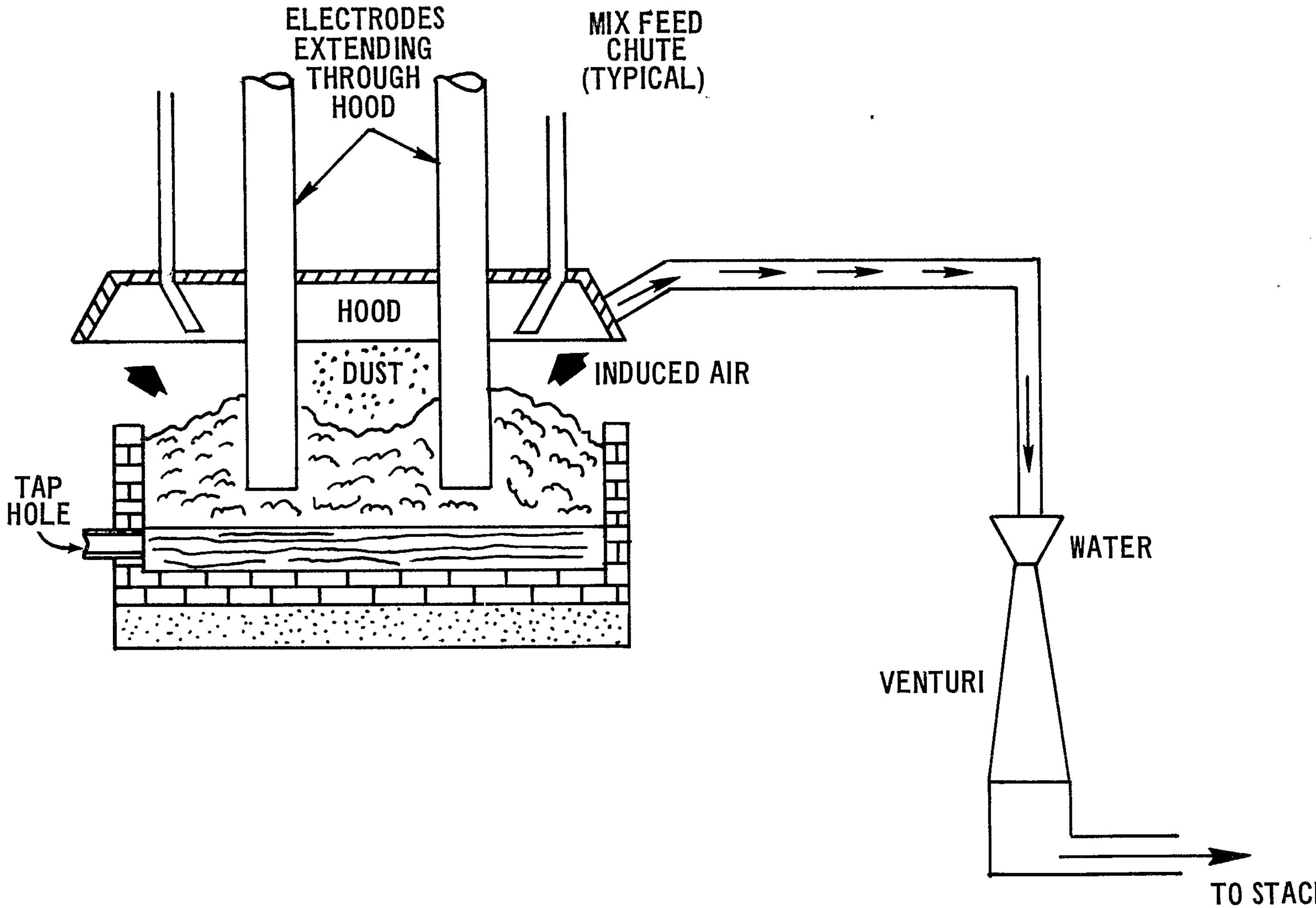


Figure III-1. Open furnace controlled by a venturi scrubber.

Gas cleaning devices used on open ferroalloy furnaces include high-energy venturi scrubbers, electrostatic precipitators, and fabric filters.

1. Venturi scrubbers applied to open furnaces.

Several designs of venturi scrubbers are used in the United States, but the one most common on open furnaces is the flooded-disc type. Because the particulate matter concentration is relatively low (the result of copious dilution air) and a high proportion of the particulate is submicron, these scrubbers must operate with very high pressure losses of 60 to 80 inches water gauge to achieve removal efficiencies of 96 to 99 percent. The venturi scrubber for an open 30-megawatt furnace producing silicomanganese requires 2,500 horsepower for the fan alone. The power required to operate these high-energy scrubbers is equivalent to approximately 10 percent of the power requirements for the furnace itself.[20], [21]

2. Electrostatic precipitators applied to open furnaces.

Only two modern electrostatic precipitators are operating on ferroalloy furnaces in the United States. Both are installed on open furnaces producing chrome alloys.

Most fumes from ferroalloy furnaces do not have proper electrical resistivity for satisfactory precipitator operation unless the gases are humidified and conditioned with agents such as ammonia, or their temperatures are maintained above 500°F.

3. Fabric filters applied to open furnaces.

Fabric filter collectors, also referred to as baghouses or bag filters, are frequently used with open furnaces. The most common type used in the United States is pressurized (fan on the inlet) and exhausts through an open top or monitor. Open grates at the bottom of the baghouse permit cooling by natural convection. Radiant coolers or dilution with cool, ambient air is used if the gas must be cooled before it enters the baghouse. Cooling with water sprays is much less common. Both felted and woven fabrics of many different materials have been used. Cleaning of the bags may be done by either reverse air or mechanical shaking. Air-to-cloth ratios vary between 1.2 and 2 actual cubic feet per minute (acfm) per square foot of cloth area. Because the particulate matter has both a high proportion of submicron particles and high electrostatic charge, the pressure drop across a filter fabric is relatively high, 10 to 18 inches of water.

B. The Semi-Enclosed Furnace

The semi-enclosed furnace (Figure III-2) has a water-cooled cover which contains gas and fume generated in the furnace. These emissions are drawn from beneath the cover through one or more ducts to a gas cleaning device. The cover completely seals the furnace except for annular spaces around the three electrodes through which raw material is charged. The feed material only partially closes the annuli and emissions still pass through them. These leaks could be eliminated or minimized in two ways. The air

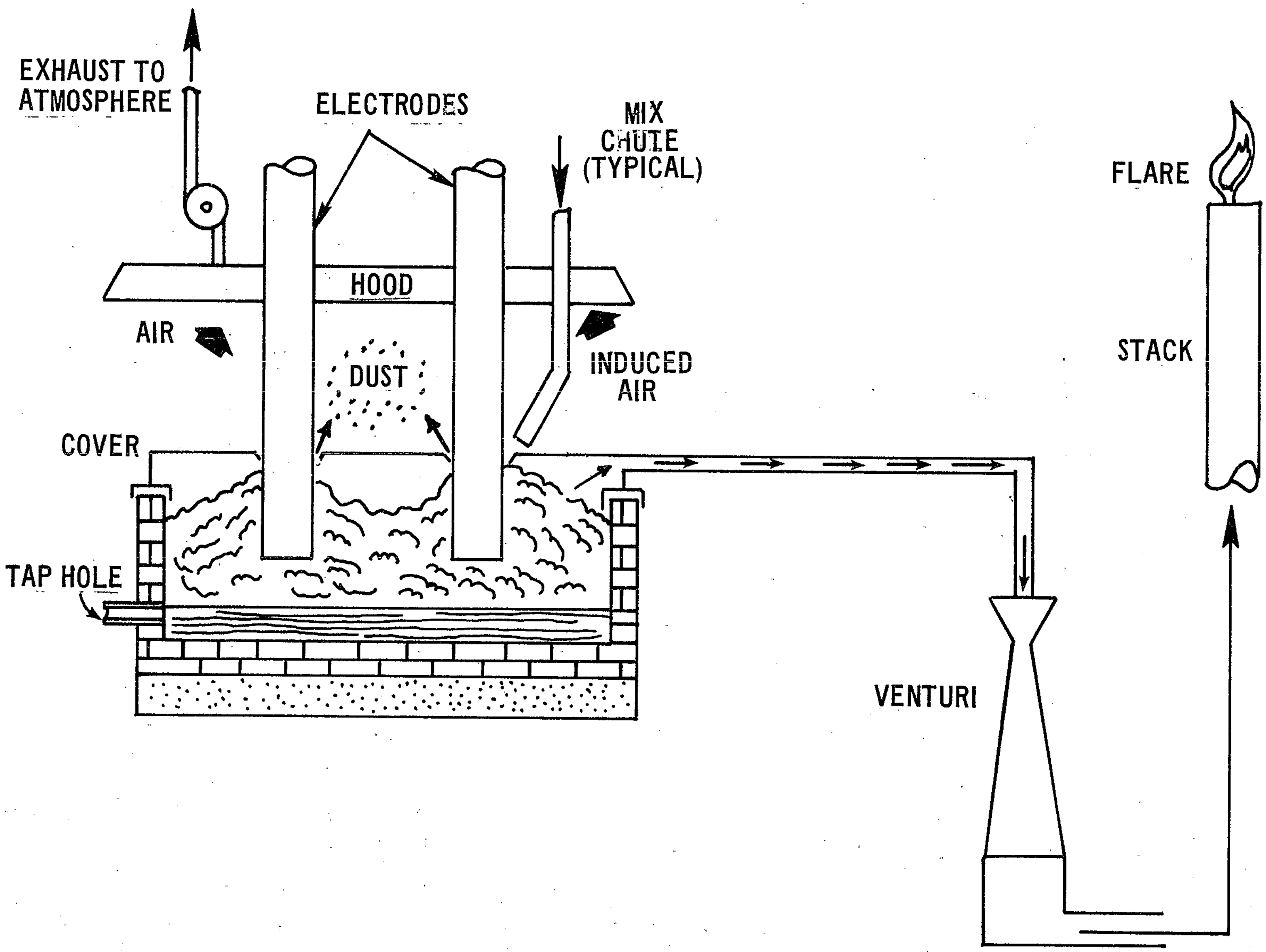


Figure III-2. Semi-enclosed furnace controlled by a venturi scrubber.

pollution control system could be designed to maintain a negative pressure within the furnace or the emissions could be captured and controlled by hoods around the electrodes.

Because very little air enters a semi-enclosed furnace, the gases from the furnace are rich in carbon monoxide and can be used as fuel.

Semi-enclosed furnaces have not been used to produce silicon metal or alloys containing over 75 percent silicon because of inability to stoke the furnace. Stoking is necessary to prevent crusting and bridging of the charge, and "blows" during production of high-silicon alloys. Crusting and bridging prevent uniform descent of the charge into the furnace and blows may damage the furnace components. "Blows" are jets of extremely hot gas that originate in the high-temperature reaction zone in the vicinity of the electrode tips, and emerge around the electrodes at high velocity.

1. <u>Wet scrubbers applied to semi-enclosed furnaces</u>.

Wet scrubbers are the most common air pollution control devices applied to semi-enclosed ferroalloy furnaces. Both multistage centrifugal scrubbers and venturi scrubbers are used. Centrifugal scrubbers are generally limited to a maximum air flow of about 2,800 acfm, sufficient for a medium-size semi-enclosed furnace.[22] For larger furnaces, parallel centrifugal scrubbers or a venturi scrubber are used. Depending on the product being made, centrifugal scrubbers may have efficiencies of up to 99 percent; venturi scrubber efficiencies are higher. Pressure losses of up to 80 inches of water are common in venturi scrubbers controlling emissions from semi-enclosed furnaces. Power and water requirements are generally higher for venturis than for centrifugal scrubbers.

Emissions from two semi-enclosed furnaces were measured by EPA. One was a 40 to 50 megawatt furnace which produces 50 percent ferrosilicon and is controlled by a venturi scrubber. The other is a 24 megawatt calcium carbide furnace controlled by a centrifugal scrubber. During these tests, large amounts of dust were emitted from the annular openings at the electrodes. These emissions were not controlled and so reduced the overall control efficiency. Emissions from the scrubber on the furnace producing ferrosilicon averaged 0.078 pound per Mw-hr (3.6 pounds per hour); however, measurements of fugitive emissions from around the electrodes indicated a total emission rate of about 390 pounds per hour. Emissions from the calcium carbide furnace scrubber averaged 0.017 pound per Mw-hr (0.40 pound per hour); however, measurements of fugitive and tap emissions which were uncontrolled indicated a total emission rate of about 4.0 pounds per Mw-hr (96 pounds per hour) for this furnace. Obviously, the emissions from the electrode ports are of major concern in a semi-enclosed furnace.

2. <u>Electrostatic precipitators and fabric filters applied to semi-enclosed furnaces</u>.

No known semi-enclosed furnaces are serviced by electrostatic precipitators or fabric filters. Fabric filters, and an electrostatic precipitator in series with venturi scrubbers have been used on sealed furnaces in Japan. The similarity in emissions from semi-enclosed and sealed furnaces seems to imply that these control devices could also be used on semi-enclosed furnaces. However, the semi-enclosed furnace has a less positive seal. Air leaks through the annuli at the electrodes may increase the danger of explosion. This could prevent use of fabric filters or electrostatic precipitators.

C. The Sealed Furnace

The tops of sealed furnaces (Figure III-3) have water-cooled covers which prevent escape of any emissions from treatment by the air pollution control system. Packing is used to seal around the electrodes and charging chutes. No other openings are required since the furnaces are not generally stoked. They are operated with a slight positive pressure to prevent leakage of air into the furnace. The furnace exhaust gas, predominantly carbon monoxide, can be used as fuel.

Because no air enters the furnace, gas volumes to the control device are minimal and can be as little as 2 to 5 percent of that from an open furnace of equivalent size. The very low gas volumes result in much lower mass of particulate matter emissions from a controlled sealed furnace than from an equivalent, well-controlled open furnace.

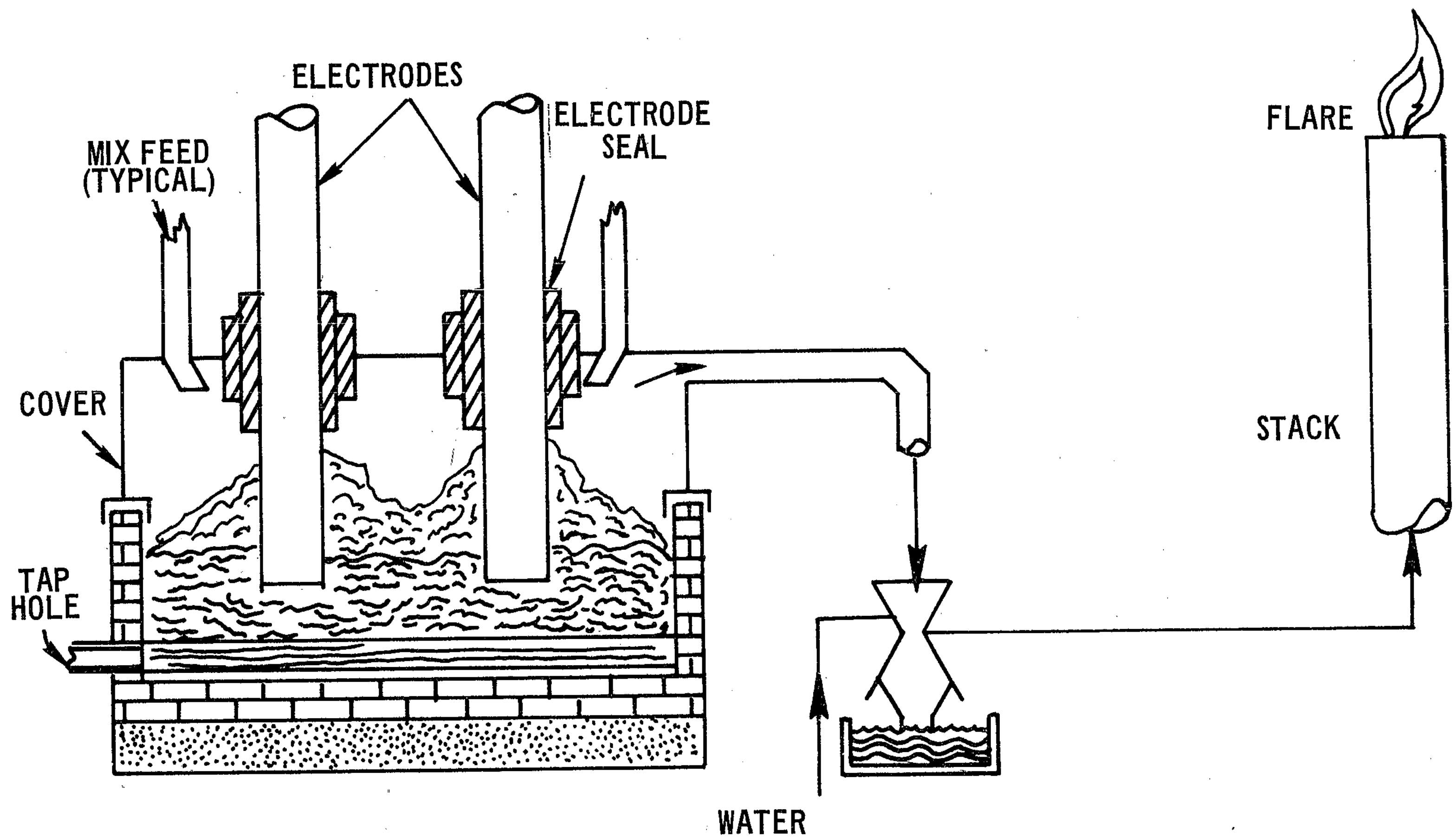


Figure III-3. Sealed furnace controlled by venturi scrubber.

Sealed furnaces have not yet been used to produce silicon metal or alloys containing over 75 percent silicon because of inability to stoke the furnace. Stoking is necessary to prevent crusting and bridging of the charge, and "blows" during production of high-silicon alloys.

1. Wet scrubbers applied to sealed furnaces.

Wet scrubbers are the most common device used to control air pollution from sealed furnaces. Both multistage centrifugal and venturi scrubbers are used. Their efficiency and energy requirements for control of sealed furnaces are similar to those for semi-enclosed furnaces.

2. Fabric filters applied to sealed furnaces.

Only one sealed ferroalloy furnace is known to use a fabric filter for air pollution control. The baghouse is a closed suction type cleaned by reverse gas flow. Air-to-cloth ratio is about 1.5 actual cubic feet per minute per square foot of cloth area. Gas from the furnace is cooled in radiant coolers before entering the baghouse. When necessary, additional cooling is obtained by running water over the surface of the radiant coolers.

3. Electrostatic precipitators applied to sealed furnaces.

No applications are known in which electrostatic precipitators alone are used with sealed ferroalloy furnaces. However, systems consisting of two venturi scrubbers and a wet electrostatic precipitator, all in series, have been used to control emissions from three sealed ferroalloy furnaces in Japan. The venturi scrubbers serve as precleaners and gas conditioners and operate at relatively low pressure drops (about 36 inches of water total). The precipitator removes about 97 percent (according to EPA tests) of the particulate remaining in the gas stream after the scrubbers.

D. Control of Fumes During Tapping

Best systems of emission reduction for ferroalloy furnaces of all types includes capture and control of tapping fumes. A hood system must be used over the tap hole and ladle to capture and direct tapping fume to a gas cleaning device. The gas cleaning device may be common to that controlling the furnace fume, or a separate fabric filter or wet scrubber.

Efficient capture of tapping fumes has been difficult. One new hood design encloses the ladle during tapping and can be retracted when tapping is complete. When in place, it provides access to the tap hole. This allows the hood to be in place to capture fume generated when the tap hole is burned open with an oxygen lance, and also allows the tap hole to be rodded during the tap to keep it open. This system provides very good capture of the tapping emissions.

IV. ENVIRONMENTAL EFFECTS

A. Impact on Air Pollution

The objective of standards of performance under section 111 of the Act, as amended, is to prevent new air pollution problems from developing by requiring affected facilities to use the best systems of emission reduction available at a cost and within a time that is reasonable. These standards pertain directly to emissions from the facility and are only indirectly related to ambient air quality. Attainment and maintenance of national ambient air quality standards is specifically covered by State implementation plans as provided under section 110 of the Act. Nevertheless, the impact of a new submerged arc ferroalloy furnace on local ambient air quality should be closely investigated. Such an investigation necessarily depends upon many specific factors such as topography, meteorological conditions, proximity of other sources of pollution and the mass of pollutants emitted from all sources in the local area. As an illustrative example, maximum ground-level concentrations of particulate matter were estimated for emissions from five hypothetical sources employing the control systems of interest using an atmospheric dispersion model. These estimates are shown in Table IV-1 for these hypothetical point sources - control system cases. Differing source configurations and surrounding terrain can cause significantly different results. The maximum concentrations were estimated for 24-hour and 1-year averaging periods for particulate matter. These averaging periods were selected to permit direct comparison with the ambient air quality standard for

Table IV-1. Estimated Ground Level Particulate Concentrations Caused by Submerged Arc Ferroalloy Furnaces for Various Downwind Distances

Case	Furnace Size, Type, and Product	Control Device	Emission Rate, g/sec	Averaging Times	Estimated Ground Level Particulate Concentration at Specified Distance from Source, μg/m³			
					0 Km.	0.3 Km	2.0 Km	20 Km
1	25 Mw, Open, Silicon Metal	Baghouse with Monitor Discharge	2.2	24 hrs.	3000	400	40	4
				1 yr.	400	50	4	0.2
2	25 Mw, Open, Silicon Metal	Baghouse with Monitor Discharge	3.2	24 hrs.	4000	600	60	6
				1 yr.	600	80	6	0.2
3	30 Mw, Open, SiMn	Baghouse with Monitor Discharge	4.0	24 hrs.	6000	800	80	8
				1 yr.	700	100	7	0.3
4	30 Mw, Open, SiMn	Baghouse with Monitor Discharge	1.9	24 hrs.	3000	400	40	4
				1 yr.	300	50	3	0.1
5	30 Mw, Sealed, SiMn	Venturi Scrubber with a 24 meter high stack and flare	0.6	24 hrs.	400	120	11	1
				1 yr.	60	14	1	0.04

particulate matter. Comparison of these maximum ground-level concentration estimates with the national ambient air quality standard will not necessarily indicate whether or not the standard (NAAQS) will be met unless there is an estimate of background concentration arising from natural and manmade sources available for the specific site. Cases 1 and 3 are based on emissions from a furnace operating in compliance with a typical State process weight regulation. Cases 2 and 4 are based on allowable emissions according to the proposed standards of performance (Chapter II) and Case 5 is based on emissions of 0.07 Kg/Mw-hr, Alternative No. 1, Chapter VIII (Alternative Standards).

The dispersion estimates were made using a Gaussian point source dispersion model developed by Meteorology Laboratory of EPA.

Because the pollutants emit from a monitor (no stack) on a baghouse in Cases 1 through 4, aerodynamic downwash is a chronic problem, particularly when wind speeds exceed 2 or 3 meters per second (mps). At very low wind speeds the plume may rise, although probably not more than 20 meters.

Many of the nation's ferroalloy plants are in valleys in hilly country such as West Virginia and eastern Ohio. Since it was readily available, and the topography and climate are similar to West Virginia and eastern Ohio, one year of hourly wind and surface stability data for Harrisburg, Pennsylvania was used for the calculations.

Maximum concentrations were estimated immediately downwind of the source, and for distances of 0.3, 2, and 20 kilometers downwind. Because of downwash, the overall maximum concentrations were likely to occur just to the lee of the emission point. The 24-hour values are estimates of typical high concentrations during any given year. Note that the 24-hour primary national ambient air quality standard (NAAQS) for particulates (260 $\mu g/m^3$) may be exceeded at distances of 0.2 to 1.0 kilometers downwind, depending on the source. The annual NAAQS (75 $\mu g/m^3$) may also be exceeded, although not as far downwind and perhaps not at all when a sealed furnace is used (Case 5).

As an indication of the degree of air pollution reduction achieved by control systems on submerged arc ferroalloy furnaces, the emission rates in Table IV-1 for controlled furnaces can be compared with estimated uncontrolled emission rates of 270 grams per second (39 Kg/Mw-hr) for an open, 25 Mw silicon furnace, and 190 grams per second (23 Kg/Mw-hr) for an open, 30 Mw silicomanganese furnace.

Installation of systems to provide the best air pollution control technology on all new plants will minimize the increase in emissions from growth of the ferroalloy industry. By promulgating standards of performance, there will be no incentive for a plant to locate in a State which has less stringent standards. Without uniform standards of performance such an indirect inducement by State and local agencies could create concentrations of industry and result in significant deterioration of local air quality.

B. Impact on Water Pollution

The control of air pollution from a ferroalloy plant need not affect water pollution problems at all since fabric filter air pollution control systems require no water. Scrubbers and electrostatic precipitators with wet gas conditioners are potential major sources of water pollution. Although up to 3,500 gallons of water per Mw-hr may be circulated through a scrubber serving an open furnace, normally the water is clarified and recirculated. As a result, the volume of actual waste water is much less and is only that required to carry the sediment from the clarifier. Because of the much larger volumes of exhaust gas from open furnaces, scrubbers serving them have much larger water requirements than those for semi-enclosed or sealed furnaces. This, of course, necessitates a larger water treatment system for scrubber-equipped open furnaces.

The Environmental Protection Agency promulgated water effluent limitations for the ferroalloy industry on February 22, 1974, (39 FR 6806).[23] For new electric ferroalloy furnaces, the standard limits discharges of water pollutants to levels attained by the "best available technology economically achievable." Typically, chemical treatment, clarifier-flocculators, sand filters, and recirculation would be required to meet the water effluent standards for electric ferroalloy furnaces if scrubbers are used.

C. Impact on Solid Waste Pollution

Increased recovery of particulate matter normally emitted to the atmosphere with the exhaust gases from a furnace can only increase the amount of solid waste for disposal. This increased quantity of solid waste is a function of the efficiency, not the type of the control device. Selection of the type of device will determine if particulate is collected as a wet or dry mass. Although the dry product from a fabric filter may be more prone to re-entrainment than the sludge from a clarifier, it can easily be wetted or pelletized to minimize wind losses during handling.

The domestic industry usually disposes of the collected material as landfill. When this method is used practices similar to proper sanitary landfill technology may be followed. The principles set forth in EPA's Land Disposal of Solid Wastes Guidelines (CFR Title 40 of Chapter 1, Part 241) may be used as guidance for acceptable land disposal techniques. If hazardous materials are to be disposed of, landfill sites should be selected to prevent horizontal or vertical migration of this contaminant to surface or ground waters. Where geologic conditions may not reasonably ensure this, adequate precautions such as impervious liners should be taken to ensure long term protection to the environment. The location of solid hazardous materials disposed of in this manner should be permanently recorded in the appropriate office of the legal jurisdiction in which the site is located.

Although most of the dust captured is hauled to a landfill site, other dispositions are possible. In some foreign ferroalloy plants, the dust captured by the control system is pelletized or sintered and returned to the furnace as feed. Some of the dust captured by baghouses serving an open 75 percent ferrosilicon furnace is sold for manufacture of fireproof building materials.

D. Energy Considerations

Because gas volumes from open furnaces are large, power requirements for the air pollution control system are generally high. A typical open furnace control system has a fan of 1,400 to 4,500 horsepower.(24) A venturi scrubber on an open furnace uses approximately 10 percent of the total power supplied to a furnace. Fabric filters or electrostatic precipitators generally require less power since they operate with lower pressure losses. One type of venturi scrubber (by Aeronetics)1/ is being used on a small, open silicomanganese furnace. It utilizes heat from the furnace exhaust gas and needs comparatively little external power, only about 10 percent of that needed by a conventional venturi type.

Semi-enclosed and sealed furnaces have much lower gas emission rates than open furnaces. Hence, the power requirements for their control systems are usually much lower than those for open furnaces. For example, a control system on a closed furnace would typically need a fan of 100 to 400 horsepower.(25) It is obvious that not only do control systems on

1/ References to commercial products are not to be considered in any sense an endorsement of the product by the Government.

closed furnaces require only about 10 percent of the power of those on open furnaces, but the power plant emissions to provide that power are also commensurately less.

The exhaust gases from sealed and semi-enclosed furnaces are rich in carbon monoxide and have significant value. Twenty to 35 percent of the power fed to the furnace can be recovered from the heat of combustion of the gases,[26] which have been used for chemical synthesis and as fuel for dryers, plant boilers, and other process equipment.

Collection and control of tapping fumes are the only areas in which a standard of performance may increase power consumption over present practice, and even this increase is slight. Efficient collection of tap fumes will require 20,000 to 60,000 cfm. If separate collectors or fans are used, they need operate only during tapping and can be shut off at other times to save power. Although relatively few furnaces now have control systems for tap fumes, in many cases these will be necessary to meet requirements of State implementation plans.

V. SUMMARY OF THE PROCEDURE FOR DEVELOPING STANDARDS

A. Literature Review and Industrial Contacts

Information initially available for use in the development of standards of performance for new stationary sources in the ferroalloy industry resulted from a joint study by EPA and The Ferroalloys Association (TFA). The study had been in progress for over 2 years prior to the initiation of a program to develop standards. The joint study was primarily concerned with emissions and control techniques of the United States ferroalloy industry. It utilized a survey of the industry (performed with questionnaires), a literature search, and measurements of emissions from several electric submerged-arc (ESA) furnaces. The study provided information on the history and trends of the ferroalloy industry, industry statistics, processes and emissions, emission control technology and procedures, and economics.[27]

After passage of the Clean Air Act Amendments of 1970, the program for development of the standard was begun. Results of the joint study by The Environmental Protection Agency and The Ferroalloys Association (EPA-TFA study) were reviewed, additional recent literature was obtained, and several State agencies and manufacturers of furnaces and control equipment were consulted. Meetings were held with the United States and Japanese ferroalloy trade associations, and producers of ferroalloys in the United States, Norway, Belgium, Canada, and Japan to obtain additional information useful in the development of standards.

B. Selection of Pollutants and Affected Facilities

Sulfur oxide emissions from ESA furnaces were investigated as part of the EPA-TFA study. Emissions were very low. The concentrations were less than 20 parts per million and the rate did not exceed 7 pounds per hour.[28] There are no nitrogen oxide emissions since NO_X is not produced by the carbon reduction process. Emissions from semi-enclosed and sealed furnaces may contain 60 to 90 volume percent carbon monoxide (CO).[29], [30]

The rate of particulate matter emissions from the United States ferroalloy industry in 1968 is estimated to have been 160,000 tons per year of which 1,000 tons were from blast furnaces, 150,000 tons from ESA furnaces, and 9,000 tons from handling of materials.[31]

Analyses of particulate matter emissions revealed no significant amount of heavy metals such as mercury, beryllium, cadmium, and arsenic.[32] As might be suspected, significant quantities of manganese are emitted when manganese ores are used. There is evidence that the manganese in particulate matter emissions resulting from production of ferromanganese and silicomanganese may be harmful to human health.[33], [34], [35], [36], [37]

Particulate control technology for electric submerged-arc furnaces (ESA), the largest source of particulate matter in ferroalloy plants, is well demonstrated. Other sources of air pollution in the ferroalloy industry are minor compared to ESA furnaces. Therefore, ESA ferroalloy furnaces were selected as the affected facility for development of the initial standards of performance for new stationary sources in the ferroalloy industry.

Only standards for emissions of particulate matter and carbon monoxide are being proposed at this time. Equipment now being used to control emissions from ESA furnaces is designed for particulate matter only; control of any other pollutants is incidental. Emissions of pollutants from ESA furnaces other than particulate matter and carbon monoxide are minor. A limitation on particulate matter emissions will also minimize the emission of materials such as manganese because they are emitted as particulate matter.

Large quantities of carbon monoxide generated within open furnaces are significantly reduced by combustion with air drawn into the furnace. Carbon monoxide from closed furnaces is usually flared at the stack outlet unless it is used for fuel or other processes. Since there is no way to measure the concentration of carbon monoxide downstream from the flare, a numerical standard can neither be defined nor enforced; however, a standard can assure that the carbon monoxide is always burned before release to the atmosphere.

Standards of performance may be developed in the future for other pollutants and other sources of pollutants in the ferroalloy industry. Possibilities are product crushing and sizing, raw material preparation, open-arc ferroalloy furnaces, casting machines, and the various exothermic reactions.

The ferroalloy industry produces a large number of products, but over 90 percent of the total United States ESA furnace ferroalloy production consists of alloys of chromium, manganese, and silicon.[38],[39] Although emission rates from uncontrolled furnaces can vary greatly among products, similar alloys often have similar levels of controlled emissions from a given type of furnace. For this reason, standards of performance for new ESA furnaces may be categorized on the basis of product groups. Each group consists of products having similar emissions (with air pollution control) and control techniques. Alternative schemes for grouping alloys and possible standards are presented and discussed in Chapter VIII of this report.

C. Plant Inspections

EPA engineers visited eight American ferroalloy plants to become familiar with the industry and to locate those domestic ferroalloy furnaces which appear to achieve the best air pollution control. Emissions from seven of these furnaces at six plants were measured as part of the EPA-TFA study of the ferroalloy industry. In addition, measurements were made on one uncontrolled ESA furnace producing ferrochrome silicon.

Literature reviews and discussions with both members of industry and manufacturers of furnaces revealed that, although there is only one sealed ferroalloy furnace in the United States, such furnaces are commonly used in foreign countries. Since the air volumes from a sealed furnace average 1/50 (and may be as little as 1/200) those from an equivalent open furnace, controlled mass emissions from closed furnaces average only 2 percent (and may be as little as 0.5 percent) of those from open furnaces of equivalent production rate.

Because of this obvious superiority for air pollution control inherent in the design of sealed furnaces, several were surveyed in Japan, Norway, Belgium, and Canada. Process, operating, and emission data were obtained. Emissions were measured from two sealed furnaces in Norway and three in Japan. Emissions were also measured from two well-controlled open furnaces in Japan. They were well hooded and used suction-type fabric filter collectors which had stacks that provide good conditions for sampling. In contrast, most open furnaces in the United States use pressure-type baghouses with roof monitors rather than stacks. These complicate emission measurements.

D. Sampling and Analytical Techniques

EPA Method 5 was used to obtain most of the data on which the ferroalloy standards are based. Certain modifications to Method 5 sampling apparatus and the sampling method were necessary at some of the facilities tested. These changes are discussed case by case in a separate document, Background Information for Standards of Performance: Electric Submerged-Arc Furnaces for the Production of Ferroalloys - Volume 2, Test Data Summary. One such modification occurred when testing sealed and semi-enclosed furnaces. The electric heaters for the sampling probe and filter were turned off because they could ignite the carbon monoxide-rich exhaust gases if an air leak occurred. For this reason, probe and filter heaters are not required by the performance test when testing gas streams which contain over 10 volume percent carbon monoxide.

The proposed particulate matter standard of performance for new ferroalloy furnaces limits the mass emission rate rather than the concentration. Thus, the flow rate must also be measured in order to calculate the mass emission rate. EPA Method 2 is used to measure gas flow. It too is specific in the procedures to be used and can be carried out simultaneously with Method 5 with little additional effort. Included in Method 2 is a procedure for analyzing the stack gas (EPA Method 3 - Orsat Analysis) which will determine compliance with the provisions of the proposed standard for carbon monoxide, since an Orsat Analysis includes measurement of carbon monoxide.

E. Emission Measurement Program

EPA has performed emission measurements on a total of 14 controlled ferroalloy furnaces. Seven were open, two semi-enclosed, and five were sealed. Tests were usually conducted for a time approximately equal to that of a full furnace cycle (or multiple cycles if they were required to obtain a sample large enough to weigh accurately). One complete tap was included (with one exception) within each sampling period so that samples were representative of all phases of furnace operation. During tests, the control system and furnace operation were monitored to detect process upsets or abnormal operation which might affect the test results. Three or more individual test runs were generally made for each furnace. No measurements from control systems on tapping operations were performed, because none were located which had adequate fume capture efficiency and which had discharges which could be accurately measured.

Particulate matter samples were obtained for all furnaces tested. In addition, chemical, particle size, gas, x-ray diffraction, and atomic absorption analyses were performed in conjunction with many of the tests, and some of the samples were examined optically.

F. Units of the Standard

Several systems of units were considered for the proposed standard for particulate matter. The units of kilograms per megawatt-hour were selected for the following reasons:

1. Concentration units (grams per standard cubic meter) permit designers of new furnaces to neglect consideration of the volumes of gases exhausted. Disparities in gas volume from existing furnaces have resulted in variations in mass emissions by a factor of 50 even though the two types of furnaces may have the same exhaust particulate concentration.

2. These units of Kg/Mw-hr do not require direct measurement of the charge to the furnace or production rates during the test period. In the ferroalloy industry, these quantities can rarely be accurately determined.

3. The average power consumed (Mw-hr) by the furnace is readily obtained from instruments already installed on furnaces.

4. The power consumption of a furnace is a function of its production and is related to emission rate. Consequently, these units are similar to those for standards based on production or raw material feed rates.

5. An open furnace with fabric filter collection may achieve lower exhaust particulate concentration than a sealed furnace which uses a scrubber, even though the total weight of emissions from the

sealed furnace is only 2 percent of those from the open furnace. Under these circumstances, a concentration standard would be more easily met by the open furnace and use of the open furnace would be encouraged even though its mass emissions are higher.

G. Development of Proposed Standards

On February 20, 1973, the Agency presented a draft technical report and standard for the ferroalloy industry to the National Air Pollution Control Techniques Advisory Committee (NAPCTAC). In summary the report concluded that best demonstrated technology for control of fumes from electric submerged arc furnaces producing ferromanganese, silicomanganese, and calcium carbide is the sealed furnace in conjunction with appropriate control equipment. The draft standard did not cover any other ferroalloy products. The particulate matter limitation in the draft standard was 0.15 lb/MW-hr and 10 percent opacity; the carbon monoxide limitation was 20 volume percent on a dry basis. The ferroalloy industry was represented at the meeting and the representatives expressed their comments to the committee members and suggested that the standard be 1.0 lb/MW-hr and 20 percent opacity. The industry representatives stated that a standard of 0.15 lb/MW-hr would preclude the use of furnaces other than sealed and not allow the use of open furnace configurations. They felt the Agency's cost estimates for controlling sealed furnaces were low and sealed furnaces presented safety hazards.

The draft technical report and standard for the ferroalloy industry were presented again to NAPCTAC on May 30, 1973. At this meeting the Agency presented additional cost information on open and sealed furnace configurations and the safety hazards of sealed furnaces. Ferroalloy industry representatives again expressed their objections to the draft standard because sealed furnaces in their opinion create safety hazards and limit the flexibility of industry to produce a broad range of ferroalloy products. They stated that the domestic industry must use open furnaces to maintain competitiveness and flexibility of furnace products.

The ferroalloy industry was again discussed at the NAPCTAC meeting on January 10, 1974. The Agency representatives emphasized the advantages (from an air pollution and energy standpoint) of sealed furnaces over open furnaces. No standard was recommended or discussed and the Committee was informed that if time permitted the standards to be proposed for the ferroalloy industry would cover the entire industry and Agency representatives had met with the industry representatives several times since the May 30th meeting to discuss the industry's position with respect to open versus sealed furnaces. The industry representatives again reaffirmed their concern to the Committee for any standard that would force the use of sealed furnaces and not allow open furnaces.

During October 1973, Agency personnel conducted an extensive testing program on several ferroalloy furnaces in Japan. During the latter part of 1973 and the early part of 1974, Agency personnel visited additional domestic furnaces and consulted with industry representatives to resolve the issue of product flexibility and the need for a standard which would allow open furnaces. The information obtained by the Agency during this period of time allowed the proposed standard to cover the entire product line of the ferroalloy industry and indicated that there is a need to allow the use of open furnaces. The rationale for the Agency's conclusion that the proposed standard should allow open furnaces is discussed in Chapter II.

VI. DATA TO SUBSTANTIATE A STANDARD

A. Concentration and Mass Data

Results of emission measurements conducted by EPA and other data on emissions from controlled ferroalloy furnaces are shown in Figures VI-1 through VI-6. Brief descriptions of each facility for which emission data were obtained and tables summarizing the data are in a separate document, Background Information for Standards of Performance: Electric Submerged-Arc Furnaces for the Production of Ferroalloys Volume 2, Test Data Summary.

Figures VI-1 and VI-2 show results of measurements of particulate matter emissions from sealed ferroalloy furnaces. Data for Furnaces A1, A2, B, S, R, and K were obtained by EPA on tests conducted in Norway and Japan. Furnaces A1 and A2 are the same. During runs designated A1, only one venturi scrubber was operated, whereas during runs designated A2, a second one was put in service, providing two separate but identical venturi scrubbers operated in parallel. Data for Furnaces D, E, F, I, J, and H are results of tests conducted by Japanese companies using the Japan Industrial Standard test method.[41] This method specifies use of a filter with at least 99 percent collection efficiency. The test method used to obtain emission data on Furnace G, a Russian facility, is unknown.[42]

Average particulate matter emissions from sealed furnaces ranged from 0.002 gr/dscf to 0.032 gr/dscf and from 0.002 lb/Mw-hr to 0.036 lb/Mw-hr, not including tapping fume. Fugitive emissions escaped at the electrode

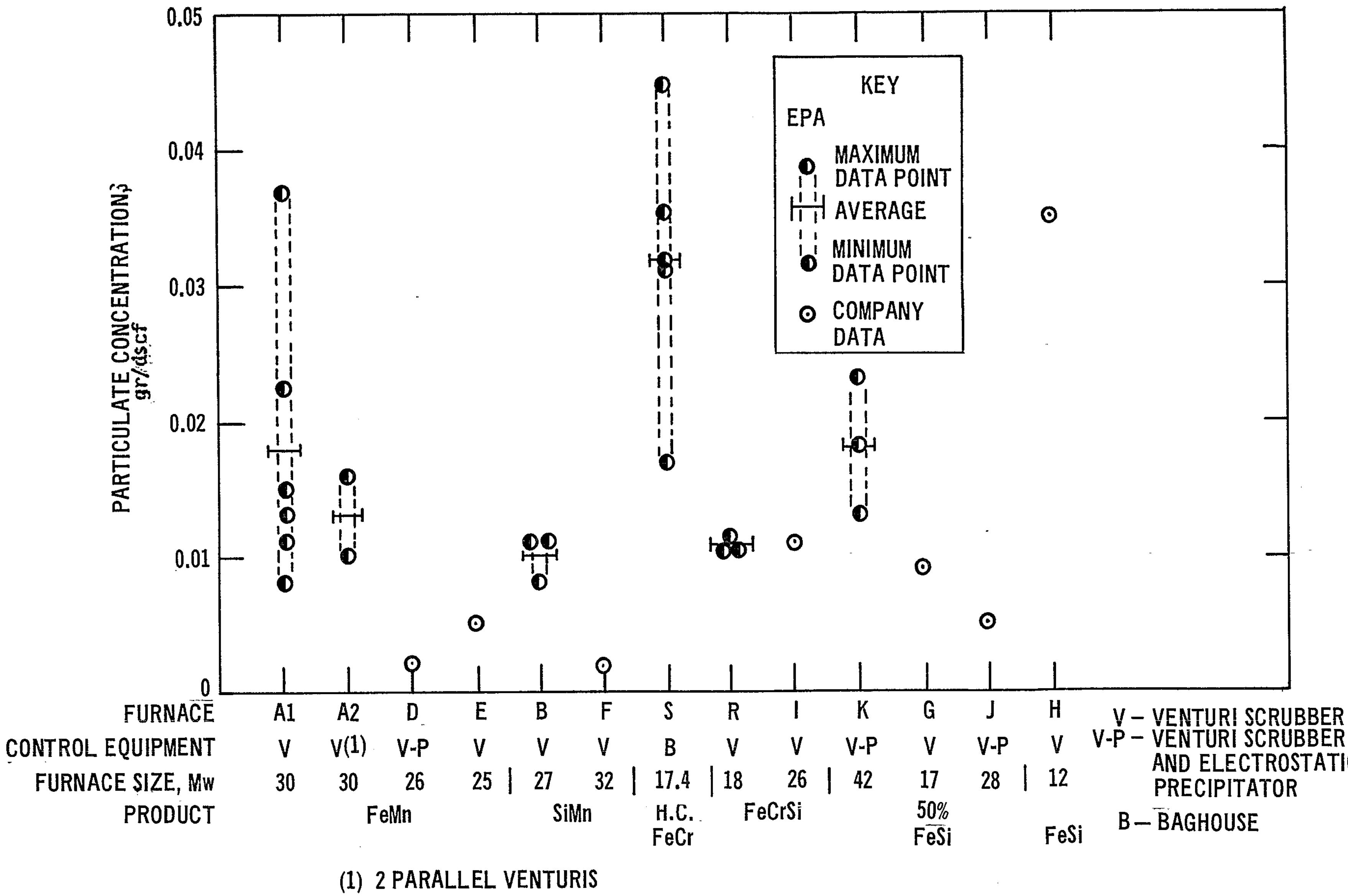


Figure VI-1. Particulate concentrations in control system exhaust from sealed electric submerged-arc furnaces producing ferroalloys.

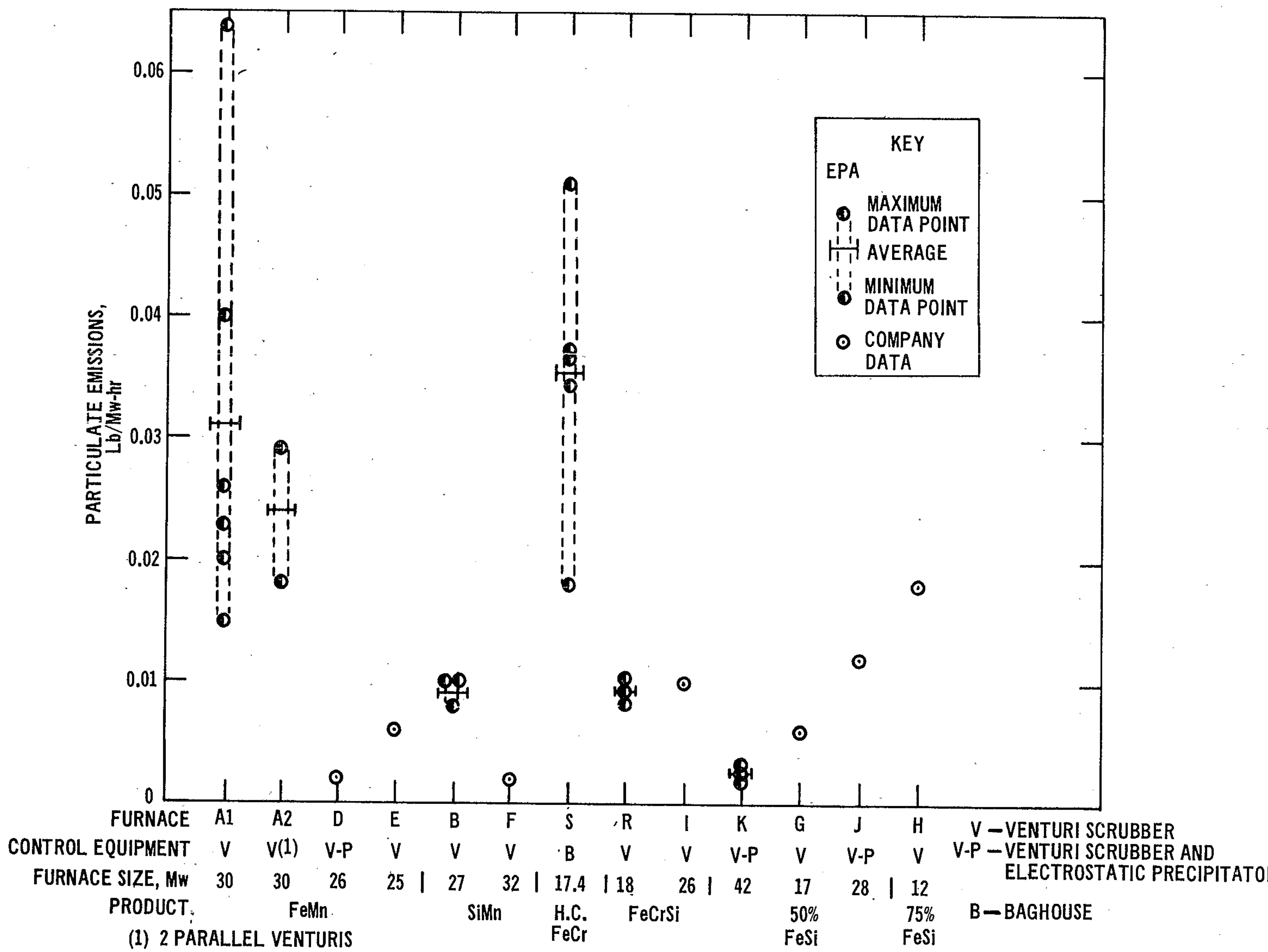


Figure VI-2. Particulate emissions (excluding tapping fumes and fugitive fumes) from sealed electric submerged-arc furnaces producing ferroalloys.

seals of Furnace K during the tests. These emissions could not be measured quantitatively; however, other sealed furnaces were observed to operate with no fugitive fumes at the electrode seals.

Two semi-enclosed furnaces (C and P) were tested by EPA. Data from these tests are shown in Figures VI-3 and VI-4. Outlet loadings from the control devices of Furnaces C and P averaged 0.030 gr/dscf and 0.058 gr/dscf (0.017 lb/Mw-hr and 0.078 lb/Mw-hr) respectively, not including tapping emissions or those which emanate from the annular openings around the electrodes. Particulate matter emissions from around the electrodes were measured as 48 lb/hr (2.0 lb/Mw-hr) for Furnace C and 390 lb/hr (8.3 lb/Mw-hr) for Furnace P.

Emissions from the spaces around the electrodes of semi-enclosed furnaces are much greater than controlled emissions from the control device. Hoods and ducts could conceivably be installed to capture fumes from the spaces around the electrodes and send them to a control device. If a control device with 99 percent overall efficiency had been used on these emissions for the furnaces tested, total emissions (excluding those from tapping) would have been 0.037 lb/Mw-hr and 0.16 lb/Mw-hr for Furnaces C and P respectively. These values are well below typical emissions from controlled open furnaces.

Emission data obtained by EPA on open ferroalloy furnaces are shown in Figures VI-5 and VI-6. Furnaces U and O are in Japan. L1, L2, and L3 are

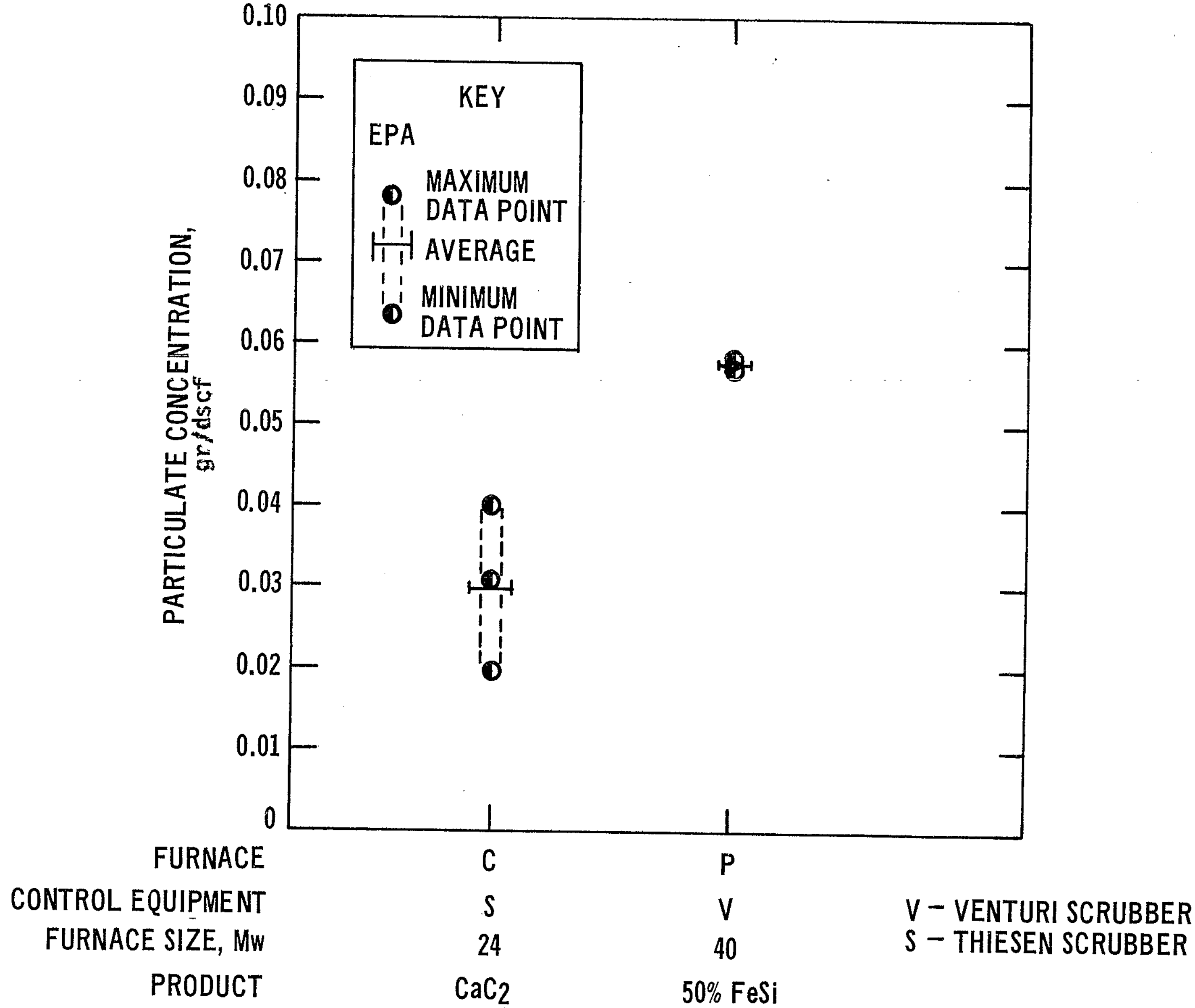
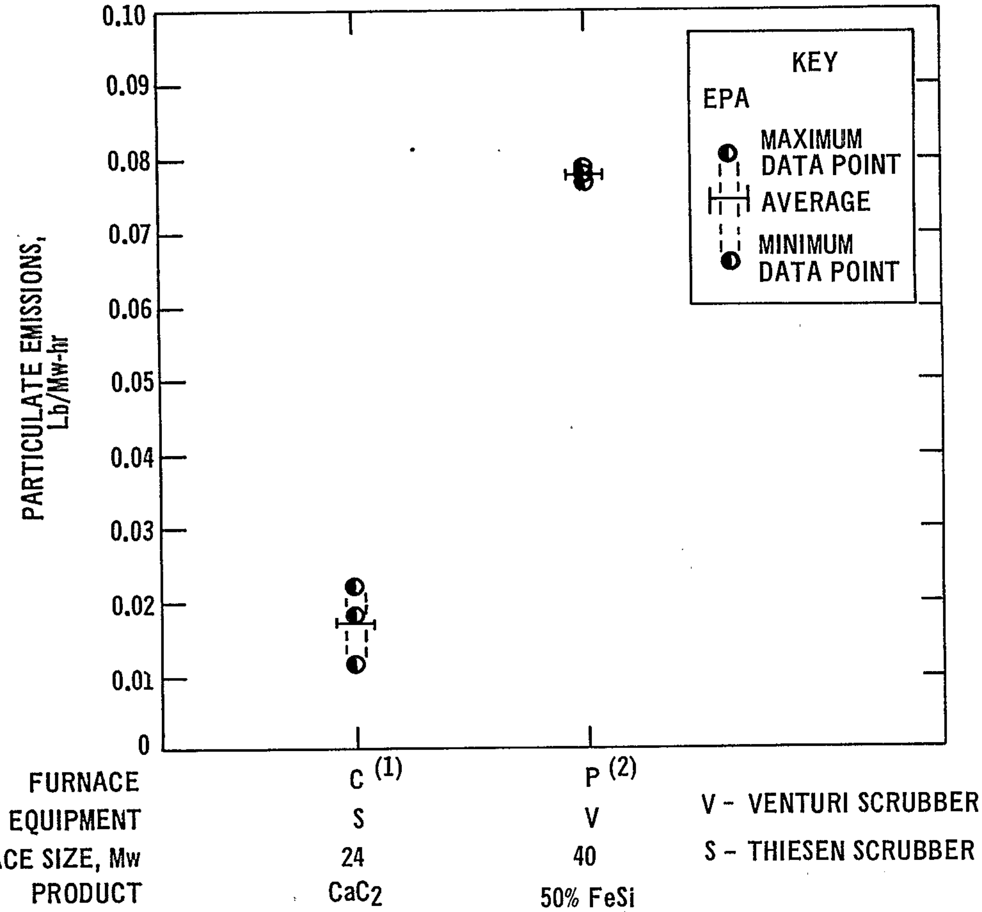


Figure VI-3. Particulate concentrations in control system exhaust from semi-enclosed electric submerged-arc furnaces producing ferroalloys.



(1) DOES NOT INCLUDE 48.2 lb/hr UNCONTROLLED FUGITIVE FUMES FROM AROUND THE ELECTRODES.

(2) DOES NOT INCLUDE 388 lb/hr UNCONTROLLED FUGITIVE FUMES FROM AROUND THE ELECTRODES.

Figure VI-4. Particulate emissions (excluding tapping fumes and fugitive fumes) from semi-enclosed electric submerged-arc furnaces producing ferroalloys.

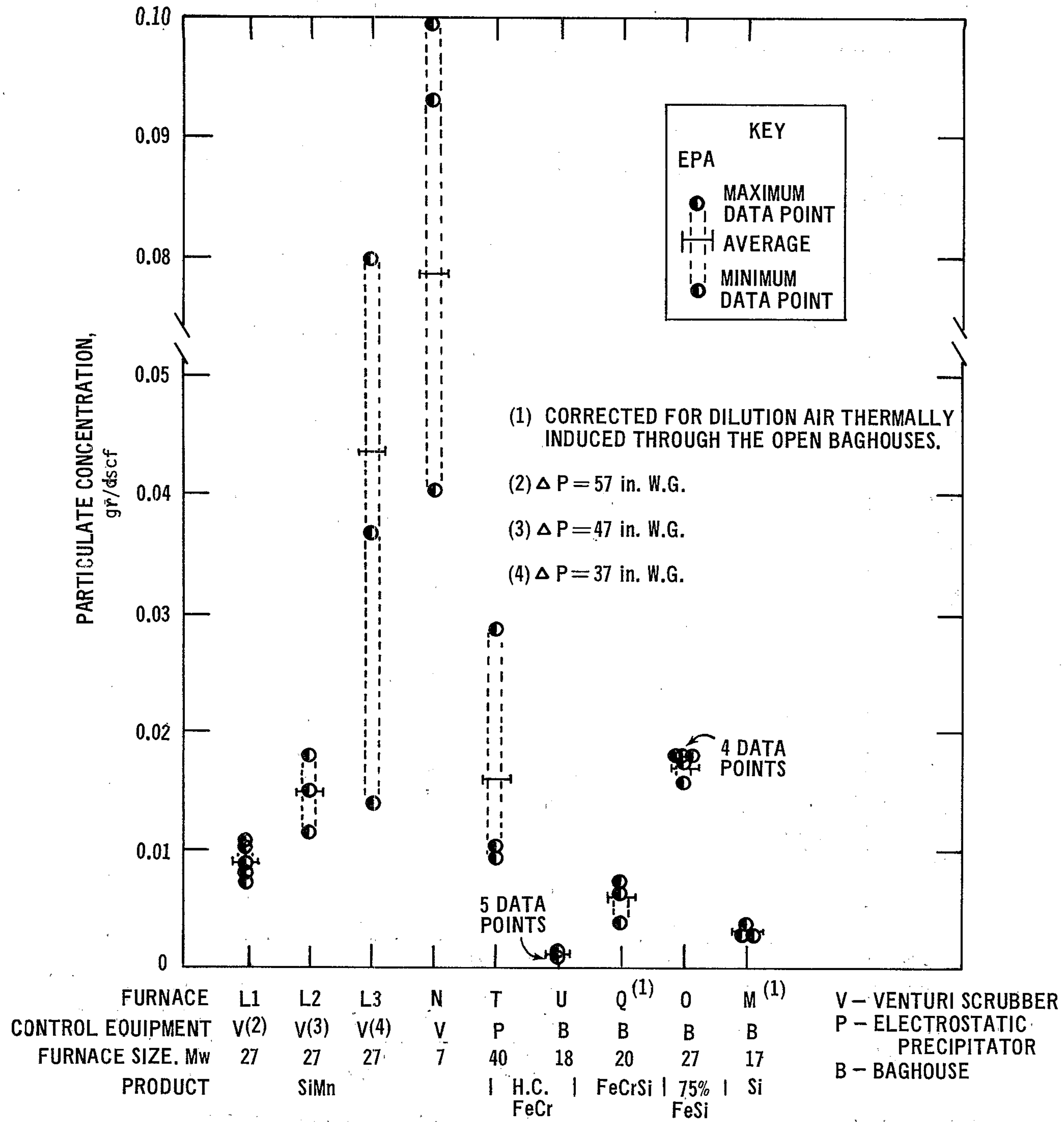


Figure VI-5. Particulate concentrations in control system exhaust from open electric submerged-arc furnaces producing ferroalloys.

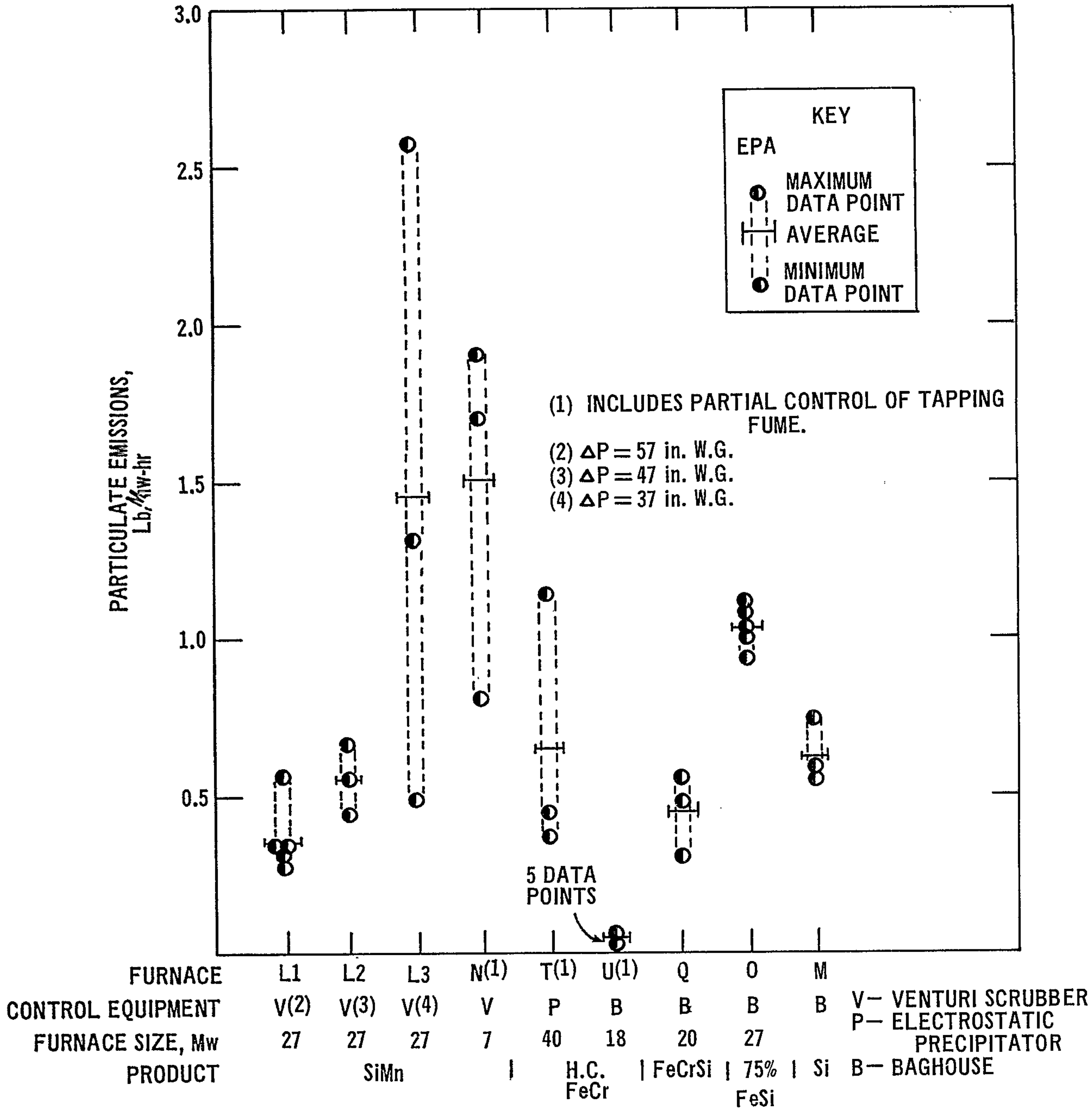


Figure VI-6. Particulate emissions from open electric submerged-arc furnaces producing ferroalloys.

the same furnace for which the energy loss across the venturi scrubber was 57, 47, and 37 inches water gauge, respectively. Average emissions ranged from 0.0010 gr/dscf to 0.079 gr/dscf, or from 0.035 lb/Mw-hr to 1.5 lb/Mw-hr. Where noted, the data in Figures VI-5 and VI-6 include fume captured in a tapping hood and ducted to the furnace control device. Capture efficiency for these tapping hoods was estimated as 20 percent for Furnace N and 80 percent for Furnaces T and U. Estimated capture efficiencies of the furnace hoods ranged from 95 to 100 percent.

The data presented in Figures VI-1, 3 and 5 present a wide variation in particulate matter concentrations, but no correlation with furnace configuration can be drawn because data for all three types of furnaces have similar variations and span roughly the same range of values. From this, one can conclude that a standard restricting the concentration of particulate matter is not a good choice since it cannot mandate the sealed furnace, which obviously provides better overall emission control. The data show that mass emissions in terms of lb/Mw-hr do vary significantly with the type of furnace. Mass emissions from semi-enclosed furnaces with uncontrolled emissions from the annular spaces around the electrodes are highest. Open furnaces with efficient control have the next highest emissions. Sealed furnaces have the lowest mass emissions and emissions from semi-enclosed furnaces which capture and efficiently control electrode emissions appear to be intermediate between open and sealed furnaces.

No measurement was made of emissions from a tapping operation with an independent control system because none was found from which they could be measured with reasonable accuracy. They were measured at three furnaces where the tapping hoods exhausted directly into the atmosphere without control. Average uncontrolled tapping emission rates were 48 lb/hr for Furnace C, 53 lb/hr for Furnace L, and 82 lb/hr for Furnace P for the duration of tapping. Furnace C is continuously tapped. If tapping emission rates for Furnaces L and P were averaged over the entire furnace cycle instead of only the tapping period, tapping emission rates would be reduced to about 18 lb/hr and 16 lb/hr respectively. Capture efficiency of the tapping hood was very good on Furnace C and was estimated as 75 percent on Furnace P. Hood capture efficiency was not estimated for Furnace L. At other plants, tapping hoods with apparent 100 percent capture efficiency have been observed.

Based on measurements of emissions from furnaces where tapping emissions are not controlled and observation of furnaces which very effectively capture tapping emissions, calculation methods have been used to determine the equivalent emissions from a furnace at which tapping emissions are captured and ducted to an efficient control device. To determine the effect of including tapping fumes, a conservatively high value of 150 lb/hr of uncontrolled tapping emissions was assumed. If these are completely captured and enter a control device with 99 percent efficiency, emissions from tapping a 30-MW, continuously tapped furnace would be 0.05 lb/Mw-hr. Continuously tapped furnaces are not common except for calcium carbide production. Tapping emissions averaged over the entire furnace cycle for a 30-MW furnace tapped for 15 minutes during a furnace cycle of 75 minutes (start of one tap to the start of the next tap) would be 0.01 lb/Mw-hr. Comparison of these calculated values for controlled tapping emissions shows they about equal emissions from well-controlled sealed ferroalloy furnaces, and are about 10 percent or less of typical emissions from well-controlled open ferroalloy furnaces.

B. Visible Emission Data

Visible emission data were obtained at several facilities. No sealed furnace had a residual visible emission after the flare. Visible emissions from the scrubber serving semi-enclosed Furnace P also were zero percent opacity. Visible emissions from control devices serving open furnaces varied. They were consistently zero percent opacity for Furnaces U, M and N during periods when samples were obtained for quantitative emission measurements. Maximum visible emissions from other open furnace control systems ranged from 5 to 15 percent opacity. In some cases, visible emissions were traced to leaking bags in baghouses. Visible emission data are summarized in a separate document, Background Information for Standards of Performance: Electric Submerged-Arc Furnaces for the Production of Ferroalloys - Volume 2, Test Data Summary.

Visible emissions from buildings which house electric submerged-arc ferroalloy furnaces were observed at 100 percent opacity for brief periods. These emissions may vary from 0 to 100 percent opacity depending on what production operation is occurring and the capture efficiency of the hoods. Possible sources of particulate matter which may cause visible emissions from buildings are fumes which escape from the furnace, tapping operations, oxygen lancing of tap holes, and reladling and pouring of the ferroalloy.

Visible emissions were observed at one tapping hood through two tapping periods, the first of 19 minutes duration, and the second of 30 minutes duration, and opacities of fume which escaped the hood were recorded. During the first tapping period observed, the hood was moved out of place twice for unknown reasons for a total of 1.5 minutes of the 19. Excluding the observations made during the 1.5 minutes when the hood was out of place, the opacities were observed to be zero percent for 12.5 minutes (or 71.4 percent of the time) and were observed to be less than 20 percent for 15.75 minutes (or 90 percent of the time). Opacities were greater than or equal to 20 percent for 1.75 minutes of the 17.5 minutes during which the hood was in place. The maximum opacity observed was 60 percent. During the second tap, the tapping hood was left in place throughout the tapping period. Opacities were observed to be zero percent for 22 minutes of the 30 minute tapping period (73.3 percent of the time), and the maximum opacity observed was 15 percent.

Visible emission readings of fume escaping furnace hoods were obtained, and furnace hood capture efficiencies were estimated at 3 open ferroalloy furnaces. In each of these cases, no visible emissions were observed escaping the hood, and capture efficiencies were estimated as 100 percent. One other open furnace was observed and judged to achieve equivalent collection, but formal opacity readings were not made. Visible emissions did not escape the covers of the sealed furnaces observed *unless the seals* around the electrodes or charging chutes were leaking. This condition can be corrected to prevent visible emissions.

VII. SUMMARY OF ECONOMIC INFORMATION

A. Introduction

This section will examine the cost of the alternative control systems, evaluate the economic impact of the control costs on the industry, and compare the cost of the proposed standard of performance to the cost of achieving State standards.

The type of furnace and the method of hooding used to capture the furnace gases have a great effect on the cost of the emission control system. The main factor influencing the cost of the control system is the gas volume that must be treated. The carbon monoxide and other gases evolved from the furnace reaction zone can be withdrawn by an exhaust system without combustion of the carbon monoxide provided the furnace has a closed water-cooled cover and mechanical seals around the electrodes. Although sealed ferroalloy furnaces cannot be used to produce all products, they offer the advantage of smaller gas volumes to clean than an open furnace. The small volume of undiluted dirty gases from a sealed furnace is typically cleaned by venturi scrubbers. Foreign installations also use electrostatic precipitators and one uses a sealed baghouse.

In the open furnace system, induced air is mixed with the carbon monoxide which burns above the charge. Depending on the design of the particular furnace, the evolution of gases may result in flows 50 to 200 times those generated in a sealed furnace system. The gas flow rate depends on the hood design, the vertical opening between hood and furnace required for stoking the charge, and the diameter of the furnace. Fabric filters (baghouses) or wet scrubbers are typically used to control open furnaces.

B. Model Plants

The control costs were developed for model ferroalloy furnaces (examples of ferroalloy furnaces typical of furnaces which may be built in the future). The values of the parameters of each model were chosen to represent the expected values for new ferroalloy furnaces. Because the trend in the industry is toward larger furnaces than in the past, the size chosen for the models is large - 30 megawatts (except for the silicon metal furnace which is 25 megawatts). Table VII-1 shows the pertinent design parameters associated with the model furnaces. Since silicomanganese (SiMn) can be made in the same furnace interchangeably with high-carbon ferromanganese (HC FeMn), we have assumed that the control equipment for the SiMn furnace will be the same as that for the HC FeMn furnace.

Another emission source that must be controlled in addition to the furnace is the tapping operation. The method of control assumed for this cost analysis depends on the furnace type. For open furnaces the tapping fumes can be collected with a separate hood and vented into the main control device. For sealed furnaces a separate fabric filter control system was assumed as the most probable method of control.

Table VII-1. Model Furnace Parameters

Parameter	Product					
	HC FeMn	SiMn	50% FeSi	HC FeCr	CaC_2	Si Metal
Power rating, Mw	30	30	30	30	30	25
Product rate,[a] tons/yr	99,000	44,000	47,500	51,000	91,000	14,100
Gas volume from sealed furnace,[b] scfm	5,000	5,000	6,000	5,000	4,000	6,000
Gas volume from open furnace,[b] acfm @ 400°F	350,000	350,000[c]	450,000	250,000	200,000	750,000
Tapping fume gas volume for all furnace types, acfm @ 150°F[d]	60,000	60,000	60,000	60,000	60,000	60,000

[a]At 90 percent of full capacity.

[b]The gas volumes represent typical values obtained from the industry survey questionnaires.

[c]Assumed to be the same for the HC FeMn since the furnace may be designed to produce either product.

[d]The figures shown for the tap fume collection are additive to the open furnace volume, based on an open furnace configuration with the collection hood 5 to 7 feet above the furnace deck.

C. Control Costs

1. Open Furnace Control Costs

Control costs for the model open furnaces shown in Table VII-1 were developed for two types of control devices - fabric filters and wet scrubbers. All costs are in 1972 dollars.

a. Fabric Filter Control Costs

Estimates of investment and operating costs required to control open furnaces using fabric filter systems are shown in Table VII-2. These costs were derived from information developed for EPA by the Industrial Gas Cleaning Institute (IGCI).[43] The tapping fume control system is vented into the fabric filter, and the costs for that system are included. The assumptions that form the basis for these cost estimates will be discussed below. The industry's cost estimates for fabric filter systems are higher than the figures in Table VII-2 because additional equipment and installation factors are considered. The industry's cost estimates are shown in Table VII-3 and will be discussed in the second part of this section.

The capital costs for fabric filter installations as received from the IGCI were plotted against the associated collector inlet volumes, and the graph is shown in Figure VII-1. The capital cost for each model furnace may be determined from Figure VII-1 by finding the capital cost that corresponds to the gas volume flow rate for that model. The capital costs from the IGCI study are based on a new plant situation (i.e., a simple duct run, no space

Table VII-2. Control Costs for Fabric Filters on Open Furnaces

Cost Item	Product				
	HC FeMn and SiMn	50% FeSi	HC FeCr	CaC_2	Si Metal
Capital cost (Thousands of $)					
Fabric Filter	$ 630	$ 770	$ 500	$ 430	$1,260
Auxiliary Equipment	210	250	160	140	520
Installation	1,060	1,280	840	730	1,420
Total Capital Cost	$1,900	$2,300	$1,500	$1,300	$3,200
Annual Cost (thousands of $ per year)					
Operating Labor	$ 53	$ 53	$ 53	$ 53	$ 53
Maintenance (6%)	114	138	90	78	192
Electricity	87	106	68	57	194
Capital Recovery (15 yr. life, 8% interest)	222	269	175	152	374
Administration (2%)	38	46	30	26	64
Taxes and Insurance (2%)	38	46	30	26	64
Total Annual Cost	$ 552	$ 658	$ 446	$ 392	$ 941
	HC FeMn SiMn				
Annual Cost Per Ton	$5.58 $12.55	$13.85	$8.75	$4.31	$66.74

Table VII-3. Control Costs for Fabric Filters on Open Furnaces (Estimated by Industry)

Cost Item	Product				
	HC FeMn and SiMn	50% FeSi	HC FeCr	CaC_2	Si Metal
Capital Cost (housands of $)					
Fabric Filter	$1,000	$1,265	$ 700	$ 630	$1,890
Auxiliary Equipment	360	455	255	220	780
Installation	1,640	2,080	1,145	1,050	2,130
Total Capital Cost	$3,000	$3,800	$2,100	$1,900	$4,800
Annual Cost (Thousands of $ per year)					
Operating Labor	$ 53	$ 53	$ 53	$ 53	$ 53
Maintenance (6%)	180	228	126	114	288
Electricity	87	106	68	57	194
Capital Recovery, (15 yr. life, 8% interest)	350	444	245	222	561
Administration (2%)	60	76	42	38	96
Taxes and Insurance (2%)	60	76	42	38	96
Total Annual Cost	$ 790	$ 983	$ 576	$ 522	$1,288
	HC FeMn SiMn				
Annual Cost Per Ton	$7.98 $17.95	$20.69	$11.29	$5.74	$91.35

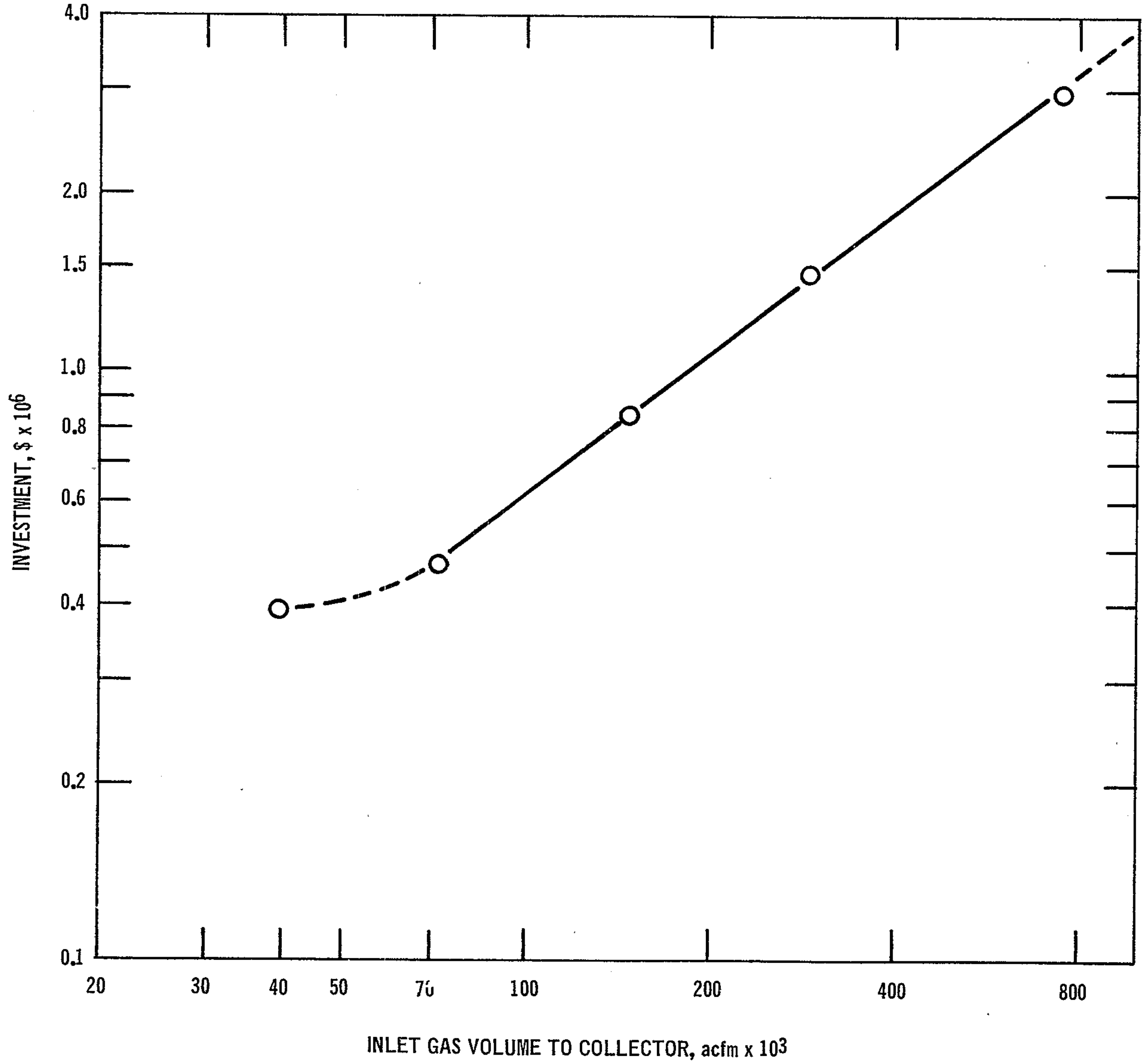


Figure VII-1. Capital costs of open furnace control with fabric filters.[43]

limitations, etc.). The costs for the furnace hood and the incremental costs for increases in electrical substation capacity are not included. The capital costs for the fabric filter installations include the baghouse, fans, upstream mechanical collector, dust storage bins with 24-hour capacity, dust hoppers and conveyors, foundation support, ductwork connections, and stack. The costs for engineering design, electrical and piping tie-ins, insulation, erection, and performance testing are all included. Fiber glass bags with a temperature resistance of 500° F are assumed to be used. The baghouse is also assumed to contain one extra compartment which permits maintenance on one section without shutting down the entire baghouse.

The following assumptions concerning annual costs of operation apply to operation of the control facility for open furnaces.

(1) Replacement parts and maintenance were estimated at 6 percent of the original plant investment for the purpose of replacing 50 percent of the bags and 10 percent of the air valves per year, and for contingencies.

(2) Manpower requirements were estimated to be 1/2 man per shift.

(3) The main component of the electrical costs is the power required by the fans to overcome the baghouse pressure drop. The pressure drop ranges from 10-12 inches of water for HC FeCr to 15-20 inches of water for 50 percent FeSi.

(4) Depreciation and interest charges are accounted for by the use of a capital recovery factor based on 15 year life and on 8 percent interest rate.

(5) Administrative costs of 2 percent of original investment, and another 2 percent for property tax and insurance were assumed.

The ferroalloy industry has estimated higher costs for fabric filter installations for the following reasons:

(1) The industry's cost figures are based mainly on installations at existing plant sites. Since these installations must be fitted into the available space, certain cost items such as ducting will be more expensive.

(2) The industry's figures also include items that were not included in the IGCI cost estimates. These items are the furnace hood cost, electrical substation expansion costs, equipment startup costs, and company engineering and contingency costs.

If these items are included and installation in an existing building is assumed, the capital costs can be as much as 50 percent higher than the IGCI costs. Table VII-3 shows the industry's cost estimates for the model furnaces.

If the average of the IGCI costs and the industry's costs are used, the annual cost per ton ranges from a low of $5.03 per ton for calcium carbide to $79.05 per ton for silicon metal.

b. Wet Scrubber Control Costs

Estimates of the investment and operating costs required to control open furnaces using wet scrubbers are shown in Table VII-4. These estimates are derived from information from the Industrial Gas Cleaning Institute (IGCI)[43] and are based on equipment and operating requirements to meet the process weight standard published in the Federal Register of August 14, 1971 (36 FR 15486). The costs have been adjusted from IGCI data to reflect the gas flows of the model plants presented in Table VII-1. The costs in Table VII-4 are based on a new plant installation and do not include the furnace hood or additional electrical substation costs. The industry's experience confirms the costs as presented in Table VII-4.

Plots of investment cost for scrubbers to control furnaces making 50 percent ferrosilicon that were developed by the IGCI are shown in Figure VII-2. The cost curve for ferrochrome was used to develop the costs for all the other alloys except 50 percent ferrosilicon. The investment costs include a venturi scrubber, a fan with at least 20 percent excess capacity, an entrainment separator, aftercoolers, a slurry settler, two filters to dewater the slurry product, and tapping emissions control. The charges for engineering design, electrical wiring, piping, insulation, erection, performance testing, and startup are all included.

Table VII-4. Control Costs for Wet Scrubbers on Open Furnaces

Cost Item	Product			
	HC FeMn and SiMn	50% FeSi	HC FeCr	CaC_2
Capital Cost (thousands of $)				
Scrubber	$ 110	$ 190	$ 96	$ 87
Auxiliary equipment	290	510	254	233
Installation	1,400	2,450	1,250	1,130
Total Capital Cost	$1,800	$3,150	$1,600	$1,450
Annual Cost (thousands of $ per year)				
Operating Labor	$ 26	$ 26	$ 26	$ 26
Maintenance (7%)	126	220	112	102
Electricity	290	595	225	190
Water	155	298	118	99
Capital recovery (15 yr. life, 8% interest)	210	368	187	169
Taxes and Insurance (2%)	36	63	32	29
Administration (2%)	36	63	32	29
Total Annual Cost	$ 879	$1,633	$ 732	$ 644
	HC FeMn SiMn			
Annual Cost Per Ton	$8.88 $19.97	$34.38	$14.35	$7.08

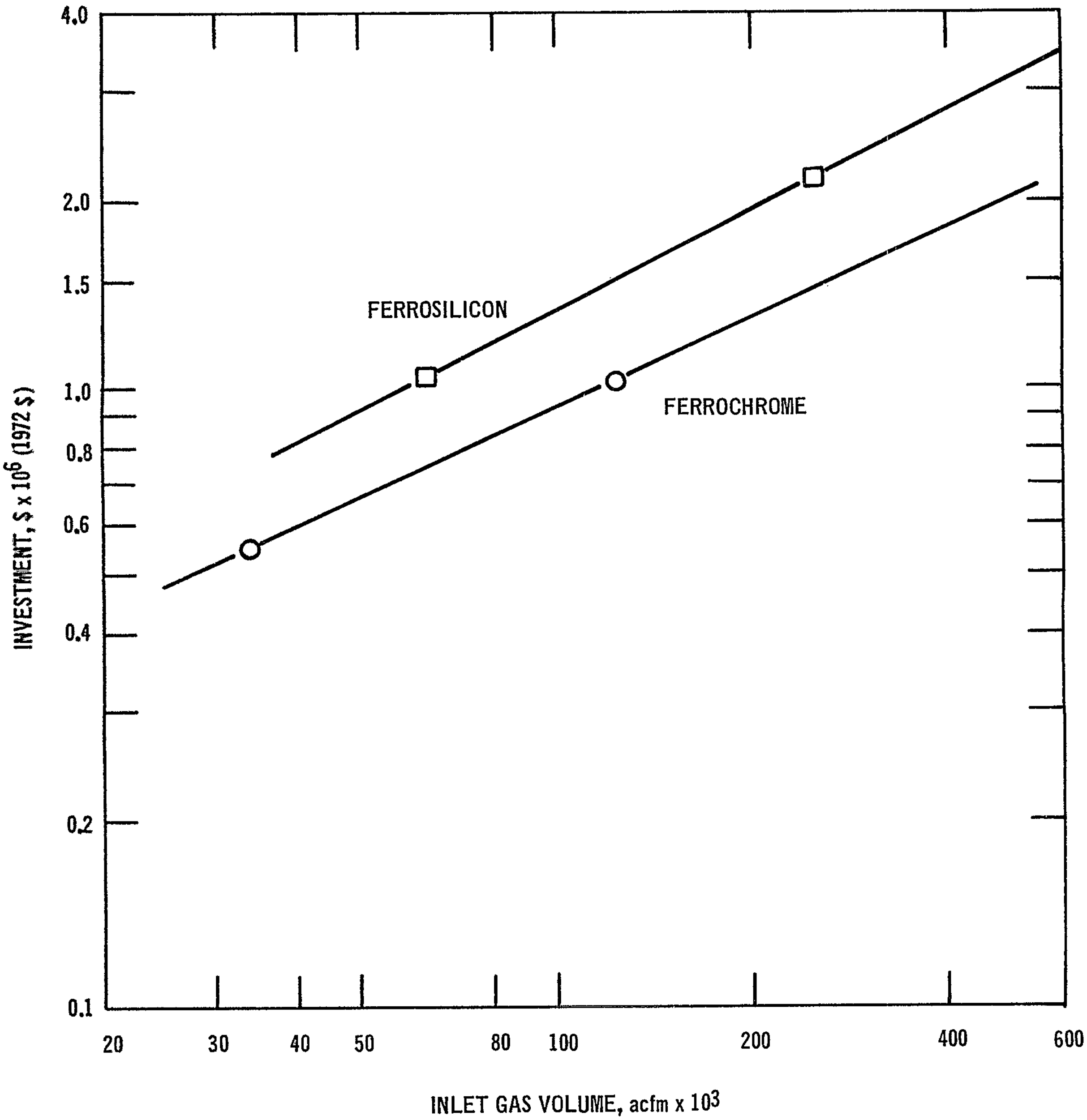


Figure VII-2. Capital costs of open furnace control with wet scrubbers.[43]

The annual cost per ton of product ranges from a low of $7.08 per ton for calcium carbide to a high of $34.38 per ton for 50 percent ferrosilicon. Wet scrubber control was not included for silicon metal because of the difficulty of achieving good control with wet scrubbers.

c. Actual Industry Costs

The Ferroalloy Association submitted to EPA the actual furnace and air pollution control equipment cost data for several recent installations.(44) The specific details of each installation are somewhat different since each installation was an addition at an existing plant, and to varying degrees existing equipment was used for the new furnace. The costs reported for the control equipment when adjusted for the year of installation range from -16 percent to +40 percent of the costs in Figures VII-1 and VII-2. Considering the differences in the bases, the actual costs compare favorably with the costs in Figure VII-1 and VII-2. Since the EPA estimates are designed to represent typical installations, some differences for specific installations are expected.

2. Sealed Furnace Control Costs

a. Furnace Fume Control Cost - Wet Scrubber

Capital and annual costs are presented in this section for control devices on sealed furnaces. Since the furnace has a tight cover with seals around the electrodes, the gas volume going to the control device is much smaller than for an open furnace. Thus, the cost of the control device is much smaller than the control device cost for an open furnace. However, the pollution control equipment is not the only consideration in a comparison of open and sealed furnaces. Actually, the open and sealed furnaces require two different sets of process equipment of which the pollution control system is one part.

In order to make a complete comparision of the two furnace types, the total system should be considered from both the process side and the air pollution control side. In this section the costs for a sealed furnace are compared to the costs for an open furnace to illustrate this point.

The costs presented here are for a large sealed furnace recently constructed in Canada. These costs should be representative of the costs that would be experienced at a U.S. location. The maximum power rating for this furnace is 33 Mw for HC FeMn and 38 Mw for SiMn.

The primary control system for the sealed furnace consists of the sealed furnace cover, a water spray cooler, a mechanical dust separator, and a variable-throat venturi scrubber followed by a mist eliminator. The pressure drop across the scrubber is in the range of 75 to 80 inches of water. The gas flow from the furnace is about 6,600 scfm, and the gas flow at the scrubber is about 9,700 scfm. The cleaned gas stream, which is rich in

CO, can be used as a fuel source in the feed pretreatment plant or diverted to a flare stack. A complete water treatment system is included; the treated water is recycled to the scrubber and the filter cake of solids is recycled to the sintering plant.

The furnace tapping system is designed with a hood over each of four tapholes. A total flow rate of 30,000 acfm is combined with another 20,000 acfm vent stream and sent to a fabric filter collector.

Table VII-5 shows the costs for the sealed furnace and its control equipment compared to the company's estimated costs for an open furnace with a fabric filter collection system. The prorated share of the project's utilities, electrical, and engineering expense for the control system is included in the control system cost. In addition to the furnace collection system and the tapping emission collection system, the company reported two other cost factors for the totally enclosed furnace that are different from those of the open furnace. The first is the incremental furnace cost which includes such items as more complex electrode columns and electrical equipment. The second item is an incremental feed pretreatment cost which includes ore and coke dryers and a sinter plant.

The decision to use the incremental feed pretreatment must be made after evaluation of the overall process. Drying and sintering allow the use of coke and ore fines and the recovered particulate matter from the air pollution control systems. Some foreign

Table VII-5. Comparison of Capital and Annual Costs for an Open and a Sealed HC FeMn and SiMn Furnace Producing HC FeMn or SiMn

Cost Item	Open Furnace	Totally Enclosed Furnace
Comparison of total capital costs(45) (thousands of $)		
Basic furnace and associated process equipment	$ 8,500	$ 8,500
Incremental furnace cost	--	1,400
Incremental feed pretreatment	--	3,000
Air pollution control systems	3,500	2,100
	$12,000	$15,000
Comparison of control equipment costs		
Capital costs(45) (thousands of $)		
Primary system	$ 3,500	$1,700[b]
Taphole system (see Table VI-7)	(inc. in above)	400
Incremental furnace cost	--	1,400
	$ 3,500	$3,500
Annual costs (thousands of $ per year)		
Operating cost	$ 143	$ 135
Maintenance (6%)	210	210
Capital recovery (@ 8% interest)	409[c]	390[d]
Administration (2%)	70	70
Taxes and insurance (2%)	70	70
	$ 902	$ 875
Annual cost per ton[a] ($/ton)		
HC FeMn	$9.11	$8.84[e]
SiMn	$20.50	$19.89[e]

Based on 30 Mw for HC FeMn and 34 Mw for SiMn, both at 90% operating rate.

[b]Incluues $900,000 for the cooler, mechanical separator, scrubber, mist eliminator, and water treatment equipment; $420,000 for the furnace cover and mechanical seals; and $380,000 for the prorated share of electrical utility and engineering costs.

[c]Depreciation life: 15 years.

[d]Depreciation lives: 10 years - furnace cover, 15 years - pollution control system, 20 years - incremental furnace costs.

[e]This does not include the annualized investment cost or operating cost of the incremental feed pretreatment equipment. The ferroalloy industry has indicated that the total manufacturing cost per ton of product is about equal for both the open furnace with control and the sealed furnace with control and feed preparation.

plants with sealed furnaces have these additional feed pretreatment steps and some do not. It is even hard to define exactly what should be included as incremental feed pretreatment equipment. For example, some open furnaces have dryers and some do not (depending on the availability of dry materials). Thus, dryers may or may not be considered as incremental equipment for totally enclosed furnaces. The incremental feed pretreatment cost could be considered as part of the air pollution control cost, or could be considered a process addition for which the economics must be justified in each individual case.

In Table VII-5 the capital cost for the incremental feed pretreatment is shown, but these costs are not included in the presentation of the annual cost of the air pollution control equipment. After an overall evaluation was made, this particular plant decided that the sealed furnace with the additional feed pretreatment was the best choice in this case. Japan Metals and Chemicals, the largest producer of ferroalloys in Japan and a ferroalloy furnace manufacturer, states that the final cost of product is the same from either an open or totally enclosed furnace.(46) The particular method of processing must be considered separately for each individual installation.

It is not possible to generalize from this case to say that in all cases the totally enclosed furnace with feed pretreatment would be the most economical. For example, in the case where a furnace is to be added at an existing plant, an open furnace could possibly use the existing feed preparation and delivery system whereas a sealed furnace might require a new, separate feed preparation and delivery system. Also, the open furnace could possibly be installed in an existing building while the taller, totally enclosed furnace would probably require a new or expanded building. These or other differences at any specific site could affect the costs enough to change the choice of the most economical type of furnace to an open furnace.

The cost data in Table VII-5 are for sealed furnaces producing HC FeMn and SiMn. Table VII-6 shows the emission control device cost for a sealed 30 megawatt CaC_2 furnace. The costs are based on extrapolation from the HC FeMn costs for the same type of system using the following relationship:

$$\text{Cost of } CaC_2 \text{ System} = \text{Cost of HC FeMn System} \times \frac{CaC_2 \text{ gas volume}}{\text{HC FeMn gas volume}}$$

Only the emission control system is shown in Table VII-6.

b. Furnace Fume Control Cost - Fabric Filter

One known company uses a fabric filter as the control device on a sealed furnace. This method of control has not been used in the U.S., and the domestic industry does not expect to use this method of control for sealed furnaces. The estimated capital cost for a conventional fabric filter control system, consisting of a radiant cooler, cyclone, fan, fabric filter, dust removal and storage equipment, water seal tanks, and flare stack,

Table VII-6. Control Costs for a Sealed CaC_2 Furnace

Cost Item	Cost
Capital Costs (Thousands of $)	
Primary Control System	$1,280
Taphole System (See Table VI-7)	400
Total Capital Cost	$1,680
Annual Costs (Thousands of $ per year)	
Operating Cost	$ 119
Maintenance (6%)	101
Capital Recovery (15 year life, 8% interest)	196
Administration (2%)	34
Taxes and Insurance (2%)	34
Total Annual Cost	$ 484
Annual Cost per ton of Product ($/ton)	$5.32

is about $250,000. However, this system would have to be specially designed because of the high concentration of CO gas. These added design considerations could substantially increase the cost.

c. Tapping Fume Control Cost

The estimated capital and annual costs presented in Table VII-7 are based on a separate fabric filter control system for emissions generated during the furnace tapping operation. The assumed flow rate was 60,000 acfm at 150° F. The system includes a hood, fan, fabric filter, and dust removal and storage equipment.

Because the tapping operation can be scheduled with some flexibility, this control system could serve more than one furnace. Possibly tapping fume hoods from two furnaces could be vented to the same fabric filter, which would reduce the control cost per furnace. However, for this analysis a separate tapping fume control system for each furnace has been assumed.

D. Discussion of the Control Costs

1. Cost Effectiveness Comparisons

In general, varying the level of control efficiency required will result in a change of the control system cost. In the case of the ferroalloy furnace controls, the costs do not follow the usual pattern. This can be seen in two comparisons. Consider first the open furnace control systems--fabric filters and wet scrubbers.

Table VII-7. Control Costs for a Separate Tapping Fume Collection System

Cost Item	Cost
Capital Cost	
Fabric Filter	$ 85,000
Auxiliary Equipment	55,000
Installation	260,000
Total Capital Cost	$400,000
Annual Cost	
Operating Labor	$ 10,000
Maintenance (10%)	40,000
Electricity	23,000
Capital Recovery (15 yr. life at 8% Interest)	47,000
Administration (2%)	8,000
Taxes and Insurance (2%)	8,000
Total Annual Cost	$136,000

The fabric filter systems can achieve the best control. If the required control efficiency is lowered, wet scrubbers could be used. But, as Tables VII-2,3, and 4 indicate, the annual costs for wet scrubbers are higher than those for fabric filters. Therefore, there is no cost advantage to setting an emisssion standard which requires a lower efficiency than what can be achieved using a fabric filter system.

A second comparison can be made looking at sealed furnaces and open furnaces for production of HC FeMn, SiMn, and CaC_2. For these products the cost of the control device for the sealed furnace (Tables VII-5,6) is lower than that for a fabric filter on an open furnace As discussed in section C.2.a., when all costs are considered there is no significant cost difference between an open furnace with fabric filter and a sealed furnace with a wet scrubber. Therefore, the choice of system will be influenced by factors other than cost.

2. Control Costs - New Source Performance Standards vs. State Standards

In order to meet typical State process weight standards, the ferroalloy furnaces must install fabric filter control systems (or equivalent) on open furnaces and provide control of tapping fumes. This is, of course, equivalent to the requirements of the proposed standard of performance. Therefore, the cost of control to meet the proposed standard of performance is no greater than what the industry must spend to meet typical State standards.

E. Economic Impact

It is estimated that five to eight new furnaces will be needed in the next 5 years to provide the required new capacity and replacements for existing units. However, only one unit is currently under construction and that is due for completion in 1975. In 1972 four producers closed their plants. Thus, there has been a net attrition rather than a slow growth in the industry. As is true with many products, ferroalloy prices were frozen at low levels which severely limited profits and consequently limited funds available for expansion. With the exception of the new unit mentioned above, the industry is investing a large proportion of available capital in pollution control equipment to meet the 1975 emission control guidelines.

The combination of price controls and the upsurge in the steel industry have caused a severe shortage of ferroalloys. Imported alloys are selling at two and three times the controlled domestic prices. With price control regulations relaxed, it is apparent the air pollution control costs ranging from 5 percent of the selling price for ferromanganese to 20 percent for silicon metal can be passed on to the consumers.

VIII. ALTERNATIVE STANDARDS

Listed below for each pollutant are alternatives which were considered in developing the proposed standards of performance.

A. Alternative Standards for Particulate Matter

1. Alternative No. 1.[1/]

No owner or operator shall cause to be discharged into the atmosphere from any affected facility any gases which:

a. Contain particulate matter in excess of 0.45 kg/Mw-hr (0.99 lb/Mw-hr) while that facility produces silicon metal, ferrosilicon (60 percent and above), calcium silicon, or silicomanganese zirconium.

b. Contain particulate matter in excess of 0.23 kg/Mw-hr (0.51 lb/Mw-hr) while that facility produces charge chrome, ferromanganese silicon, or silvery iron (5 to 24 percent silicon).

c. Contain particulate matter in excess of 0.07 kg/Mw-hr (0.15 lb/Mw-hr) while that facility produces silicomanganese,

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1/ The limitations of parts (a) and (b) of Alternatives 1 and 2 can be achieved by an open furnace with good control equipment such as a fabric filter. Part (c) will probably require a well-controlled sealed furnace although a tightly hooded open furnace with very good control may suffice (see data for Plant U in Chapter VI).

ferromanganese, calcium carbide, high-carbon ferrochrome, nominal 50 percent ferrosilicon, or ferrochrome silicon.

Advantages

1) This option mandates "best technology."

2) It strongly encourages use of sealed furnaces for those product lines for which they have been demonstrated. This has the following advantages:

   (a) A sealed furnace results in nearly 100 percent capture of emissions.

   (b) Restriction of air flow rate through the control system minimizes emissions.[2/]

   (c) Emissions of CO from a sealed furnace are sufficiently concentrated that CO can be recovered for fuel or chemical synthesis.[3/]

2/ Air volumes and therefore mass emissions (for a fixed exit concentration) from a sealed furnace are only about 2 percent as much as from an equivalent open furnace.

3/ The recoverable energy from a sealed furnace may approximate 20 to 35 percent of the total power input. For a 30 megawatt furnace this is approximately equivalent to 15,000 gallons of fuel oil per day. In foreign countries, this gas is commonly used to fire dryers and plant boilers, or for chemical synthesis.

(d) This limitation improves the working environment of employees because the sealed furnace maximizes capture at the furnace of emissions potentially harmful to human health.

(e) Sealed furnaces maximize product yield by minimizing loss of charge material through the stack or as fugitive emissions.

(f) The sealed furnace minimizes power requirements for air pollution control to about 10 percent that required for open furnaces.[4/]

(g) Large sealed furnaces can be readily automated to reduce labor and operating costs.

(h) Capital cost of control equipment is minimized because sealed furnaces with their attendant low volumes of exhaust gas require smaller and less expensive control devices.

(i) The use of sealed furnaces may provide for closer process control by analysis and monitoring of gas consitutents.

3) Open furnaces with good control systems are permitted for those products for which sealed furnace technology is not known to be demonstrated.

4/ Energy requirements for equipment to control air pollution on open furnaces approximate 10 percent of the power input to the furnace. For a sealed furnace, control equipment power requirements approximate one percent of the furnace power input.

4) This alternative permits the use of scrap steel in open furnaces for the production of silvery iron.

5) This alternative requires control of tap fumes for all furnace configurations and also requires control of any emissions occurring from the annular openings at the electrodes of semi-enclosed furnaces.

Disadvantages

1) A regulation that requires sealed furnaces:

   (a) Would restrict their use to a certain "family" of products (precluding manufacture of certain other products), thereby restricting the flexibility of new furnaces to respond to market demands.

   (b) Could indirectly encourage construction of open furnaces outside of the United States where pollution requirements are less stringent in order to retain the flexibility.[5/]

2) Sealed furnaces require additional safety precautions and facilities for the transfer and treatment of CO gas. (See Issue 2, Chapter XI.)

5/ Such a trend could ultimately make the United States dependent on foreign sources for steel additives (ferroalloys) necessary for defense and consumer goods. However, this reason is somewhat mitigated by our present dependence on foreign sources for ferroalloy ores (such as manganese). Foreign suppliers are already beginning to process their own ores and may one day ship only the ferroalloy to United States markets.

3) Sealed furnaces may require additional pretreatment of raw materials for production of some ferroalloys. (See Issue 3, Item 1, Chapter XI).

4) This alternative could prevent the use of scrap steel turnings in the production of 50 percent ferrosilicon, thereby increasing costs and reducing capacity for production of this ferroalloy. (See Issue 3, Item 3, Chapter XI).

5) Limited data are available for sealed furnaces producing some alloys included in Part 3 of this alternative.

(a) Only one sealed furnace each is known to produce high-carbon ferrochrome and ferrochrome silicon.

(b) Only two sealed furnaces are known to produce 50 percent ferrosilicon.

2. Alternative No. 2.[1/], [6/]

No owner or operator shall cause to be discharged into the atmosphere from any affected facility any gases which:

a. Contain particulate matter in excess of 0.45 kg/Mw-hr (0.99 lb/Mw-hr) while that facility produces silicon

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6/ The emission limits of Alternatives 1 and 2 are identical. Some ferroalloys have been taken out of category c and put into categories a and b.

metal, ferrosilicon (50 percent and above), calcium silicon, or silicomanganese zirconium.

b. Contain particulate matter in excess of 0.23 kg/Mw-hr (0.51 lb/Mw-hr) while that facility produces high-carbon ferrochrome, ferrochrome silicon, silvery iron, ferromanganese silicon, or charge chrome.

c. Contain particulate matter in excess of 0.07 kg/Mw-hr (0.15 lb/Mw-hr) while that facility produces silicomanganese, ferromanganese, or calcium carbide.

Advantages

1) This alternative is consistent with the "best technology (taking into account the cost)" requirement of the Clean Air Act.

2) This alternative permits 50 percent ferrosilicon, high-carbon ferrochrome, and ferrochrome silicon to be produced in open furnaces.

3) This alternative permits the use of scrap steel turnings for producing 50 percent ferrosilicon and silvery iron. (See Issue No. 3, Item 3, Chapter XI).

4) The technology to produce ferromanganese, silicomanganese and calcium carbide in sealed furnaces is well demonstrated by over 20 years experience in foreign countries.

5) This alternative increases the industry's flexibility. Fewer sealed furnaces will be built since fewer products will be required to be produced in them.

6) This alternative minimizes the number of products which will require pretreatment of raw materials.[7/]

7) This alternative, by increasing the allowable number of open furnaces, may decrease any tendency of the domestic industry to build new furnaces outside the United States.

8) Advantage 5 of Alternative Number 1 applies.

9) The emission limitations of categories a and b of this alternative could be easily met through use of sealed furnaces for those products for which sealed furnaces have been demonstrated.

10) For category c of this alternative, Advantages 2(a) through 2(i) of Alternative Number 1 apply.

Disadvantages

1) Open furnaces, with their inherently larger air volumes, will:

(a) Emit more particulate than the sealed furnace.[2/]

7/ Ferromanganese, silicomanganese, and calcium carbide are produced in sealed furnaces in foreign countries without substantial feed pretreatment.

(b) Consume greater quantities of energy and incur higher operating costs for air pollution control than sealed furnaces.

2) This alternative fails to encourage the development of technology to overcome the limitations in product flexibility of the sealed furnace.

3) Disadvantages 1 and 2 of Alternative Number 1 apply to category c.

3. <u>Alternative No. 3</u>.

No owner or operator shall cause to be discharged into the atmosphere from any affected facility any gases which:

a. Contain particulate matter in excess of 0.45 kg/Mw-hr (0.99 lb/Mw-hr) while that facility produces silicon metal, ferrosilicon (50 percent and above), calcium silicon, or silicomanganese zirconium.

b. Contain particulate matter in excess of 0.23 kg/Mw-hr (0.51 lb/Mw-hr) while that facility produces high-carbon ferrochrome, ferrochrome silicon, silvery iron, charge chrome, silicomanganese, ferromanganese, ferromanganese silicon, or calcium carbide.

Advantages

1) This alternative permits the use of open furnaces for the production of all ferroalloys.

2) This alternative permits the use of scrap steel for the production of ferrosilicon.

3) This alternative does not introduce any problems of product flexibility.

4) This alternative will not encourage the domestic industry to build new furnaces outside the United States.

5) This alternative will also permit use of sealed furnaces where appropriate.

6) Advantage 5 of Alternative Number 1 applies.

Disadvantages

1) Disadvantages 1 and 2 of Alternative Number 2 apply.

2) This alternative does not require new facilities to utilize the best methods of air pollution control for some ferroalloy products.

4. Alternative No. 4.

No owner or operator shall cause to be discharged into the atmosphere from:

a. Any affected open furnace facility any gases which contain particulate matter in excess of 0.45 kg/Mw-hr (0.99 lb/Mw-hr) while that facility produces silicon metal, ferrosilicon (50 percent silicon and above), calcium silicon, or silicomanganese zirconium.

b. Any affected open furnace facility any gases which contain particulate matter in excess of 0.23 kg/Mw-hr (0.51 lb/Mw-hr) while that facility produces high-carbon ferrochrome, ferrochrome silicon, silvery iron, charge chrome, silicomanganese, ferromanganese, ferromanganese silicon, or calcium carbide.

c. Any affected sealed furnace facility any gases which contain particulate matter in excess of 0.07 kg/Mw-hr (0.15 lb/Mw-hr) while that facility produces silicomanganese, ferromanganese, calcium carbide, high-carbon ferrochrome, nominal 50 percent ferrosilicon, or ferrochrome silicon.

Advantages

1) Advantages 1 through 4 of Alternative Number 3 apply to categories a and b of this limitation.

2) Categories a and b of this limitation require any operator installing open furnaces to use best control technology for open furnaces.

3) Category c of this limitation requires any operator installing sealed furnaces to use best control technology for sealed furnaces.

4) Advantage 5 of Alternative Number 1 applies.

Disadvantages

1) Disadvantages 1 and 2 of Alternative Number 2 apply to categories a and b of this limitation.

2) This alternative permits greater emissions from an open furnace than from a sealed furnace even when producing the same product. This could discourage the installation of sealed furnaces.

B. Alternative Standards for Carbon Monoxide (CO)

1. Alternative No. 1.[8/]

No owner or operator shall cause to be discharged into the atmosphere from any affected facility any gases which contain on a dry basis, 20 or greater volume percent of carbon monoxide. Combustion of such gases under conditions acceptable to the Administrator shall constitute compliance with this requirement.

8/ Consultation with a manufacturer of CO flares and incinerators revealed that CO will support combustion in air at 12.5 percent or greater CO by volume. (The lower limit is subject to minor variation depending on the gas's temperature and humidity.) In the open furnace, CO burns upon contact with ingested air at the surface of the charge material. In semi-enclosed and sealed furnaces, which operate at slight positive pressure, the CO exits from the furnace at a concentration of between 50 and 90 percent by volume.

Advantages

1) The operation of open furnaces is not affected.

2) The operator using semi-enclosed or sealed furnaces must flare the furnace gas or use it as fuel.

3) Enforcement and compliance are simple and inexpensive.

Disadvantages

None apparent.

2. Alternative No. 2.

Set no standard of performance for CO. Individual States will set standards on the basis of air quality.

Advantages

None apparent.

Disadvantages

1) This would not require installation of best demonstrated technology to preclude the creation of new air pollution problems by sealed or semi-enclosed furnaces.

2) This could result in high localized concentrations of CO.

C. Alternative Standards for Visible Emissions

1. Alternative No. 1.

No owner or operator shall cause to be discharged into the atmosphere from any affected facility any gases which exhibit 10 percent opacity or greater.

Advantages

1) This alternative is consistent with the intent of the Clean Air Act to mandate best technology.

2) This alternative requires control of tap fumes.

3) Open furnaces with scrubber or baghouse control devices can meet this limitation.

4) This alternative minimizes the emissions since visibility of the exhaust is a gross indication of particulate matter content.

Disadvantage

It is possible that this limitation can be exceeded while the mass emission limitation is being met.[9/]

9/ One open furnace producing 75 percent ferrosilicon equipped with a closed suction baghouse had emissions of up to 15 percent opacity while nearly meeting a mass standard of 0.99 lb/Mw-hr.

2. Alternative No. 2.

No owner or operator shall cause to be discharged into the atmosphere from any affected facility any gases which exhibit 20 percent opacity or greater.

Advantages

1) Advantages 1 through 3 of Alternative No. 1 apply.

2) It is not likely that this requirement can be exceeded while still meeting the mass emission requirement.

Disadvantage

This alternative would permit greater emissions.

IX. ENFORCEMENT ASPECTS OF THE PROPOSED STANDARDS

The proposed standard includes limitations on particulate matter, visible, and carbon monoxide emissions. Open, sealed, and semi-enclosed furnaces with proper control equipment could be used to meet the proposed standard.

A. Particulate Matter Standard

The proposed standard limits all emissions of particulate matter from the electric submerged arc furnace and includes those which occur during the tap cycle of the furnace. Uncontrolled particulate matter emissions will vary with the alloy produced, type and size of raw materials, operating techniques, furnace design, and the input power at which the furnace is operated.

When a new furnace is installed, a record should be made of the products for which the furnace is designed and the maximum furnace power rating for each. The control system must be designed to assure that the standards of performance for each product will be achieved when the furnace is producing at the maximum power input for that product. If possible, the performance test should be performed when the furnace is producing the product having the emissions most difficult to control. For example, the performance test for a furnace designed to produce 75 percent ferrosilicon and silicon metal should be performed while producing silicon metal.

Control devices on existing furnaces exhaust the effluent in three possible ways: (1) through a single stack, (2) through multiple stacks, and (3) unconstrained (total absence of a stack or duct). Enforcement aspects of measuring particulate matter which vary according to these categories, are discussed below:

1. Effluent discharged through a single stack.

This configuration is most easily tested. The methods for measurement of particulate emissions are specified in 40 CFR 60 (Reference Methods 1, 2, 3, 4, and 5).

New sources should be designed to assure optimum sampling conditions. For example, the optimum sampling location is not less than 8 diameters downstream and two diameters upstream from anything in the duct which might disturb the gas flow. Although the Methods permit deviation from these optimum criteria, there should be a design goal to ensure the most accurate and precise results possible of any measurements of emissions.

Platforms, utilities and sampling ports should be located to facilitate sampling at new or modified sources.

2. Effluent exhausted through multiple stacks.

The problems presented by this possibility are merely time and expense. The number of tests required and their attendant costs may make a rigorous compliance test impractical. In such a case, the source and the enforcement agency should agree on a specific plan for measuring emissions which will provide the data necessary to determine compliance at a reasonable cost. The optimum plan will vary from source to source.

Portable opacity instruments have recently become available and represent low-cost means of showing comparability between stacks. These instruments may be a desirable tool for use in a test plan.

3. Effluent not constrained within a stack.

This category includes emissions that discharge through roof monitors, open or pressurized baghouses, and, in some cases, open-faced filters. Performance test methods for this category have not been specified because of the lack of proven test techniques, a consequence of limited sampling experience.

Several problems surface when attempts are made to measure unconstrained effluent. The first is the difficulty of obtaining a representative sample. Large and sometimes multiple areas (cross sections) from which emissions exhaust make it impractical or impossible to sample at sufficient points to represent the entire discharge area. The accuracy of any alternative depends on the validity of the engineering assumptions necessary. One alternative is to subdivide the total flow area into sub-areas which are then sampled. Sampling may parallel Method 5, or other techniques such as high-volume sampling may be used. One scheme includes traversing across the horizontal cross section of a roof monitor with a high-volume sampler. Another, used in the aluminum industry, requires multipoint sampling by a permanent sampling manifold mounted beneath the roof monitor. The manifold discharges to a small stack which can be sampled using Method 5.

A second problem results from the very low flow rates commonly encountered in these systems. Often they cannot be measured with conventional sampling equipment. This precludes accurate isokinetic sampling and determination of volumetric flow rates. The isokinetic sampling problem is usually resolved by determining average velocities using extremely sensitive measuring devices and then sampling at this average rate. Volumetric flow rate may be determined in a similar manner. (It is usually possible to determine volumetric flow rate more accurately by measuring flow on the inlet side of the control device.)

The presence of dilution air presents a third and equally serious impediment to determining accurate emission values. To determine if a source complies with a concentration limitation, a correction must be made for any dilution air present. To determine a mass emission rate requires knowledge of the actual volumetric flow rate at the sampling location. In either case, it is necessary to measure dilution air flow rates. The difficulty in measuring dilution air may prevent or at least will seriously limit accurate emission measurements.

Due to these problems, the accuracy and precision with which the mass rate of emissions can be determined appears limited and, in fact, the configuration of certain sources totally defies representative sampling. Because of the potential cost of testing, the source and the enforcement agency should agree on a specific test plan or means for determining compliance prior to construction of a new source.

EPA is reviewing discharge configurations from control devices being sold in an attempt to improve test procedures. As this investigation progresses, certain criteria can probably be specified which will improve the accuracy of testing. Until such criteria are available, new plants should be equipped with exhaust systems which will allow representative sampling.

B. Visible Emissions Standards

The visible emissions standards serve three purposes:

1. To assure the capture and control of all particulate matter emissions from the furnace and its tapping station.

2. To provide a quick and inexpensive means of enforcing proper maintenance and operation of the control device, furnace hoods, tapping hoods, and ducting.

3. To ensure that dust captured by the control device(s) is properly handled and not reentrained in the atmosphere.

C. Carbon Monoxide Standard

Enforcement of the CO standard is easy. An open furnace cannot violate the standard since the CO is burned with ingested air at the surface of the charge material.

The gases exhausted from the control device on a semi-enclosed or sealed furnace contain 50 to 90 volume percent CO. The exhaust gases from these furnaces must be flared prior to entering the atmosphere or must be used in other processes.

D. Emission Monitoring

The proposed standard requires that a photoelectric or other type smoke detector and recorder be installed to continuously monitor and record the opacity of gases discharged into the atmosphere from the control device(s).

EPA proposed performance specifications for opacity monitors on September 11, 1974 (39 FR 32852). Instruments commercially available which conform to these specifications are capable of measuring opacity within a narrow path 50 or more feet long. Instruments which are installed and operated in accordance with the specifications will produce reliable opacity data. Effluent discharged through a stack or duct can be readily monitored.

E. Monitoring of Operations

To ensure that the furnace and pollution control systems are being operated within design parameters and at conditions for which the compliance tests are representative, the following records must be made:

1. A daily record of the product being produced.

2. A daily record of the charge constituents to the furnace including the proportions by weight of each constituent.

3. Records of the average power input to the furnace during each cycle, in megawatts.

4. Records of the time and duration of each tapping period and the identification of material tapped (slag or product).

In addition, a wattmeter must be installed, calibrated, maintained, and operated to continuously monitor and record the power consumption of the furnace.

X. MODIFICATIONS

Under conditions defined in section 111 of the Clean Air Act and supplemented in §60.2 of 40 CFR 60, an existing source which is modified may become subject to standards of performance.

Modifications to a ferroalloy furnace which could render the facility subject to standards of performance are changes in raw materials which force physical alterations to the furnace, changes in product grades or "families" which increase emissions, and increasing the transformer capacity to increase production (hence emission) rates. These changes are ways to meet market demands, increase production, or respond to availability of raw materials without investment of the large amount of capital necessary for an entirely new furnace.

Any such modification will require that the air pollution control system on an existing furnace be upgraded to meet the standards of performance. This may be very costly, and in some cases almost physically impossible. Reasons for this are:

A. The building which houses the furnace may prevent installation of a hood or furnace cover because of space limitations above the furnace.

B. Prohibitively expensive revisions of electrical components may be required to install a hood or cover.

C. Installation of a hood or cover may require changes in the furnace feed delivery system.

D. Extensive changes to electrode columns and suspension systems might be required.

Changes to the ferroalloy electric submerged arc furnace that would not be considered a modification include:

A. Changing proportions of the charge materials to the furnace if the products are ferroalloys for which the furnace was originally designed.

B. Changes in reducing agents, types of scrap steel, or use of slags to produce ferroalloys for which the furnace was originally designed.

C. Replacement of carbon hearths, furnace linings, mix chutes, furnace covers, hoods, ductwork, replacement of transformers in kind, furnace digouts, tap hole repairs, or electrode spacing adjustments, so long as production capacity was not increased and the modifications did not result in changing the furnace capability to permit manufacture of products other than those for which the furnace was originally designed.

The impact of compliance with the standards of performance for new sources will vary depending on the type of furnace. It is generally accepted that the open and perhaps even the semi-enclosed furnaces cannot be economically altered to achieve the standards of performance if it is based on technology or emission rates from sealed furnaces. In such a case it would be less expensive to construct an entirely new facility.

A. Open Furnaces

An existing open furnace can be substantially modified, upgraded and controlled for about \$3 to \$5 million. An equivalent new installation would cost \$15 to \$20 million. Obviously, the economics dictate upgrading. A modified existing open furnace with proper control equipment can comply with the proposed standards of performance for a new furnace.

B. Semi-Enclosed Furnaces

If the cover is removed from an existing semi-enclosed furnace to permit the manufacture of a greater variety of alloys, the modified furnace should become subject to the standards of performance. As with the open furnace, a semi-enclosed furnace modified in this way probably can comply with the standards if proper control equipment and adequate hooding are used.

C. Sealed Furnaces

The possibility of a modification to an existing sealed furnace is remote since there is only one in the United States. It is difficult to imagine a modification which would preclude the ability of a sealed furnace to meet the standards of performance for new sources. One possible (but highly improbable) modification would be conversion to an open furnace. The incentive would be to permit production of a different product family than that for which it was designed. This very expensive change would also require significant alterations to the transformer and electrodes. The modified furnace could be controlled to meet the proposed standard of performance.

XI. MAJOR ISSUES CONSIDERED

The mandate to base the standards of performance for ferroalloy electric submerged arc furnaces on the best air pollution control technology which has been demonstrated and which is economically viable seems clear. In effect, however, repercussions from a standard which would allow only sealed furnaces could be felt far beyond the ferroalloy industry.

A standard which restricts new furnaces to the totally sealed configuration could:

A. Result in multinational corporations building new open furnaces outside the United States where pollution requirements are less stringent.

B. Cause the demise of portions of the United States ferroalloy industry and place the country in the untenable position of dependence on foreign sources of some steel additives (ferroalloys) necessary for defense and consumer goods.[1/]

The major areas of issue are tabulated as follows:

A. Do sealed furnaces represent demonstrated technology?

1/ This reason is somewhat ameliorated by the fact that the United States ferroalloy industry must rely on foreign sources for some ores (such as manganese and chromium ores). These foreign suppliers are beginning to process their own ores and may soon ship only the ferroalloy to the United States market.

B. Does use of the sealed furnace create a safety hazard?

C. Does use of the sealed furnace place the United States industry at an economic disadvantage in the world market?

A. Issue 1. Does the Sealed Furnace Represent Demonstrated Technology?

Discussion

Section 111(a)(1) of the Clean Air Act, as amended, states: "The term 'standard of performance' means a standard for emissions of air pollutants which reflects the degree of emission limitation achievable through the application of the best system of emission reduction which (taking into account the cost of achieving such reduction) the Administrator determines has been adequately demonstrated." The term "available control technology" is further defined in a report of the Committee on Public Works, United States Senate, when air pollution control was still a function of the Department of Health, Education and Welfare, as follows: ". . . 'available control technology,' is intended to mean that the Secretary should examine the degree of emission control that has been or can be achieved through the application of technology which is available or normally can be made available. This does not mean that the technology must be in actual routine use somewhere. It does mean that the technology must be available at a cost and at a time which the Secretary determines to be reasonable. This implicit consideration of economic factors in determining whether technology is 'available' should not affect the usefulness of this section. The overriding purpose of this section would be to prevent new air pollution problems, and toward that end, maximum feasible control of new sources at the time of their construction is seen by the Committee as the most effective and in the long run, the least expensive approach."[47]

Sealed furnaces have been used in foreign countries to manufacture silicomanganese, ferromanganese and calicum carbide since about 1954.[48], [49] In Japan and Norway, all standard ferromanganese is produced in sealed furnaces.[50] Almost all silicomanganese produced in Norway is made in sealed furnaces and future plans presume that, ultimately, all will be produced in them.[50] EPA measured emissions from sealed furnaces producing silicomanganese and ferromanganese in Porsgrunn, Norway.[51], [52]

Sealed furnaces have been used to produce ferromanganese, silicomanganese and calcium carbide in Japan since at least 1962.[53], [54] The Japanese also use sealed furnaces to produce 50 percent ferrosilicon (two furnaces which have operated since 1968 and 1972 respectively), 75 percent ferrosilicon (one furnace which has operated for 2 to 3 years), ferrochrome silicon (one furnace, operated since 1970), and high-carbon ferrochrome (one furnace, operated since 1971). These are the only sealed furnaces known to be producing these ferroalloys.[55] Emission measurements were also made by EPA on sealed furnaces in Japan producing 50 percent ferrosilicon, ferrochrome silicon, and high-carbon ferrochrome.[56]

Union Carbide of Canada has installed and is operating a large sealed furnace for the production of ferromanganese and silicomanganese, and

Interlake Steel Corporation is planning a similar installation in Mexico. The *only* known sealed furnace for the production of ferromanganese and silicomanganese in the United States is operated by Airco Alloys and Carbide at its Theodore, Alabama, plant.

Conclusions

Ferroalloy manufacturers compete in the world market not only for the sale of ferroalloys, but for ores and other raw materials as well. Since foreign producers economically make a variety of ferroalloys in sealed furnaces using raw materials also available to the United States ferroalloy industry, it must be concluded that use of sealed furnaces is technically feasible in the United States and that sealed furnaces are "demonstrated technology."

B. Issue 2. Does the Use of Sealed Furnaces Present a Safety Hazard?

The United States ferroalloy industry has stated that sealed furnaces are unsafe for the following reasons:[(57), (58)]

1. Fusion or bonding together of the raw material charge is characteristic of production processes for 75 percent ferrosilicon and silicon metal. Similar behavior, but to a lesser degree, can occur in the production of the high-silicon grades of ferrochrome silicon and silicomanganese. Silicomanganese operations may be subject to "slag boils" where the charge materials become crusted over with slag which prevents uniform descent of the feed material

within the furnace. Such fusion or crusting of materials requires the use of open furnaces to permit the charge to be "stoked" to allow its uniform descent and uniform evolution of gas formed by the reduction of the ores.

2. Moisture from water in the charge or from water leaks in furnace components can result in an explosive-type gas release which may lift the furnace cover and eject a major portion of the furnace contents.

3. Production of high-silicon ferrosilicon and silicon metal is characterized by high-temperature gas "blows," generally in the vicinity of the electrodes. Jets of hot gas originate directly from the high-temperature zones of the furnace near the bottom of the electrodes. Hot as a cutting torch, they can destroy furnace components.

4. Scrap steel is normally used for the domestic production of ferrosilicon alloys. Such a highly conductive raw material can short out the electrodes through the charge chutes, causing component damage and water leaks if sealed furnaces are used.

5. The sealed furnaces generate carbon monoxide, a hazard to personnel. In open furnaces, the carbon monoxide is combusted to carbon dioxide with ingested air at the hot surface of the charge material.

Discussion

The preceding items were investigated during the development of standards of performance for the industry with results as follows:

1. The problems of slag boils and crusting or bridging of the furnace charge constituents are more commonly associated with production of the high-silicon (> 75 percent) ferroalloys. These problems are no longer considered serious for the production of calcium carbide, ferromanganese, and silicomanganese in sealed furnaces.[(59), (60), (61), (62)] "Enclosed furnaces are being used increasingly where raw materials do not collect to build bridges within the furnace, but instead sink evenly of their own accord. Examples include the production of pig iron, carbide, and the ferroalloys ferromanganese and silicomanganese."[(63)]

   In a meeting with EPA engineers, a representative of one major ferroalloy producer in the United States stated that properly operated sealed furnaces producing ferromanganese, silicomanganese, and calcium carbide are no more dangerous than equivalent open furnaces producing these products.

2. EPA engineers discussed with personnel of foreign plants the danger of explosions from water contained in the feed or from water leaks. Foreign industry personnel state that they feel safe working around a sealed furnace and that working conditions

are vastly improved by them.[64], [65] They elaborated that fatalities are not unique to sealed furnaces; injuries and fatalities have also been caused by expulsion of the charge from open furnaces during gas "blows."[66]

Explosions did occur during early development of sealed furnace technology, but this type of hazard has been overcome with increased knowledge of the operation and design of closed furnaces. Such incidents are precluded by:[67], [68], [69], [70], [71], [72]

a. Where necessary, proper pretreatment of furnace charge materials.

b. Proper design of the furnace and its charging system.

c. Proper monitoring of the process. This may involve monitoring: (1) furnace feed and product rates; (2) chemical compositions of furnace feed, product and slag; (3) furnace temperatures; (4) moisture content of charge material; (5) furnace power consumption; (6) furnace off-gas chemical composition, and possibly other furnace operating parameters.

3. It is generally agreed that the technology has not been developed to produce silicon metal and ferrosilicon which contains greater than 75 percent silicon in sealed furnaces. However, a Japanese manufacturer of electric submerged arc furnaces predicts that silicon metal will be produced in sealed furnaces by 1977.[73]

4. Scrap steel is normally used by the United States industry for the open furnace production of ferrosilicon alloys. Union Carbide is using a semi-enclosed furnace with steel scrap feed to produce 50 percent ferrosilicon.

The Japanese use pelletized iron ore as a feed material to their sealed furnaces producing 50 percent ferrosilicon and "mill scale" to the sealed furnace producing 75 percent ferrosilicon. They state that a reason for this is that large quantities of high-quality steel scrap are not available and economics justifies use of the iron ore.

One reason given by the United States industry for inability to use scrap steel in a sealed furnace (although it is used in the semi-enclosed furnace) is that it can conduct electricity from the electrodes to the mix delivery bins and cause arcing which could severely damage furnace components.

5. Foreign plants with sealed furnaces use CO alarm systems, proper building ventilation and proper maintenance of the CO handling system to minimize hazards of this gas. Semi-enclosed furnaces, which present the same CO hazards, have been used for years by the United States industry. Obviously, the methods for safely handling CO gas are proven.

Conclusions

The following conclusions are made regarding the safety aspects of ferroalloy production in sealed furnaces:

1. Sealed furnaces for the production of silicomanganese, ferromanganese, and calcium carbide have been used in foreign countries for over 20 years. When properly monitored, operated, and maintained, sealed furnaces for the manufacture of those products appear to be more dangerous than open furnaces.

2. There is no known technology for the production of ferrosilicon with greater than 75 percent silicon in sealed furnaces.

3. Production of 50 percent ferrosilicon in sealed furnaces is being safely accomplished in Japan with iron ores as a feed material. Although no known use of scrap steel as feed material to a sealed furnace exists, it does appear technically possible.

4. The safe handling of carbon monoxide gas has been accomplished by the domestic and foreign ferroalloy industries.

5. The Japanese are also safely using sealed furnaces as follows:

    a. One has produced 75 percent ferrosilicon since about September 1971.

    b. One has produced high-carbon ferrochrome since 1971.

c. One has produced ferrochrome silicon since June 1970.

These are the only known sealed furnaces producing these products.

6. The safe production of ferromanganese, silicomanganese and calcium carbide in sealed furnaces has been demonstrated. A standard for these products could be recommended based on the sealed furnace.

Recommendations

Since the safe production of 50 percent ferrosilicon has been demonstrated only when using iron ore feed, and since only one sealed furnace each exists to produce 75 percent ferrosilicon, ferrochrome silicon, and high-carbon ferrochrome, standards for these products should be based on open furnaces. Standards for these products should be reviewed as additional experience with sealed furnaces is accumulated.

C. Issue 3. Would a Regulation That Mandates Sealed Furnaces Place the United States Industry at an Economic Disadvantage in the World Market?

The United States ferroalloy industry has stated that successful sealed furnace technology and economics in foreign countries cannot be directly extrapolated to the domestic industry for the following reasons:[74], [75]

1. Sealed furnace operation requires extensive pretreatment of raw material. This may include sintering or pelletizing.

2. Foreign producers have operating schedules and practices which allow greater furnace downtime for maintenance.

3. The only known sealed furnaces producing 50 percent ferrosilicon use iron ore instead of scrap steel. This is not economical in the United States where steel scrap is abundant and cheap.

4. A sealed furnace is restricted to production of one "family" of products. Unless a large captive market for that family exists, the United States industry must maintain the flexibility to produce a variety of products required by rapidly changing world demands.

Discussion

1. Pretreatment of raw materials.

Almost all ferroalloy producers pretreat their raw materials in some way to obtain smooth furnace operation and the desired quality of the product.[(76), (77), (78)] Pretreatment processes include crushing, sizing, mixing, drying, sintering, and pelletizing. Crushing and sizing of raw materials are performed at nearly all ferroalloy plants and for all types of furnaces. Raw materials are also mixed at nearly all ferroalloy plants, regardless of the furnace type, to meet product specifications and to obtain the composition, physical properties, and (sometimes) moisture content desirable for safe, smooth furnace operation.[(79), (80), (81), (82)] Raw materials are often dried for all three types of furnaces. Dry feed materials result in reduced off-gas volumes and smoother furnace operation. Sintering and pelletizing are less common pretreatment processes. These could be used in conjunction with any type of furnace, but are most commonly used with foreign sealed furnaces. Both pelletizing and sintering are means of upgrading less expensive or friable ores which could not otherwise be used in ferroalloy furnaces because of bridging (i.e., charge material fusing to prevent uniform descent of charge into a furnace's reaction zone), high raw material losses caused by its entrainment in the furnace gases, and low porosity which would prevent escape of gases from the reaction zone. Also, by pelletizing or sintering dust captured by the air pollution control system, it can be recycled as feed to the furnace.

Ferromanganese and silicomanganese are produced in sealed furnaces without drying, sintering, or pelletizing raw materials. Such furnaces were observed in Norway and Belgium by EPA engineers and a representative of The Ferroalloys Association.[(83), (84)] EPA engineers monitored the process and measured emissions from two of these furnaces in Norway, one producing silicomanganese and the other producing ferromanganese. A sealed furnace in the United States has produced ferromanganese and silicomanganese without extensive material pretreatment. EPA engineers observed sealed furnaces producing these products in Japan. Some used drying, sintering, and pelletizing as pretreatment processes, while others only performed routine mixing, crushing, and sizing.

The Japanese sealed furnace producing high-carbon ferrochrome uses materials which are dried, crushed, pelletized, dry roasted, and then "hot charged" at 900°C to the furnace. Pellets charged to the furnace may be either "prereduced" (provided coke is added to the ore before pelletizing) or not. Cheaper friable ores are used in this furnace.

Pretreatment for the Japanese sealed furnace producing ferrochrome silicon consists of material sizing and drying. No special pretreatment of charge materials is performed for the Japanese sealed furnace producing 75 percent ferrosilicon. Fine iron ore is pelletized and baked in a shaft furnace prior to being fed to the sealed furnaces producing 50 percent ferrosilicon.

Although some sealed furnaces may be used without pretreatment processes such as drying, pelletizing, or sintering, several reasons may favor such preprocessing:

a. Even with the added cost of preprocessing, cheap and abundant fine-sized or friable ores may be less expensive than the relatively expensive lump ore. (Use of friable ores may become more common as world supplies of high-grade "lump" ores are depleted.)[85], [86], [87]

b. Preprocessing ores increases the product yield.[87], [88]

c. Twenty to 35 percent of the energy supplied to a closed furnace can be recovered by fueling preprocessing equipment such as dryers, pellet furnaces, and sintering machines with carbon monoxide-rich exhaust gas from the furnace.[89]

d. Preprocessing may decrease furnace power consumption by as much as 10 percent.[90], [91], [92]

e. One preprocessing step, sintering, may reduce coke consumption and increase furnace thermal efficiency.[93]

f. Preprocessing reduces furnace particulate emissions.[93], [94]

g. Preprocessing equipment permits recycle of particulate matter collected by emission control equipment.[95], [96] (For a closed furnace producing ferromanganese, some 21.2 tons of particulate may be recovered and recycled for every 100 tons of alloy produced.)[96]

2. Foreign operating practices allow more furnace down-time.

Personnel at foreign installations who have experience with all three types of furnaces state that maintenance requirements are no greater for sealed furnaces than for other types of comparable size.[97], [98], [99] "Due to the heat from the burning reaction gases above open furnaces, there has been, throughout the years, a tendency towards more down-time on these furnaces than on covered ones, in spite of the latter's more complicated equipment."[100]

Operating schedules and practices for installations in foreign countries do not appear to allow any greater furnace down-time for maintenance and repair than that experienced at United States installations. Company personnel estimate that the sealed furnaces tested by EPA in Norway operate 97 to 98 percent of the time for the ferromanganese furnace, and 96.2 to 98.2 percent of the time for the silicomanganese furnace.(101) Japanese ferroalloy manufacturers estimate that sealed furnaces producing ferromanganese, silicomanganese, high-carbon ferrochrome, and ferrochrome silicon operate from 95 to almost 100 percent of the time based on their experience to date.(102) The United States ferroalloy industry estimates that normal furnace operating times in the United States vary from 90 to 95 percent. A large percentage of furnace down-time is for maintenance of air pollution control equipment common to all three types of furnaces.(103) Maintenance for the much larger air pollution control equipment on open furnaces should far exceed that for similar equipment on totally enclosed furnaces, primarily because the open-furnace equipment must handle gas volumes typically 50 times larger.

3. <u>Sealed furnaces producing 50 percent ferrosilicon are charged with iron ore. Use of ore is not economical in the United States.</u>

The two known sealed furnaces which produce 50 percent ferrosilicon (located in Japan) use iron ore as a feed material instead of the scrap steel feed normally used by the United States industry. The United States ferroalloy industry used about 270,000 tons of scrap steel for the production of 50 percent ferrosilicon and about 500,000 tons of scrap steel for the production of all grades of ferrosilicon in 1972. Their reasons for using steel scrap rather than iron ore are as follows:(104)

a. Steel scrap turnings have historically been abundant and low priced. (They are the lowest cost iron sources for United States ferrosilicon production.)

b. The use of steel scrap results in less electrical energy and coke consumption than if iron ore or mill scale were used.

c. Because of decreased charge resistance, furnace production capacity is greater with steel scrap than with iron ore or mill scale. This increased capacity is equivalent to about 60,000 tons per year of 50 percent ferrosilicon which has a value of about $9,600,000.

d. The type of scrap steel used for ferroalloy production is not suitable for recycling to new steel and, if not used for ferroalloys, would add to the solid waste disposal problem.

e. Delivered price is high for the select grades of iron ore required to produce 50 percent ferrosilicon.

In discussions with Japanese ferroalloy producers, EPA engineers asked if use of the sealed furnace for producing 50 percent ferrosilicon would preclude the use of scrap metal and how the use of iron ore affected the economics of production. They answered that the use of iron ore in a sealed furnace is economically better than the use of scrap steel and that this is true in the United States as well as Japan because:[105]

a. Japan has to import iron ores while the United States has natural iron ore resources.

b. Iron ore assures a more stable furnace operation.

c. Iron ore provides easier control against product impurities in production of 50 percent ferrosilicon compared to scrap steel.[106]

Although no unequivocal conclusion can be drawn from the above, it appears that scrap steel has the economic advantage as a raw material for 50 percent ferrosilicon production in the United States.

4. Sealed furnaces do not have the flexibility necessary to produce a variety of products.

Manufacturers of ferroalloy products and manufacturers of ESA furnaces stated the following:

a. For a given furnace design, only certain products can be economically manufactured, regardless of whether the furnace construction is the open or totally enclosed type. It is not economical to design and use a large ESA ferroalloy furnace for several product lines. To do so requires movable electrodes and multiple transformer capacities, since combinations of raw materials differ in resistivity for different ferroalloy products. Consequently, crucible size, electrode spacing, and transformer size are a function of the product being manufactured. Therefore, to minimize capital investment in the transformer, to reduce down-time for changeover (moving electrodes, etc.), to reduce waste produced by a furnace, and to optimize furnace efficiency, companies design furnaces for manufacture of only one family of products. Within those families, it is possible to switch products in a totally enclosed furnace just as readily as in an open furnace. For products outside of the design family of products, however, the furnace must undergo substantial reconstruction for changing the electrode spacings. On a sealed furnace this change requires replacement of the furnace cover. This reconstruction of sealed furnaces to produce other products is prohibitively expensive. Modification of an open furnace to produce another family of products requires replacement of the hood. The costs for changing from one product family to another for open furnaces is significantly less than those for sealed furnaces. Limited product flexibility could ultimately result in decreased intercorporate competition.

b. In order to remain competitive, manufacturers of ferroalloy products are converting to use of larger furnaces.[107], [108], [109], [110] New ferroalloy furnaces will probably be 30 Mw or larger because large furnaces require less labor, less raw material and less electric power per ton of product. In most cases, the large furnace also requires a lower capital investment per ton of production.

Conclusions

Based on the information available, the following conclusions are made:

1. a. Ferromanganese and silicomanganese can be safely and economically produced in sealed furnaces with or without substantial pretreatment of feed material.

   b. Calcium carbide can be safely produced in sealed furnaces without additional pretreatment beyond that already performed by domestic producers.

   c. For products other than those listed in (a) and (b) above, foreign manufacturers use varying levels of feed pretreatment, but can safely and economically produce 50 percent ferrosilicon, 75 percent ferrosilicon, high-carbon ferrochrome, and ferrochrome silicon in sealed furnaces.

2. The argument that maintenance requirements and operating schedules of foreign manufacturers are significantly different from those of domestic users seems unfounded.

3. There appear to be several economic advantages for the United States industry to use steel scrap rather than iron ore for the production of ferrosilicon.

4. It appears that the use of sealed furnaces would place the domestic industry at a competitive disadvantage in the world market by restricting the flexibility of new furnaces to respond to fluctuating market demands.

Recommendations

It is recommended that the standards of performance allow open furnaces to be used in conjunction with the best available control equipment. Although sealed furnaces are superior from an air pollution control aspect, restricting the industry to this process could ultimately result in limited product flexibility and possible decreased intercorporate competition. The disadvantages arising from decreased competition outweigh the incremental benefits of the additional reduction in air pollution. EPA's Control Systems Laboratory is further investigating the technical and economic feasibility of using sealed furnaces to produce all types of ferroalloys. This study could ultimately result in standards of performance based on sealed furnaces.

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This volume is the first in a series on the standard of performance for electric submerged arc furnaces producing ferroalloys. This volume provides background information and the rationale used in the development of the proposed standard of performance. The economic and environmental impacts of the standard are discussed.

17. KEY WORDS AND DOCUMENT ANALYSIS

a. DESCRIPTORS	b. IDENTIFIERS/OPEN ENDED TERMS	c. COSATI Field/Group
Air Pollution, Calcium Silicon Pollution Control, Ferromanganese Silicon Standards of Performance, Charge Chrome Ferroalloys, Silicomanganese Zirconium Silicon Metal, High-Carbon Ferrochrome 50% Ferrosilicon, Ferrochrome Silicon, Silvery Iron 65-75% Ferrosilicon, Ferromanganese, Calcium Carbide	Air Pollution Control	

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