

**BACKGROUND REPORT**

**AP-42 SECTION 12.9**

**SECONDARY COPPER SMELTING, REFINING, AND ALLOYING**

**Prepared for**

**U.S. Environmental Protection Agency  
OAQPS/TSD/EIB  
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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 (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 for the revision of AP-42 Section 12.9 *Secondary Copper Smelting, Refining, and Alloying*.

Including the introduction (Chapter 1), this report contains four chapters. Chapter 2 gives a description of the secondary copper 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 processing zinc scrap.

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.

## **2.0 INDUSTRY DESCRIPTION**

### **2.1 General**

As of 1992, the 700,000 megagrams (800,000 tons)<sup>1</sup> of secondary copper produced in the U.S. accounted for more than 40 percent of supply. This production volume is remaining relatively steady. Secondary copper includes such items as machine shop punchings, turnings, and borings; manufacturing facility defective or surplus goods; automobile radiators, pipes, wires, bushings, and bearings; and metallurgical process skimmings and dross. This secondary copper can be refined into relatively pure metallic copper, alloyed with zinc or tin to form brass or bronze, incorporated into chemical products, or used in a number of smaller applications. The operator, location, approximate annual capacity, and processes of each of the five secondary copper smelter/refineries and five other refineries in the U.S. are listed in Table 2.1-1. A large number of mills and foundries reclaim relatively pure copper scrap for alloying purposes.

### **2.2 Process Description**

Secondary copper recovery is divided into four separate operations: scrap pretreatment, smelting, alloying, and casting. Pretreatment includes the cleaning and consolidation of scrap in preparation for smelting. Smelting consists of heating and treating the scrap for separation and purification of specific metals. Alloying involves the addition of one or more other metals to copper to obtain desirable qualities characteristic of the combination of metals. The major secondary copper smelting operations are shown in Figure 2.2-1; brass and bronze alloying operations are shown in Figure 2.2-2.

Scrap *pretreatment* may be achieved through manual, mechanical, pyrometallurgical, or hydrometallurgical methods. Manual and mechanical methods include sorting, stripping, shredding, and magnetic separation. The scrap may then be compressed into briquettes in a hydraulic press. Pyrometallurgical pretreatment may include sweating (the separation of different metals by slowly staging furnace air temperatures to liquefy each metal separately), burning insulation from copper wire, and drying in rotary kilns to volatilize oil and other organic compounds. Hydrometallurgical pretreatment methods include flotation and leaching to recover copper from slag. Flotation is typically used when slag contains greater than ten percent copper. The slag is slowly cooled such that large, relatively pure

**Table 2.1-1: Secondary Copper Smelters and Refineries**

Operator	Location	Annual Capacity (Mg/yr)	Processes
Cerro Copper Products	Sauget, Illinois	125,000	fire-refining, electrolytic refining
Chemetco	Alton, Illinois	135,000	one-stage (top-blown rotary converter) smelting/refining
Gaston Recycling Industries	Gaston, South Carolina	110,000	smelting, fire-refining, electrolytic refining
Franklin Smelting and Refining	Philadelphia, Pennsylvania	16,000	smelting
Southwire	Carrollton, Georgia	100,000	smelting, fire-refining, electrolytic refining
Cyprus	Warrenton, Missouri	32,000	fire-refining
Essex	Fort Wayne, Indiana	44,000	fire-refining (wire manufacture)
North Chicago Smelting and Refining	North Chicago, Illinois	500	fire-refining (anode manufacture)
Reading Metals	Reading, Pennsylvania	70,000	fire-refining (tube manufacture)
Thermal Reduction Co.	Philadelphia, Pennsylvania	4,500	fire-refining

crystals are formed and recovered. The remaining slag is cooled, ground, and combined with water and chemicals that facilitate flotation. Compressed air and the flotation chemicals separate the ground slag into various fractions of minerals. Additives cause the copper to float in a foam of air bubbles for subsequent removal, dewatering, and concentration.

Leaching is used to recover copper from slime, a byproduct of electrolytic refining. In this process, sulfuric acid is circulated through the slime in a pressure filter. Copper dissolves in the acid to form a solution of copper sulfate ( $\text{CuSO}_4$ ), which can then be either mixed with the

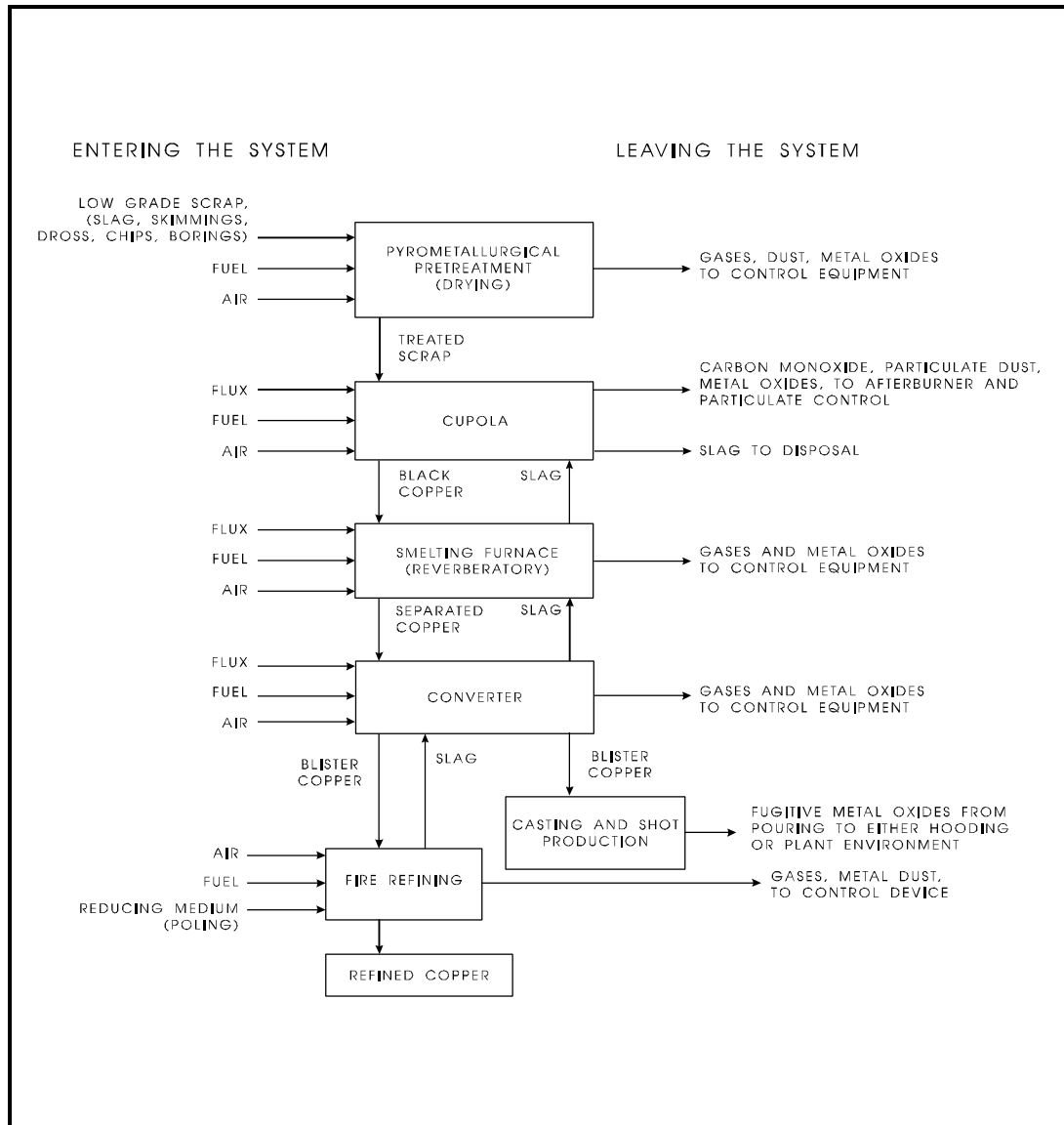


Figure 2.2-1 Low-grade copper recovery

electrolyte in the refinery cells or sold as a product.

*Smelting* of low-grade copper scrap begins with melting in either a blast or a rotary furnace, resulting in slag and impure copper. If a blast furnace is used, this copper is charged to a converter, where the purity is increased to about 80 to 90 percent, and then to a reverberatory furnace, where copper of about 99 percent purity is achieved. The final step is known as fire-refining. In these pyrometallurgical processes, flux is added to the copper and air is blown upward through the mixture to oxidize impurities. These impurities are then removed as slag. Then, by



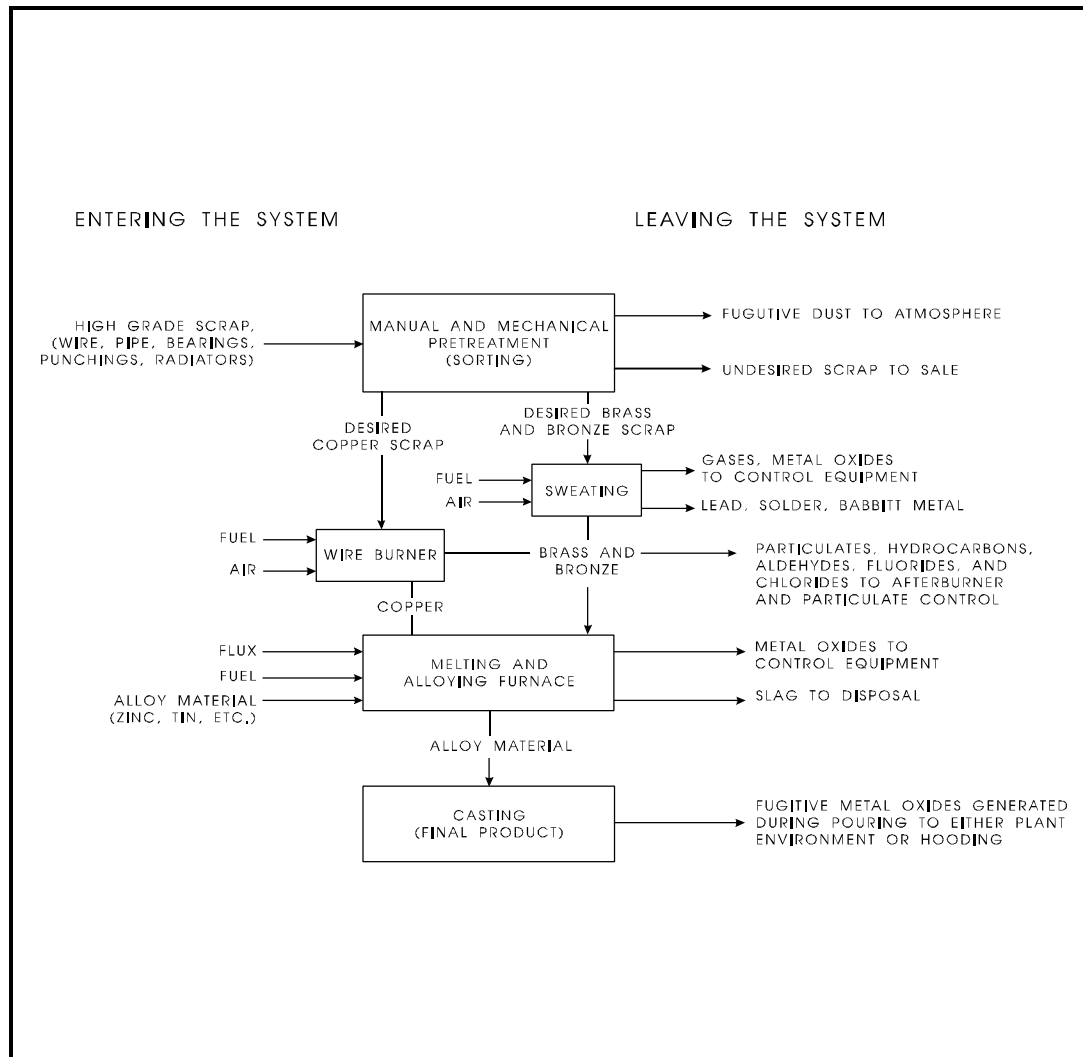


Figure 2.2-2 High-grade brass and bronze alloying

reducing the furnace atmosphere, cuprous oxide (CuO) is converted to copper. Fire-refined copper can be cast into either anodes, which are used during electrolysis, or billets. The anodes are submerged in a sulfuric acid solution containing copper sulfate. As copper is dissolved from the anodes, it deposits on the cathode. Then the cathode copper, which is as much as 99.99 percent pure, is extracted and recast. The blast furnace and converter may be omitted from the process if average copper content of the scrap being used is greater than about 90 percent.

The process used by one U.S. facility involves the use of a patented top-blown rotary converter in lieu of the blast, converting, and reverberatory furnaces and the electrolytic refining

process described above. This facility begins with low-grade copper scrap and conducts its entire refining operation in a single vessel.

In *alloying*, copper-containing scrap is charged to a melting furnace along with one or more other metals such as tin, zinc, silver, lead, aluminum, or nickel. Fluxes are added to remove impurities and to protect the melt against oxidation by air. Air or pure oxygen may be blown through the melt to adjust the composition by oxidizing excess zinc. The alloying process is, to some extent, mutually exclusive of the smelting and refining processes described above that lead to relatively pure copper.

*Casting* of alloyed or refined copper products is the final step used by the secondary copper industry in the recovery of copper from scrap material. The molten metal is poured into molds from ladles or small pots serving as surge hoppers and flow regulators. The resulting products include shot, wirebar, anodes, cathodes, ingots, or other cast shapes.

### **2.3 Emissions and Controls**

The principal pollutant emitted from secondary copper smelting activities is particulate matter. As is characteristic of secondary metallurgical industries, pyrometallurgical processes used to separate or refine the desired metal, such as the burning of insulation from copper wire, result in emissions of metal oxides and unburned insulation. Similarly, drying of chips and borings to remove excess oils and cutting fluids can cause discharges of volatile organic compounds (VOC) and products of incomplete combustion.

The smelting process utilizes large volumes of air to oxidize sulfides, zinc, and other undesirable constituents of the scrap. This oxidation procedure generates particulate matter in the exhaust gas stream. A broad spectrum of particle sizes and grain loadings exists in the escaping gases due to variations in furnace design and in the quality of furnace charges. Another major factor contributing to differences in emission rates is the amount of zinc present in scrap feed materials. The low-boiling zinc volatilizes and is oxidized to produce copious amounts of zinc oxide as submicron particulate.

Fabric filter baghouses are the most effective control technology applied to secondary copper smelters. The control efficiency of these baghouses may exceed 99 percent, but cooling systems may be needed to prevent hot exhaust gases from damaging or destroying the bag filters. Electrostatic precipitators are not as well suited to this application, because they have a low

collection efficiency for dense particulate such as oxides of lead and zinc. Wet scrubber installations are ineffective as pollution control devices in the secondary copper industry because scrubbers are useful for particles larger than one micron ( $\mu\text{m}$ ), and the metal oxide fumes generated are generally submicron in size.

Particulate emissions associated with drying kilns can also be controlled with baghouses. Drying temperatures up to  $150^{\circ}\text{C}$  ( $300^{\circ}\text{F}$ ) produce exhaust gases that require no precooling prior to the baghouse inlet. Wire burning generates large amounts of particulate matter, primarily composed of partially combusted organic compounds. These emissions can be effectively controlled by direct-flame incinerators called afterburners. An efficiency of 90 percent or more can be achieved if the afterburner combustion temperature is maintained above  $1000^{\circ}\text{C}$  ( $1800^{\circ}\text{F}$ ). If the insulation contains chlorinated organics such as polyvinyl chloride, hydrogen chloride gas will be generated. Hydrogen chloride is not controlled by the afterburner and is emitted to the atmosphere.

Fugitive emissions occur from each process associated with secondary copper smelter operations. These emissions occur during the pretreating of scrap, the charging of scrap into furnaces containing molten metals, the transfer of molten copper from one operation to another, and from material handling. When charging scrap into furnaces, fugitive emissions often occur when the scrap is not sufficiently compact to allow a full charge to fit into the furnace prior to heating. The introduction of additional material onto the liquid metal surface produces significant amounts of volatile and combustible materials and smoke. If this smoke exceeds the capacity of the existing capture devices and control equipment, it can escape through the charging door. Forming scrap bricquettes offers a possible means of avoiding the necessity of fractional charges. When fractional charging cannot be eliminated, fugitive emissions are reduced by turning off the furnace burners during charging. This reduces the flow rate of exhaust gases and allows the exhaust control system to better accommodate the additional temporary emissions.

Fugitive emissions of metal oxide fumes are generated not only during melting, but also while pouring molten metal into molds. Additional dusts may be generated by the charcoal or other lining used in the mold. The method used to make "smooth-top" ingots involves covering the metal surface with ground charcoal. This process creates a shower of sparks, releasing emissions into the plant environment in the vicinity of the furnace top and the molds being filled.

The electrolytic refining process produces emissions of sulfuric acid mist, but no data quantifying these emissions are available.

Emission factor averages and ranges for six different types of furnaces are presented in the revised AP-42 Section 12.9, along with PM<sub>10</sub> emission rates and reported fugitive and lead emissions. Several of the metals contained in much of the scrap used in secondary copper smelting operations, particularly lead, nickel, and cadmium, are hazardous air pollutants (HAP's) as defined in Title III of the 1990 Clean Air Act Amendments. These metals will exist in the particulate matter emitted from these processes in proportions related to their existence in the scrap.

#### **2.4 Review of References for Chapter 2.0**

During the revision of AP-42 Section 12.9, the following sources were contacted in order to obtain the most up-to-date information on industrial processes, emission stream characterization, and control technology concerning the secondary copper smelting industry:

*U.S. Department of the Interior, Bureau of Mines, Washington, DC.*

A series of telephone conversations with the copper specialist with this government agency provided assistance in locating secondary copper smelters and refineries, and provided estimates of the capacities of these facilities. Much of the information presented in the revised AP-42 section concerning the uses of copper and the secondary copper industry as a whole is based upon two documents published by the Bureau of Mines (Reference 1: "Copper," Mineral Commodities Summary 1992 and Reference 2: "Copper," Minerals Yearbook 1989), both of which examine this industry from a primarily commercial standpoint. In addition, the more detailed Minerals Yearbook provided brief descriptions of the processes utilized in secondary copper smelting and refining, which were also used in the revision of the AP-42 section.

*Association of Brass and Bronze Ingot Manufacturers, Chicago, IL.*

This agency recommended several modifications to the text of AP-42 Section 12.9. These recommendations were incorporated into the section revision.

*Cerro Copper Products, Sauget, IL.*

Environmental personnel at this facility were contacted by telephone and, at their request, by mail in order to obtain the results of recently performed emission testing. No response was received.

*Chemetco, Alton, IL.*

Environmental personnel at this facility were contacted by telephone and, at their request, by mail in order to obtain the results of recently performed emission testing. No response was received.

*Franklin Smelting and Refining, Philadelphia, PA.*

Environmental personnel at this facility were contacted by telephone and, at their request, by mail in order to obtain the results of recently performed emission testing. No response was received.

*Gaston Recycling Industries, Gaston, SC.*

A telephone conversation with engineers at Gaston revealed that this facility is owned by a subsidiary of Southwire (see below), and was purchased in 1990. In the short time that this company has owned this facility, no emissions data have been compiled, and none from the previous operator are available. Emissions testing to meet regulatory requirements is planned for the near future.

*Southwire, Carrollton, GA.*

Environmental personnel at this facility were contacted by telephone and, at their request, by mail in order to obtain the results of recently performed emission testing. No response was received before the section revision was completed.

*New Jersey Department of Environmental Protection, Trenton, NJ.*

The emission test files of the Technical Services Bureau of this agency were examined for documents that could be useful in emission factor development. An emission test report for Kearny Smelting and Refining in Harrison, NJ, was among those found. This report is utilized in emission factor development for rotary smelting furnaces at copper alloying facilities, and is summarized in Section 4.3 of this background report.

## **2.5           References for Chapter 2.0**

1.    J.L.W. Jolly, "Copper," Mineral Commodity Summaries 1992, U.S. Department of the Interior, Bureau of Mines, Washington, DC, 1992.
2.    J.L.W. Jolly, "Copper," Minerals Yearbook 1989, U.S. Department of the Interior, Bureau of Mines, Washington, DC, 1990.

### 3.0 GENERAL EMISSION DATA REVIEW AND ANALYSIS PROCEDURES

#### 3.1 Literature Search and Screening

The first step of the investigation into emissions from the secondary copper smelting industry involved a search of available literature. This search included the following references:

- 1) *AP-42 background files maintained by the Emission Factor and Methodologies Section*. The references from which most of the emission factors presented in both the previous and revised versions of AP-42 Section 12.9 are derived were obtained from these files, and are summarized in Chapter 4.0 of this background report.
- 2) *"Locating and Estimating" reports* published by the Emission Factor and Methodologies Section. None of the pollutants for which these reports have been compiled is emitted from secondary copper processing facilities, and thus no useful information was contained in these reports.
- 3) PM<sub>10</sub> "gap filling" documents as listed below; none of these documents contained data of a quality suitable for development of emission factors.
  - 3a) "PM<sub>10</sub> Emission Factor Listing Developed by Technology Transfer" (EPA-450/4-89-022).
  - 3b) "Gap Filling PM<sub>10</sub> Emission Factors for Selected Open Area Dust Sources" (EPA-450/88-003).
  - 3c) "Generalized Particle Size Distributions for Use in Preparing Size Specific Particulate Emission Inventories" (EPA-450/4-86-013).
- 4) *Handbook of Emission Factors*, Parts I and II, Ministry of Health and Environmental Protection, The Netherlands, 1980/1983. No information concerning the secondary copper processing industry is contained in this handbook.
- 7) The EPA databases, including but not limited to the *VOC/Particulate Matter (PM) Speciation Database Management System (SPECIATE)*, the *Crosswalk/Air Toxic Emission Factor Data Base Management System (XATEF)*, and the *Test Methods Storage and Retrieval System* maintained by the Emission Measurement Technical Information Center (EMTIC/TSAR). No emissions test data for the secondary copper processing industry are contained in these databases.

- 6) The EPA *Clearinghouse for Inventories and Emission Factors* (CHIEF) and *National Air Toxics Information Clearinghouse* (NATICH). No emissions test data for the secondary copper processing industry are contained in these databases.

The following general criteria were used to select pertinent references:

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.

For source categories for which no primary emissions data were found and emission factors in the previous version of the corresponding AP-42 section were based entirely upon secondary data, these secondary data were again used for emission factor development. The quality of these factors was reevaluated based upon the criteria discussed below, and emission factor quality ratings were assigned accordingly. The final set of reference materials utilized in this AP-42 section revision is discussed in Chapter 4.0.

### **3.2 Emission Data Quality Rating System**

As part of the emission data analysis, 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.



The rating system used by the OAQPS for the preparation of AP-42 sections is given below:

**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 are 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 occurs, an evaluation is made of the extent to which 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 are assigned a lower rating.
4. Analysis and calculations. The test reports contain original raw data sheets. The nomenclature and equations used are 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 industry. 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 3.0**

1. Technical Procedures for Developing AP-42 Emission Factors and Preparing AP-42 Sections. U.S. Environmental Protection Agency, Office of Air Quality Planning and Standards, Technical Support Division, Research Triangle Park, NC, 27711, April 1992. [Note: this document is currently being revised at the time of this printing.]
2. Compilation of Air Pollutant Emission Factors, Volume I: Stationary Point and Area Sources, 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 Emission Data**

#### Particulate Matter

Due to a lack of usable data for most processes associated with the secondary copper processing industry, revised particulate matter emission factors were developed only for rotary smelting furnaces during this update. These revised factors for rotary smelting furnaces are based upon a recent emission test series documented in Reference 4, which is discussed in more detail in Section 4.3 of this background report. The resulting controlled and uncontrolled particulate matter emission factors have been assigned quality ratings of "C" and "D," respectively.

The sources from which the emission factors presented in the previous AP-42 section are derived were reviewed, and the factors appear to have been calculated and compiled correctly. Fugitive particulate matter emission factors presented in the previous version of this section were omitted, because the method by which they were estimated had no technical basis. All of these fugitive factors were simply five percent of the corresponding uncontrolled stack emissions. The sources of most of the remaining emission factors are not available for review. As a result, these factors have been assigned ratings of "E" due to uncertainty as to their representativeness of current industry operations.

#### Lead

Due to a lack of usable data for most processes associated with the secondary copper processing industry, lead emission factors were developed only for rotary smelting furnaces during this update. These factors for rotary smelting furnaces are based upon a recent emission test series documented in Reference 4, which is discussed in more detail in Section 4.3 of this background report. The resulting controlled lead emission factors have been assigned a quality rating of "B."

The sources from which the emission factors presented in the previous AP-42 section are derived were not available for review. These references are not primary sources of emission test data. As a result, these factors have been assigned ratings of "E" due to uncertainty as to their representativeness of current industry operations.

**TABLE 4.1-1 (METRIC UNITS)  
FILTERABLE PARTICULATE MATTER**

Reference #	Test Rating	Test Method	Run #	Production Rate <sup>a</sup>	Emission Rate <sup>b</sup>	Emission Factor <sup>c</sup>
Control devices: ESP/Baghouse - nominal 99.8% efficiency						
<b>4</b> Alloying: Rotary Furnace	B	5	1	1.59	163	103
			2	1.51	93	62
			3	1.55	140	90
			<b>Average</b>	1.55	132	85
Control device: Baghouse						
<b>3a</b> Alloying: Rotary Furnace	C	N/A	Charging	1.13	13.54	12.0
			Melting	1.13	19.04	16.8
			Pouring	1.13	3.85	3.4
			<b>Average</b>	1.13	N/A	N/A
Control device: Baghouse						
<b>3b</b> Alloying: Reverberatory Furnace	C	N/A	Charging	2.43	87.7	36.1
			Melting	2.43	72.2	29.7
			Pouring	2.43	5.8	2.4
			<b>Average</b>	2.43	N/A	N/A
Control device: Baghouse						
<b>3c</b> Alloying: Cupola	D	N/A	1	2.3	95.8	47

<sup>a</sup> Units in megagrams per hour.

<sup>b</sup> Units in kilograms per hour, uncontrolled basis.

<sup>c</sup> Units in kilograms per megagram of charge, uncontrolled basis.

**TABLE 4.1-1 (ENGLISH UNITS)  
FILTERABLE PARTICULATE MATTER**

Reference #	Test Rating	Test Method	Run #	Production Rate <sup>a</sup>	Emission Rate <sup>b</sup>	Emission Factor <sup>c</sup>
Control devices: ESP/Baghouse - nominal 99.8% efficiency						
<b>4</b> Alloying: Rotary Furnace	B	5	1	1.75	360	206
			2	1.66	205	123
			3	1.71	310	181
			<b>Average</b>	1.71	291	170
Control device: Baghouse						
<b>3a</b> Alloying: Rotary Furnace	C	N/A	Charging	1.24	29.85	24.0
			Melting	1.24	41.98	33.7
			Pouring	1.24	8.48	6.8
			<b>Average</b>	1.24	N/A	N/A
Control device: Baghouse						
<b>3b</b> Alloying: Reverberatory Furnace	C	N/A	Charging	2.68	193.4	72.2
			Melting	2.68	159.2	59.4
			Pouring	2.68	12.8	4.8
			<b>Average</b>	2.68	N/A	N/A
Control device: Baghouse						
<b>3c</b> Alloying: Cupola	D	N/A	1	2.5	211.2	93

<sup>a</sup> Units in tons per hour.

<sup>b</sup> Units in pounds per hour, uncontrolled basis.

<sup>c</sup> Units in pounds per ton of charge, uncontrolled basis.

**TABLE 4.1-2 (METRIC UNITS)  
 FILTERABLE PLUS INORGANIC CONDENSIBLE PARTICULATE MATTER**

Reference #	Test Rating	Test Method	Run #	Production Rate <sup>a</sup>	Emission Rate <sup>b</sup>	Emission Factor <sup>c</sup>
Control device: Baghouse						
<b>3a</b> Alloying: Rotary Furnace	C	N/A	Charging	1.13	13.63	12.1
			Melting	1.13	19.39	17.2
			Pouring	1.13	4.33	3.8
			<b>Average</b>	1.13	N/A	N/A
Control device: Baghouse						
<b>3b</b> Alloying: Reverberatory Furnace	C	N/A	Charging	2.43	88.1	36.2
			Melting	2.43	72.2	29.7
			Pouring	2.43	5.8	2.4
			<b>Average</b>	2.43	N/A	N/A
Control device: Baghouse						
<b>3c</b> Alloying: Cupola	D	N/A	1	2.3	97.9	43

<sup>a</sup> Units in megagrams per hour.

<sup>b</sup> Units in kilograms per hour, uncontrolled basis.

<sup>c</sup> Units in kilograms per megagram of charge, uncontrolled basis.

**TABLE 4.1-2 (ENGLISH UNITS)  
 FILTERABLE PLUS INORGANIC CONDENSIBLE PARTICULATE MATTER**

Reference #	Test Rating	Test Method	Run #	Production Rate <sup>a</sup>	Emission Rate <sup>b</sup>	Emission Factor <sup>c</sup>
Control device: Baghouse						
<b>3a</b> Alloying: Rotary Furnace	C	N/A	Charging	1.24	30.05	24.1
			Melting	1.24	42.75	34.3
			Pouring	1.24	9.54	7.7
			<b>Average</b>	1.24	N/A	N/A
Control device: Baghouse						
<b>3b</b> Alloying: Reverberatory Furnace	C	N/A	Charging	2.68	194.2	24.0
			Melting	2.68	159.3	59.4
			Pouring	2.68	12.8	4.8
			<b>Average</b>	2.68	N/A	N/A
Control device: Baghouse						
<b>3c</b> Alloying: Cupola	D	N/A	1	2.5	215.2	86

<sup>a</sup> Units in tons per hour.

<sup>b</sup> Units in pounds per hour, uncontrolled basis.

<sup>c</sup> Units in pounds per ton of charge, uncontrolled basis.



**TABLE 4.1-3 (METRIC UNITS)  
LEAD**

Reference #	Test Rating	Test Method	Run #	Production Rate <sup>a</sup>	Emission Rate <sup>b</sup>	Emission Factor <sup>c</sup>
Control devices: ESP/Baghouse						
<b>4</b> Alloying: Rotary Furnace	B	12	1	1.59	0.000372	0.00023
			2	1.51	0.000338	0.00022
			3	1.55	0.000476	0.00031
			<b>Average</b>	1.55	0.000395	0.00026

<sup>a</sup> Units in megagrams per hour.

<sup>b</sup> Units in kilograms per hour, uncontrolled basis.

<sup>c</sup> Units in kilograms per megagram of charge, uncontrolled basis.

**TABLE 4.1-3 (ENGLISH UNITS)  
LEAD**

Reference #	Test Rating	Test Method	Run #	Production Rate <sup>a</sup>	Emission Rate <sup>b</sup>	Emission Factor <sup>c</sup>
Control devices: ESP/Baghouse						
<b>4</b> Alloying: Rotary Furnace	B	12	1	1.75	0.000821	0.00047
			2	1.66	0.000745	0.00045
			3	1.71	0.00105	0.00061
			<b>Average</b>	1.71	0.000872	0.00051

<sup>a</sup> Units in tons per hour.

<sup>b</sup> Units in pounds per hour, uncontrolled basis.

<sup>c</sup> Units in pounds per ton of charge, uncontrolled basis.

### Carbon Monoxide.

Due to a lack of usable data for most processes associated with the secondary copper processing industry, carbon monoxide emission factors were developed only for rotary smelting furnaces during this update. These factors for rotary smelting furnaces are based upon a recent emission test series documented in Reference 4, which is discussed in more detail in Section 4.3 of this background report. The resulting carbon monoxide emission factors, which are reported as uncontrolled because the only devices serving the rotary furnace tested are a baghouse and an ESP, have been assigned a quality rating of "B" due to inconsistency in the test results.

### Nonmethane Organic Compounds.

Due to a lack of usable data for most processes associated with the secondary copper processing industry, organic compound emission factors were developed only for rotary smelting furnaces during this update. These factors for rotary smelting furnaces are based upon a recent emission test series documented in Reference 4, which is discussed in more detail in Section 4.3 of this background report. This testing utilized a gas chromatograph with a flame ionization detector and quantified total organic compound content in the stack gas, with no adjustment made for compounds such as methane that are considered non-photochemically reactive. The resulting total organic compound emission factors, which are reported as uncontrolled because the only devices serving the rotary furnace tested are a baghouse and an ESP, have been assigned a quality rating of "B" due to inconsistency in the test results.

**TABLE 4.1-4 (METRIC UNITS)  
CARBON MONOXIDE**

Reference #	Test Rating	Test Method	Run #	Production Rate <sup>a</sup>	Emission Rate <sup>b</sup>	Emission Factor <sup>c</sup>
Control devices: ESP/Baghouse						
<b>4</b> Alloying: Rotary Furnace	B	10	1	1.59	0.63	0.40
			2	1.51	2.13	1.42
			3	1.55	0.50	0.32
			<b>Average</b>	1.55	1.09	0.72

<sup>a</sup> Units in megagrams per hour.

<sup>b</sup> Units in kilograms per hour, uncontrolled basis.

<sup>c</sup> Units in kilograms per megagram of charge, uncontrolled basis.

**TABLE 4.1-4 (ENGLISH UNITS)  
CARBON MONOXIDE**

Reference #	Test Rating	Test Method	Run #	Production Rate <sup>a</sup>	Emission Rate <sup>b</sup>	Emission Factor <sup>c</sup>
Control devices: ESP/Baghouse						
<b>4</b> Alloying: Rotary Furnace	B	10	1	1.75	1.4	0.80
			2	1.66	4.7	2.83
			3	1.71	1.1	0.64
			<b>Average</b>	1.77	2.4	1.43

<sup>a</sup> Units in tons per hour.

<sup>b</sup> Units in pounds per hour, uncontrolled basis.

<sup>c</sup> Units in pounds per ton of charge, uncontrolled basis.

**TABLE 4.1-5 (METRIC UNITS)  
TOTAL ORGANIC COMPOUNDS  
(as methane)**

Reference #	Test Rating	Test Method	Run #	Production Rate <sup>a</sup>	Emission Rate <sup>b</sup>	Emission Factor <sup>c</sup>
Control devices: ESP/Baghouse						
4 Alloying: Rotary Furnace	B	NJ3	1	1.59	0.221	0.14
			2	1.51	3.110	2.06
			3	1.55	0.530	0.34
			<b>Average</b>	1.55	1.287	0.83

<sup>a</sup> Units in megagrams per hour.

<sup>b</sup> Units in kilograms per hour, uncontrolled basis.

<sup>c</sup> Units in kilograms per megagram of charge, uncontrolled basis.

**TABLE 4.1-5 (ENGLISH UNITS)  
TOTAL ORGANIC COMPOUNDS  
(as methane)**

Reference #	Test Rating	Test Method	Run #	Production Rate <sup>a</sup>	Emission Rate <sup>b</sup>	Emission Factor <sup>c</sup>
Control devices: ESP/Baghouse						
4 Alloying: Rotary Furnace	B	NJ3	1	1.75	0.488	0.28
			2	1.66	6.857	4.13
			3	1.71	1.169	0.68
			<b>Average</b>	1.77	2.838	1.70

<sup>a</sup> Units in tons per hour.

<sup>b</sup> Units in pounds per hour, uncontrolled basis.

<sup>c</sup> Units in pounds per ton of charge, uncontrolled basis.

### Sulfur Dioxide.

Due to a lack of data quantifying sulfur dioxide emissions from processes associated with the secondary copper processing industry, no emission factors for this pollutant are presented in either the previous or revised versions of AP-42 Section 12.9.

### Nitrogen Oxides.

No data on emissions of oxides of nitrogen were found directly from processes associated with the secondary copper processing industry. It can be assumed that these compounds are emitted from in-process heating units, but no quantitative data are available.

## **4.2 Noncriteria Pollutant Emission Data**

### Hazardous Air Pollutants.

Hazardous Air Pollutants (HAP's) are defined in the 1990 Clean Air Act Amendments. Included in this list are lead, nickel, and other heavy metals contained in the scrap that is the primary raw material for the secondary copper processing industry. No quantitative emissions data suitable for use in emission factor development are available for any HAP's other than lead, which is discussed in Section 4.1 of this background report.

### Global Warming Gases.

Pollutants such as methane (CH<sub>4</sub>), carbon dioxide (CO<sub>2</sub>), and nitrous oxide (N<sub>2</sub>O) have been found to contribute to overall global warming. No data on emissions of any of these pollutants were found for processes associated with the secondary copper processing industry. The prevalence of pyrometallurgical processes makes the likelihood of carbon dioxide emissions high, but data to quantify these emissions are not available.

### Stratospheric Ozone-Depleting Gases.

Chlorofluorocarbons, hydrochlorofluorocarbons, carbon tetrachloride, methyl chloroform, and halons have been found to contribute to stratospheric ozone depletion. Because none of these compounds is used in any of the processes associated with secondary copper processing, no data on emissions of these pollutants were found nor expected.

### 4.3 Review of Specific Data Sets

Reference 1: *Emission Factors and Emission Source Information for Primary and Secondary Copper Smelters*

This 1977 document examines the secondary copper smelting and alloying industries for the purpose of upgrading emission factors for these processes. This document is not referenced in the two most recent (1977 and 1980) versions of AP-42 Section 7.9 as a source of emission factors, but is the basis for all point source particulate matter emission factors in both. Intensive data collection efforts were undertaken for the development of this document. Responses were received from a large number of local, state, and regional air pollution control agencies. Unfortunately, many of these responses contained no data pertaining to secondary copper processes; others contained data that were not supported by emission tests; and several were no longer available in the AP-42 background files maintained by the Emission Factors and Methodologies Section. These responses form the basis for the list of agencies cited as the source of the emission factors in Table 12.9-1 in the 1980 revision of Section 7.9. Emission factors for six types of furnaces are presented in this document, but no derivations of these factors are provided.

For blast furnaces, or cupolas, particulate matter emission factors for three different classes of charge material are presented. The uncontrolled factor for scrap copper charge is derived from testing on one furnace. Both controlled and uncontrolled emission factors for insulated copper wire charge are also derived from one test. Both controlled and uncontrolled emission factors for scrap copper and brass charge are derived from two tests at one facility. None of these emission tests is available for review.

For reverberatory furnaces, an uncontrolled particulate matter emission factor for copper charge is derived from an unspecified number of tests on 12 facilities. A controlled emission factor for copper charge is derived from two tests on separate facilities. Both controlled and uncontrolled emission factors for brass and bronze charge are derived from two tests on separate facilities. None of these emission tests is available for review. One emission test report obtained by the EPA after the publication of this document is available for review, and is summarized as Reference 2 below.

For rotary furnaces, an uncontrolled particulate matter emission factor for brass and bronze charge is derived from two tests on separate facilities. A controlled emission factor for brass and bronze charge is derived from three tests on separate facilities. An uncontrolled emission factor for foundry brass charge is derived from one test, and a controlled emission factor for foundry brass

charge is derived from three tests on a single facility. None of these emission tests is available for review.

For crucible and pot furnaces with brass and bronze charge, an uncontrolled particulate matter emission factor is derived from 17 tests on 13 facilities, and a controlled emission factor is derived from five tests on three facilities. None of these emission tests is available for review.

For electric arc furnaces, an uncontrolled particulate matter emission factor for copper charge is derived from three tests on two facilities, and a controlled emission factor for copper charge is derived from two tests on a single facility. An uncontrolled emission factor for brass and bronze charge is derived from three tests on two facilities, and a controlled emission factor for brass and bronze charge is derived from one test. None of these emission tests is available for review.

For electric induction furnaces, an uncontrolled particulate matter emission factor for brass and bronze charge is derived from an unspecified number of tests on 18 facilities. A controlled emission factor for brass and bronze charge is derived from an unspecified number of tests on six facilities. Emission factors for copper charge on both an uncontrolled basis and a controlled-by-baghouse basis are derived from one test each. None of these emission tests is available for review. Two emission test reports conducted on an electric induction furnace before and after installation of a cyclone dust collector are available and are summarized as References 3a and 3b below.

Reference 2: Emission Test Report - Southwire, Carrollton, GA, May 1980

In response to an EPA request for emission data for secondary copper and aluminum processes, the Georgia Department of Natural Resources submitted several pages summarizing the results of a test performed on a furnace at this Georgia facility. The average charge rate during this test was 49 tons per hour, and emission rates of 31.5 tons per hour for particulate matter and 5.5 tons per hour for lead were calculated.

References 3a-b:            Emission Test Reports - Wolverine Tube Division, Decatur, AL, May 1972 and June 1974

In response to an EPA request for emission data for secondary copper and aluminum processes, the EPA Region IV office in Atlanta submitted two emission test reports conducted on an electric induction furnace at this Alabama facility. The first test indicates an uncontrolled filterable particulate matter emission factor of 7.6 lb/ton, which was not in compliance with the facility's permitted emission limits. As a result, a mechanical cyclone-type dust collector was installed shortly thereafter, and a performance test was conducted in 1974. This second test revealed a controlled filterable particulate matter emission factor of 1.7 lb/ton. Both of these test reports are fairly well documented, but the methodologies used are not described in adequate detail. They are not deemed to be superior to the emission factors presented in the 1980 version of AP-42 Section 7.9.

Reference 4:            Compliance Stack Sampling Report - Kearny Smelting and Refining, Harrison, NJ, December 1991

This report details the results of testing for particulate matter and lead (using EPA Reference Method 12), carbon monoxide (EPA Reference Method 10), and total hydrocarbons (NJ Air Test Method 3). The testing was performed on a rotary smelting furnace charged with alloy scrap, including about 86 percent copper, 8 percent zinc, 4 percent tin, 2 percent lead, and less than 1 percent iron and nickel. The smelting process takes about fifteen hours per batch, and is followed by a three-hour "blowing" or refining process. Blowing involves the introduction of compressed air under the surface of the molten metal, causing some of the zinc to exit the furnace as zinc oxide.

Since this test was to demonstrate compliance with permitted emission limitations, testing was performed only downstream of the control equipment and only during the smelting process. Emissions of particulate from this furnace are controlled by a spray cooling tower, an electrostatic precipitator (ESP), and a two-stage baghouse filter. The design efficiency of the ESP is 50 percent, and that of the baghouse filter is 99.6 percent, for a combined 99.8 percent control efficiency. Results of the three test runs for each pollutant, and corresponding test-specific emission factors, are tabulated in Tables 4.1-1 and 4.1-3 through 4.1-5. Emission factors for gaseous pollutants (CO, TOC) can be considered uncontrolled, because the control equipment is effective only for particulate matter. The emission factor for filterable particulate is given on an uncontrolled basis



by applying a nominal efficiency of 99.8 percent to the measured controlled emission rate. The emission factor for lead is given on a controlled basis because no differentiation was made in the test report between front- and back-half lead catch, so a control efficiency cannot be applied in the same manner as for filterable particulate. These emission data have been assigned quality ratings of "B" because they are based on test data on controlled processes. Emission data for carbon monoxide and total organic compounds are also rated "B," because the results of these tests are somewhat inconsistent.

Reference 5: Source Test Report - North Chicago Smelters and Refiners, North Chicago, IL, July 1968

This report details the results of emission testing for particulate matter (using a method similar to EPA Reference Method 5). Testing was performed by a crew from the Engineering Section of the Public Health Service, in order to provide data on baghouse efficiencies for copper-based scrap melting furnaces. No field nor laboratory data are included in this test report, precluding the examination of documentation of sampling and analysis procedures. Otherwise, the report is thorough, including a description of the methodology used. It appears from the report that no velocity traverse was conducted, absence of cyclonic flow was not verified, and particulate sampling was performed at only one point for each location (probably the centroid). The results of this test are thus not judged to provide an accurate representation of emissions from this type of source.

The first test period was conducted at the inlet and outlet of the baghouse serving a rotary furnace charged with 16.4 tons of scrap, consisting of about 85 percent copper and 5 percent each of zinc, lead, and tin. Total (filterable plus inorganic condensible) particulate matter emissions at the inlet to the baghouse during the charging step averaged 29.85 pounds per hour (lb/hr); during the refining step, 41.98 lb/hr; and during the pouring step, 8.48 lb/hr. Particulate matter emissions at the outlet from the baghouse averaged 1.613 lb/hr during the entire cycle.

The second test period was conducted with two rotary furnaces and a cupola venting to the baghouse being tested, precluding the use of the data for emission factor development.

The third test period was conducted at the inlet and outlet of the baghouse serving a reverberatory furnace charged with 52.5 tons of scrap, again consisting of about 85 percent copper and five percent each of zinc, lead, and tin. Total (filterable plus inorganic condensible) particulate matter emissions at the inlet to the baghouse during the charging step averaged 194.2 pounds per

hour (lb/hr); during the refining step, 159.3 lb/hr; and during the pouring step, 12.81 lb/hr. Particulate matter emissions at the outlet from the baghouse averaged 3.32 lb/hr during the entire cycle.

The fourth test period, like the second, was conducted with multiple operating sources being vented to the baghouse being tested, precluding the use of these data in emission factor development.

The fifth test period was conducted at the inlet and outlet of the baghouse serving a cupola that was being charged at a rate of 2.5 tons per hour. Total (filterable plus inorganic condensible) particulate matter emissions for the one 45-minute test run conducted at the inlet to the baghouse were 215.9 pounds per hour (lb/hr); those at the outlet from the baghouse averaged 8.00 lb/hr.

Results of the testing for filterable particulate matter and total (filterable plus inorganic condensible) particulate matter at the inlets to the baghouses for the first, third, and fifth test periods are presented in Tables 4.1-1 and 4.1-2, respectively. Because these emission test results are not felt to be highly representative, the AP-42 emission factors for the processes tested have not been revised.

Reference 6: EPA Test Report - West Coast Smelting and Refining, Chino, CA, November 1971

This report details the results of emission testing for particulate matter (using EPA Reference Method 5). Testing was performed by a contractor of the EPA, in order to provide a basis for determination of federal emission standards for new sources within the brass and bronze refining industry. No description of the furnace being tested is provided in the report, nor is the process rate during testing documented. It is documented that testing was performed downstream of a baghouse filter. Otherwise, the report is thorough, including a description of the methodology used. Values for condensible particulate matter for the first two test runs are not representative, due to the use of a soap solution in rinsing the impingers. Because a velocity traverse revealed highly turbulent flow near the walls of the stack being tested, sampling time was increased at points nearer the center of the stack where gas velocity could be measured reliably. The calculated emission rate, which is based upon concentration of particulate in the gas as well as the volumetric flow rate of the gas, is thus not judged to provide an accurate representation of emissions from this type of source. No emission factor can be calculated based upon this emission test report due to its lack of process data.

Reference 7: EPA Test Report - R.L. Lavin & Sons, Inc., Chicago, IL, November 1971

This report details the results of emission testing for particulate matter (using EPA Reference Method 5). Testing was performed by a contractor of the EPA, in order to provide a basis for determination of federal emission standards for new sources within the brass and bronze refining industry. No description of the furnace being tested is provided in the report, nor is the process rate during testing documented. It is documented that testing was performed downstream of a baghouse filter. Otherwise, the report is thorough, including a description of the methodology used. No emission factor can be calculated based upon this emission test report due to its lack of process data.

Reference 8: EPA Test Report - American Smelting and Refining Co., San Francisco, CA, December 1971

This report details the results of emission testing for particulate matter (using EPA Reference Method 5). Testing was performed by a contractor of the EPA, in order to provide a basis for determination of federal emission standards for new sources within the brass and bronze refining industry. No description of the furnace being tested is provided in the report, nor is the process rate during testing documented. It is documented that testing was performed downstream of a baghouse filter. Otherwise, the report is thorough, including a description of the methodology used. No emission factor can be calculated based upon this emission test report due to its lack of process data.

#### **4.4 Data Gap Analysis**

While very little emission test data were available to enable development of revised emission factors for AP-42 Section 12.9, it is not felt that a severe shortage of test data exists for this industry. Telephone conversations with industry personnel indicated that several facilities have been tested in recent years, and that others plan testing in the near future. These facilities were, unfortunately, not willing to provide the results of these emission tests. Similarly, state and local air pollution control agencies have much data on file but are generally unable to catalog or provide copies of the associated test reports. Collection of these additional emission data for secondary copper smelting, refining, and alloying processes is recommended to the EPA to be a primary option for further development of revised emission factors.

#### 4.5 References for Chapter 4.0

1. Emission Factors and Emission Source Information for Primary and Secondary Copper Smelters, EPA-450/3-77-051, U.S. Environmental Protection Agency, Research Triangle Park, NC, December 1977.
2. Emission Test Report - Southwire, Carrollton, GA, CDS Labs, Carrollton, GA, May 1980.
3. Emission Test Reports - Wolverine Tube Division, Decatur, AL, United Oil Products, Air Correction Division, Darien, CT, May 1972 and June 1974.
4. Compliance Stack Sampling Report - Kearny Smelting and Refining, Harrison, NJ, 11-13 December 1991, Air Recon, Raritan, NJ, January 1992.
5. Test No. 68-12: North Chicago Refiners and Smelters, North Chicago, IL, 7-11 July 1968, Department of Health, Education, and Welfare, Public Health Service, National Air Pollution Control Administration, Abatement Program, Field Operations Activity Engineering Section, Source Testing Unit.
6. EPA Test No. - - - : West Coast Smelting and Refining, Chino, CA, 10-11 November 1971, Engineering-Science, Inc., Washington, DC, December 1971.
7. EPA Test No. 71-C1-26: R.L. Lavin & Sons, Inc., Chicago, IL, 1-5 November 1971, Engineering-Science, Inc., Washington, DC, March 1972.
8. EPA Test No. 71-C1-27: American Smelting and Refining Co., San Francisco, CA, 29 November - 4 December 1971, Engineering-Science, Inc., Washington, DC, February 1972.

**TABLE 4.5-1**

**LIST OF CONVERSION FACTORS**

<b>Multiply:</b>	<b>by:</b>	<b>To obtain:</b>
mg/dscm	$4.37 \times 10^{-4}$	gr/dscf
m <sup>2</sup>	10.764	ft <sup>2</sup>
m <sup>3</sup>	35.31	ft <sup>3</sup>
m	3.281	ft
kg	2.205	lb
kPa	0.145	psia
kg/Mg	2.0	lb/ton
Mg	1.1023	ton

**Temperature conversion equations:**

Fahrenheit to Celsius:

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

Celsius to Fahrenheit:

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