BACKGROUND REPORT

AP-42 SECTION 12.8

SECONDARY ALUMINUM

Prepared for

U.S. Environmental Protection Agency
OAQPS/TSD/EIB
Research Triangle Park, NC 27711

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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 one test report to support future revision of emission factors for secondary aluminum industry.

Including the introduction (Chapter 1) this report contains four chapters. Chapter 2 gives a description of the secondary aluminum 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 recycling aluminum metal.

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.

2.0 INDUSTRY DESCRIPTION

2.1 GENERAL

Secondary aluminum producers recycle aluminum from aluminum-containing scrap, while primary aluminum producers convert bauxite ore into aluminum. The secondary aluminum industry was responsible for 27.5 percent of domestic aluminum produced in 1989. There are approximately 116 plants with a recovery capacity of approximately 2.4 million megagrams (2.6 million tons) of aluminum per year. Actual total secondary aluminum production was relatively constant during the 1980s. However, increased demand for aluminum by the automobile industry has doubled in the last ten years to an average of 78.5 kilograms (173 pounds) per car. Recycling of used aluminum beverage cans (UBC) increased more than 26 percent from 1986 to 1989. In 1989, 1.3 billion kilograms (2.9 billion pounds) of UBCs were recycled, representing over 60 percent of cans shipped. Recycling aluminum requires only five percent of the energy required to refine primary aluminum from bauxite ore, making the secondary aluminum economically viable.

2.2 PROCESS DESCRIPTION

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) ALCOA, Pittsburgh, PA.
2) Noranda Aluminum, Inc., Brentwood, TN.
3) Chas Licht Engineering Assoc., Inc., Aurora, IL.
4) Noranda Aluminum, Inc., New Madrid, MO.
5) Reynolds Aluminum Recycling, Richmond, VA.
6) U.S. Reduction, Inc., Munster, IN.
7) The Aluminum Association, Washington, DC.
8) The Aluminum Recycling Association, Washington, DC.
9) ALCAN Aluminum Corporation, Cleveland, OH.
10) Metallics Systems, Inc., Solon, OH.
11) The Carborundum Company, Solon, OH.
12) Ross Brothers Smelting Corporation, East Syracuse, NY.
13) State of New Jersey, Dept. of Environmental Protection.

Responses have primarily been related to process operations, with receipt of one emission test. Process information and source emission data was requested from each of the above organizations. Respondents included ALCOA, The Aluminum Association, U.S. Reduction, The Carborundum Company, Ross Brothers Smelting Corporation, and the State of New Jersey. The State of New Jersey sent an excellent source emission test using EPA method 5. Pacific Environmental Services has incorporated relevant information received from these sources into the AP-42 background report.

Secondary aluminum production involves two general categories of operations, scrap pretreatment and smelting/refining. Pretreatment operations include sorting, processing and cleaning scrap. Smelting/refining operations include cleaning, melting, refining, alloying, and pouring of aluminum recovered from scrap. The processes used to convert scrap aluminum to products such as lightweight aluminum alloys for industrial castings are presented in Figures 2.2-1A and 2.2-1B. Some or all the steps in these figures may be involved at any one facility. Some steps may be combined or reordered, depending on scrap quality, source of scrap, auxiliary equipment available, furnace design, and product specifications. Plant configuration, scrap type usage, and product output varies throughout the secondary aluminum industry.

Scrap Pretreatment

Aluminum scrap comes from a variety of sources. "New" scrap is generated by pre-consumer sources, such as drilling and machining of aluminum castings, scrap from aluminum fabrication and manufacturing operations, and aluminum bearing residual material (dross) skimmed off molten aluminum during smelting operations. "Old" aluminum scrap is material that has been used by the consumer and discarded. Examples of old scrap include used appliances, aluminum foil, automobile and airplane parts, aluminum siding, and beverage cans.

Scrap pretreatment involves sorting and processing scrap to remove contaminants and to prepare the material for smelting. Sorting and processing separates the aluminum from other metals, dirt, oil, plastics, and paint. Pretreatment cleaning processes are based on mechanical, pyrometallurgical and hydrometallurgical techniques.

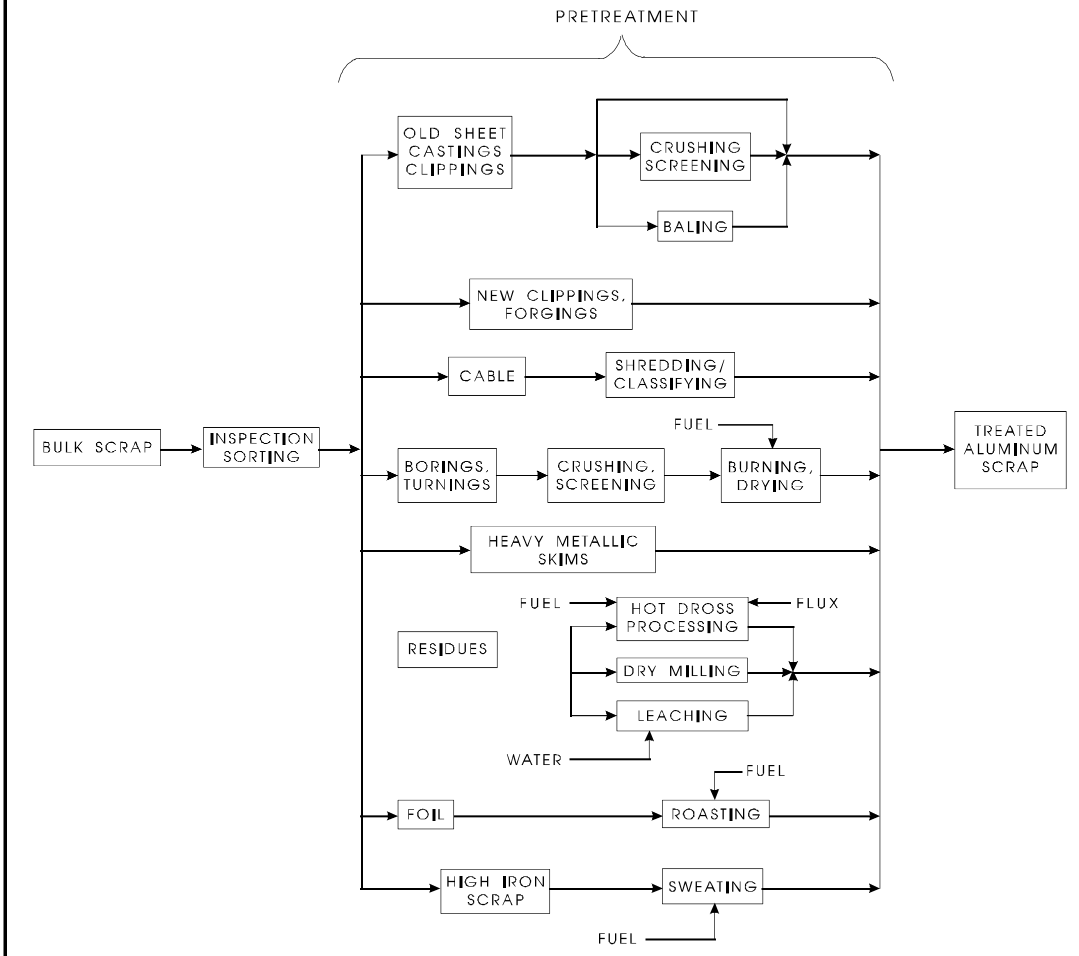

Figure 2.2-1A Typical process diagram for secondary aluminum processing industry

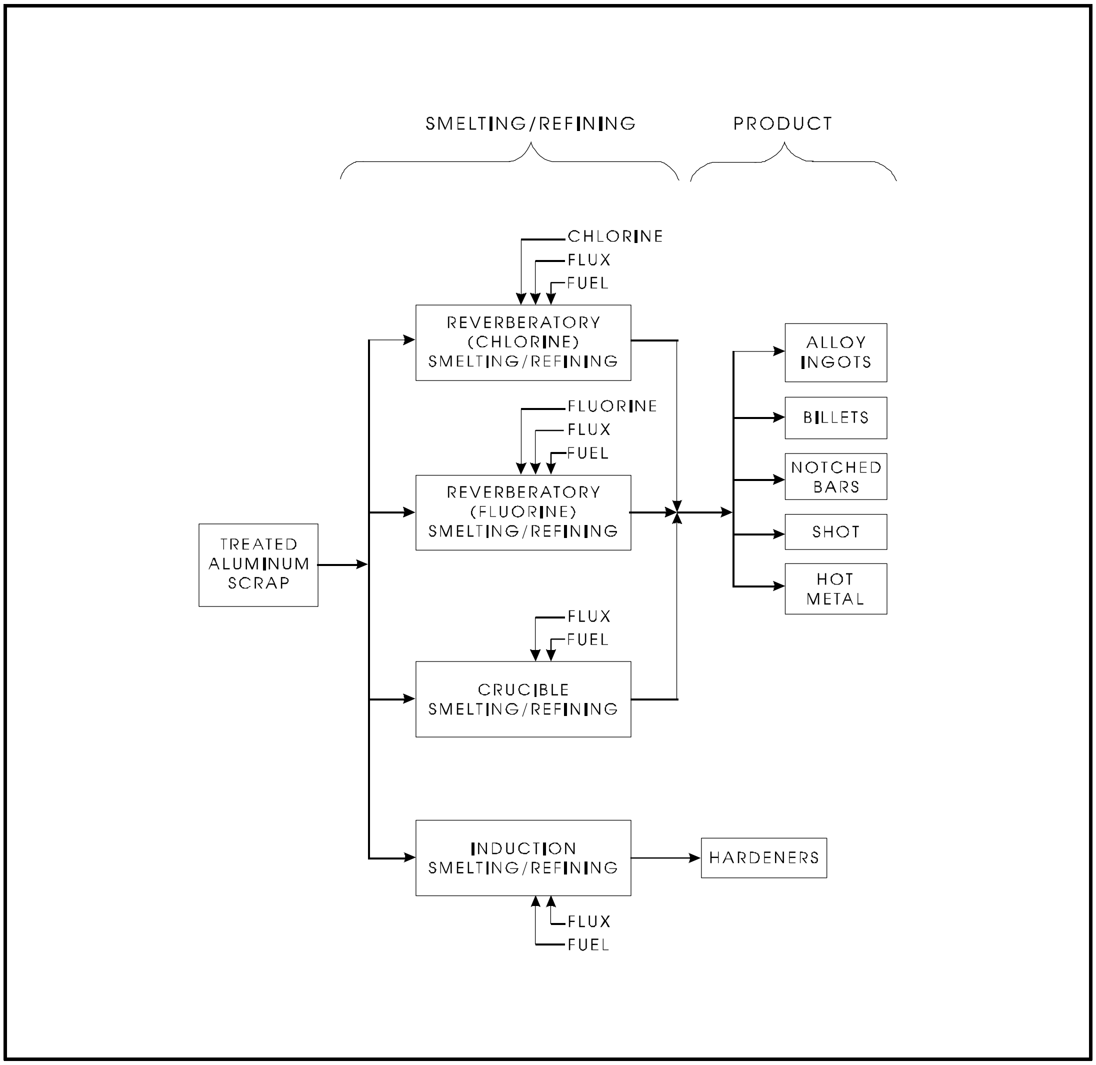

Figure 2.2-1B Typical process diagram for secondary aluminum processing industry (continued)

Mechanical Cleaning

Mechanical cleaning includes the physical separation of aluminum from other scrap, with hammer mills, ring rushers, and other machines to break scrap containing aluminum into smaller pieces. This improves the efficiency of downstream recovery by magnetic removal of iron. Other recovery processes include vibratory screens and air classifiers.

An example of mechanical cleaning is the dry milling process. Cold aluminum-laden dross and other residues are processed by milling and screening to obtain a product containing at least 60 to 70 percent aluminum. Ball, rod or hammer mills can be used to reduce oxides and nonmetallic particles to fine powders for ease of removal during screening.

Pyrometallurgical Cleaning

Pyrometallurgical techniques (called drying in the industry) use heat to separate aluminum from contaminates and other metals. Pyrometallurgical techniques include roasting and sweating. The roasting process involves heating aluminum scrap that contains organic contaminates in rotary dryers to temperatures high enough to vaporize or carbonize organic contaminates, but not high enough to melt aluminum (660°C; 1220°F). An example of roasting is the APROS delacquering and preheating process used during the processing of used beverage cans (shown in Figure 2.2-2). The sweating process involves heating aluminum scrap containing other metals in a sweat furnace to temperatures above the melting temperature of aluminum, but below that of the other metal. For example, sweating recovers aluminum from high iron content scrap by heating the scrap in an open flame reverberatory furnace. The temperature is raised and maintained above the melting temperature of aluminum, but below the melting temperature of iron. This condition causes aluminum and other low melting constituents to melt and trickle down the sloped hearth, through a grate and into air cooled molds or collecting pots. This product is called "sweated pig." The higher-melting materials, including iron, brass, and the oxidation products formed during the sweating process, are periodically removed from the furnace.

In addition to roasting and sweating, a catalytic technique may also be used to clean aluminum dross. Dross is a layer of impurities and semisolid flux that has been skimmed from the surface of molten aluminum. Aluminum may be recovered from dross by batch fluxing with a salt/cryolite mixture in a mechanically rotated, refractory-lined barrel furnace. Cryolite acts as a catalyst that decreases aluminum surface tension and therefore increases recovery rates. Aluminum is tapped periodically through a hole in the base of the furnace.

Hydrometallurgical Cleaning

Hydrometallurgical techniques use water to clean and process aluminum scrap. Hydrometallurgical techniques include leaching and heavy media separation. Leaching is used to

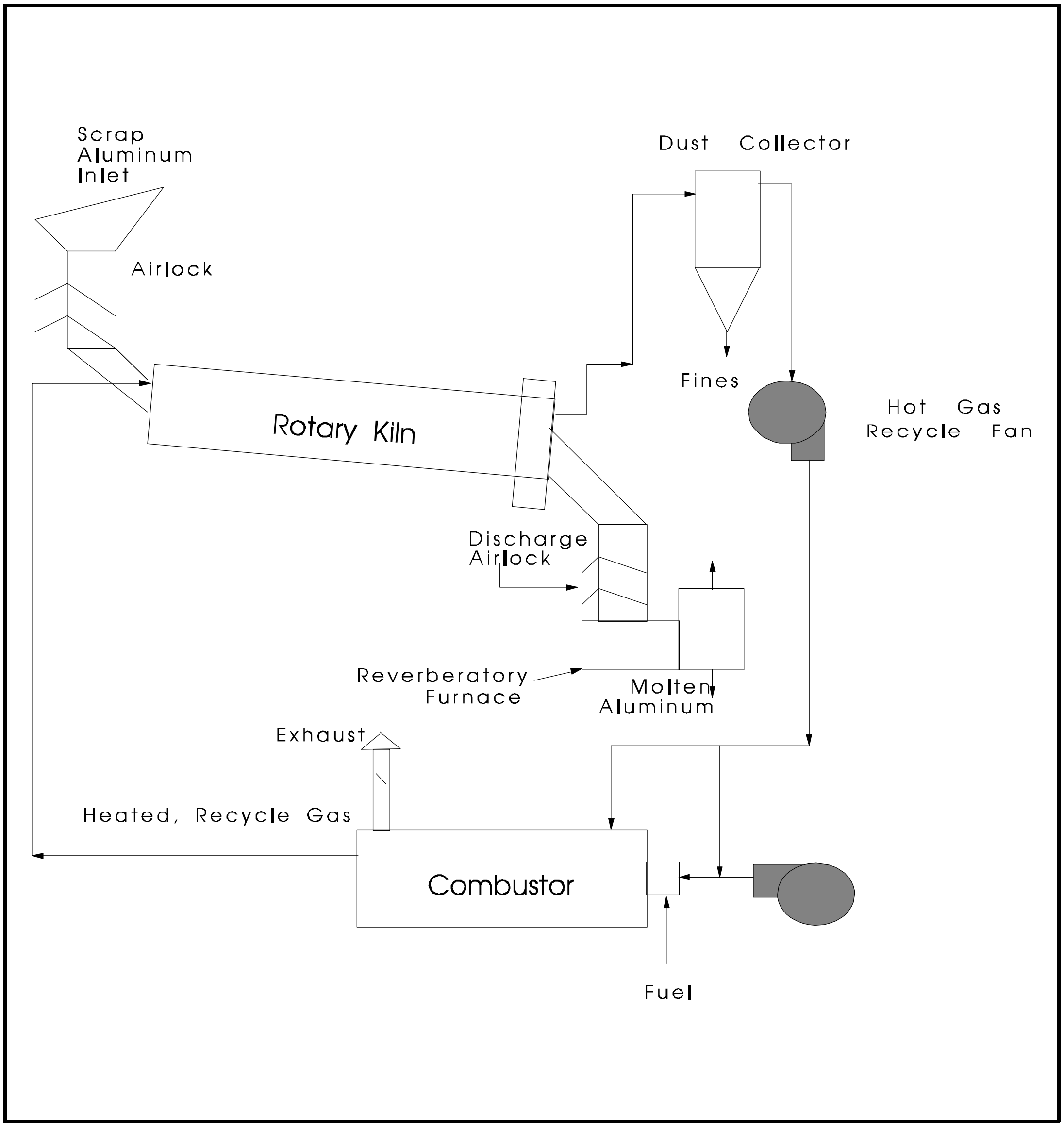

Figure 2.2-2 APROS delacquering and preheating process

recover aluminum from dross, furnace skimmings, and slag. It requires wet milling, screening, drying, and finally magnetic separation to remove fluxing salts and other waste products from the aluminum. First, raw material is fed into a long rotating drum or a wet ball mill where water soluble contaminants are rinsed into waste water and removed (leached). The remaining washed material is then screened to remove fines and undissolved salts. The screened material is then dried and passed through a magnetic separator to remove ferrous materials.

The heavy media separation hydrometallurgical process separates high density metal from low density metal using a viscous medium, such as copper and iron, from aluminum. Heavy media separation has been used to concentrate aluminum recovered from shredded cars. The cars are shredded after large aluminum components have been removed (shredded material contains approximately 30 percent aluminum) and processed in heavy media to further concentrate aluminum to 80 percent or more.

Smelting/Refining

After scrap pretreatment, smelting and refining is performed. Smelting and refining in secondary aluminum recovery takes place primarily in reverberatory furnaces. These furnaces are brick-lined and constructed with a curved roof. The term reverberatory is used because heat rising from ignited fuel is reflected (reverberated) back down from the curved furnace roof and into the melted charge. A typical reverberatory furnace has an enclosed melt area where the flame heat source operates directly above the molten aluminum. The furnace charging well is connected to the melt area by channels through which molten aluminum is pumped from the melt area into the charging well. Aluminum flows back into the melt section of the furnace under gravity.

Most secondary aluminum recovery facilities use batch processing in smelting and refining operations. It is common for one large melting reverberatory furnace to support the flow requirements for two or more smaller holding furnaces. The melting furnace is used to melt the scrap, remove impurities and entrained gases. The molten aluminum is then pumped into a holding furnace. Holding furnaces are better suited for final alloying, and for making any additional adjustments necessary to insure that the aluminum meets product specifications. Pouring takes place from holding furnaces, either into molds or as feed stock for continuous casters.

Smelting and refining operations can involve the following steps: charging, melting, fluxing, demagging, degassing, alloying, skimming, and pouring. Charging consists of placing pretreated aluminum scrap into a melted aluminum pool (heel) that is maintained in melting furnaces. The scrap, mixed with flux material, is normally placed into the furnace charging well, where heat from the molten aluminum surrounding the scrap causes it to melt by conduction. Flux materials combine with contaminates and float to the surface of the aluminum, trapping impurities and providing a barrier (up to 6 inches thick) that reduces oxidation of the melted aluminum. To minimize aluminum oxidation (melt loss), mechanical methods are used to submerge scrap into the heel as quickly as possible. Scrap may be charged as high density bales, loosely packed bales, or as dry shredded scrap that is continuously fed from a conveyor and into the vortex section of the charging well. The continuous feed system is advantageous when processing uniform scrap directly from a drier (such as a delacquering operation for UBCs).

Demagging reduces the magnesium content of the molten charge from approximately 0.5 percent to about 0.1 percent (a typical product specification). In the past, when demagging with liquid chlorine, chlorine was injected under pressure to react with magnesium as the chlorine bubbled to the surface. The pressurized chlorine was released through carbon lances directed under the heel surface, resulting in high chlorine emissions.

A more recent chlorine aluminum demagging process has replaced the carbon lance procedure. Molten aluminum in the furnace charging well gives up thermal energy to the scrap as scrap is melted. In order to maintain high melt rates in the charging well, a circulation pump moves high temperature molten aluminum from the melt section of the reverberatory furnace to the charging well. Chlorine gas is metered into the circulation pump's discharge pipe. By inserting chlorine gas into the turbulent flow of the molten aluminum at an angle to the aluminum pump discharge, small chlorine-filled gas bubbles are sheared off and mixed rapidly in the turbulent flow found in the pump's discharge pipe. In actual practice, the flow rate of chlorine gas is increased until a slight vapor (aluminum chloride) can be seen above the surface of the molten aluminum. Then the flow rate is decreased until no more vapor is seen. It is reported that chlorine usage approaches the stoichiometric relationship using this process. Stack tests showing chlorine emissions resulting from this procedure have not been made available. It is anticipated that reductions of chlorine emissions will be reported in the future.

Other chlorinating agents or fluxes, such as anhydrous aluminum chloride or chlorinated organics, are used in demagging operations. Demagging with fluorine is similar to demagging with chlorine, except that aluminum fluoride (AlF_3) is employed instead of chlorine. The AlF_3 reacts with magnesium to produce molten metallic aluminum and solid magnesium fluoride salt that floats to the surface of the molten aluminum and is trapped in the flux layer.

Degassing is a process used to remove gases entrained in molten aluminum. High pressure inert gases are released below the molten surface to violently agitate the melt. This agitation causes the entrained gasses to rise to the surface to be absorbed in the floating flux. In some operations, degassing is combined with the demagging operation. A combination demagging and degassing process has been developed that uses a ten percent concentration of chlorine gas mixed with a nonreactive gas (either nitrogen or argon). The combined high pressure gases are force through a hand held nozzle that has a designed distribution pattern of hole sizes across the face of the nozzle. The resulting high turbulent flow and the diluted chlorine content primarily degasses the melt. Chlorine emissions resulting from this process are not available.

Alloying combines aluminum with an alloying agent in order to change its strength and ductility. Alloying agents include zinc, copper, manganese, magnesium, and silicon. The alloying steps include an analysis of the furnace charge, addition of the required alloying agents, and then a reanalysis of the charge. This iterative process continues until the correct alloy is reached.

The skimming operation physically removes contaminated semisolid fluxes (dross, slag or skimmings) by ladling them from the surface of the melt. Skimming is normally conducted several times during the melt cycle, particularly if the pretreated scrap contains high levels of contamination. Following the last skimming, the melt is allowed to cool before pouring into molds or casting machines.

The crucible smelting/refining process is used to melt small batches of aluminum scrap, generally limited to 500 kg (1,100 lb) or less. The metal-treating process steps are essentially the same as those of reverberatory furnaces.

The induction smelting and refining process is designed to produce aluminum alloys with increased strength and hardness by blending aluminum and hardening agents in an electric induction furnace. The process steps include charging scrap, melting, adding and blending the hardening agent, skimming, pouring and casting into notched bars. Hardening agents include manganese and silicon.

2.3 EMISSIONS AND CONTROLS

The major sources of emissions from scrap pretreatment processes are scrap crushing and screening operations, scrap driers, sweat furnaces, and UBC delacquering systems. Although each step in scrap treatment and smelting/refining is a potential source of emissions, emission factors for scrap treatment processes have not been sufficiently characterized and documented and are therefore not presented below.

Smelting and refining emission sources originate from charging, fluxing, and demagging processes. Table 2.3-1 presents emission factors for sweating furnaces, crucible furnaces, reverberatory furnaces, and chlorine demagging process.

Scrap Pretreatment Emissions

Mechanical cleaning techniques involve crushing, shredding, and screening and produce metallic and nonmetallic particulates. Burning and drying operations (pyrometallurgic techniques) emit particulates and organic vapors. Afterburners are frequently used to convert unburned VOCs to carbon dioxide and water vapor. Other gases that may be present, depending on the composition of the contaminants, include chlorides, fluorides and sulfur oxides. Specific emission factors for these gases are not presented due to lack of data. Oxidized aluminum fines blown out of the dryer by the combustion gases contain particulate emissions. Wet scrubbers or fabric filters are sometimes used in conjunction with afterburners.

Mechanically generated dust from rotating barrel dross furnaces constitutes the main air emission of hot dross processing. Some fumes are produced from the fluxing reactions. Fugitive emissions are controlled by enclosing the barrel furnace in a hood system and by ducting the emissions to a fabric filter. Furnace offgas emissions, mainly fluxing salt fume, are often controlled by a venturi scrubber.

Emissions from sweating furnaces vary with the feed scrap composition. Smoke may result from incomplete combustion of organic contaminants (e.g., rubber, oil and grease, plastics, paint, cardboard, paper) that may be present. Fumes can result from the oxidation of magnesium and zinc contaminants and from fluxes in recovered dross and skims.

In dry milling, large amounts of dust are generated from the crushing, milling, screening, air classification and materials transfer steps. Leaching operations (hydrometallurgic techniques) may produce particulate emissions during drying. Particulate emissions from roasting result from the charring of carbonaceous materials (ash).

TABLE 2.3-1 (METRIC UNITS)
PARTICULATE EMISSION FACTORS FOR SECONDARY ALUMINUM OPERATIONS[a]

All Emission Factors are in kg/Mg of Product
Ratings (A-E) Follow Each Factor

Operation	SCC's	Uncontrolled		Baghouse		Electrostatic precipitator	
Sweating furnace[b]	3-04-001-01	7.25	E	1.65	E		
Smelting							
Crucible furnace[b]	3-04-001-02	0.95	E				
Reverberatory[c]	3-04-001-03	2.15	E	0.65[e]	E	0.65	E
Chlorine demagging[d]	3-04-001-04	500	E	25	E		E

[a] Reference 2. Emission factors for sweating and smelting furnaces expressed as units per unit weight of metal processed. For chlorine demagging, emission factor is kg/Mg (lb/ton) of chlorine used.

[b] Based upon averages of two source tests.

[c] Uncontrolled, based on averages of ten source tests. Standard deviation of uncontrolled emission factor is 1.75 kg/Mg that of controlled factor is 0.15 kg/Mg.

[d] Based on average of ten source tests. Standard deviation of uncontrolled emission factor is 215 kg/Mg of control factor, 18 kg/Mg.

[e] This factor may be lower if a coated baghouse is used.

TABLE 2.3-1 (ENGLISH UNITS)
PARTICULATE EMISSION FACTORS FOR SECONDARY ALUMINUM OPERATIONS[a]

All Emission Factors are in lb/ton of Product
Ratings (A-E) Follow Each Factor

Operation	SCC's	Uncontrolled		Baghouse		Electrostatic precipitator	
Sweating furnace[b]	3-04-001-01	14.5	E	3.3	E		
Smelting							
Crucible furnace[b]	3-04-001-02	1.9	E				
Reverberatory[c]	3-04-001-03	4.3	E	1.3[e]	E	1.3	E
Chlorine demagging[d]	3-04-001-04	1000	E	50	E		

[a] Reference 2. Emission factors for sweating and smelting furnaces expressed as units per unit weight of metal processed. For chlorine demagging, emission factor is kg/Mg (lb/ton) of chlorine used.

[b] Based upon averages of two source tests.

[c] Uncontrolled, based on averages of ten source tests. Standard deviation of uncontrolled emission factor is 3.5 lb/ton, that of controlled factor is 0.3 lb/ton.

[d] Based on average of ten source tests. Standard deviation of uncontrolled emission factor is 430 lb/ton; of control factor, 36 lb/ton.

[e] This factor may be lower if a coated baghouse is used.

Smelting/Refining Emissions

Emissions from reverberatory furnaces represent a significant fraction of the total particulate and gaseous effluent generated in the secondary aluminum industry. Emissions from the charging well consist of organic and inorganic particulate, unburned organic vapors, and carbon dioxide. Emissions from furnace burners contain carbon monoxide, carbon dioxide, sulfuric oxide, and nitrogen oxide. Furnace burner emissions are usually separated from process emissions.

Emissions that result from fluxing operations are dependent upon both the type of fluxing agents and the amount required, which are a function of scrap quality. Emissions may include common fluxing salts such as sodium chloride, potassium chloride, and cryolite. Aluminum and magnesium chloride also may be generated from the fluxing materials being added to the melt. Studies have suggested that fluxing particulate emission are typically less than one micron in diameter. Specific emission factors for these compounds are not presented due to lack of information.

In the past, demagging represented the most severe source of emissions for the secondary aluminum industry. A more recent process change where chlorine gas is mixed into molten aluminum from the furnace circulation pump discharge may reduce chlorine emissions. However, total chlorine emissions are directly related to the amount of demagging effort and product specifications (the magnesium content in the scrap and the required magnesium reduction). Also, as the magnesium percentage decreases during demagging, a disproportional increase in emissions could result due to the decreased efficiency of the scavenging process.

Both the chlorine and aluminum fluoride demagging processes create highly corrosive emissions. Chlorine demagging results in the formation of magnesium chloride that contributes to fumes leaving the dross. Excess chloride combines with aluminum to form aluminum chloride, a vapor at furnace temperatures, but one that condenses into submicron particles as it cools. Aluminum chloride has an extremely high affinity for water (hygroscopic) and combines with water vapor to form hydrochloric acid. Aluminum chloride and hydrochloric acid are irritants and corrosive. Free chlorine that does not form compounds may also escape from the furnace and become an emission.

Aluminum fluoride (AlF_3) demagging results in the formation of magnesium fluoride as a byproduct. Excess fluorine combines with hydrogen to form hydrogen fluoride. The principal emissions resulting from aluminum fluoride demagging is a highly corrosive fume containing aluminum fluoride, magnesium fluoride, and hydrogen fluoride. The use of AlF_3 rather than chlorine in the demagging step reduces demagging emissions. Fluorides are emitted as gaseous fluorides (hydrogen fluoride, aluminum and magnesium fluoride vapors, and silicon tetrafluoride) or as dusts. Venturi scrubbers are usually used for gaseous fluoride emission control.

Table 2.3-2 presents particle size distributions and corresponding emission factors for uncontrolled chlorine demagging and metal refining in secondary aluminum reverberatory furnaces.

According to the VOC/PM Speciate Database Management System (SPECIATE) database, the following hazardous air pollutants (HAPs) have been found in emissions from reverberatory furnaces: chlorine, and compounds of manganese, nickel, lead, and chromium. In addition to the HAPs listed for reverberatory furnaces, general secondary aluminum plant emissions have been found to include HAPs such as antimony, cobalt, selenium, cadmium, and arsenic, but specific emission factors for these HAPs are not presented due to lack of information.

In summary, typical furnace effluent gases contain combustion products, chlorine, hydrogen chloride and metal chlorides of zinc, magnesium and aluminum, aluminum oxide and various metals and metal compounds, depending on the quality of scrap charged.

2.4 REVIEW OF REFERENCES

Specific changes to the process description expands the industry description and discusses the newest method of demagging with chlorine using a circulation pump. In addition, process information was expanded using published EPA documents and Shreve's Chemical Process Industries, fifth edition, McGraw Hill, 1984.

Emission factors contained in emission tables in the section are downgraded to E. The reasons for this change is discussed in Chapter 4.3.

2.5 REFERENCES FOR CHAPTER 2

1. W.M. Coltharp, et al., Multimedia Environmental Assessment of the Secondary Nonferrous Metal Industry, Draft Final Report, 2 vols., EPA Contract No. 68-02-1319, Radian Corporation, Austin, TX, June 1976.

2. W.F. Hammond and S.M. Weiss, Unpublished report on air contaminant emissions from metallurgical operations in Los Angeles County, Los Angeles County Air Pollution Control District, July 1964.

3. Emission test data from Environmental Assessment Data Systems, Fine Particle emission Information System (EPEIS), Series Report No. 231, U. S. Environmental Protection agency, Research Triangle Park, NC, June 1983.

4. Environmental Assessment Data Systems, op.cit., Series Report No. 331.

5. Danielson, John., "Secondary Aluminum-Melting Processes." Air Pollution Engineering Manual, 2nd Ed., U. S. Environmental Protection Agency, Washington, D.C., Report Number AP-40, May 1973.

6. Secondary Aluminum Reverberatory Furnace, Speciation Database. U.S. Environmental Protection Agency. Research Triangle Park, NC. Profile Number 20101. 1989.

7. Secondary Aluminum Plant—General, Speciation Database. U.S. Environmental Protection Agency. Research Triangle Park, NC. Profile Number 90009. 1989.

TABLE 2.3-2. (METRIC UNITS)
PARTICLE SIZE DISTRIBUTION AND SIZE-SPECIFIC EMISSION FACTORS FOR UNCONTROLLED REVERBERATORY FURNACES IN SECONDARY ALUMINUM OPERATIONS[a]

Ratings (A-E) Follow Each Factor

Aerodynamic particle diameter (μm)	Particle size distribution[b]		Size specific emission factor[c], kg/Mg			
	Chlorine demagging	Refining	Chlorine demagging	Rating	Refining	Rating
2.5	19.8	50.0	99.5	E	1.08	E
6.0	36.9	53.4	184.5	E	1.15	E
10.0	53.2	60.0	266.0	E	1.30	E

[a] References 3-4.

[b] Cumulative weight percent is less than the aerodynamic particle diameter, µm.

[c] Size-specific emission factor equals total particulate emission factor multiplied by particle size distribution, (percent)/100. From Table 12.8-1, total particulate emission factor for chloride demagging is 500 kg/Mg chlorine used, and for refining, 2.15 kg/Mg aluminum processed.

TABLE 2.3-2. (ENGLISH UNITS)
PARTICLE SIZE DISTRIBUTION AND SIZE-SPECIFIC EMISSION FACTORS FOR UNCONTROLLED REVERBERATORY FURNACES IN SECONDARY ALUMINUM OPERATIONS[a]

Ratings (A-E) Follow Each Factor

Aerodynamic particle diameter (μm)	Particle size distribution[b]		Size specific emission factor[c], lb/ton			
	Chlorine demagging	Refining	Chlorine demagging	Rating	Refining	Rating
2.5	19.8	50.0	398	E	2.12	E
6.0	36.9	53.4	738	E	2.3	E
10.0	53.2	60.0	1,064	E	2.6	E

[a] References 3-4.

[b] Cumulative weight percent is less than the aerodynamic particle diameter, µm.

[c] Size-specific emission factor equals total particulate emission factor multiplied by particle size distribution, (percent)/100. From Table 2.3-1, total particulate emission factor for chloride demagging is 1,000 lb/ton chlorine used, and for refining, 4.3 lb/ton aluminum processed.

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 secondary aluminum production. This search included, but was not limited to, the following references:

1) AP-42 background files maintained by the Emission Factor and Methodologies Section. This is the source of the six air tests that are reviewed below.
2) Files maintained by the Emission Standards Division. Although no files are available at this time, the ESD is currently collecting emission rates from the individual corporations that comprise the secondary aluminum industry. This information may be available by the end of 1992.
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 source tests included in the documents reviewed.
5) Information in the *Air Facility Subsystems* (AFS) of the EPA *Aerometric Information Retrieval System* (AIRS). Three and a half boxes of computer printouts were reviewed. PES was unable to retrieve any useful information for this application.
6) Handbook of Emission Factors, Parts I and II, Ministry of Health and Environmental Protection, The Netherlands, 1980/1983. This information substantiated existing AP-42 Section information. 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 USEPA Environmental Research Center library was visited in an attempt to

get primary emission source tests for secondary aluminum facilities. No primary emission source tests for secondary aluminum 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.

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

3.2 EMISSION DATA QUALITY RATING SYSTEM

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

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

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

A

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

B

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

C

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

D

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

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

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

No source test data, fulfilling the requirements of Sections 3.1 and 3.2 on emissions of volatile organic compounds, lead, sulfur dioxide and nitrogen oxides were found for the secondary aluminum industry.

Carbon monoxide.

During September 1990 at State Metal Industries, Inc., compliance emission tests were conducted on a fabric filter serving as a pollution control device for charging wells on three aluminum scrap smelting furnaces, and each of the three independent uncontrolled smelting furnace burner exhaust flues (one for each furnace). These compliance tests are "A" rated and listed as reference 7 for this chapter. Listed below are the carbon monoxide emission rates from each smelting furnace burner flue. PES believes many more carbon monoxide tests of randomly chosen smelting furnace burners is appropriate prior to being reported in Section 7-8. This belief is based on the variation in emissions that occur during batch operations associated with most secondary smelting operations.

TABLE 4.1-1 (METRIC UNITS)
CARBON MONOXIDE

Control Equipment	Test Rating	Test Method	Run #	Production Rate[a]	Emission Rate[b]	Emission Factor[c]
1. Plibrico Flue[d]						
None	A		1	2.08	0.054	0.026
			2	2.06	0.145	0.071
			3	2.08	0.200	0.096
			Average	2.07	0.135	0.064
2. North American Flue[d]						
None	A		1	0.3	0.018	0.061
			2	0.3	0.023	0.076
			3	0.3	0.027	0.091
			Average	0.3	0.023	0.068
3. United Flue[d]						
None	A		1	.72	0.145	0.203
			2	.72	0.086	0.121
			3	.72	0.091	0.127
			Average	.72	0.104	0.150

[a] Units in Mg/hr.

[b] Units in kg/hr.

[c] Units in kg/Mg.

[d] Analysis utilized nondispersal infrared techniques. Samples were collected in 80-liter Tedlar bags at a rate of 0.5 to 0.81 per minute. The measurement instrument was calibrated with EPA Protocol-1 CO standards.

TABLE 4.1-1 (ENGLISH UNITS)
CARBON MONOXIDE

Source Test #	Test Rating	Test Method	Run #	Production Rate[a]	Emission Rate[b]	Emission Factor[c]
1. Plibrico Flue[d]						
None	A		1	2.29	0.12	0.052
			2	2.27	0.32	0.141
			3	2.29	0.44	0.192
			Average	2.28	0.29	0.128
2. North American Flue[d]						
None American Flue[d]	A		1	.33	0.04	0.121
			2	.33	0.05	0.152
			3	.33	0.06	0.182
			Average	.33	0.05	0.152
3. United Flue[d]						
None	A		1	.79	0.32	0.405
			2	.79	0.19	0.241
			3	.79	0.20	0.253
			Average	.79	0.23	0.300

[a] Units in ton/hr.

[b] Units in lb/hr.

[c] Units in lb/ton.

[d] Analysis utilized nondispersal infrared techniques. Samples were collected in 80-liter Tedlar bags at a rate of 0.5 to 0.81 per minute. The measurement instrument was calibrated with EPA Protocol-1 CO standards.

Total Suspended Particulate & PM$_{10}$.

PM$_{10}$ is a subset of total suspended particulate (TSP) and consists of particles having a diameter of less than ten microns (µm). There is no single method which is universally accepted for the determination of particle size. A number of different techniques can be used which measure the size of particles according to their basic physical properties. Since there is no "standard" method for particle size analysis, a certain degree of subjective evaluation was used to determine if a test series was performed using a sound methodology for particle sizing.

For pollution studies, the most common types of particle sizing instruments are cyclones, rotoclones, and cascade impactors. Traditionally, cyclones and rotoclones have been used as a preseparator ahead of a cascade impactor to remove the larger particles. These devices are of the standard reverse-flow design whereby the flue gas enters the cyclone through a tangential inlet and forms a vortex flow pattern. Particles move outward toward the cyclone wall with a velocity that is determined by the geometry and flow rate in the cyclone and by their size. Large particles reach the wall and are collected. A series of cyclones with progressively decreasing cut-points can be used to obtain particle size distributions.

Cascade impactors used for the determination of particle size in process streams consist of a series of plates or stages containing either small holes or slits with the size of the openings decreasing from one plate to the next. In each stage of an impactor, the gas stream passes through the orifice or slit to form a jet directed toward an impaction plate. For each stage, there is a characteristic particle diameter that has a 50 percent probability of impaction. This characteristic diameter is called the cut-point (D50) of the stage. Typically, commercial instruments have six to eight impaction stages with a backup filter to collect those particles which are either too small to be collected by the last stage or which are re-entrained off the various impaction surfaces by the moving gas stream.

The tables listed below reflect controlled particulate from a fabric filter that is the control device for charging wells serving three independent smelting furnaces, and the uncontrolled particulate emissions from each of three separate smelting furnace burner flues. The source test used to build these tables is a compliance emission test at State Metal Industries, Inc., during September 1990. The test data is an "A" rated test and is listed as reference 7. Pacific Environmental Services did not add this information to Section 7-8 because the data represents only one company's operation and variations in emission rates reflect the batch operation normally found in secondary aluminum smelting facilities. Additional random testing at other facilities needs to be conducted in order to establish a more reliable emission factor.

TABLE 4.1-2 (METRIC UNITS)
TOTAL SUSPENDED PARTICULATE AND PM_{10}

Control Equipment	Test Rating	Test Method	Run #	Production Rate[a]	Emission Rate[b]	Emission Factor[c]
1. (For 3 charging wells)[d]						
Fabric filter	A	5	1	3.12	0.717	0.230
			2	3.11	0.229	0.074
			3	3.10	0.087	0.028
			Average	3.11	0.341	0.110
2. Plibrico Burner Flue[d]						
None	A	5	1	2.08	1.773	0.854
			2	2.06	0.139	0.067
			3	2.08	0.106	0.051
			Average	2.07	0.564	0.494
3. North American Burner Flue[d]						
None	A	5	1	0.30	0.024	0.082
			2	0.30	0.018	0.060
			3	0.30	0.020	0.068
			Average	0.30	0.020	0.070
4. United Flue[d]						
None	A	5	1	0.72	0.380	0.529
			2	0.72	0.115	0.160
			3	0.72	0.178	0.248
			Average	0.72	0.224	0.312

[a] Units in kg/hr.

[b] Units in kg/Mg.

[c] Units in kg/Mg.

[d] Analysis utilized nondispersal infrared techniques. Samples were collected in 80-liter Tedlar bags at a rate of 0.5 to 0.81 per minute. The measurement instrument was calibrated with EPA Protocol-1 CO standards.

TABLE 4.1-2 (ENGLISH UNITS)
TOTAL SUSPENDED PARTICULATE AND PM_{10}

Control Equipment	Test Rating	Test Method	Run #	Production Rate[a]	Emission Rate[b]	Emission Factor[c]
1. (For 3 charging wells)[d]						
Fabric filter	A	5	1	3.44	1.58	0.459
			2	3.43	0.504	0.147
			3	3.42	0.192	0.056
			Average	3.43	0.752	0.219
2. Plibrico Burner Flue[d]						
None	A	5	1	2.29	3.91	1.707
			2	2.27	0.306	0.134
			3	2.29	0.234	0.102
			Average	2.28	1.243	0.545
3. North American Burner Flue[d]						
None	A	5	1	.325	0.053	0.163
			2	.325	0.039	0.120
			3	.325	0.044	0.135
			Average	.325	0.045	0.139
4. United Flue[d]						
None	A	5	1	0.793	0.838	1.057
			2	0.793	0.254	0.320
			3	0.793	0.393	0.496
			Average	0.793	0.495	0.624

[a] Units in lb/hr.

[b] Units in lb/ton.

[c] Units in lb/ton.

[d] Analysis utilized nondispersal infrared techniques. Samples were collected in 80-liter Tedlar bags at a rate of 0.5 to 0.81 per minute. The measurement instrument was calibrated with EPA Protocol-1 CO standards.

4.2 NONCRITERIA POLLUTION EMISSION DATA

Hazardous Air Pollutants.

Hazardous Air Pollutants (HAPs) are defined in the 1990 Clean Air Act Amendments. No source test data fulfilling the requirements of Sections 3.1 and 3.2 for HAPs were found for the secondary aluminum industry.

Global Warming Gases.

Pollutants such as methane, carbon dioxide, and N_2O have been found to contribute to overall global warming. No source test data fulfilling the requirements of Sections 3.1 and 3.2 for methane, carbon dioxide, and N_2O were found for the secondary aluminum industry.

Ozone Depletion Gases.

Chlorofluorocarbons have been found to contribute to ozone depletion. No source test data, fulfilling the requirements of Sections 3.1 and 3.2 for chlorofluorocarbons were found for the secondary aluminum industry.

4.3 REVIEW OF SPECIFIC DATA SETS

Pacific Environmental Services lowered all the emission factors in Table 2.3-1 and Table 2.3-2 to "E" to reflect the reference sources used to build emission rates in the tables. Table 2.3-1 is based upon an unpublished report on contaminates written in July, 1964. Another Table 2.3-1 footnote describing tabulated emission rates as being the average of ten unidentified source tests. Table 2.3-2 references AP-40 and the Environmental Assessment Data System as the emission rate sources. In accordance with guidance found in Chapter 3, PES believes it is justified in lowering the emission factor.

The following air source tests were reviewed by PES for possible use in Section 7-8 of AP-42. Each source is identified and technical problems discovered during the review are discussed. Only one of the six tests contained data judged to be accurate.

1. Rochester Smelting and Refining Company: October 22, 1976

Coated Baghouse: control of emissions from charging and demagging operations from secondary aluminum. Smelter work completed on 10/22/76.

This emission test was reviewed by PES and not found acceptable for inclusion because of radically fluctuating baghouse efficiency data. In addition, daily production information had been averaged from three smelting furnaces operating during the day and two operating at night. The baghouse outlet probe was not heated as required by Method 5 during the night collection period. Chlorine measurements were made over a full particulate collection period, and a second run after all demagging had been completed. Of five test runs, only three of the five samples were collected simultaneously. There were also no field notes, equipment calibration documentation, and no real-time production activity related to emission data. (Reference 2).

2. Vista Metals Corporation: September 1981

A scrubber is used to capture chlorine and chlorine compounds from submerged chlorinator section of smelting furnace. Tests also includes particle size distribution at scrubber inlet.

This is an excellent source test for what is believed to be a unique chlorine/chloride control system consisting of a submerged furnace vapor capture area, a settling chamber and scrubber.

PES believes the chlorine/chloride values are accurate, but because of the uniqueness of the system, that data is not incorporated into the Section or this background report. A copy of the report is available in the US EPA files at Research Triangle Park, NC as EMB Report 80-GAL-2 of August 1981. (Reference 3).

3. North American Smelting Company: January 1981

This source test was designed to evaluate stack sampling techniques for secondary aluminum. The outlets from a coated baghouse for a charging well and an outlet from a high pressure venturi chlorination scrubber were tested. Production information along with control inlet data was not included in the testing, so this source test is not incorporated into this report. (Reference 4).

4. Barnet Industries: April 1978

Dross recovery rotary furnaces with baghouse control.

Available documentation is not enough to document a reliable emission test rating or emission factor. (Reference 5).

5. Hall Aluminum Company: October 1979

This is a compliance test, measuring emissions downstream from an afterburner controlling a rotary dryer.

The test results showed compliance, but did not include the elements of a source test needed for AP-42 source tests. (Reference 6).

6. State Metal Industries, Inc.: September 1990

Compliance emission tests on a fabric filter serving as control for the charging wells of three aluminum scrap smelting furnaces, and compliance testing each of the three independent uncontrolled smelting furnace burner exhaust flues (one for each furnace). The fabric filter emission was tested for particulate, hydrochloric acid and chlorine. Each smelting furnace burner exhaust flue was tested for nitrogen oxide, total hydrocarbons, carbon monoxide and particulate. The testing results for hydrochloric acid and chlorine is not used in this chapter because chlorine emission is normally based upon free chlorine, aluminum chloride, magnesium chloride, and hydrochloric acid. It should be noted that hydrochloric acid could be derived from other sources unrelated to demagging (i.e., burning PVC pipe in aluminum scrap charged in the smelter). Total hydrocarbon samples were taken from each smelting burner flue and tested in accordance with the principles of NJ Air Test Method 3, Section 3-9. Volatile organic compounds in the sample are not available as no distinction is made between methane and non-methane hydrocarbons. Nitrogen oxides are not tabulated in this chapter because out of 9 samples taken, only one sample was found to exceed the method's detectible level (detection level = 1.4 mg/sample) with an emission rate of 2.3 lbs/hr. Therefore, only controlled particulate emission rates (after the fabric filter) and uncontrolled particulate and carbon monoxide emission rate from each smelting furnace burner flue are included in chapter 4. Despite these limitations, this compliance test is an "A" rated test provided by the State of New Jersey. (Reference 7).

4.4 DATA GAP ANALYSIS

Available data for emissions for secondary aluminum industry processes have emission factor ratings of E. The emission factor is a measure of the confidence level that can be attached to the reported emission values. The low emission factor ratings are dictated by a deficiency of quality source tests with accurate production rates that meet the stringent quality control requirements discussed in Chapter 3. However, low emission factor ratings should not be used to infer that reported emission rates are in error or are of little value. Emission rates reported in Chapter 2 are the best information available at this time.

Secondary aluminum emissions are greatly influenced by the quality of scrap metals processed (the amount of contaminates such as oil, paint, dirt and non- aluminum metals). There are 116 secondary aluminum recovery facilities in the U.S., each with one or more scrap sources. Each scrap source may supply multiple scrap streams with varying degrees of contamination and nonaluminum metal mix. As a result, not only can emissions from similar secondary aluminum recovery facilities vary, but emissions from an individual plant can vary from day to day depending on the mix of scrap. The quality of scrap being charged during emission testing should be monitored and reported as one of the classifications needed when tabulating emissions from the secondary aluminum industry.

General secondary aluminum plant emissions have been found to include HAPs such as antimony, cobalt, selenium, cadmium, and arsenic. These elements and their compounds need to be tested for to establish their emission rates.

In order to assign importance related to future source testing, the following prioritized list for testing is based upon both quantity and the constituents found in uncontrolled emissions that have been reported in earlier emission studies. The list includes production equipment that generates the emission, the emissions generated and pollution equipment normally used to control that emission. In order to maximize testing resource, reverberatory furnaces should be tested first.

- Reverberatory furnaces,
- burning and drying operations,
- UBC delacquering systems,
- rotating barrel dross furnaces,
- sweating furnaces,
- dry milling and leaching operations

- and scrap pretreatment emissions.

TABLE 4-4.
LIST OF CONVERSION FACTORS

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

Temperature conversion equations:

Fahrenheit to Celsius:

$$°C = \frac{(°F - 32)}{1.8}$$

Celsius to Fahrenheit:

$$°F = 1.8(°C) + 32$$

4.5 REFERENCES FOR CHAPTER 4

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. Rochester Smelting and Refining Company. October 22, 1976. U.S EPA, Office of Air Quality, Research Triangle Park, NC 27711.

3. Vista Metals Corporation - September 1981. EMB Report 80-SAL-2 August 1981, U.S EPA, Office of Air Quality Planning and Standards, Research Triangle Park, NC 27711.

4. North American Smelting Company, January 1981. Contract No. 68-02-2815, U.S. EPA, Emission Measurement Branch, Research Triangle Park, NC 27711.

5. Barnet Industries - April 1978. U.S EPA, Office of Air Quality, Research Triangle Park, NC 27711.

6. Hall Aluminum Company, October 1979. U.S EPA, Office of Air Quality Planning and Standards, Research Triangle Park, NC 27711.

7. State Metal Industries, Inc. September 1990. U.S EPA, Office of Air Quality Planning and Standards, Research Triangle Park, NC 27711.