BACKGROUND REPORT

AP-42 SECTION 12.10

IRON FOUNDRIES

Prepared for

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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 18 test reports to support revision of emission factors for iron foundries.

Including the introduction (Chapter 1), this report contains four chapters. Chapter 2 gives a description of the iron foundries 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 iron 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

Iron foundries produce high-strength castings used in industrial machinery and heavy transportation equipment manufacturing. Castings include crusher jaws, railroad car wheels, and automotive and truck assemblies.

Iron foundries cast three major types of iron: gray iron, ductile iron, and malleable iron. Cast iron is an iron-carbon-silicon alloy, containing from 2 to 4 percent carbon and 0.25 to 3.00 percent silicon, along with varying percentages of manganese, sulfur, and phosphorus. Alloying elements such as nickel, chromium, molybdenum, copper, vanadium, and titanium are sometimes added. Table 2.1-1 lists different chemical compositions of irons produced.

TABLE 2.1-1
CHEMICAL COMPOSITION OF FERROUS CASTINGS BY PERCENTAGES

Element	Gray Iron	Malleable Iron (as white iron)	Ductile Iron	Steel
Carbon	2.0 - 4.0	1.8 - 3.6	3.0 - 4.0	<2.0[a]
Silicon	1.0 - 3.0	0.5 - 1.9	1.4 - 2.0	0.2 - 0.8
Manganese	0.40 - 1.0	0.25 - 0.80	0.5 - 0.8	0.5 - 1.0
Sulfur	0.05 - 0.25	0.06 - 0.20	<0.12	<0.06
Phosphorus	0.05 - 1.0	0.06 - 0.18	<0.15	<0.05

[a] Steels are classified by carbon content: low carbon is less than 0.20 percent; medium carbon is 0.20-0.5 percent; and high carbon is greater than 0.50 percent.

Mechanical properties of iron castings are determined by the type, amount, and distribution of various carbon formations. In addition, the casting design, chemical composition, type of melting scrap, melting process, rate of cooling of the casting, and heat treatment determine the final properties of iron castings. Demand for iron casting in the U.S. in 1989 was estimated at 9,540 million megagrams (10,530 million tons), while domestic production during the same period was

7,041 million megagrams (7,772 million tons). The difference is a result of imports. Half of the total iron castings were used by the automotive and truck manufacturing companies, while half the total ductile iron castings were pressure pipe and fittings.

2.2 PROCESS DESCRIPTION[1-5,39]

The major production operations in iron foundries are raw material handling and preparation, metal melting, mold and core production, and casting and finishing.

Raw Material Handling And Preparation

Handling operations include the conveying of all raw materials for furnace charging, including metallics, fluxes, and fuels. Metallic raw materials are pig iron, iron and steel scrap, foundry returns, and metal turnings. Fluxes include carbonates (limestone, dolomite), fluoride (fluorospar) and carbide compounds (calcium carbide). Fuels include coal, oil, natural gas, and coke. Coal, oil, and natural gas are used to fire reverberatory furnaces. Coke, a derivative of coal, is used for electrodes required for heat production in electric arc furnaces.

As shown in Figure 2.2-1, the raw materials, metallics, and fluxes are added to the melting furnaces directly. For electric induction furnaces, however, the scrap metal added to the furnace charge must first be pretreated to remove grease and oil. Scrap metals may be degreased with solvents, by centrifugation, or by preheating to combust the organics.

Metal Melting

The furnace charge includes metallics, fluxes and fuels. Composition of the charge depends upon specific metal characteristics required. The basic melting process operations are: furnace operations, including charging, melting, and backcharging; refining, during which the chemical composition is adjusted to meet product specifications; slag removal; and molding of the molten metal.

Furnace Operations

The three most common furnaces used in the iron foundry industry are cupolas, electric arc, and electric induction furnaces. The cupola is the major type of furnace used in the iron foundry industry. It is typically a cylindrical steel shell with a refractory-lined or water-cooled

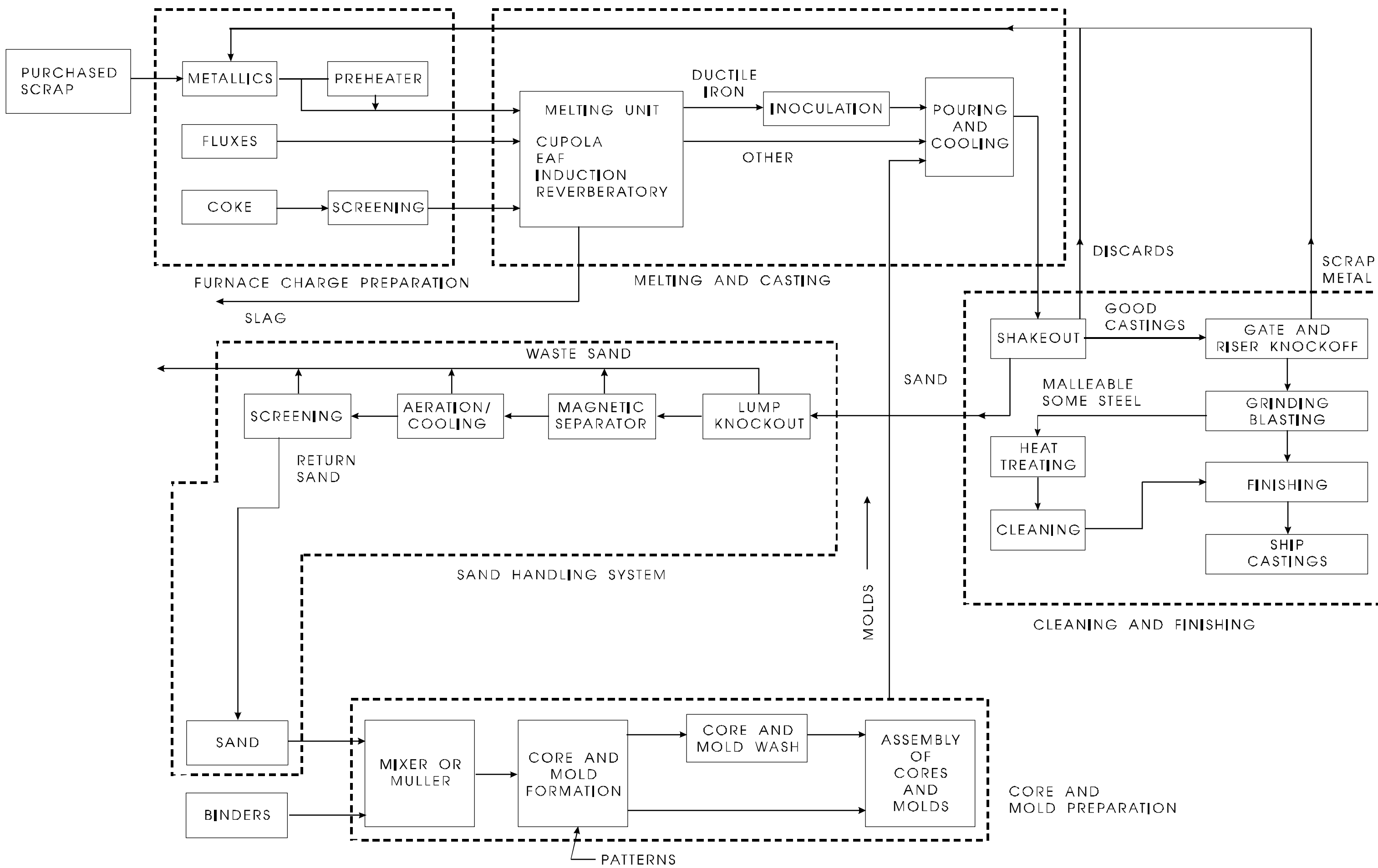

Figure 2.2-1. Flow diagram of a typical iron foundry

inner wall. The cupola is the only furnace type that uses coke as a fuel. Iron is melted by the burning coke and flows down the cupola. As the melt proceeds, new charges are added at the top. The flux combines with nonmetallic impurities in the iron to form slag, which can be removed. Both the molten iron and the slag are removed at the bottom of the cupola.

Electric arc furnaces (EAFs) are large, welded steel cylindrical vessels equipped with a removable roof through which three retractable carbon electrodes are inserted. The electrodes are lowered through the roof of the furnace and are energized by three phase alternating current, creating arcs that melt the metallic charge with their heat. Electric arc furnace capacities range from 5 to 345 megagrams (6 to 380 tons). Additional heat is produced by the resistance of the metal between the arc paths. Once the melting cycle is complete, the carbon electrodes are raised and the roof is removed. The vessel can then be tilted to pour the molten iron.

Electric induction furnaces are cylindrical or cup-shaped refractory-lined vessels that are surrounded by electrical coils. When these coils are energized with high frequency alternating current, they produce a fluctuating electromagnetic field which heats the metal charge. The induction furnace is simply a melting furnace to which high-grade scrap is added to make the desired product. Induction furnaces are kept closed except when charging, skimming, and tapping. The molten metal is tapped by tilting and pouring through a hole in the side of the vessels.

Refining

Refining is the process in which magnesium and other elements are added to molten iron to increase ductility. Ductile iron is formed as a steel matrix containing spheroidal particles (or nodules) of graphite. Ordinary cast iron contains flakes of graphite. Each flake acts as a crack, which makes cast iron brittle. Ductile irons have high tensile strength and are silvery in appearance.

Two widely used refining processes are the plunge method and the pour-over method. In plunging, magnesium or a magnesium alloy is loaded into a graphite "bell" which is plunged into a ladle of molten iron. A turbulent reaction takes place as the magnesium boils under the heat of the molten iron. As much as 65 percent of the magnesium may be evaporated. The magnesium vapor ignites in air, creating large amounts of smoke.

In the pour-over method, magnesium alloy is placed in the bottom of a vessel and molten iron is poured over it. Although this method produces more emissions and is less efficient than plunging, it requires no capital equipment other than air pollution control equipment.

Slag Removal and Molding

Slag is removed from furnaces through a tapping hole or door. Since slag is lighter than molten iron, it remains on top of the molten iron and can be raked or poured out. After slag has been removed, the iron is cast into molds.

Mold And Core Production

Molds are forms used to shape the exterior of castings. Cores are molded sand shapes used to make internal voids in castings. Molds are prepared from wet sand, clay and organic additives, and are usually dried with hot air. Cores are made by mixing sand with organic binders or organic polymers, molding the sand into a core and baking the core in an oven. Used sand from castings shakeout is recycled and cleaned to remove any clay or carbonaceous buildup. The sand is screened and reused to make new molds.

Casting And Finishing

Molten iron is tapped into a ladle or directly into molds. In larger, more mechanized foundries, filled molds are conveyed automatically through a cooling tunnel. The molds are then placed on a vibrating grid to shake the mold sand and core sand loose from the casting.

2.3 EMISSIONS AND CONTROLS[9,31,52]

Emission points and types of emissions from a typical foundry are shown in Figure 2.3-2.

Raw Material Handling and Preparation

Fugitive particulate emissions are generated from the receiving, unloading, and conveying of raw materials. These emissions can be controlled by enclosing the points of disturbance (e.g., conveyor belt transfer points) and routing air from enclosures through fabric filters or wet collectors.Scrap preparation with heat will emit smoke, organic compounds, and carbon monoxide; scrap preparation with solvent degreasers will emit organics. Catalytic incinerators and afterburners can control about 95 percent of organic and carbon monoxide emissions (see AP-42, Section 4.6, "Solvent Degreasing").

Metal Melting

Emissions released from melting furnaces include particulate matter, carbon monoxide, organic compounds, sulfur dioxide, nitrogen oxides, and small quantities of chloride and fluoride compounds. The particulates, chlorides, and fluorides are generated from incomplete combustion of carbon additives, flux additions, and dirt and scale on the scrap charge. Organic material on scrap and furnace temperature affect the amount of carbon monoxide generated. Fine particulate fumes emitted from melting furnaces results from the condensation of volatilized metal and metal oxides. The highest concentrations of furnace emissions occur when furnace doors are open during charging, backcharging, alloying, slag removal, and tapping operations. These emissions can escape into the furnace building or can be collected and vented through roof openings. Emission controls for melting and refining operations involve venting furnace gases and fumes directly to a control device. Canopy hoods or special hoods near furnace doors and tapping points capture emissions and route them to emissions control systems.

Cupolas

Coke burned in cupola furnaces produces several emissions. Incomplete combustion of coke causes carbon monoxide emissions, and sulfur in the coke gives rise to sulfur dioxide emissions. High energy scrubbers and fabric filters are used to control particulate emissions from cupolas and electric arc furnaces and can achieve efficiencies of 95 and 98 percent, respectively. A cupola furnace typically has an afterburner as well, which achieves up to 95 percent efficiency. The afterburner is located in the furnace stack to oxidize carbon monoxide and burn organic fumes, tars, and oils. Reducing these contaminants protects the particulate control device from possible plugging and explosion.

Toxic emissions from cupolas include both organic and inorganic materials. Cupolas produce the most toxic emissions compared to other melting equipment.

Electric Arc Furnaces

During melting in an electric arc furnace, particulate emissions of metallic and mineral oxides are generated by the vaporization of iron and transformation of mineral additives. This

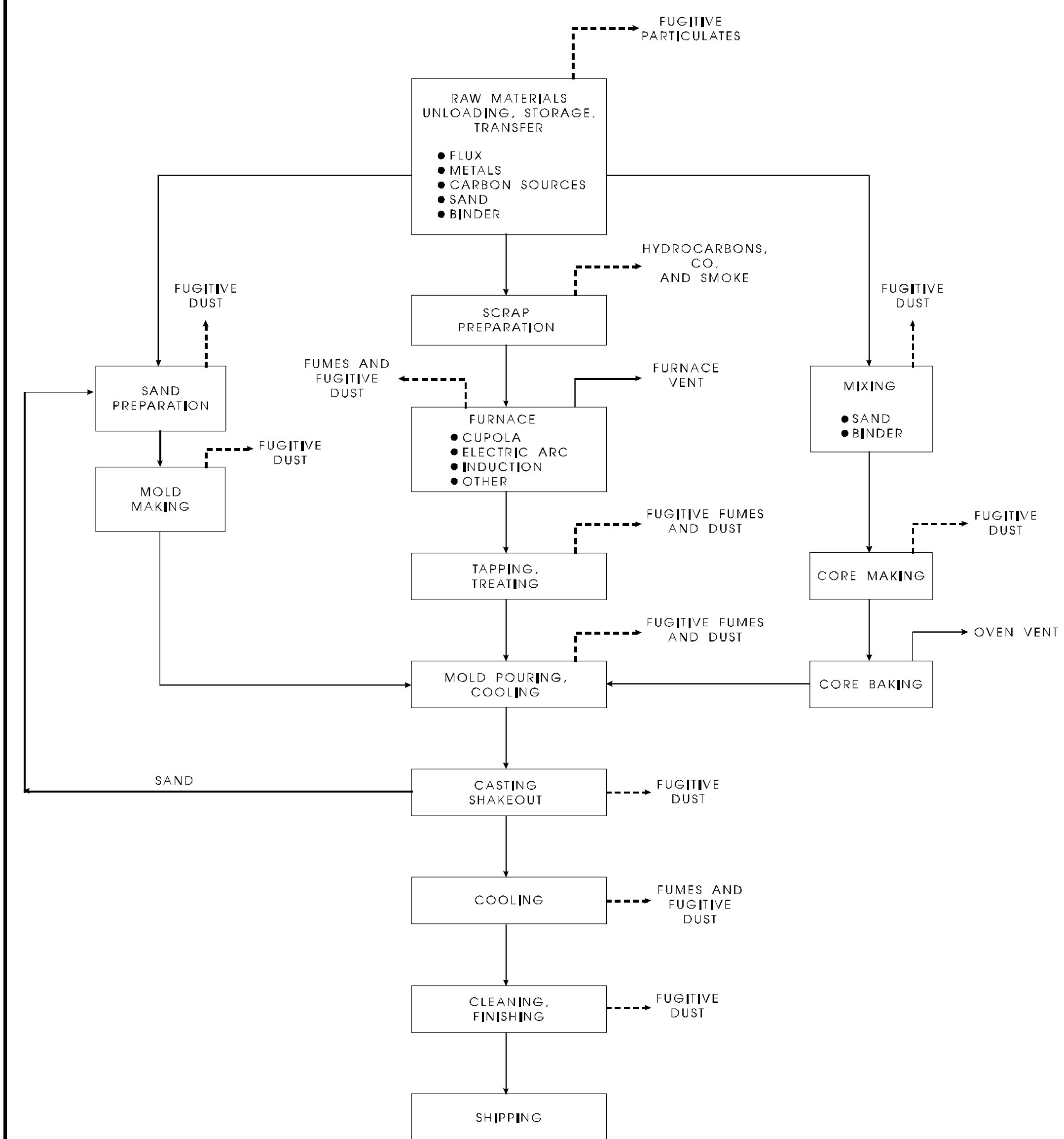

Figure 2.3-1. Emission points in a typical iron foundry

particulate matter is controlled by high-energy scrubbers (45 percent efficiency) and fabric filters (98 percent efficiency). Carbon monoxide emissions result from combustion of graphite from electrodes and carbon added to the charge. Hydrocarbons result from vaporization and incomplete combustion of any oil remaining on the scrap iron charge.

Electric Induction Furnaces

Electric induction furnaces using clean steel scrap produce particulate emissions comprised largely of iron oxides. High emissions from clean charge emissions are due to cold charges, such as the first charge of the day. When contaminated charges are used, higher emission rates result.

Dust emissions from electric induction furnaces also depend on the charge material composition, the melting method (cold charge or continuous), and the melting rate of the materials used. The highest emissions occur during a cold charge.

Because induction furnaces emit negligible amounts of hydrocarbon and carbon monoxide emissions and relatively little particulate, they are typically uncontrolled, except during charging and pouring operations.

Refining

Particulate emissions are generated during the refining of molten iron before pouring. The addition of magnesium to molten metal to produce ductile iron causes a violent reaction between the magnesium and molten iron, with emissions of magnesium oxides and metallic fumes. Emissions from pouring consist of metal fumes from the melt, and carbon monoxide, organic compounds, and particulate evolved from the mold and core materials. Toxic emissions of particulate, arsenic, chromium, halogenated hydrocarbons, and aromatic hydrocarbons, are released in the refining process. Emissions from pouring normally are captured by a collection system and vented, either controlled or uncontrolled, to the atmosphere. Emissions continue as the molds cool. A significant quantity of particulate is also generated during the casting shakeout operation. These fugitive emissions are controlled by either high energy scrubbers or fabric filters.

Mold and Core Production

The major pollutant emitted in mold and core production operations is particulate from sand reclaiming, sand preparation, sand mixing with binders and additives, and mold and core forming.

Organics, carbon monoxide, and particulate are emitted from core baking and organic emissions from mold drying. Fabric filters and high energy scrubbers generally are used to control particulate from mold and core production. Afterburners and catalytic incinerators can be used to control organics and carbon monoxide emissions.

In addition to organic binders, molds and cores may be held together in the desired shape by means of a cross-linked organic polymer network. This network of polymers undergoes thermal decomposition when exposed to the very high temperatures of casting, typically 1,400°C (2,550°F). At these temperatures it is likely that pyrolysis of the chemical binder will produce a complex of free radicals which will recombine to form a wide range of chemical compounds having widely differing concentrations.

There are many different types of resins currently in use having diverse and toxic compositions. There are no data currently available for determining the toxic compounds in a particular resin which are emitted to the atmosphere and to what extent these emissions occur.

Casting and Finishing

Emissions during pouring include decomposition products of resins, other organic compounds, and particulate matter. Finishing operations emit particulates during the removal of imperfections such as burrs, risers, and gates and during shot blast cleaning. These emissions are controlled by cyclone separators and fabric filters. Emissions are related to mold size, mold composition, sand to metal ratio, pouring temperature, and pouring rate.

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.

Responses were received from the American Foundryman's Society and the U.S. EPA (Sources 2 and 12). No responses were received from the remaining sources. The American Foundryman's Society indicated that cupolas are still used in iron foundries, but induction furnaces are expected to increase in popularity. They also said their society is already working with the EPA on gathering emissions data. The EPA indicated that the program for updating iron foundry emissions data had just started, and no information was therefore available.

2.5 REFERENCES FOR CHAPTER 2

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3. Systems Analysis of Emissions and Emission Control in the Iron Foundry Industry, Volume II: Exhibits, APTD-0645, U.S. Environmental Protection Agency, Research Triangle Park, NC, February 1971.

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6. P. Fennelly and P. Spawn, Air Pollution 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.

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9. Particulate Emission Test Report On A Gray Iron Cupola at Cherryville Foundry Works, Cherryville, NC, Department of Natural and Economic Resources, Raleigh, NC, December 18, 1975.

10. Statistical Analysis of the Operating Parameters Which Affect Cupolas Emissions, DOE Contract No. EY-76-5-02-2840.*000, Center for Air Environment Studies, Pennsylvania State University, University Park, PA, December 1977.

11. Air Pollution Engineering Manual, Second Edition, AP-40, U.S. Environmental Protection Agency, Research Triangle Park, NC, May 1973. Out of print.

12. Written communication from Dean Packard, Department of Natural Resources, Madison, WI, to Douglas Seeley, Alliance Technology, Bedford, MA, April 15, 1982.

13. Particulate Emissions Testing at Opelika Foundry, Birmingham, AL, Air Pollution Control Commission, Montgomery, AL, November 1977 - January 1978.

14. Written communication from Minnesota Pollution Control Agency, St. Paul, MN, to Mike Jasinski, Alliance Technology, Bedford, MA, July 12, 1982.

15. Stack Test Report, Dunkirk Radiator Corporation Cupola Scrubber, State Department of Environmental Conservation, Region IX, Albany, NY, November 1975.

16. Particulate Emission Test Report For A Scrubber Stack For A Gray Iron Cupola At Dewey Brothers, Goldsboro, NC, Department Of Natural Resources, Raleigh, NC, April 7, 1978.

17. Stack Test Report, Worthington Corp. Cupola, State Department Of Environmental Conservation, Region IX, Albany, NY, November 4-5, 1976.

18. Stack Test Report, Dresser Clark Cupola Wet Scrubber, Orlean, NY, State Department Of Environmental Conservation, Albany, NY, July 14 & 18, 1977.

19. Stack Test Report, Chevrolet Tonawanda Metal Casting, Plant Cupola #3 And Cupola #4, Tonawanda, NY, State Department Of Environmental Conservation, Albany, NY, August 1977.

20. Stack Analysis For Particulate Emission, Atlantic States Cast Iron Foundry/Scrubber, State Department Of Environmental Protection, Trenton, NJ, September 1980.

21. Fine Particle Scrubber Performance, EPA-650/2-74-093, U.S. Environmental Protection Agency, Cincinnati, OH, October 1974.

22. National Dust Collector Model 850 Variable Rod Module Venturi Scrubber Evaluation, EPA-600/2-76-282, U.S. Environmental Protection Agency, Cincinnati, OH, December 1976.

23. Source Test, Electric Arc Furnace At Paxton-Mitchell Foundry, Omaha, NB, Midwest Research Institute, Kansas City, MO, October 1974.

24. Source Test, John Deere Tractor Works, East Moline, IL, Gray Iron Electric Arc Furnace, Walden Research, Willmington, MA, July 1974.

25. Characterization Of Inhalable Particulate Matter Emissions From An Iron Foundry, Lynchburg Foundry, Archer Creek Plant, EPA-600/X-85-328, U.S. Environmental Protection Agency, Cincinnati, OH, August 1984.

26. Particulate Emissions Measurements From The Rotoclone And General Casting Shakeout Operations Of United States Pipe & Foundry, Inc., Anniston, AL, Black, Crow and Eidsness, Montgomery, AL, November, 1973.

27. Report Of Source Emissions Testing At Newbury manufacturing, Talladega, AL, State Air Pollution Control Commission, Montgomery, AL, May 15-16, 1979.

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32. Emissions Study Of Industrial Sources Of Lead Air Pollutants, 1970, APTD-1543, U.S. Environmental Protection Agency, Research Triangle Park, NC, April 1973.

33. Emission Test No. EMB-71-CI-27, Office Of Air Quality Planning and Standards, U.S. Environmental Protection Agency, Research Triangle Park, NC, February 1972.

34. Emission Test No. EMB-71-CI-30, Office Of Air Quality Planning And Standards, U.S. Environmental Protection Agency, Research Triangle Park, NC, March 1972.

35. Assessment Of Fugitive Particulate Emission Factors For Industrial Processes, EPA-450/3-78-107, U.S. Environmental Protection Agency, Research Triangle Park, NC, September 1978.

36. Gray Iron Foundry Industry Particulate Emissions: Source Category Report, EPA-600/7-86-054, U.S. Environmental Protection Agency, Cincinnati, OH, December, 1986.

37. PM_{10} Emission Factor Listing Developed By Technology Transfer, EPA-450/4-022, November 1989.

38. Generalized Particle Size Distributions For Use In Preparing Size Specific Particulate Emission Inventories, EPA-450/4-86-013, July 1986.

39. Emission Factors For Iron Foundries - Criteria And Toxic Pollutants, EPA Control Technology Center, Research Triangle Park, EPA-600/2-90-044, August 1990.

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43. Compilation of Air Pollutant Emissions Factors, AP-42, (NTIS PB 89-128631), Supplement B, Volume I, Fourth Edition, U.S. Environmental Protection Agency, 1988.

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45. Environmental Assessment of Iron Casting, EPA-600/2-80-021 (NTIS PB 80-187545), U.S. Environmental Protection Agency, 1980.

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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 iron foundries. This search included the following references:

1) AP-42 background files maintained by the Emission Factor and Methodologies Section. This is the source of the 13 emission tests that are reviewed in Section 4.3.
2) Files maintained by the Emission Standards Division. Although no files are available at this time, 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). Reviewed but not used due to uncertain quality of data.
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.
8) The EPA databases, including *Speciation Database Management System* (SPECIATE), the *Crosswalk/Air Toxic Emission Factor Data Base Management System* (XATEF). Both of these database systems were reviewed without tangible benefits.
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 in an attempt to get primary emission source tests for iron foundries. No primary emission source tests for iron foundries were found.

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 (e.g., 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 the EPA reference test methods, although these 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. Source operation. 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. Sampling procedures. 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

Nonmethane Organic Compounds.

No data on nonmethane organic compounds (NMOC) emissions were found for the iron foundry process. However, PES has calculated total NMOC emission factors from source tests using cupola and electric arc furnaces. Measurements of methane are not included in these source tests. The cupola uses coke as fuel to create the temperatures required to melt steel and iron. The electric arc furnace uses electrical resistance to melt metal. Neither of these processes use methane gas as a fuel. PES believes that most, if not all, hydrocarbon emissions from cupolas and electric arc furnaces represent nonmethane organic compounds. This engineering judgment is a candidate for rigorous evaluation. However, until the issue is resolved, PES offers Table 4.1-1 as the best information available concerning emissions of NMOC.

Analyzers were used during source tests (References 9 and 10) to record organic compound concentrations in parts per million (ppm), as discussed in Section 4.3. Reference 9 is a source test documenting organic compound emissions as concentrations (ppm) from an electric arc furnace. Test results have a range of 1.74 to 14.7 ppm, with a mean of approximately 10 ppm. Reference 10 is another source test that documents hydrocarbon emission rates that range from 0.55 to 1.25 kg/hr, with a mean emission rate value of 0.87 kg/hr (1.21 to 2.76 lbs/hr with a mean emission rate of 1.91 lbs/hr). PES calculated an emission factor based upon the mean value and a production rate of 4 Mg/hr (8 tons/hr). The emission factor for organic compounds from an electric arc furnace is 0.12 kg/Mg (0.24 lbs/ton). This emission factor is within the TNMOC range of 0.03 to 0.15 kg/Mg, as shown in Table 2.32. Organic compound emission factors found in a iron foundry casting operation, as reported in the Reference 12 source test, are given in Table 4.1-1.

Lead.

Table 2.3-2 contains emission factors for lead from cupola, electric induction, and reverberatory furnaces. Table 78 of the AP-40 lists lead as being approximately 19 percent by qualitative spectrographic analysis in two samples of baghouse dust from a cupola furnace. Reference 32 of Chapter 2.0 reports that tests have shown foundry furnace emissions range from 0.5 to 17 percent lead. The report relates lead emissions to the quality of scrap used in the furnace. No emission source test listed lead emissions.

TABLE 4.1-1 (METRIC UNITS)
TOTAL NMOC

Reference, Source Test #	Test Rating	Test Method	Run #	Production Rate[a]	Emission Rate[b]	Emission Factor[c]
Control device: Uncontrolled (casting)						
12	D		1	10.9	1.60	0.15
			2	10.9	1.56	0.15
			3	10.9	1.75	0.16
			Average	10.9	1.64	0.15

[a]Units in kg/hr.
[b]Units in kg/hr.
[c]Units in kg/Mg.

TABLE 4.1-1 (ENGLISH UNITS)
TOTAL NMOC

Reference, Source Test #	Test Rating	Test Method	Run #	Production Rate[a]	Emission Rate[b]	Emission Factor[c]
Control device: Uncontrolled (casting)						
12	D		1	12	3.53	0.29
			2	12	3.43	0.29
			3	12	3.86	0.32
			Average	12	3.61	0.30

[a]Units in lb/hr.
[b]Units in lb/hr.
[c]Units in lb/ton.

Sulfur dioxide.

Data on emissions of sulfur dioxide (SO_2) were found in two of the emission source tests reviewed by PES for the iron foundry process. Reference 9 is a source test reporting SO_2 emissions. The SO_2 range is from 1.7 to 17.7 ppm, with a mean of 2.5 ppm. Reference 10 is a source test that measured SO_2 emissions and provided emission rates and production rates. These values have been used by PES to calculate emission factors found in Table 4.1-2. The average controlled (baghouse) emission factor is 0.12 kg/Mg for an electric arc furnace. Table 2.3-2 lists SO_2 emissions from electric arc furnaces as negligible.

TABLE 4.1-2 (METRIC UNITS)
SULFUR DIOXIDE

Reference, Source Test #	Test Rating	Test Method	Run #	Production Rate[a]	Emission Rate[b]	Emission Factor[c]
Control device: Baghouse (electric arc furnace)						
10			1	7.26	0.84	0.12
			2	7.26	0.20	0.03
			3	7.26	0.40	0.06
			Average	7.26	0.48	0.07

[a]Units in kg/hr.
[b]Units in kg/hr.
[c]Units in kg/Mg.

TABLE 4.1-2 (ENGLISH UNITS)
SULFUR DIOXIDE

Reference, Source Test #	Test Rating	Test Method	Run #	Production Rate[a]	Emission Rate[b]	Emission Factor[c]
Control device: Baghouse (electric arc furnace)						
10			1	8	1.86	0.23
			2	8	0.45	0.06
			3	8	0.88	0.11
			Average	8	1.06	0.13

[a]Units in lb/hr.
[b]Units in lb/hr.
[c]Units in lb/ton.

Nitrogen oxides.

Data on nitrogen oxides is reported in Reference 10 (controlled emissions from an electric arc furnace) as emission rates along with production rates. PES has calculated emission factors for the two sampling periods and report them in Table 4.1-3. The average emission factor of 0.23 kg/Mg of nitrogen oxides is within the range of 0.02 to 0.3 kg/Mg for an electric arc furnace, as shown in Table 2.3-2.

TABLE 4.1-3 (METRIC UNITS)
NITROGEN OXIDES

Reference, Source Test #	Test Rating	Test Method	Run #	Production Rate[a]	Emission Rate[b]	Emission Factor[c]
Control device: Baghouse (Electric arc furnace)						
1			1	7.26	0.68	0.10
			2	7.26	1.13	0.16
			Average	7.26	0.91	0.13

[a]Units in kg/hr.
[b]Units in kg/hr.
[c]Units in kg/Mg.

TABLE 4.1-3 (ENGLISH UNITS)
NITROGEN OXIDES

Reference, Source Test #	Test Rating	Test Method	Run #	Production Rate[a]	Emission Rate[b]	Emission Factor[c]
Control device: Baghouse (Electric arc furnace)						
1			1	8	1.51	0.19
			2	8	2.50	0.31
			Average	8	2.00	0.25

[a]Units in lb/hr.
[b]Units in lb/hr.
[c]Units in lb/ton.

Carbon monoxide.

Reference 9 is a source test containing emissions for carbon monoxide (CO). An analyzer was used to sample CO concentrations. Carbon monoxide readings had a range of 19 to 294 ppm, and a mean of approximately 120 ppm. Reference 10 also used an analyzer, but reported carbon monoxide emissions as emission rates. However, the emission rates are expressed as operating within a range of 3.70 to 17.3 kg/hr, with a mean emission rate value of 10.1 kg/hr (8.1 to 38.2 lbs/hr with a mean emission rate of 22.2 lbs/hr). A calculated emission factor based upon the mean value and a production rate of 4 Mg/hr (8 tons/hr), results in an emission factor is 2.53 kg/Mg (2.78 lbs/ton) for carbon monoxide. Table 2.3-2 lists the range of carbon monoxide at 0.5 to 19 kg/Mg for an electric arc furnace.

Particulate Matter.

Eight sets of particulate emission factors are depicted in Table 4.1-4 . They are developed from referenced source tests discussed in Section 4.3. Proper use of these emission factors is enhanced when used in conjunction with a review of the specific emission source test discussion in Section 4.3. The Reference 1 source test (cupola) and Reference 9 source test (electric arc furnace) have average calculated emission factors of 7.88 kg/Mg and 8.73 kg/Mg, respectively. Table 2.3-1 lists the emission factors for the same uncontrolled sources as 6.9 and 6.3 kg/Mg. No emissions data for particles less than 10 micrometers in diameter (PM_{10}) were available.

TABLE 4.1-4 (METRIC UNITS)
PARTICULATE

Reference, Source Test #	Test Rating	Test Method	Run #	Production Rate[a]	Emission Rate[b]	Emission Factor[c]
Control device: Uncontrolled (Cupola)						
1	A	5	1	3.08	15.10	4.90
			2	3.08	11.88	3.87
			3	4.17	17.14	4.11
			Average	3.45	14.71	4.29
Control device: Scrubber (Cupola)						
3	A	5	1	12.90	7.71	0.60
			2	13.82	6.01	0.45
			3	14.61	5.69	0.39
			Average	13.77	6.47	0.47
Control device: Impingement-type scrubber						
4	B	5	1	8.26	15.51	1.88
			2	8.26	16.87	2.05
			3	8.26	20.23	2.45
			Average	8.26	17.54	2.13
Control device: Venturi scrubber						
5	A	5	1	15.65	28.43	1.82
			2	16.73	38.75	2.32
			3	14.50	34.88	2.41
			Average	15.63	34.02	2.18

[a]Units in kg/hr.
[b]Units in kg/hr.
[c]Units in kg/Mg.

TABLE 4.1-4 (METRIC UNITS) (*continued*)
PARTICULATE

Reference, Source Test #	Test Rating	Test Method	Run #	Production Rate[a]	Emission Rate[b]	Emission Factor[c]
Control device: Uncontrolled (Electric arc furnace)						
9	A	5	1	1.81	31.76	8.76
			2	1.81	27.24	7.51
			3	1.81	35.99	9.92
			Average	1.81	31.66	8.73
Control device: Fabric filter						
9	A	5	1	1.81	1.389	0.50
			2	1.81	0.247	0.07
			3	1.81	0.353	0.1
			Average	1.81	0.663	0.19
Control device: Fabric filter (Filtered particulate)						
10	B	5	1	3.63	1.69	0.24
			2	3.63	1.04	0.14
			3	3.63	0.96	0.13
			Average	3.63	1.23	0.17
Control device: Fabric filter (Total particulate)						
10	A	5	1	3.63	2.80	0.50
			2	3.63	1.72	0.24
			3	3.63	1.28	0.18
			Average	3.63	1.93	0.27

[a]Units in kg/hr.
[b]Units in kg/hr.
[c]Units in kg/Mg.

TABLE 4.1-4 (METRIC UNITS) (*concluded*)
PARTICULATE

Reference, Source Test #	Test Rating	Test Method	Run #	Production Rate[a]	Emission Rate[b]	Emission Factor[c]
Control device: Centrifugal separator and fabric filter						
13	D	5	1	1.35	4.88	3.62
			2	1.35	2.02	1.50
			3	1.35	3.24	2.40
			Average	1.35	3.38	2.50
Control device: Scrubber (Filterable casting and mold sand handling)						
15	C	5	1	10.89	0.78	0.07
			2	10.89	0.58	0.06
			3	10.89	0.75	0.07
			Average	10.89	0.70	0.06
Control device: Scrubber						
15	C	5	1	10.89	1.60	0.15
			2	10.89	1.56	0.15
			3	10.89	1.75	0.16
			Average	10.89	1.64	0.15

[a]Units in kg/hr.
[b]Units in kg/hr.
[c]Units in kg/Mg.

TABLE 4.1-4 (ENGLISH UNITS)
PARTICULATE

Reference, Source Test #	Test Rating	Test Method	Run #	Production Rate[a]	Emission Rate[b]	Emission Factor[c]
Control device: Uncontrolled (Cupola)						
1	A	5	1	3.40	33.3	9.79
			2	3.39	26.2	7.73
			3	4.60	37.8	8.22
			Average	3.80	32.4	8.58
Control device: Scrubber (Cupola)						
3	A	5	1	14.22	16.99	1.195
			2	15.23	13.25	0.890
			3	16.10	12.55	0.780
			Average	15.18	14.26	0.948
Control device: Impingement-type scrubber						
4	B	5	1	9.10	34.2	3.76
			2	9.10	37.2	4.09
			3	9.10	44.6	4.90
			Average	9.10	38.6	4.25
Control device: Venturi scrubber						
5	A	5	1	17.25	32.69	3.63
			2	18.44	85.45	4.63
			3	16.00	76.90	4.81
			Average	17.23	75.01	4.36

[a]Units in lb/hr.
[b]Units in lb/hr.
[c]Units in lb/ton.

TABLE 4.1-4 (ENGLISH UNITS) (*continued*)
PARTICULATE

Reference, Source Test #	Test Rating	Test Method	Run #	Production Rate[a]	Emission Rate[b]	Emission Factor[c]
Control device: Uncontrolled						
9	A	5	1	2	70.02	17.51
			2	2	60.05	15.01
			3	2	79.35	19.84
			Average	2	69.81	17.45
Control device: Fabric filter						
9	A	5	1	2	3.06	0.99
			2	2	0.55	0.14
			3	2	0.78	0.20
			Average	2	1.46	0.37
Control device: Fabric filter (Filtered particulate)						
10	A	5	1	8	3.72	0.47
			2	8	2.26	0.28
			3	8	2.11	0.26
			Average	8	2.71	0.34
Control device: Fabric filter (Total particulate)						
10	A	5	1	8	6.17	0.99
			2	8	3.81	0.48
			3	8	2.83	0.35
			Average	8	4.27	0.53

[a]Units in lb/hr.
[b]Units in lb/hr.
[c]Units in lb/ton.

TABLE 4.1-4 (ENGLISH UNITS) (*concluded*)
PARTICULATE

Source Test #	Test Rating	Test Method	Run #	Production Rate[a]	Emission Rate[b]	Emission Factor[c]
Control device: Centrifugal separator and fabric filter						
13	D	5	1	1.49	10.77	7.23
			2	1.49	4.46	2.99
			3	1.49	7.14	4.79
			Average	1.49	7.46	5.00
Control device: Scrubber (Filterable casting and mold sand handling)						
15	C	5	1	12	1.72	0.14
			2	12	1.27	0.11
			3	12	1.65	0.14
			Average	12	1.55	0.12
Control device: Scrubber						
15	D	5	1	12	3.53	0.29
			2	12	3.43	0.29
			3	12	3.86	0.32
			Average	12	3.61	0.30

[a]Units in lb/hr.
[b]Units in lb/hr.
[c]Units in lb/ton.

4.2 NONCRITERIA POLLUTANT EMISSION DATA

Hazardous Air Pollutants.

Hazardous Air Pollutants (HAPs) are defined in the 1990 Clean Air Act Amendments. Reference 14, a source test discussed in Section 4.3, reported the xylene (CAS No. 1330207) emission rate at 0.017 kg/hr (0.037 lb/hr) and an emission rate for 1,2,2 trifluoroethane (CAS No. 79016) of 0.018 kg/hr (0.039 lb/hr) from a mold curing oven. The SPECIATE data base references testing of 12 binder and sand formulations during a casting operation in an iron foundry. This emission test reports the following HAPS were found; formaldehyde (CAS No. 50-00-0), acrolein (CAS No. 107-02-8), benzene (CAS No. 71-43-2), toluene (CAS No. 108-88-3), o-xylene CAS No. 95-47-6), m-xylene (CAS No. 108-95-2), phenol (CAS No. 108-95-2), and naphthalene (CAS No. 91-20-3). Insufficient data were presented to develop emission factors from these sources.

Global Warming Gases.

Pollutants such as methane, carbon dioxide, and nitrous oxide have been found to contribute to overall global warming. No data on emissions of these pollutants were found for the iron foundry process.

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 the emissions tests utilized in developing emission factors for iron foundry production, as with 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.

Stratospheric Ozone-Depleting Gases.

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

4.3 REVIEW OF SPECIFIC DATA SETS

The major change to Section 12.10 is related to a review of references footnoted in the emission tables. Table 2.3-1 emission factors have been downgraded from "B" and "C" to "D" and "E" ratings in this edition. Emission factors for control devices with "E" ratings are not based on rated emission tests, but instead depend upon general studies that used emission tests not available for review. The "D" ratings are based on general studies and one emission source test reviewed below. In each case, the emission factor calculated from information in the source test is different from the emission factor listed in the October 1986 revision of Section 12.10. The original emission factors have not been changed in this edition from those published in 1986. PES believes that previously published emission factors should not be changed if found to be different based on a single source test calculated emission factor.

The emission factors for Table 2.3-2 were downgraded from "B" to "E" because the emission factors listed are based entirely upon general studies and unfounded assumptions. The table has been reformatted to permit emission factors for individual control devices to be changed in future editions as more emission source tests become available for review and the assignment of rating factors. PES believes that lead emission rates are not fixed, but are instead variable, and primarily a function of the amount of lead contamination found in scrap metals. More information is needed to establish a range of emission rates of lead in the iron foundries industry. The sulfur dioxide (SO_2) emission factor is assumed to be equal to 30 percent of the sulfur content found in coke fuel. This emission rate assumption also requires additional study.

PES reviewed a total of 18 source tests. Thirteen were found in the EFMS AP-42 files. The remaining five were provided by state agencies. Compliance test procedures used in iron foundries for particulate emissions are based upon process charge (total material charged) and not production rate. The production rate is used to calculate emission factors. Process charge is normally made up from iron and scrap steel, coke, lime, flux, and in some cases alloy metals. When a compliance source test lists components of the process charge, PES calculated the emission factor based on product produced. However, if the process charge in the source test does not delineate the metal weight, either the test information is not used or the emission rate is only considered here and is not included in emission factor tables. Each source test is reviewed below.

TABLE 4.3-1 (METRIC UNITS)
PARTICULATE EMISSION FACTORS FOR IRON FURNACES
All Emission Factors in kg/Mg Iron Produced
Ratings (A-E) Follow Each Factor

Process	Control Device	Total Particulate	
Cupola	Uncontrolled[a]	6.9	D
(SCC 30400301)	Scrubber[b]	1.6	D
	Venturi scrubber[c]	1.5	D
	Electrostatic precipitator[d]	0.7	D
	Baghouse[e]	0.3	D
	Single wet cap[f]	4.0	E
	Impingement scrubber[f]	2.5	E
	High energy scrubber[f]	0.4	D
Electric arc furnace (SCC 30400304)	Uncontrolled[g]	6.3	D
	Baghouse[h]	0.2	D
Electric induction furnace (SCC 30400303)	Uncontrolled[i]	0.5	E
	Baghouse[j]	0.1	E
Reverberatory (SCC 30400302)	Uncontrolled[k]	1.1	E
	Baghouse[j]	0.1	E

[a] References 1, 4, 9 and 10.
[b] References 12 and 15. Includes averages for wet cap and other scrubber types not already listed.
[c] References 12, 17 and 19.
[d] References 8 and 11.
[e] References 12 through 14.
[f] References 8, 11, 29 and 30.
[g] References 1, 6 and 23.
[h] References 6, 23 and 24.
[i] References 1 and 12. For metal melting only.
[j] Reference 4.
[k] Reference 37.

TABLE 4.3-1 (ENGLISH UNITS)
PARTICULATE EMISSION FACTORS FOR IRON FURNACES
All Emission Factors in lbs/ton Iron Produced
Ratings (A-E) Follow Each Factor

Process	Control Device	Total Particulate	
Cupola (SCC 30400301)	Uncontrolled[a]	13.8	D
	Scrubber[b]	3.1	D
	Venturi scrubber[c]	3.0	D
	Electrostatic precipitator[d]	1.4	D
	Baghouse[e]	0.7	D
	Single wet cap[f]	8.0	E
	Impingement scrubber[f]	5.0	E
	High energy scrubber[f]	0.8	D
Electric arc furnace (SCC 30400304)	Uncontrolled[g]	12.7	D
	Baghouse[h]	0.4	D
Electric induction furnace (SCC 30400303)	Uncontrolled[i]	0.9	E
	Baghouse[j]	0.2	E
Reverberatory (SCC 30400302)	Uncontrolled[k]	2.1	E
	Baghouse[j]	0.2	E

[a] References 1, 4, 9 and 10.
[b] References 12 and 15. Includes averages for wet cap and other scrubber types not already listed.
[c] References 12, 17 and 19.
[d] References 8 and 11.
[e] References 12 through 14.
[f] References 8, 11, 29 and 30.
[g] References 1, 6 and 23.
[h] References 6, 23 and 24.
[i] References 1 and 12. For metal melting only.
[j] Reference 4.
[k] Reference 37.

TABLE 4.3-2 (METRIC UNITS)
CRITERIA GASEOUS AND LEAD EMISSION FACTORS FOR IRON FOUNDRIES

All Emission Factors in Weight of Iron Produced
Ratings (A-E) Follow Each Factor
Units in kg/Mg

Furnace type	CO		SO_2		NO_x		VOC		Lead[a]	
Cupola (SCC 30400301)										
Uncontrolled	73[b]	E	0.6S[c]	E					0.05-0.6	E
High energy scrubber			0.3S[c]	E						
Electric arc[d] (SCC 30400304)	0.5-19	E	Neg	E	0.02-0.3	E	0.03-0.15	E		
Electric induction[e] (SCC 30400303)	Neg	E	Neg	E					0.005-0.05	E
Reverberatory (SCC 30400302)									0.006-0.07	E

[a]References 11, 31, 34.
[b]Reference 2.
[c]Reference 4. S = % sulfur in the coke. Assumes 30 percent of sulfur is converted to SO_2.
[d]Reference 4,6.
[e]References 8, 11, 29, 30.

TABLE 4.3-2 (ENGLISH UNITS)
CRITERIA GASEOUS AND LEAD EMISSION FACTORS FOR IRON FOUNDRIES

All Emission Factors in Weight of Iron Produced
Ratings (A-E) Follow Each Factor
Units in lb/ton

Furnace type	CO		SO_2		NO_x		VOC		Lead[a]	
Cupola (SCC 30400301)										
Uncontrolled	145[b]	E	$1.2S$[c]	E					0.1-1.1	E
High energy scrubber			$0.6S$[c]	E						
Electric arc[d] (SCC 30400304)	1-37	E	Neg	E	0.04-0.6	E	0.06-0.3	E		
Electric induction[e] (SCC 30400303)	Neg	E	Neg	E					0.009-0.1	E
Reverberatory (SCC 30400302)									0.012-0.14	E

[a]References 11, 31, 34.
[b]Reference 2.
[c]Reference 4. S = % sulfur in the coke. Assumes 30 percent of sulfur is converted to SO_2.
[d]Reference 4,6.
[e]References 8, 11, 29, 30.

TABLE 4.3-3 (METRIC UNITS)
PARTICULATE EMISSION FACTORS FOR ANCILLARY OPERATIONS AND FUGITIVE SOURCES AT IRON FOUNDRIES

All Emission Factors in kg/Mg Iron Produced

Ratings (A-E) Follow Each Factor

Process	SCC's	Control Device	Total Emission Factor		Emitted to Work Environment		Emitted to Atmosphere	
Scrap and charge handling, heating[a]	30400315	Uncontrolled	0.3	E	0.25	E	0.1	E
Magnesium treatment[b]	30400310	Uncontrolled	0.9	E	0.9	E	0.2	E
Refining[c]	30400310	Uncontrolled	1.5-2.5	E				
Pouring, cooling[d]	30400320	Uncontrolled	2.1	E				
Shakeout[e]	30400333	Uncontrolled[b]	1.6	E				
Cleaning, finishing[a]	30400352	Uncontrolled	8.5	E	0.15	E	0.05	E
Sand handling (in kg/Mg sand handled)	30400355	Uncontrolled[b] Scrubber[f] Baghouse[g]	1.8 0.023 0.10	E D E				
Core making, baking[a]	30400371	Uncontrolled	0.6	E	0.6	E	0.6	E

[a]Reference 4.
[b]Reference 1,4.
[c]Reference 35.
[d]References 1, 3, 25.
[e]Reference 1.
[f]References 12, 27.
[g]Reference 12.

TABLE 4.3-3 (ENGLISH UNITS)
PARTICULATE EMISSION FACTORS FOR ANCILLARY OPERATIONS AND FUGITIVE SOURCES AT IRON FOUNDRIES

All Emission Factors in lb/ton of Iron Produced

Ratings (A-E) Follow Each Factor

Process	SCC'S	Control Device	Total Emission Factor		Emitted to Work Environment		Emitted to Atmosphere	
			lb/ton	Rating	lb/ton	Rating	lb/ton	Rating
Scrap and charge handling, heating[a]	30400315	Uncontrolled	0.6	E	0.5	E	0.2	E
Magnesium treatment[b]	30400310	Uncontrolled	1.8	E	1.8	E	0.4	E
Refining[c]	30400310	Uncontrolled	3-5	E				
Pouring, cooling[d]	30400320	Uncontrolled	4.2	E				
Shakeout[e]	30400333	Uncontrolled[c]	3.2	E				
Cleaning, finishing[a]	30400352	Uncontrolled	17	E	0.3	E	0.1	E
Sand handling (in lb/ton of sand handled)	30400355	Uncontrolled[b] Scrubber[f] Baghouse[g]	3.6 0.046 0.20	E D E				
Core making, baking[a]	30400371	Uncontrolled	1.1	E	1.1	E	1.1	E

[a]Reference 4.
[b]Reference 1, 4.
[c]Reference 35.
[d]References 1, 3, 25.
[e]Reference 1.
[f]References 12, 27.
[g]Reference 12.

TABLE 4.3-4 (METRIC UNITS)
PARTICLE SIZE DISTRIBUTION DATA AND EMISSION FACTORS FOR IRON FOUNDRIES[a]
All Emission Factors in kg/Mg of Metal Produced
Ratings (A-E) Follow Each Factor

Source	Particle size (µm)	Cumulative mass % ≤ state size[b]	Cumulative mass emission factor	Rating
Cupola Furnace[b] (SCC 30400301)				
Uncontrolled	0.5	44.3	3.1	C
	1.0	69.1	4.8	
	2.0	79.6	5.5	
	2.5	84.0	5.8	
	5.0	90.1	6.2	
	10.0	90.1	6.2	
	15.0	90.6	6.3	
		100.0	6.9	
Controlled by baghouse[c]	0.5	83.4	0.33	E
	1.0	91.5	0.37	
	2.0	94.2	0.38	
	2.5	94.9	0.38	
	5.0	94.9	0.38	
	10.0	95.0	0.38	
	15.0	100.0	0.4	
Controlled by venturi scrubber[d]	0.5	56.0	0.84	C
	1.0	70.2	1.05	
	2.0	77.4	1.16	
	2.5	77.7	1.17	
	5.0	77.7	1.17	
	10.0	77.7	1.17	
	15.0	77.7	1.17	
		100.0	1.5	

[a] Mass emission rate data available in Tables 2.3-1 and 2.3-3 to calculate size-specific emission factors.
[b] References 13, 21, 22, 25, 26.
[c] Reference 3, Exhibit VI-15. Averaged from data on two foundries. Because original test data could not be obtained, emission factor rating is E.
[d] Pressure drop across venturi: approximately 102 inches of water.

TABLE 4.3-4 (METRIC UNITS) (*continued*)
PARTICLE SIZE DISTRIBUTION DATA AND EMISSION FACTORS FOR IRON FOUNDRIES[a]
All Emission Factors in kg/Mg of Metal Produced
Ratings (A-E) Follow Each Factor

Source	Particle size (µm)	Cumulative mass % ≤ state size[b]	Cumulative mass emission factor	Rating
Electric Arc Furnace[d] (SCC 30400304)				
Uncontrolled	1.0	13.0	0.8	E
	2.0	57.5	3.7	
	5.0	82.0	5.2	
	10.0	90.0	5.8	
	15.0	93.5	6.0	
		100.0	6.4	
Pouring, cooling[b] (SCC 30400320 & 30400325)				
Uncontrolled	0.5	d		D
	1.0	19.0	0.40	
	2.0	20.0	0.42	
	2.5	24.0	0.50	
	5.0	34.0	0.71	
	10.0	49.0	1.03	
	15.0	72.0	1.51	
		100.0	2.1	
Shakeout[b] (SCC 30400333)				
Uncontrolled	0.5	23.0	0.37	E
	1.0	37.0	0.59	
	2.0	41.0	0.66	
	2.5	42.0	0.67	
	5.0	44.0	0.70	
	10.0	70.0	1.12	
	15.0	99.9	1.60	
		100.0	1.60	

[a] Mass emission rate data available in Tables 2.3-1 and 2.3-3 to calculate size-specific emission factors.
[b] References 13, 21, 22, 25, 26.
[c] Reference 3, Exhibit VI-15. Averaged from data on two foundries. Because original test data could not be obtained, Emission Factor Rating is E.
[d] Pressure drop across venturi: approximately 102 inches of water.

TABLE 4.3-4 (ENGLISH UNITS)
PARTICLE SIZE DISTRIBUTION DATA AND EMISSION FACTORS FOR IRON FOUNDRIES[a]
All Emission Factors in lb/ton of Metal Produced
Ratings (A-E) Follow Each Factor

Source	Particle size (µm)	Cumulative mass % ≤ state size[b]	Cumulative mass emission factor (lb/ton metal)	Rating
Cupola Furnace[b] (SCC 30400301)				
Uncontrolled	0.5	44.3	6.2	C
	1.0	69.1	9.6	
	2.0	79.6	11.0	
	2.5	84.0	11.6	
	5.0	90.1	12.4	
	10.0	90.1	12.4	
	15.0	90.6	12.6	
		100.0	13.8	
Controlled by baghouse[c]	0.5	83.4	0.66	E
	1.0	91.5	0.74	
	2.0	94.2	0.76	
	2.5	94.9	0.76	
	5.0	94.9	0.76	
	10.0	95.0	0.76	
	15.0	100.0	0.8	
Controlled by venturi scrubber[d]	0.5	56.0	1.68	C
	1.0	70.2	2.10	
	2.0	77.4	2.32	
	2.5	77.7	2.34	
	5.0	77.7	2.34	
	10.0	77.7	2.34	
	15.0	77.7	2.34	
		100.0	3.0	

[a] Mass emission rate data available in Tables 2.3-1 and 2.3-3 to calculate size-specific emission factors.
[b] References 13, 21, 22, 25, 26.
[c] Reference 3, Exhibit VI-15. Averaged from data on two foundries. Because original test data could not be obtained, emission factor rating is E.
[d] Pressure drop across venturi: approximately 102 inches of water.

TABLE 4.3-4 (ENGLISH UNITS) (*continued*)
PARTICLE SIZE DISTRIBUTION DATA AND EMISSION FACTORS FOR IRON FOUNDRIES[a]
All Emission Factors in lb/ton of Metal Produced
Ratings (A-E) Follow Each Factor

Source	Particle size (µm)	Cumulative mass % ≤ state size[b]	Cumulative mass emission factor (lb/ton metal)	Rating
Electric Arc Furnace[d] (SCC 30400304)				
Uncontrolled	1.0 2.0 5.0 10.0 15.0	13.0 57.5 82.0 90.0 93.5 100.0	1.6 7.4 10.4 11.6 12.0 12.8	E
Pouring, cooling[b] (SCC 30400320 & 30400325)				
Uncontrolled	0.5 1.0 2.0 2.5 5.0 10.0 15.0	d 19.0 20.0 24.0 34.0 49.0 72.0 100.0	 0.80 0.84 1.00 1.42 1.06 3.02 4.2	D
Shakeout[b] (SCC 30400331)				
Uncontrolled	0.5 1.0 2.0 2.5 5.0 10.0 15.0	23.0 37.0 41.0 42.0 44.0 70.0 99.9 100.0	0.74 1.18 1.32 1.34 1.40 2.24 3.20 3.20	E

[a] Mass emission rate data available in Tables 2.3-1 and 2.3-3 to calculate size-specific emission factors.
[b] References 13, 21, 22, 25, 26.
[c] Reference 3, Exhibit VI-15. Averaged from data on two foundries. Because original test data could not be obtained, Emission Factor Rating is E.
[d] Pressure drop across venturi: approximately 102 inches of water.

Reference 1: Particulate Emission Test Report On A Gray Iron Cupola at Cherryville Foundry Works, Cherryville, NC, Department of Natural and Economic Resources, Raleigh, NC, December 18, 1975.

This source test was conducted to prove compliance for uncontrolled particulate emissions from a gray iron cupola. The process involves melting scrap iron for the production of municipal castings. No fluxing agents were used. Emission factors are listed in Table 4.1-4 as Source 1. This test is rated "A."

Reference 2: Particulate Emissions Testing at Opelika Foundry, Birmingham, AL, Air Pollution Control Commission, Montgomery, AL, November 1977 - January 1978.

This compliance source test measures emissions from a fabric filter serving as a particulate control device for a cupola. The emissions pass through an afterburner, a quench tower, and through a fabric filter prior to being exhausted into the atmosphere. This test is rated "A." However, information available in the test report does not break down the process feed. Therefore, emission information from this test is not used.

Reference 3: Stack Test Report, Dunkirk Radiator Corporation Cupola Scrubber, State Department of Environmental Conservation, Region IX, Albany, NY, November 1975.

This compliance particulate source test is to check emissions from a scrubber that serves a cupola. The test report includes a breakdown of the process weight, of which 2,000 pounds of metal scrap is in each charge. The report includes the number of charges made during testing. PES has calculated the emission factors found in Table 4.1-4, listed as Reference 3. This test is rated "A."

Reference 4: Particulate Emission Test Report For A Scrubber Stack For A Gray Iron Cupola At Dewey Brothers, Goldsboro, NC, Department Of Natural Resources, Raleigh, NC, April 7, 1978.

This particulate compliance test is reporting emissions from an impingement type scrubber that serves as a control device for two cupolas. Only one cupola is operated at a time. This test is rated "B" because production rates are reported as an hourly average instead of actual production during the testing periods. Calculated emission factors for this source test are listed in Table 4.1-4 as the Reference 4 source test.

Reference 5: Stack Test Report, Worthington Corp. Cupola, State Department of Environmental Conservation, Region IX, Albany, NY, November 4-5, 1976.

This emission test is for controlled particulate from a venturi scrubber that controls emissions from two cupolas. The emissions are listed in Table 4.1-4 as the Reference 5 source test. This test report is rated "A."

Reference 6: Stack Test Report, Dresser Clark Cupola Wet Scrubber, Orlean, NY, State Department Of Environmental Conservation, Albany, NY, July 14 & 18, 1977.

This test report is rated "B" as it has documentation to permit an accurate emission factor development. However, particulates during the study test period doubled without explanation, even though production charges appear to have remained constant throughout the test.

Reference 7: Stack Test Report, Chevrolet Tonawanda Metal Casting, Plant Cupola #3 And Cupola #4, Tonawanda, NY, State Department Of Environmental Conservation, Albany, NY, August 1977.

This is a compliance test on two cupolas, each with a different control device. This test is rated "A." However, no emission factors could be developed as there was no breakdown of components in the process charge. This report was not used.

Reference 8: Stack Analysis For Particulate Emission, Atlantic States Cast Iron Foundry/Scrubber, State Department Of Environmental Protection, Trenton, NJ, September 1980.

This compliance report is not used in this background document because production information is not available in order to calculate emission factors.

Reference 9: Source Test, Electric Arc Furnace At Paxton-Mitchell Foundry, Omaha, NB, Midwest Research Institute, Kansas City, MO, October 1974.

Emission testing was conducted at this foundry as part of a New Source Performance Standard study. The test is rated "A." The test appears to have been conducted correctly, but the copy of the test used in this review does not include field notes for particulates. Also, the derivation of the emission factor is based upon an engineering estimate of the production rate. Testing included particulate emissions from an electric arc furnace, with samples reported both before and after a fabric filter. Of concern during particulate sampling is a 21 percent variation in exhaust flow rates. In addition, total hydrocarbons, carbon monoxide (CO), and sulfur dioxide (SO_2) measurements are reported. Uncontrolled and controlled particulate emission factors are reported in Table 4.1-4 as source test 9. Total hydrocarbons and CO are sampled with appropriate analyzers. Total hydrocarbons had a range of 1.74 to 14.7 parts per million (ppm), with a mean of approximately 10 ppm. Carbon monoxide readings had a range of 19 to 294 ppm, and a mean of approximately 120 ppm. Sulfur dioxide samples were taken at the fabric filter outlet. The production process does not use sulfur. The SO_2 emission is believed be the result of oxidized lubrication and cutting oils contaminating the scrap metal charge in the electric arc furnace. The sulfur dioxide emission range is reported to be from 1.7 to 17.7 ppm, with a mean of 2.5 ppm.

<u>Reference 10: Source Test, John Deere Tractor Works, East Moline, IL, Gray Iron Electric Arc Furnace, Walden Research, Willmington, MA, July 1974.</u>

This source test is a part of a New Source Performance Standard study. The production system tested consisted of two electric arc furnaces, with alternating operating periods (both are never operated at the same time), with emissions controlled by a fabric filter. Testing included controlled particulate, sulfur dioxide (SO_2), Nitrogen oxides (NO_x), hydrocarbons and carbon monoxide (CO). This report fulfills the requirements of an "A" rating.

Particulate emission rates are calculated for both filterable and total particulates (front and back half). The production rate is reported as 24 tons of metal in a 3-hour period on average. Using this information, PES has generated particulate emission factors for filterable and total particulates as shown on Table 4.1-4 for the Reference 10 source test. The test report contains SO_2 emissions that are provided as emission rates and have been changed to the emission factors found in Table 4.1-2 for the Reference 10 source test.

Nitrogen oxide concentrations are reported for two of the three test periods. PES calculated emission factors for NO_x and recorded the values in Table 4.1-3 for the Reference 10 source test. This information is listed for comparison with additional NO_x emission factors as they become available.

Analyzers were used to record both hydrocarbons and CO emissions in parts per million (ppm). The sampling port was installed in the fabric filter exhaust stack. Hydrocarbon had an emission rate with a range of 0.55 to 1.25 kg/hr, with a mean emission rate value of 0.87 kg/hr (1.21 to 2.76

lbs/hr with a mean emission rate of 1.91 lbs/hr). The emission rate for carbon monoxide ranged from 3.70 to 17.3 kg/hr, with a mean emission rate value of 10.1 kg/hr (8.1 to 38.2 lbs/hr with a mean emission rate of 22.2 lbs/hr). A calculated emission factor for each, based upon the mean values and a production rate of 4 Mg/hr (8 tons/hr), results in a hydrocarbon emission factor of 0.22 kg/Mg (0.24 lbs/ton). For CO the emission factor is 2.53 kg/Mg (2.78 lbs/ton).

Reference 11: S. Gronberg, *Characterization Of Inhalable Particulate Matter Emissions From An Iron Foundry*, Lynchburg Foundry, Archer Creek Plant, EPA-600/X-85-328, U.S. Environmental Protection Agency, Cincinnati, OH, August 1984.

The purpose of this "A"-rated source test was to measure fugitive particulates in an iron foundry during pouring and mold cooling operations. Emissions from pouring and cooling are uncontrolled and were measured at the roof monitors. Method 5 testing was performed during four pouring and five cooling periods. The report contains a calculated particulate emission factor of 0.021 kg/Mg (0.043 lb/ton) during pouring operations, and an emission factor of 0.044 kg/Mg (0.086 lb/ton) during cooling operations in molds. Particulate emission factors during combination pouring and cooling runs were reported as 0.056 kg/Mg (0.111 lb/ton).

Reference 12: Report Of Source Emissions Testing At Hardy and Newsom, Inc., La Grange, NC, North Carolina Division of Environmental Management, August 2 & 3, 1977.

This report is a compliance emission test for controlled particulate from a cupola. The elements of the control system are; a settling chamber, a water-cooled heat exchanger, one mechanical centrifugal separator, and a fabric filter (sock type filter). This "B" rated compliance test does not discuss why the apparent stack exhaust flow for Run 1 is almost 200 percent higher than that of Run 3. Run 1 also is reported to have the highest emission rate (10.77 lb/hr) as compared to Run 3 (7.14 lb/hr). The reported production rate is 400 lbs of iron in every charge, with a total of 82 charges made during 660 minutes. PES calculated the production rate at 1.49 tph. Calculated emission factors are listed in Table 4.1-4 under the Reference 13 source test.

Reference 13: Report Of Source Emissions Testing At Sprout-WP, Inc., Muncy, PA, Homeon Associates, Inc. Report of December 1, 1988.

This emission test measured phenol, organic, and formaldehyde contained in the uncontrolled mold curing oven roof stack. Four 1-hour samples were taken during production. This "D" rated emission source test lacks enough information such as isokinetic calculations and values, and field notes to permit a validation of the test. Also, assumptions are made with regard to downtime instead of maintaining a documentation of process related operations and their effect on production rates. The copy used by PES does not include test set up information. The flow rate was calculated using calibrated SKC pumps due to the DGM sticking (no rotometer used). The limit of detection of all compounds is 0.1 ppm. No phenols were detected, and formaldehyde readings may have been influenced by the problems with the DGM. The tabulated information contained in this emission report is not used. However, due to the uniqueness of the emissions (mold curing operations), PES has elected to report the average emission rates as they may be within an order of magnitude of actual values. To put these emission rates in perspective with production rates, the average production rate is reported to be approximately 80 molds per hour. Each mold weighs approximately 350 pounds. Emission averages are Varsol = 0.459 lb/hr, heptanol = 0.528 lb/hr, Freon 113 (1,1,2 Trichloro, 1,2,2 trifluoroethane) = 0.039 lb/hr, and xylene = 0.037 lb/hr. This information is not used elsewhere in this background report.

Reference 14: Report Of Source Emissions Testing At Benton Foundry, Inc., Benton, PA, Commonwealth of Pennsylvania Report of 8-7-79.

This "C"-rated compliance source test measured total particulate (front and back half) according to standard procedures for isokinetic collection as specified in Chapter 139 of the Pennsylvania Department of Environmental Resources' Rules and Regulations. Only one 72-minute sample run was conducted on controlled cupola emissions. The emission control system consists of two afterburners, a venturi scrubber, and a cyclonic moisture separator. In addition, the isokinetic flow was 87.3 percent (outside the 90 to 110 percent flow criteria). Total controlled particulate emission rate is reported as 15.4 lb/hr, with a corrected value of 13.4 lb/hr when the low isokinetic flow of 87.3 percent is taken into account. Total pig iron, scrap iron, and returns charged during the 72-minute test period was 11,900 pounds. From this information, PES calculates a production rate of 4.96 tph, and an emission factor of 0.37 lb/ton. The reason for including this information is that the production equipment and pollution control system is typical for many small operations. This information is not referred to elsewhere in this report.

Reference 15: Report Of Source Emissions Testing At Newbury manufacturing, Talladega, AL, State Air Pollution Control Commission, Montgomery, AL, May 15-16, 1979.

This source emission test measured controlled emissions leaving a casting and sand handling system controlled by an orifice scrubber. The test includes both filterable and total controlled particulate. This "C"-rated compliance test does not have uncontrolled emissions and, it lacks a significant amount of background data. Both particulate rates are converted to emission factors based upon an approximate production of 12 tons of metal per hour.

This information is given in Table 4.1-4 under the Reference 15 source test.

4.4 DATA GAP ANALYSIS

Additional source tests during iron foundry operations are necessary to build a larger data base that will satisfy the accuracy and statistical randomness requirements of AP-42 emission factors. As discussed in Chapter 2, iron foundry operations use a wide variety of production equipment and pollution control systems. The review of specific data sets in Section 4.3 demonstrates a need for additional quality source tests, both before and after air pollution control systems, along with corresponding production rates.

Metal melting operations release the major portion of total particulates. A series of emission source tests is required for each type of furnace, with particular attention given to charging and pouring operations that cause peak emission loads. The chemical composition of these emissions also needs additional study, incorporating information such as scrap composition and cleanliness, and production and operating procedures.

Emissions released during pouring and casting should be thoroughly evaluated with regard to both organic and inorganic emissions. A future study should include formulations of mold binders used during source tests, along with material balance and a chemical analysis of used sand after shaking out castings.

Refining techniques can cause rapid emission release as a result of dynamic and violent reactions of iron with alloy metals. These operations require additional testing to identify the relative magnitude of air toxic and criteria pollutants.

4.5 REFERENCES FOR CHAPTER 4

1. Particulate Emission Test Report On A Gray Iron Cupola at Cherryville Foundry Works, Cherryville, NC, Department of Natural and Economic Resources, Raleigh, NC, December 18, 1975.

2. Particulate Emissions Testing at Opelika Foundry, Birmingham, AL, Air Pollution Control Commission, Montgomery, AL, November 1977 - January 1978.

3. Stack Test Report, Dunkirk Radiator Corporation Cupola Scrubber, State Department of Environmental Conservation, Region IX, Albany, NY, November 1975.

4. Particulate Emission Test Report For A Scrubber Stack For A Gray Iron Cupola At Dewey Brothers, Goldsboro, NC, Department Of Natural Resources, Raleigh, NC, April 7, 1978.

5. Stack Test Report, Worthington Corp. Cupola, State Department Of Environmental Conservation, Region IX, Albany, NY, November 4-5, 1976.

6. Stack Test Report, Dresser Clark Cupola Wet Scrubber, Orlean, NY, State Department Of Environmental Conservation, Albany, NY, July 14 & 18, 1977.

7. Stack Test Report, Chevrolet Tonawanda Metal Casting, Plant Cupola #3 And Cupola #4, Tonawanda, NY, State Department Of Environmental Conservation, Albany, NY, August 1977.

8. Stack Analysis For Particulate Emission, Atlantic States Cast Iron Foundry/Scrubber, State Department Of Environmental Protection, Trenton, NJ, September 1980.

9. Source Test, Electric Arc Furnace At Paxton-Mitchell Foundry, Omaha, NB, Midwest Research Institute, Kansas City, MO, October 1974.

10. Source Test, John Deere Tractor Works, East Moline, IL, Gray Iron Electric Arc Furnace, Walden Research, Willmington, MA, July 1974.

11. S. Gronberg, Characterization Of Inhalable Particulate Matter Emissions From An Iron Foundry, Lynchburg Foundry, Archer Creek Plant, EPA-600/X-85-328, U.E. Environmental Protection Agency, Cincinnati, OH, August 1984.

12. Reference 13: Report Of Source Emissions Testing At Hardy and Newsom, Inc., La Grange, NC, North Carolina Division of Environmental Management, August 2 & 3, 1977.

13. Report Of Source Emissions Testing At Sprout-WP, Inc., Muncy, PA, Homeon Associates, Inc. Report of 12-1-88.

14. Report Of Source Emissions Testing At Benton Foundry, Inc., Benton, PA, Commonwealth of Pennsylvania Report of 8-7-79.

15. Report Of Source Emissions Testing At Newbury manufacturing, Talladega, AL, State Air Pollution Control Commission, Montgomery, AL, May 15-16, 1979.

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
M^3	35.31	ft^3
m	3.281	ft
kg	2.205	lb
kPa	1.45×10^{-1}	psia
kg/Mg	2.0	lb/ton
Mg	1.1023	ton

Temperature conversion equations:

Fahrenheit to Celsius:

$$^\circ C = \frac{(^\circ F - 32)}{1.8}$$

Celsius to Fahrenheit:

$$^\circ F = 1.8(^\circ C) + 32$$