BACKGROUND REPORT

AP-42 SECTION 12.13

STEEL FOUNDRIES

Prepared for

U.S. Environmental Protection Agency
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AP-42 Background Report

TECHNICAL SUPPORT DIVISION

U.S. ENVIRONMENTAL PROTECTION AGENCY
Office of Air Quality Planning and Standards
Research Triangle Park, NC 27711

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1.0 INTRODUCTION

The document "Compilation of Air Pollutant Emission Factors" (AP-42) has been published by the U.S. Environmental Protection Agency (the EPA) since 1972. Supplements to AP-42 have been routinely published to add new emission source categories and to update existing emission factors. AP-42 is routinely updated by the EPA to respond to new emission factor needs of the EPA, State, and local air pollution control programs and industry.

An emission factor relates the quantity (weight) of pollutants emitted to a unit of activity of the source. The uses for the emission factors reported in AP-42 include:

1. Estimates of area-wide emissions;
2. Emission estimates for a specific facility; and
3. Evaluation of emissions relative to ambient air quality.

The purpose of this report is to provide background information from process information obtained from industry comment and 5 new test reports.

Including the introduction (Chapter 1) this report contains four chapters. Chapter 2 gives a description of the Steel Foundry industry. It includes a characterization of the industry, an overview of the different process types, a description of emissions, and a description of the technology used to control emissions resulting from Steel Foundries.

Chapter 3 is a review of emissions data collection and analysis procedures. It describes the literature search, the screening of emission data reports, and the quality rating system for both emission data and emission factors. Chapter 4 details criteria and noncriteria pollutant emission factor development. It includes the review of specific data sets and the results of data analysis. Particle size determination and particle size data analysis methodology are described when applicable.

2.0 INDUSTRY DESCRIPTION

2.1 GENERAL

Steel foundries produce steel castings weighing from a few ounces to over 180 megagrams (200 tons). These castings are used in machinery, transportation, and other industries requiring parts that are strong and reliable. In 1989, 1030 million megagrams (1137 million tons) of steel (carbon and alloy) were cast by U.S. steel foundries, while demand was calculated at 1332 million megagrams (1470 million tons). Imported steel accounts for the difference between the amount cast and demand the amount. Steel casting is done by small and medium size manufacturing companies.[1]

Commercial steel castings are divided into three classes: 1) carbon steel, 2) low-alloy steel, and 3) high-alloy steel. Different compositions and heat treatments of steel castings results in a tensile strength range of 400 to 1700 MPa (60,000 to 250,000 psi).

2.2 PROCESS DESCRIPTION

Steel foundries produce steel castings by the melting scrap, alloying, molding, and finishing. The process flow diagram of a typical steel foundry with fugitive emission points is presented in Figure 2.2-1. The major processing operations of a typical steel foundry are raw materials handling, metal melting, mold and core production, and casting and finishing.

2.2.1 Raw Materials Handling

Raw material handling operations include receiving, unloading, storing, and conveying all raw materials for the foundry. Some of the raw materials used by steel foundries are iron and steel scrap, foundry returns, metal turnings, alloys, carbon additives, fluxes (limestone, soda ash, fluorspar, calcium carbide), sand, sand additives and binders. These raw materials are received in ships, railcars, trucks, and containers, and are transferred by trucks, loaders, and conveyors to both open pile and enclosed storage areas. They are then transferred by similar means from storage to the subsequent processes.

2.2.2 Metal Melting

Metal melting process operations are: 1) scrap preparation; 2) furnace charging, in which metal, scrap, alloys, carbon, and flux are added to the furnace; 3) melting, during which the

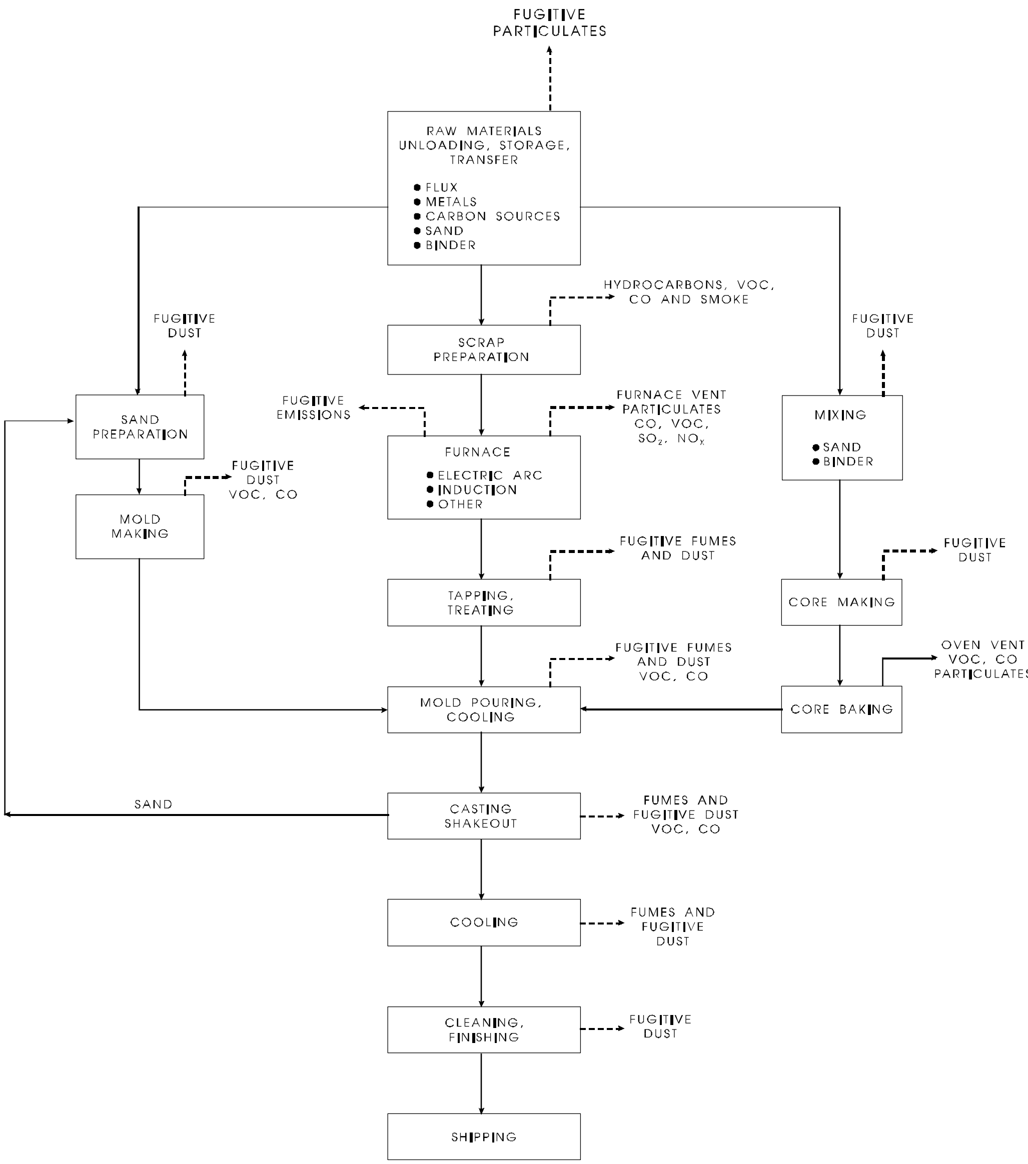

Figure 2.2-1 Flow diagram of a typical steel foundry

furnace remains closed; 4) backcharging, which is the addition of more metal and possibly alloys; 5) refining by single (oxidizing) slag or double (oxidizing and reducing) slagging operations; 6) oxygen lancing, which is injecting oxygen into the molten steel to adjust the chemistry of the metal and speed up the melt; and 7) tapping the molten metal into a ladle or directly into molds. After preparation, the scrap, metal, alloy, and flux are weighed and charged to the furnace.

Steel foundries use electric furnaces almost exclusively for melting and formulating steel. There are two types of electric furnaces: direct arc and induction. Electric arc furnaces are charged with raw materials by removing the lid, through a chute opening in the lid, or through a door in the side. The molten metal is tapped by tilting and pouring through a spout on the side. Melting capacities range up to 10 megagrams (11 tons) per hour.

Melting in an electric arc furnace is accomplished by conversion of electrical energy to heat. An alternating current applied to the electrodes causes current to flow through the charge between the electrode tips. This provides a reaction zone at temperatures up to 2000°C (3632°F). The tip of each electrode changes polarity continuously as the alternating current flows between the tips. To maintain a uniform electric load, electrode depth is continuously varied automatically by mechanical or hydraulic means.

A typical electric arc furnace design is depicted in Figure 2.2-2. The lower part of the direct electric arc furnace is composed of a cylindrical steel shell with a flat bottom or hearth.
The interior of the shell is lined with two or more layers of carbon blocks. The furnace shell is water cooled to protect it from the heat of the process. A water-cooled cover and fume collection hood are mounted over the furnace shell. Normally, three carbon electrodes arranged in a triangular formation extend through the cover and into the furnace shell opening. Raw materials are charged to the furnace through feed chutes from above the furnace. The surface of the furnace charge, which contains both molten material and unconverted charge during operation, is typically maintained near the top of the furnace shell. The lower ends of the electrodes are maintained at about 1.0 to 1.5 meters (3 to 5 feet) below the charge surface. Three-phase electric current arcs from electrode to electrode, passing through the charge material. The charge material melts and reacts to form the desired product as the electric energy is converted into heat. The carbonaceous material in the furnace charge reacts with oxygen in the metal oxide of the charge and reduces it to base metal.

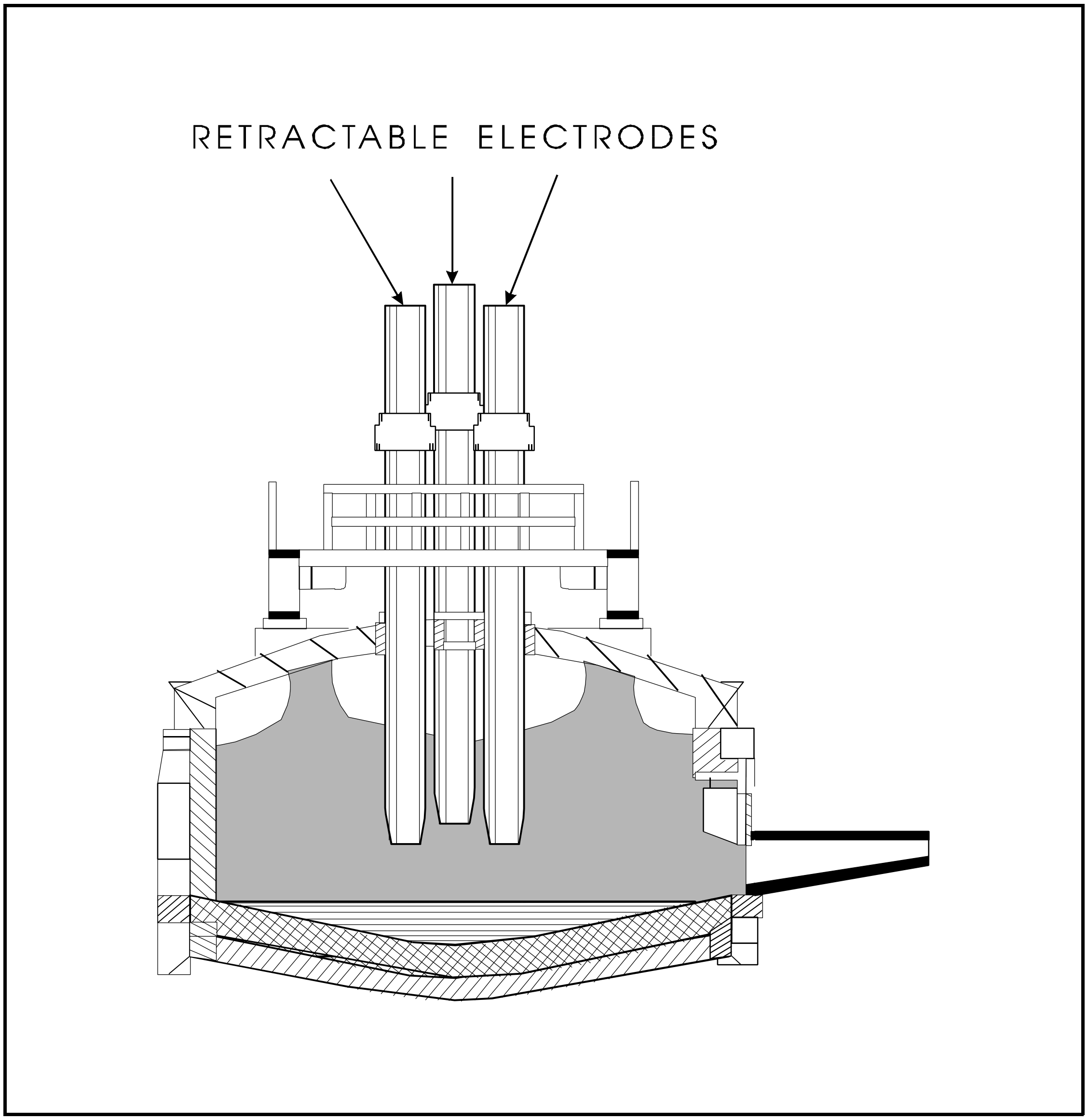

Figure 2.2-2 Electric arc steel furnace

The reactions produce large quantities of carbon monoxide (CO) which passes upward through the furnace charge. The molten metal and slag are removed (tapped) through one or more tap holes extending through the furnace shell at the hearth level. Feed materials may be charged continuously or intermittently. Power is applied continuously. Tapping is intermittent based on production rate of the furnace.

Direct electric arc furnaces are of two basic types, open and covered. Most of the direct electric arc furnaces in the U.S. are open furnaces. Open furnaces have a fume collection hood at least one meter (3.3 feet) above the top of the furnace shell. Moveable panels or screens are sometimes used to reduce the open area between the furnace and hood, and to improve emissions capture efficiency. Carbon monoxide rising through the furnace charge burns in the area between the charge surface and the capture hood. This substantially increases the volume of gas the containment system must handle. Additionally, the vigorous open combustion process entrains finer material in the charge. Fabric filters are typically used to control emissions from open furnaces.

Covered furnaces have a water-cooled steel cover which fits closely to the furnace shell. The objective of covered furnaces is to reduce air infiltration into the furnace gases, which reduces combustion of that gas. This reduces the volume of gas requiring collection and treatment. The cover has holes for the charge and electrodes to pass through. Covered furnaces which partially close these hood openings with charge material are referred to as "mix-sealed" or "semi-enclosed furnaces." Although these covered furnaces significantly reduce air infiltration, some combustion still occurs under the furnace cover. Covered furnaces that have mechanical seals around the electrodes and sealing compounds around the outer edges are referred to as "sealed" or "totally closed." These furnaces have little, if any, air infiltration and undercover combustion. Water leaks from the cover into the furnace must be minimized as this leads to excessive gas production and unstable furnace operation. Products prone to highly variable releases of process gases are typically not made in covered furnaces for safety reasons. As the degree of enclosure increases, less gas is produced for capture by the hood system and the concentration of carbon monoxide in the furnace gas increases. Wet scrubbers are used to control emissions from covered furnaces. The scrubbed, high carbon monoxide content gas may be used within the plant or flared.

An indirect arc furnace consists of a steel cylinder lined with refractory insulator resting on power driven rollers which allow rocking of the cylinder. One graphite electrode supported by port blocks, enters the center of the shell from each end allowing for an arc to be struck in the chamber center. The molten metal is not part of the electrical circuit. The furnace is rocked at predetermined increments, exposing more surface area of the refractory lining, allowing additional radiant heat as well as arc heat for more uniform melting.

An induction furnace is a vertical refractory-lined cylinder surrounded by coils energized with alternating current. The resulting fluctuating magnetic field heats the metal. Induction furnaces are kept closed except when charging, skimming, and tapping. The molten metal is tapped by tilting and pouring through a spout on the side. Induction furnaces are also used in conjunction with other furnaces, to hold and superheat a charge previously melted and refined in another furnace. A very small fraction of the secondary steel foundry industry also uses crucible and pneumatic converter furnaces. A less common furnace used in steel foundries is the open hearth furnace, a very large shallow refractory-lined batch operated vessel. The open hearth furnace is fired at alternate ends, using the hot waste combustion gases to heat the incoming combustion air.

2.2.3 Mold and Core Production

Cores are forms used to make the internal features in castings. Molds are forms used to shape the casting exterior. Cores are made of sand with organic binders, molded into a core and baked in an oven. Molds are made of sand with clay or chemical binders. Increasingly, chemical binders are being used in both core and mold production. Used sand from castings shakeout operations is usually recycled to the sand preparation area, where it is cleaned, screened and reused.

2.2.4 Casting and Finishing

When the melting process is complete, the molten metal is tapped and poured into a ladle. The molten metal may be treated in the ladle by adding alloys and other chemicals. The treated metal is then poured into molds and allowed to partially cool under carefully controlled conditions. When cooled, the castings are placed on a vibrating grid and the sand of the mold and core are shaken away from the casting.

In the cleaning and finishing process, burrs, risers and gates are broken or ground off to match the contour of the casting. Afterward, the castings may be shot-blasted to remove any remaining mold sand and scale.

2.3 EMISSIONS AND CONTROLS[1,19]

Emissions from the raw materials handling operations are fugitive particulates generated from receiving, unloading, storing, and conveying all raw materials for the foundry. These emissions are controlled by enclosing the major emission points and routing the air from the enclosures through fabric filters.

Emissions from scrap preparation consist of hydrocarbons if solvent degreasing is used and consist of smoke, organics, and carbon monoxide (CO) if heating is used. Catalytic incinerators and afterburners with approximately 95 percent control efficiency for carbon monoxide and organics can be applied to these sources.

Emissions from melting furnaces are particulates, carbon monoxide, organics, sulfur dioxide, nitrogen oxides, and small quantities of chlorides and fluorides. The particulates, chlorides and fluorides are generated from the flux. Scrap may contains volatile organics (VOCs) and dirt particles, along with oxidized phosphorus, silicon and manganese. In addition, organics on scrap and the carbon additives increase CO emissions. Trace constituents such as nickel, hexavalent chromium, lead, cadmium, and arsenic have been found in the emissions. The highest concentrations of furnace emissions occur when the furnace lids and doors are opened during charging, backcharging, alloying, oxygen lancing, slag removal and tapping operations. These emissions escape into the furnace building and are vented through roof vents. Controls for emissions during melting and refining operations focus on venting the furnace gases and fumes directly to an emission collection duct and control system. Controls for fugitive furnace emissions involve either the use of building roof hoods or special hoods near the furnace doors, to capture emissions and route them to emission control systems. Emission control systems commonly used to control particulate emissions from electric arc furnaces and induction furnaces are bag filters, cyclones and venturi scrubbers. However, induction furnaces in most cases are uncontrolled. Ferroalloys are used to produce steel alloys and adjust the oxygen content while the molten steel is in the ladle. Emissions consist of iron oxides during tapping in addition to oxide fumes from alloys added to the ladle.

The major pollutant from mold and core production are particulates from sand reclaiming, sand preparation, sand mixing with binders and additives, and mold and core forming. Particulate, VOC, and CO and emissions result from core baking and VOC emissions occur during mold drying. Bag filters and scrubbers can be used to control particulates from mold and core production. Afterburners and catalytic incinerators can be used to control VOC and CO emissions.

During casting operations, large quantities of particulates can be generated in the steps prior to pouring. Emissions from pouring consist of fumes, CO, VOC and particulates from the mold and core materials when contacted by the molten steel. Emissions continue as the mold cools. A significant quantity of particulate emissions is generated during the casting shakeout operation. The particulate emissions from the shakeout operations can be controlled by either high efficiency cyclone separators or bag filters. Emissions from pouring are usually uncontrolled.

Emissions from finishing operations consist of particulates resulting from the removal of burrs, risers, and gates and during shot blasting. Particulates from finishing operations can be controlled by cyclone separators.

Nonfurnace emissions sources in steel foundries are very similar to those in iron foundries. Nonfurnace emissions factors and particle size distributions for iron foundry emission sources for criteria and toxic pollutants are presented in Section 12.10, "Gray Iron Foundries."

2.4 REVIEW OF REFERENCES

Pacific Environmental Services (PES) contacted the following sources to obtain the most up-to-date information on process descriptions and emissions for this industry:

1) Alabama Department of Environmental Management, Montgomery, AL.
2) American Foundryman's Society, Des Plaines, IL.
3) American Iron and Steel Institute, Washington, DC.
4) Florida Department of Environmental Reg., Tallahassee, FL.
5) Georgia Department of Natural Resources, Atlanta, GA.
6) Indiana Department of Environmental Management., Indianapolis, IN.
7) Kansas Department of Health and Environment, Topeka, KS.
8) Michigan Department of Natural Resources, Lansing, MI.
9) Missouri Department of Natural Resources, Jefferson City, MO.
10) Ohio Environmental Protection Agency, Columbus, OH.
11) Pennsylvania Department of Environmental Resources, Harrisburg, PA.

12) U.S. EPA Regional Operations Branch, Air Quality Management Division, Research Triangle Park, NC.

13) Process Metallurgy International, Inc., Arlington Heights, IL.

Responses were received from the American Foundryman's Society, the U.S. EPA, and Process Metallurgy International, Inc. (Sources 2, 12, and 13). No responses were receiv77ed from the other sources contacted. The American Foundryman's Society indicated that electric arc furnaces were the type of furnaces most used in steel foundries, and that improving the melt rate and economic efficiency of electric arc furnaces through the development of direct current and ultra power conversions appeared to be the direction the steel foundry industry was pursuing. The society is working with the EPA on gathering emissions data. The EPA indicated that the program for collecting steel foundry emissions data has started with the mailing of generic information collection requests to known steel foundries. No new information is available. Process Metallurgy International indicated that no new electric arc furnaces are being purchased and installed by the steel foundry industry. Modifications to improve efficiency of existing units appears to be the industry's response to foreign competition. The future changes in production equipment composition appears to be toward the use of ladle furnaces. Ladle furnaces are sized up to six ton capacities. They receive a generic alloy molten steel melt from an electric arc furnace that supplies one or more ladle furnaces. The ladle furnace lacks the power to melt steel, but can maintain the melt temperature during metallurgical operations that results in specific steel specifications being satisfied. According to Process Metallurgy International, there are 200 plus electric arc furnaces in operation in the United States. At the same time, there are only 12 to 16 argon-oxygen decarburization furnaces in operation. Argon-oxygen decarburization furnaces provide the cleanest steel, used for special applications.

2.5 REFERENCES FOR CHAPTER 2

1. 1989 Mineral Yearbook, Vol. 1, Bureau of Mines, United States Department of the Interior.

2. Air Pollution Aspects of the Iron and Steel Industry, National Center for Air Pollution Control, Cincinnati, OH, June 1963.

3. Foundry Air Pollution Control Manual, 2nd Edition, Foundry Air Pollution Control Committee, Des Plaines, IL, 1967.

4. "Smoke, Dust, Fumes Closely Controlled in Electric Furnaces", Iron Age, 173:107-110, January 14, 1954.

5. Air Pollution Aspects of the Iron and Steel Industry, National Center for Air Pollution Control, Cincinnati, OH, June 1963.

6. "Fume Control Electric Melting Furnaces," American Foundryman, 18:33-34, November 1950.

7. Air Pollution Aspects of the Iron and Steel Industry, National Center for Air Pollution Control, Cincinnati, OH, June 1963.

8. "Electric Furnace Steel," Proceedings of the American Institute of Mining and Metallurgical Engineers, 11:160-161, 1953.

9. Air Pollution Aspects of the Iron and Steel Industry, p. 109.

10. "Direct Fume Extraction and Collection Applied to a Fifteen-Ton Arc Furnace," Special Report on Fume Arrestment, Iron and Steel Institute, 1964, pp. 144, 149.

11. Inventory of Air Contaminant Emissions, New York State Air Pollution Control Board, Table XI, pp. 14-19. Date unknown.

12. "Metallurgical Dust Collection in Open Hearth and Sinter Plant," Canadian Mining and Metallurgical Bulletin, 55(606):724-732, October 1962.

13. "Air Pollution Problems of the Steel Industry," JAPCA, 10(3):208-218, March 1960.

14. Unpublished data, Resources Research, Incorporated, Reston, VA.

15. PM10 Emission Factor Listing Developed By Technology Transfer, EPA-450/4-89-022.

16. Emission Factors For Iron and Steel Sources - Criteria and Toxic Pollutants, E.H. Pachan and Associates, Inc., EPA-600/2-50-024, June 1990.

17. Toxic Air Pollutant Emission Factors A Compilation for Selected Air Toxic Compounds and Sources, Second Edition, Radian Corporation, EPA-450/2-90-011, October 1990.

18. Electric Arc Furnaces and Argon-Oxygen Decarburization Vessels in the Steel Industry: Background Information for Proposed Revisions to Standards, EPA-450/3-B-020A, U.S. Environmental Protection Agency, Research Triangle Park, NC, July 1983.

3.0 GENERAL EMISSION DATA REVIEW AND ANALYSIS PROCEDURES

3.1 LITERATURE SEARCH AND SCREENING

The first step of this investigation involved a search of available literature relating to criteria and noncriteria pollutant emissions associated with steel foundries. This search included, but was not limited to, the following references:

1) AP-42 background files maintained by the Emission Factor and Methodologies Section. No emission source tests were used from the steel foundry files.
2) Files maintained by the Emission Standards Division. ESD is currently collecting emissions data from the individual corporations.
3) "PM_{10} Emission Factor Listing Developed by Technology Transfer (EPA-450/4-89-022). This document has been used as a reference in the revised emission Table 12.13-1.
4) Background Information Documents for NSPS and NESHAPS. No emission tests were included in the documents reviewed.
5) Information in the *Air Facility Subsystems* (AFS) of the EPA *Aerometric Information Retrieval System* (AIRS). Computer printouts were reviewed. PES was unable to retrieve any information for this application.
6) Handbook of Emission Factors, Parts I and II, Ministry of Health and Environmental Protection, The Netherlands, 1980/1983. No actual emission test data available.
7) The EPA *Clearinghouse for Inventories and Emission Factors* (CHIEF). CHIEF referenced emission source data as coming from AP-42. No new information was found.
8) The EPA databases, including *Speciation Database Management System* (SPECIATE), the *Crosswalk/Air Toxic Emission Factor Data Base Management System* (XATEF) and the *Emission Measurement Technical Information Center's Test Methods Storage and Retrieval System* (TSAR). SPECIATE and XATEF were reviewed, but no information was incorporated. TSAR was searched and provided the listing of emission tests reviewed and used during discussions of emissions in Chapter 4 of this report.

9) A literature search was conducted in the Duke University library, including a computer network search of the University of North Carolina and the North Carolina State University. In addition, the EPA Environmental Research Center library was visited where approximately half of all the source tests reviewed for steel foundries were located. The remainder of the primary emission source tests reviewed for steel foundries were located in EMB files.

To reduce the amount of literature collected to a final group of references pertinent to this report, the following general criteria were used:

1. Emissions data must be from a primary reference, i.e. the document must constitute the original source of test data. For example, a technical paper was not included if the original study was contained in the previous document.
2. The referenced study must contain test results based on more than one test run.
3. The report must contain sufficient data to evaluate the testing procedures and source operating conditions (e.g., one-page reports were generally rejected).

If no primary data were found and the previous update utilized secondary data, these secondary data were still used and the Emission Factor Rating lowered. A final set of reference materials was compiled after a thorough review of the pertinent reports, documents, and information according to these criteria. The final set of reference materials is given in Chapter 4.0.

3.2 EMISSION DATA QUALITY RATING SYSTEM

As part of Pacific Environmental Services' analysis of the emission data, the quantity and quality of the information contained in the final set of reference documents were evaluated. The following data were always excluded from consideration.

1. Test series averages reported in units that cannot be converted to the selected reporting units;
2. Test series representing incompatible test methods (i.e., comparison of the EPA Method 5 front-half with the EPA Method 5 front- and back-half);
3. Test series of controlled emissions for which the control device is not specified;
4. Test series in which the source process is not clearly identified and described; and

5. Test series in which it is not clear whether the emissions were measured before or after the control device.

Data sets that were not excluded were assigned a quality rating. The rating system used was that specified by the OAQPS for the preparation of AP-42 sections. The data were rated as follows:

A

Multiple tests performed on the same source using sound methodology and reported in enough detail for adequate validation. These tests do not necessarily conform to the methodology specified in either the inhalable particulate (IP) protocol documents or the EPA reference test methods, although these documents and methods were certainly used as a guide for the methodology actually used.

B

Tests that were performed by a generally sound methodology but lack enough detail for adequate validation.

C

Tests that were based on an untested or new methodology or that lacked a significant amount of background data.

D

Tests that were based on a generally unacceptable method but may provide an order-of-magnitude value for the source.

The following criteria were used to evaluate source test reports for sound methodology and adequate detail:

1. <u>Source operation</u>. The manner in which the source was operated is well documented In the report. The source was operating within typical parameters during the test.
2. <u>Sampling procedures</u>. The sampling procedures conformed to a generally acceptable methodology. If actual procedures deviated from accepted methods, the deviations are well documented. When this occurred, an evaluation was made of the extent such alternative procedures could influence the test results.

3. Sampling and process data. Adequate sampling and process data are documented in the report. Many variations can occur unnoticed and without warning during testing. Such variations can induce wide deviations in sampling results. If a large spread between test results cannot be explained by information contained in the test report, the data are suspect and were given a lower rating.

4. Analysis and calculations. The test reports contain original raw data sheets. The nomenclature and equations used were compared to those (if any) specified by the EPA to establish equivalency. The depth of review of the calculations was dictated by the reviewer's confidence in the ability and conscientiousness of the tester, which in turn was based on factors such as consistency of results and completeness of other areas of the test report.

3.3 EMISSION FACTOR QUALITY RATING SYSTEM

The quality of the emission factors developed from analysis of the test data was rated utilizing the following general criteria:

A (Excellent)

Developed only from A-rated test data taken from many randomly chosen facilities in the industry population. The source category is specific enough so that variability within the source category population may be minimized.

B (Above average)

Developed only from A-rated test data from a reasonable number of facilities. Although no specific bias is evident, it is not clear if the facilities tested represent a random sample of the industries. As in the A-rating, the source category is specific enough so that variability within the source category population may be minimized.

C (Average)

Developed only from A- and B-rated test data from a reasonable number of facilities. Although no specific bias is evident, it is not clear if the facilities tested represent a random sample of the industry. As in the A-rating, the source category is specific enough so that variability within the source category population may be minimized.

D (Below average) The emission factor was developed only from A- and B-rated test data from a small number of facilities, and there is reason to suspect that these facilities do not represent a random sample of the industry. There also may be evidence of variability within the source category population. Limitations on the use of the emission factor are noted in the emission factor table.

E (Poor)

The emission factor was developed from C- and D-rated test data, and there is reason to suspect that the facilities tested do not represent a random sample of the industry. There also may be evidence of variability within the source category population. Limitations on the use of these factors are always noted.

The use of these criteria is somewhat subjective and depends to an extent on the individual reviewer.

3.4 REFERENCES FOR CHAPTER 3

1. Technical Procedures for Developing AP-42 Emission Factors and Preparing AP-42 Sections. U.S. Environmental Protection Agency, Emissions Inventory Branch, Office of Air Quality Planning and Standards, Research Triangle Park, NC, 27711, April, 1992. [Note: this document is currently being revised at the time of this printing.]

2. AP-42, Supplement A, Appendix C.2, "Generalized Particle Size Distributions." U.S. Environmental Protection Agency, October, 1986.

4.0 POLLUTANT EMISSION FACTOR DEVELOPMENT

4.1 CRITERIA POLLUTANT EMISSIONS DATA

Volatile Organic Compounds.

No data on volatile organic compound emissions were found for the steel foundry process.

Lead.

No data on emissions of lead pollutants with production numbers were found for the steel foundry process. However, lead emissions are believed to be primarily a function of lead contamination in scrap used in electric arc furnaces (EAF). Past iron foundry furnace emission tests have found lead emissions to be in a range of 0.5 to 17 percent of total particulates.[18] Lead emissions can vary from plant to plant, and may even vary from day to day at the same plant, depending on the quality of scrap used in each melt.

Sulfur dioxide.

Reference 21 provides SO_2 emissions from two EAFs during three method 6 test runs that lasted over 3 hours for each testing period (one complete melt cycle per test run). No production rates were available in the emission test report. Although the tabulated information below represents uncontrolled SO_2 emissions generated from two EAF in an iron foundry, PES believes this method 6 information should be included in this background report to establish an order of magnitude.

Sulfur Dioxide Emissions

Emission Test #	kg/hr	lb/hr
1	1.71	3.78
2	1.80	3.93
3	1.51	3.32
Average	1.67	3.68

Nitrogen Oxides.

Data on emissions of nitrogen oxides were found without production rates for the steel foundry process. However, Reference 21 and Reference 22 do report three test runs each, along with furnace capacity. Modified emission factors are reported in Table 4.1-1 for nitrogen oxides based on furnace capacity instead of tons of product.

Carbon monoxide.

No data on emissions of carbon monoxide were found for the steel foundry process that were accompanied by production values reported in tons per hour. However, furnace capacities are reported for carbon monoxide emission rates in Reference 21 and Reference 22. PES has calculated modified emission factors for carbon monoxide and tabulated them below in Table 4.1-2 based upon tons of furnace capacity instead of ton of product produced per hour. While this emission factor is irregular by virtue of its units, the emission factor does provide a relative numerical emission factor.

Total Suspended Particulate .

Emissions of particulate matter can be divided into three categories: filterable, organic condensable, and inorganic condensable. Filterable particulate matter is that which collects on the filter and in the sampling probe assembly of a particulate sampling train. When emissions testing is performed in accordance with Method 5, the filter and probe are maintained at approximately 120°C (248°F); materials that condense at a temperature lower than this will pass through the filter. Many emissions tests also quantify emissions of condensable particulate matter, typically that which condenses at or above 20°C (68°F). This condensable particulate matter is collected by passing the effluent gas through ice water-cooled impingers such that the gas exiting the last impinger is at a temperature less than 20°C. Table 4.1-3 contains emission factors for filterable particulate from two steel foundries.

TABLE 4.1-1 (METRIC UNITS)
NITROGEN OXIDES
(Units in lb/Mg of Furnace Capacity)

Source Test #	Test Rating	Test Method	Run #	Furnace Capacity	Emission Rate	Emission Factor
Control device: Uncontrolled -EAF						
21	A	7	1	136	6.8	0.05
			2	136	3.1	0.02
			3	136	5.2	0.04
			Average	136	5.0	0.04
Control device: Uncontrolled - EAF						
22	A	7	1	150	12.9	0.09
			2	150	10.3	0.07
			3	150	6.0	0.04
			Average	150	9.8	0.07

TABLE 4.1-1 (ENGLISH UNITS)
NITROGEN OXIDES
(Units in lb/ton Furnace Capacity)

Source Test #	Test Rating	Test Method	Run #	Furnace Capacity	Emission Rate	Emission Factor
Control device: Uncontrolled - EAF						
22	A	7	1	150	14.9	0.10
			2	150	6.9	0.05
			3	150	11.5	0.08
			Average	150	11.1	0.07
Control device: Uncontrolled - EAF						
23	A	7	1	165	28.4	0.17
			2	165	22.7	0.14
			3	165	13.3	0.08
			Average	165	21.5	0.13

TABLE 4.1-2 (METRIC UNITS)
CARBON MONOXIDE
(Units in kg/Mg of Furnace Capacity)

Source Test #	Test Rating	Test Method	Run #	Furnace Capacity	Emission Rate	Emission Factor
Control device: Uncontrolled - EAF						
22	A	10	1	136	39.0	0.29
			2	136	33.4	0.25
			3	136	15.8	0.12
			Average	136	29.8	0.22
Control device: Uncontrolled - EAF						
23	A	10	1	150	9.3	0.06
			2	150	14.7	0.10
			3	150	23.3	0.16
			Average	150	15.8	0.11

TABLE 4.1-2 (ENGLISH UNITS)
CARBON MONOXIDE
(Units in lb/ton of Furnace Capacity)

Source Test #	Test Rating	Test Method	Run #	Furnace Capacity	Emission Rate	Emission Factor
Control device: Uncontrolled - EAF						
22	A	10	1	150	85.9	0.57
			2	150	73.6	0.49
			3	150	34.8	0.23
			Average	150	65.8	0.43
Control device: Uncontrolled - EAF						
23	A	10	1	165	20.6	0.12
			2	165	32.4	0.20
			3	165	51.4	0.31
			Average	165	34.8	0.21

TABLE 4.1-3 (METRIC UNITS)
FILTERABLE PARTICULATE
(Units in kg/Mg Product)

Reference Test #	Test Rating	Test Method	Run #	Production Rate	Emission Rate	Emission Factor
Control device: Uncontrolled - EAF						
19	A	5	1	28.9	194.1	6.7
			2	30.2	190.9	6.3
			3	28.2	291.6	10.3
			Average	29.1	225.5	7.8
Control device: Uncontrolled - EAF						
20	A	5	1	9.5	70.5	7.4
			2	8.6	70.5	8.2
			3	9.3	101.2	10.9
			Average	9.1	80.7	8.8

TABLE 4.1-3 (ENGLISH UNITS)
FILTERABLE PARTICULATE
(Units in lb/ton Product)

Reference Test #	Test Rating	Test Method	Run #	Production Rate	Emission Rate	Emission Factor
Control device: Uncontrolled - EAF						
19	B	5	1	31.9	428	13.4
			2	33.3	421	12.6
			3	31.1	643	20.7
			Average	32.1	498	15.6
Control device: Uncontrolled - EAF						
20	A	5	1	10.5	155.4	14.8
			2	9.5	155.3	16.4
			3	10.3	223.0	21.7
			Average	10.1	177.9	17.6

4.2 NONCRITERIA POLLUTION EMISSION DATA

Hazardous Air Pollutants.

Hazardous Air Pollutants (HAPs) are defined in the 1990 Clean Air Act Amendments. Dust collected in fabric filters from steel foundry electric arc furnace emissions have been found to contain compounds of lead, cadmium, arsenic, and hexavalent chromium. These compounds are listed as HAPs. No data on emission rates of these pollutants were found for the steel foundry process.

Global Warming Gases.

Pollutants such as methane, carbon dioxide, and nitrous oxide have been found to contribute to overall global warming. The combustion of fossil fuels is one of the main anthropogenic sources of CO_2 emissions. For source testing purposes, the concentration of carbon dioxide in the stack gas being tested is measured in order to approximate the molecular weight of the stack gas. In most emissions tests, this measurement is performed in such a way that its level of accuracy is less than that of the primary pollutants of interest.

The preferred method of quantifying emissions of carbon dioxide from combustion processes is through fuel analyses. All of the carbon in the fuel, minus that contained in unburned hydrocarbons and carbon monoxide in the effluent gases, can be assumed to be in the form of carbon dioxide. However, in the case of steel foundries and the predominate use of EAFs, electrical energy is used to melt the steel. CO_2 emissions are the result of oxidation of CO. Reference 22 contains an observation that when CO concentrations increased, NO_x concentrations decreased, and when CO concentrations decreased, NO_x concentrations increased. Changes in the O_2 concentration could account for this relationship. More O_2 would cause a higher temperature in the melt, and a greater conversion of CO to CO_2. In addition, the higher temperature would support more NO_x formation. No emissions of global warming gases were found.

Ozone Depletion Gases.

Chlorofluorocarbons have been found to contribute to ozone depletion. No data on emissions of these pollutants were found for the steel foundry process.

4.3 REVIEW OF SPECIFIC DATA SETS

Table 4.3-1 is representative of Table 12.13-1 that is a part of AP-42, Section 12.13, Steel Foundries. The emission factor ratings for this previously published table have been changed to "E" as Table 4.3-1 references are secondary informational sources. There are no primary emission source tests in these references. PES has added PM_{10} particulate emissions to Table 4.3-1 and has rated the emission factors as "E" as the reference source is PM_{10} Emission Listing Developed By Technological Transfer, EPA-450/4-89-022.

The following data set review discusses each of the source tests used in Chapter 4 during discussions of steel foundry criteria and noncriteria pollution emissions.

Reference 19. Emission Source Test: Altech Specialty Steel Corporation, Albany,NY. EMB Test Report No. 80-ELC-07, March 1, 1981. This "B" rated particulate emissions test measured emissions from two steel foundry furnaces concurrently. The first furnace was an electric arc furnace, while the second was an argon-oxygen decarburization furnace. The tests are rated a "B" due to production equipment problems that may have influenced the second and third test run. This information is found in Table 4.1-3.

Reference 20. Emission Source Test: Carpenter Technology Corporation, Reading ,PA. EMB Test Report No. 80-ELC-10. April 1, 1981. This emission source test is rated "A". Particulates were measured that were generated from an electric arc furnace. A particulate size distribution was also taken, resulting in a finding that indicated 50 percent by weight of collected dust consisted of particle diameters of 1.6 micrometers or less. Particulate emission factors are listed in Table 4.1-3.

Reference 21. Emission Source Test: John Deere Tractor Works, Waterloo, Iowa. EMB Test Report No. 74-GFE-01. January 1, 1974. This emission testing effort measured a variety of pollutants from two electric arc furnaces in an iron foundry. No production rates were included in the report. PES did use the sulfur dioxide emission rates (method 6) that were listed in pounds per hour, primarily because the testing periods included the entire heat periods (3 hours) and should provide at least an order of magnitude of this pollutant. The emission rates are listed in tabular form only under the SO_2 discussion. This emission test is rated as an "A" rating.

TABLE 4.3-1 (METRIC UNITS)
EMISSION FACTORS FOR STEEL FOUNDRIES
All Emission Factors are in kg/Mg of Metal Processed
Ratings (A-E) Follow Each Factor

Process	SCC's	Particulates[a] (TSP)		Nitrogen oxides		PM_{10}	
Melting							
Electric arc[b,c]	30400701	6.5 (2 to 20)	E	0.1	E		
Open hearth[d,e]	30400702	5.5 (1 to 10)	E	0.005	E		
Open hearth oxygen lanced[f,g]	30400703	5 (4 to 5.5)	E				
Electric induction[h]	30400705	0.05	E			0.045	E
Sand grinding/ handling in mold and core making[i]	30400706					0.27 3.0	E E
Core ovens[i]	30400707					1.11 0.45	E E
Pouring and casting[i]	30400708					1.4	E
Casting cleaning[i]	30400725					0.85	E
Charge handling[i]	30400712					0.18	E
Casting cooling[i]	30400713					0.7	E

[a]Expressed as units per unit weight of metal processed. If the scrap metal is very dirty or oily, or if increased oxygen lancing is employed, the emission factor should be chosen from the high side of the factor range.
[b]Electrostatic precipitator, 92 to 98% control efficiency; baghouse (fabric filter), 98 to 99% control efficiency; venturi scrubber, 94 to 98% control efficiency.
[c]References 2 to 10
[d]Electrostatic precipitator, 95 to 98% control efficiency; baghouse , 99.9% control efficiency; venturi scrubber, 96 to 99% control efficiency.
[e]References 2, 11 to 13
[f]Electrostatic precipitator, 95 to 98% control efficiency; baghouse, 99% control efficiency; venturi scrubber, 95 to 98% control efficiency.
[g]References 6 and 14
[h]Usually not controlled.
[i]Reference 16

TABLE 4.3-1 (ENGLISH UNITS)
EMISSION FACTORS FOR STEEL FOUNDRIES
All Emission Factors are in lb/ton of Metal Processed
Ratings (A-E) Follow Each Factor

Process	SCC's	Particulates[a] (TSP)		Nitrogen oxides		PM^{10}	
Melting							
Electric arc[b,c]	30400701	13 (4 to 40)	E	0.2	E		
Open hearth[d,e]	30400702	11 (2 to 20)	E	0.01	E		
Open hearth oxygen lanced[f,g]	30400703	10 (8 to 11)	E				
Electric induction[h]	30400705	0.1	E			0.09	E
Sand grinding/handling in mold and core making[i]	30400706					0.54 6.0	E E
Core ovens[i]	30400707					2.22 0.90	E E
Pouring and casting[i]	30400708					2.8	E
Casting cleaning[i]	30400725					1.7	E
Charge handling[i]	30400712					0.36	E
Casting cooling[i]	30400713					1.4	E

[a]Expressed as units per unit weight of metal processed. If the scrap metal is very dirty or oily, or if increased oxygen lancing is employed, the emission factor should be chosen from the high side of the factor range.
[b]Electrostatic precipitator, 92 to 98% control efficiency; baghouse (fabric filter), 98 to 99% control efficiency; venturi scrubber, 94 to 98% control efficiency.
[c]References 2 to 10
[d]Electrostatic precipitator, 95 to 98% control efficiency; baghouse , 99.9% control efficiency; venturi scrubber, 96 to 99% control efficiency.
[e]References 2, 11 to 13
[f]Electrostatic precipitator, 95 to 98% control efficiency; baghouse, 99% control efficiency; venturi scrubber, 95 to 98% control efficiency.
[g]References 6 and 14
[h]Usually not controlled.
[i]Reference 16

Reference 22. Emission Source Test: Bethlehem Steel Corporation, Steelton, PA. EMB Test Report No. 73-ELC-02. January 1, 1973. An electric arc furnace was tested for CO (non-dispersive infrared analyzer with strip recorder) and NO_x (chemiluminescence instrument and strip recorded) that had a furnace capacity of 150 tons. The production rate of the furnace was not included in the report. However, the continuous data collection for each heat lasted during the entire melt for each run and was reported as pounds per hour. PES has modified the emission factor to reflect CO and NO_x pollutant emissions in pounds per ton of furnace capacity. This emission test is rated as an "A" rating.

Reference 23. Emission Source Test: Armco Steel Corporation, Butler, PA. EMB Test Report No. 73-ELC-03. January 1, 1973. This "A" rated test is identical to Reference 22 from the standpoint of equipment tested and used to record the emissions of CO and NO_x. This test is the first to attempt to explain that wide swings in CO emissions may be inversely related concentrations of NO_x, and CO_2. The relationship appears related to the use of O_2 to reduce carbon levels in steel foundry melts, resulting in an increase in metal temperature due to the exothermic reaction. In the emission test, a lower carbon content in the scrap used during the third melt is held as a possible explanation of the approximately 48 percent increase in CO above the average CO emission rate, and a 62 percent reduction in NO_x below the average of the three heats. PES incorporated CO and NO_x emissions into Table 4.1-2 and Table 4.1-1 respectively.

4.4 DATA GAP ANALYSIS

More study and emission source testing is needed to identify and quantify VOCs related to the use of sand binders used during core and mold manufacturing, emission constituents resulting from the use of oxygen lances in the melt, and the relationship of melt temperature to emissions of carbon monoxide and nitrous oxides.

When molten steel is poured into molds, VOCs and organic compounds are emitted, not only when the steel first contacts the cores and molds, but also as the metal cools. Time and temperature may cause known organic compounds to be modified and recombined to form new previously unknown organic compounds, to be emitted into the steel foundry. New sand binder formulations are marketed each year. This VOC and organic analysis of sand core and mold binders should be an ongoing program.

The use of oxygen lances reduces the amount of carbon in the melt and speeds up the melt. The relationship of increased nitrous oxides accompanied by a decrease in carbon monoxide needs further study.

The amount of quality primary emission testing is very limited. Additional emission source tests for criteria and noncriteria emissions is necessary to construct a larger data base for uncontrolled emissions from steel foundries.

4.5 REFERENCES FOR CHAPTER 4.

1. Air Pollutant Control Techniques for Electric Arc Furnaces in the Iron and Steel Foundry Industry, EPA-450/2-78-024, U.S. Environmental Protection Agency, Research Triangle Park, NC, June 1978.

2. Air Pollution Aspects of the Iron and Steel Industry, National Center for Air Pollution Control, Cincinnati, OH, June 1963.

3. Foundry Air Pollution Control Manual, 2nd Edition, Foundry Air Pollution Control Committee, Des Plaines, IL, 1967.

4. "Smoke, Dust, Fumes Closely Controlled in Electric Furnaces", Iron Age, 173:107-110, January 14, 1954.

5. Air Pollution Aspects of the Iron and Steel Industry, p. 109.

6. "Fume Control Electric Melting Furnaces," American Foundryman, 18:33-34, November 1950.

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14. Unpublished data, Resources Research, Incorporated, Reston, VA.

15. PM10 Emission Factor Listing Developed By Technology Transfer, EPA-450/4-89-022.

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17. Electric Arc Furnaces and Argon-Oxygen Decarburization Vessels in the Steel Industry: Background Information for Proposed Revisions to Standards, EPA-450/3-B-020A, U.S. Environmental Protection Agency, Research Triangle Park, NC, July 1983.

18. A Method For Characterization and Quantification of Fugitive Lead Emissions From Secondary Lead Smelters, Ferroalloy Plants, and Gray Iron Foundries. EPA-450/3-78-003, U.S. Environmental Protection Agency, Research Triangle Park, NC, January 1978.

19. Emission Source Test: Altech Specialty Steel Corporation, Albany,NY. EMB Test Report No. 80-ELC-07, March 1, 1981.

20. Emission Source Test: Carpenter Technology Corporation, Reading ,PA. EMB Test Report No. 80-ELC-10. April 1, 1981.

21. Emission Source Test: John Deere Tractor Works, Waterloo, Iowa. EMB Test Report No. 74-GFE-01. January 1, 1974.

22. Emission Source Test: Bethlehem Steel Corporation, Steelton, PA. Emb Test Report No. 73-ELC-02. January 1, 1973.

23. Emission Source Test: Armco Steel Corporation, Butler, PA. EMB Test Report No. 73-ELC-03. January 1, 1973.

TABLE 4.5-1

LIST OF CONVERSION FACTORS

Multiply:	**by:**	**To obtain:**
mg/dscm	4.37×10^{-4}	gr/dscf
m^2	10.764	ft^2
acm/min	35.31	acfm
m/s	3.281	ft/s
kg/hr	2.205	lb/hr
kPa	1.45×10^{-1}	psia
kg/Mg	2.0	lb/ton
Mg	1.1023	ton

Temperature conversion equations:

Fahrenheit to Celsius:

$$°C = \frac{(°F - 32)}{1.8}$$

Celsius to Fahrenheit:

$$°F = 1.8(°C) + 32$$