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MULTIMEDIA ENVIRONMENTAL ASSESSMENT OF THE SECONDARY NONFERROUS METAL INDUSTRY

VOLUME II: INDUSTRY PROFILE

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FOREWARD

Man and his environment must be protected from the adverse effects of pesticides, radiation, noise, and other forms of pollution, and the unwise management of solid wastes. Efforts to protect the environment require a focus that recognizes the interplay between the components of our physical environment -- air, water, and land. The Industrial and Environmental Research Laboratory contributes to this multidisciplinary focus through programs engaged in:

- studies on the effects of environmental contaminants on the biosphere, and

- a search for ways to prevent contamination and to recycle valuable resources.

In this report, the results of a multimedia environmental assessment of the environmental impact of the secondary nonferrous metal industry are presented. These results include the characterization of the industry and its segments, the evaluation of the industry's multimedia environmental problems, and the evaluation of pollution control technology used in the industry. As a result of this study, key information and research needed to develop programs which will lead to more effective control of environmental impacts from reprocessing nonferrous metals were identified.

ABSTRACT

The major objectives of this study were to perform multimedia environmental assessment of the secondary nonferrous metal industry and to identify research, development, and demonstration needs to more effectively control the environmental impacts associated with this industry.

The results and conclusions of this study included: (a) characterization of the industry and its segments, (b) evaluation of the industry's environmental problems, and (c) evaluation of the pollution control technology. The secondary nonferrous metal industry is comprised of 334 companies which are mostly located around urban areas. The industry can be divided into eighteen segments based on the type of metals processed. Of these segments, the Aluminum, Copper, Brass and Bronze, Lead/Antimony, and Zinc Segments account for approximately 95% of the total industry production.

The pollution problems associated with this industry were identified and it was determined that many processes used in the industry were similar with similar environmental impacts. Five specific processes were identified as being major sources of multimedia pollution: (a) Reverberatory Smelting with chlorine/fluorine demagging (Aluminum Segment), Insulation Burning (Copper, Brass and Bronze Segment), Reverberatory/Blast Furnace Smelting (Lead/Antimony Segment), Battery Breaking (Lead/Antimony Segment), and Electrolytic Refining (Copper, Brass and Bronze Segment).

The multimedia emissions from many of the processes used in this industry can have very hazardous effects on health and the environment. There are at least 143 toxic and hazardous compounds, many of which are suspected carcinogens, that can be emitted.

Health and epidemiological studies have also shown toxic effects of these emissions on health and the environment.

Based on the results, recommendations for key secondary nonferrous metal industry research needs were source characterization and development and demonstration needs. The degree of source characterization required for each process would depend on the amounts and toxicity of the waste streams. Development and demonstration needs included process modifications, and retrofit pollution control technologies.

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CONTENTS

Page

FOREWARD ii

ABSTRACT iii

1.0 INTRODUCTION 1

2.0 INDUSTRY OVERVIEW 3

3.0 SECONDARY NONFERROUS METAL INDUSTRY SUMMARIES .. 8

- 3.1 Secondary Aluminum Segment 10
  - 3.1.1 Segment Description - Secondary Aluminum 10
  - 3.1.2 Segment Analysis - Secondary Aluminum 16
  - 3.1.3 Environmental Impact - Secondary Aluminum 57
- 3.2 Secondary Copper, Brass and Bronze Segment.. 65
  - 3.2.1 Segment Description - Secondary Copper, Brass and Bronze 65
  - 3.2.2 Segment Analysis - Secondary Copper 72
  - 3.2.3 Environmental Impact - Secondary Copper, Bronze and Brass 117
- 3.3 Secondary Lead/Antimony Segment 132
  - 3.3.1 Segment Description - Secondary Lead/Antimony 132
  - 3.3.2 Segment Analysis - Secondary Lead/Antimony 137
  - 3.3.3 Environmental Impact - Secondary Lead/Antimony 165
- 3.4 Secondary Zinc Segment 179
  - 3.4.1 Industry Description - Secondary Zinc 179
  - 3.4.2 Segment Analysis - Secondary Zinc 185
  - 3.4.3 Environmental Impact - Secondary Zinc.225

CONTENTS (CONTINUED)

Page

3.5 Secondary Beryllium Segment 232
  3.5.1 Segment Description - Secondary Beryllium 232
  3.5.2 Segment Analysis - Secondary Beryllium 233
  3.5.3 Environmental Impact - Secondary Beryllium 234
3.6 Secondary Cadmium Segment 236
  3.6.1 Segment Description - Secondary Cadmium 236
  3.6.2 Segment Analysis - Secondary Cadmium 237
  3.6.3 Environmental Impact - Secondary Cadmium 245
3.7 Secondary Cobalt Segment 247
  3.7.1 Segment Description - Secondary Cobalt 247
  3.7.2 Segment Analysis - Secondary Cobalt 248
  3.7.3 Environmental Impact - Secondary Cobalt 256
3.8 Secondary Germanium Segment 258
  3.8.1 Segment Description - Secondary Germanium 258
  3.8.2 Segment Analysis - Secondary Germanium 259
  3.8.3 Environmental Impact - Secondary Germanium 264
3.9 Secondary Hafnium 266
  3.9.1 Segment Description - Secondary Hafnium 266
  3.9.2 Segment Analysis - Secondary Hafnium 266
  3.9.3 Environmental Impact - Secondary Hafnium................. 267

CONTENTS (CONTINUED)

Page

3.10 Secondary Indium Segment 268

- 3.10.1 Segment Description - Secondary Indium 268
- 3.10.2 Segment Analysis - Secondary Indium 268
- 3.10.3 Environmental Impact - Secondary Indium 269

3.11 Secondary Magnesium Segment 271

- 3.11.1 Segment Description - Secondary Magnesium 271
- 3.11.2 Segment Analysis - Secondary Magnesium 272
- 3.11.3 Environmental Impact - Secondary Magnesium 278

3.12 Secondary Mercury Segment 280

- 3.12.1 Segment Description - Secondary Mercury 280
- 3.12.2 Segment Analysis - Secondary Mercury 283
- 3.12.3 Environmental Impact - Secondary Mercury 298

3.13 Secondary Nickel Segment 303

- 3.13.1 Segment Description - Secondary Nickel 303
- 3.13.2 Segment Analysis - Secondary Nickel 305
- 3.13.3 Environmental Impact - Secondary Nickel 315

3.14 Secondary Precious Metals Segment 318

- 3.14.1 Segment Description - Secondary Precious Metals 318

CONTENTS (CONTINUED)

Page

3.14.2 Segment Analysis - Secondary Precious Metals 320

3.14.3 Environmental Impact - Secondary Precious Metals 330

3.15 Secondary Selenium Segment 333

3.15.1 Segment Description - Secondary Selenium 333

3.15.2 Segment Analysis - Secondary Selenium 334

3.15.3 Environmental Impact - Secondary Selenium 342

3.16 Secondary Tin Segment 345

3.16.1 Segment Description - Secondary Tin 345

3.16.2 Segment Analysis - Secondary Tin 347

3.16.3 Environmental Impact - Secondary Tin 363

3.17 Secondary Titanium Segment 367

3.17.1 Segment Description - Secondary Titanium 367

3.17.2 Segment Analysis - Secondary Titanium 368

3.17.3 Environmental Impact - Secondary Titanium 380

3.18 Secondary Zirconium Segment 383

3.18.1 Segment Description - Secondary Zirconium 383

3.18.2 Segment Description - Secondary Zirconium 383

CONTENTS (CONTINUED)

Page

4.0 NOISE POLLUTION 385
4.1 Noise Emissions 385
4.2 Noise Control 385
5.0 POLLUTANT HEALTH AND ENVIRONMENTAL IMPACTS 389
REFERENCES 400

LIST OF FIGURES
(Continued)

Figure No.	Title	Page
2.0-2	Company Location Map For The Secondary Nonferrous Metal Industry	4
3.1-1	Process Flow Diagram For The Aluminum Segment Of The Secondary Nonferrous Metal Industry	18
3.2-1	Process Flow Diagram For The Copper, Brass, And Bronze Segment Of The Secondary Nonferrous Metal Industry	73
3.3-1	Process Flow Diagram For the Lead/Antimony Segment Of The Secondary Nonferrous Metal Industry	138
3.4-1	Process Flow Diagram For The Zinc Segment Of The Secondary Nonferrous Metal Industry	186
3.6-1	Process Flow Diagram For The Cadmium Segment Of The Secondary Nonferrous Metal Industry	238
3.7-1	Process Flow Diagram For The Cobalt Segment Of The Secondary Nonferrous Metal Industry	249
3.8-1	Process Flow Diagram For The Germanium Segment Of The Secondary Nonferrous Metal Industry	260
3.10-1	Process Flow Diagram For The Indium Segment Of The Secondary Nonferrous Metal Industry	270
3.11-1	Process Flow Diagram For The Magnesium Segment Of The Secondary Nonferrous Metal Industry	273
3.12-1	Process Flow Diagram For The Mercury Segment Of The Secondary Nonferrous Metal Industry	284
3.13-1	Process Flow Diagram For The Nickel Segment Of The Secondary Nonferrous Metal Industry	308

LIST OF FIGURES
(Continued)

Figure No.	Title	Page
3.14-1	Process Flow Diagram For The Precious Metals Segment Of The Secondary Nonferrous Metal Industry	321
3.15-1	Process Flow Diagram For The Selenium Segment Of The Secondary Nonferrous Metal Industry	335
3.16-1	Process Flow Diagram For The Tin Segment Of The Secondary Nonferrous Metal Industry	348
3.17-1	Process Flow Diagram For The Titanium Segment Of The Secondary Nonferrous Metal Industry	369

LIST OF TABLES

Table No.	Title	Page
2.0-1	Population and Production of Segments Within The Secondary Nonferrous Metal Industry	6
2.0-2	Quantities and Costs of Fuels Purchased By The Secondary Nonferrous Metal Industry In 1973	7
3.1-1	U.S. Consumption Of Aluminum Scrap and Sweated Pig In 1973[1]	13
3.1-2	A.S.R.I. Aluminum Scrap Classifications	14
3.1-3	Production Of Secondary Aluminum Alloys By Independent Smelters In 1973	17
3.1-4	Chemical Analysis Of A Typical Rotary Aluminum Furnace Slag	30
3.1-5	Typical Analyses Of Settled Wastewaters From Aluminum Residue Leaching Operations	33
3.1-6	Particle Size Data - Aluminum Sweating Furnace	36
3.1-7	Character of Wastewater from Molten Metal Cooling and Quenching	44
3.1-8	Scrubber Collection Efficiencies For Emissions From Secondary Aluminum (Chlorinated) Reverberatory Smelters	46
3.1-9	Average Particulate Collection Efficiency Obtained By Using Various Devices On Emissions From Secondary Aluminum (Chlorinated) Reverberatory Smelters	47
3.1-10	Character of Cooling Wastewater From Aluminum (Chlorine) Reverberatory Furnaces	48
3.1-11	Character of Untreated Wastewater From Chlorination Fume Scrubbing	49
3.1-12	Effluent Limitations For Treated Fume Scrubber Wastewater Generated During Chlorine Demagging To Be Achieved by July 1, 1977, Based On The Best Practicable Control Technology Currently Available	59

LIST OF TABLES
(Continued)

Table No.	Title	Page
3.1-13	Effluent Limitations For Treated Wastewater From Residue Milling To Be Achieved By July 1, 1977, Based On The Best Practicable Control Technology Currently Available	60
3.1-14	Process Pollutant and Control Summary - Aluminum Segment	61
3.2-1	Domestic Consumption Of And Recovery From Purchased New And Old Copper-Base Scrap In 1971 Through 1973	67
3.2.2	National Association Of Secondary Materials Industries Classifications For Copper-Bearing Scrap Materials	69
3.2-3	Nominal Chemical Specifications For Brass And Bronze Ingot Institute Standard Alloys	70
3.2-4	Character of Wastewater From Slag Quenching And Granulation Or Slag Milling After Settling	80
3.2-5	Wire Incineration Furnace Operating Parameters	83
3.2-6	Wire Incinerator Effluents (Typical Rubber-Covered Wire Charge)	85
3.2-7	Character Of Wastewater From Molten Metal Cooling And Quenching	101
3.2-8	Typical Electrolytic Copper Refining Parameters	108
3.2-9	Character of Wastewater From Electrolytic Refining (Treated Before Discharge[a])	110
3.2-10	Air Pollution Control Processes Used By Smelters And Refiners Of Secondary Brass And Bronze and Secondary Copper	118
3.2-11	Summary Of Wastewater Handling Practice and Disposition Used By Secondary Copper Industry	118

LIST OF TABLES
(Continued)

Table No.	Title	Page
3.2-12	Process Pollutant And Control Summary - Copper, Brass, and Bronze Segment	120
3.3-1	Consumption Of Lead Scrap In 1973	134
3.3-2	Chemical Requirements For Soft Lead	136
3.3-3	Process Pollutant And Control Summary - Lead/Antimony Segment	170
3.3-4	Major Sources Of Air Emissions In The Secondary Lead Industry	175
3.3-5	Efficiencies of Particulate Control Equipment Associated With Secondary Lead Smelting Furnaces	177
3.4-1	Grades Of Zinc Scrap and Drosses	181
3.4-2	Consumption Of New and Old Zinc Scrap In The United States In 1973	183
3.4-3	Secondary Zinc Products Produced In 1975	185
3.4-4	Emission Factors For Reverberatory Sweating	189
3.4-5	Emissions From Zinc Reverberatory Sweating Furnace Controlled By Baghouse	190
3.4-6	Analyses Of Particulate Emissions From Zinc Sweat Processing	197
3.4-7	Process and Pollutant Control Summary - Zinc Segment	227
3.5-1	Process Pollutant and Control Summary - Beryllium Segment	235
3.6-1	Process Pollutant and Control Summary - Cadmium Segment	246
3.7-1	Process Pollutant and Control Summary - Cobalt Segment	257

LIST OF TABLES
(Continued)

Table No.	Title	Page
3.8-1	Process Pollutant and Control Summary - Germanium Segment	265
3.11-1	Process Pollutant and Control Summary - Magnesium Segment	279
3.12-1	U.S. Mercury Consumption And Production In 1974 And 1975	280
3.12-2	Mercury Consumed In The United States In 1973	281
3.12-3	Mercury Emissions By Source In 1968	298
3.12-4	Process Pollutant and Control Summary - Mercury Segment	301
3.13-1	Consumption Of New And Old Scrap In The United States In 1973	304
3.13-2	Nickel Recovered From Nonferrous Scrap Process In The United States	306
3.13-3	Process Pollutant and Control Summary - Nickel Segment	316
3.14-1	Production Of Precious Metals	319
3.14-2	Process Pollutant and Control Summary - Precious Metals Segment	331
3.15-1	Major Uses of Selenium	333
3.15-2	Process Pollutant and Control Summary - Selenium Segment	343
3.16-1	Process Pollutant and Control Summary - Tin Segment	364
3.17-1	Process Pollutant and Control Summary - Titanium Segment	381
4.1-1	Sound Pressure Levels For Selected Equipment Items	386

LIST OF TABLES
(Continued)

Table No.	Title	Page
4.2-1	Sources And Abatement Techniques For Noise Pollution	388
5.0-1	Preliminary Pollutant Health and Environmental Impact Table	392

1.0 INTRODUCTION

In this report, a multimedia (air, water, solid waste and noise) environmental assessment of the secondary nonferrous metal industry is presented. In Volume I, the results and conclusions of the study are summarized and recommendations for current research needs in the secondary industry are discussed. In this volume, a detailed summary is presented of the results of the industry characterization and environmental assessment subtasks.

A general overview of the secondary nonferrous metal industry is presented in Section 2.0. In Section 3.0, a series of 18 industry description documents are presented, one for each of the secondary industry segments which are identified in Section 2.0.

Within each industry description, an overview of the segment, an analysis of its processes and a summary of its multimedia environmental impacts are presented. An exception to this approach is represented by the method of presenting the noise pollution problem. Because the features of this impact category are similar for all segments, this subject is discussed on an industry-wide basis in Section 4.0. A summary tabulation of the health and environmental effects of pollutants which can be emitted by secondary sources is presented in Section 5.0.

Volume III contains Appendices A, B, C, D, and E that list the companies which make up this industry and the raw materials consumed and products produced by each. A bibliography of references that also provided background information for this study is included in Appendix F. Appendix G is a glossary of commonly used terms.

All of the process data presented in this volume are expressed in metric units. English equivalents are generally given in parentheses. Conversions were carried out maintaining levels of accuracy consistent with the original source of the data.

2.0 INDUSTRY OVERVIEW

The secondary nonferrous metal industry is made up of 334 companies. These companies are listed in the Company Directory (Volume III - Appendix A). The locations of these companies are illustrated in Figure 2.0-1. This Company/Location Map for the industry shows that the greatest concentration of companies in this industry is in the New York City area. The other five areas having high industry population densities are the Cleveland, Chicago, Detroit, Philadelphia and Los Angeles locales. The major reason for this is the high concentrations of scrap producers and markets for products.

The total value of shipments of secondary metals for all segments as reported in the <u>1972 Census of Manufacturers</u> was nearly 2.1 billion dollars (US-276). It is estimated that the total employment for the industry is approximately 17,800 including 13,200 production workers. These figures were based on a total industry population of 381 establishments, a decrease from the 403 establishments as indicated by the 1967 Census.

From the Company Product and Raw Material lists in Appendices B and C of Volume III, respectively, it can be seen that many companies are engaged in the production of more than one metal. To aid in characterizing the industry, the secondary nonferrous metal industry is divided into eighteen segments listed below.

- Aluminum
- Copper, Brass, and Bronze
- Lead/Antimony
- Zinc
- Beryllium
- Cadmium
- Cobalt
- Germanium
- Hafnium
- Indium
- Magnesium
- Mercury
- Nickel
- Precious Metals
- Selenium
- Tin
- Titanium
- Zirconium

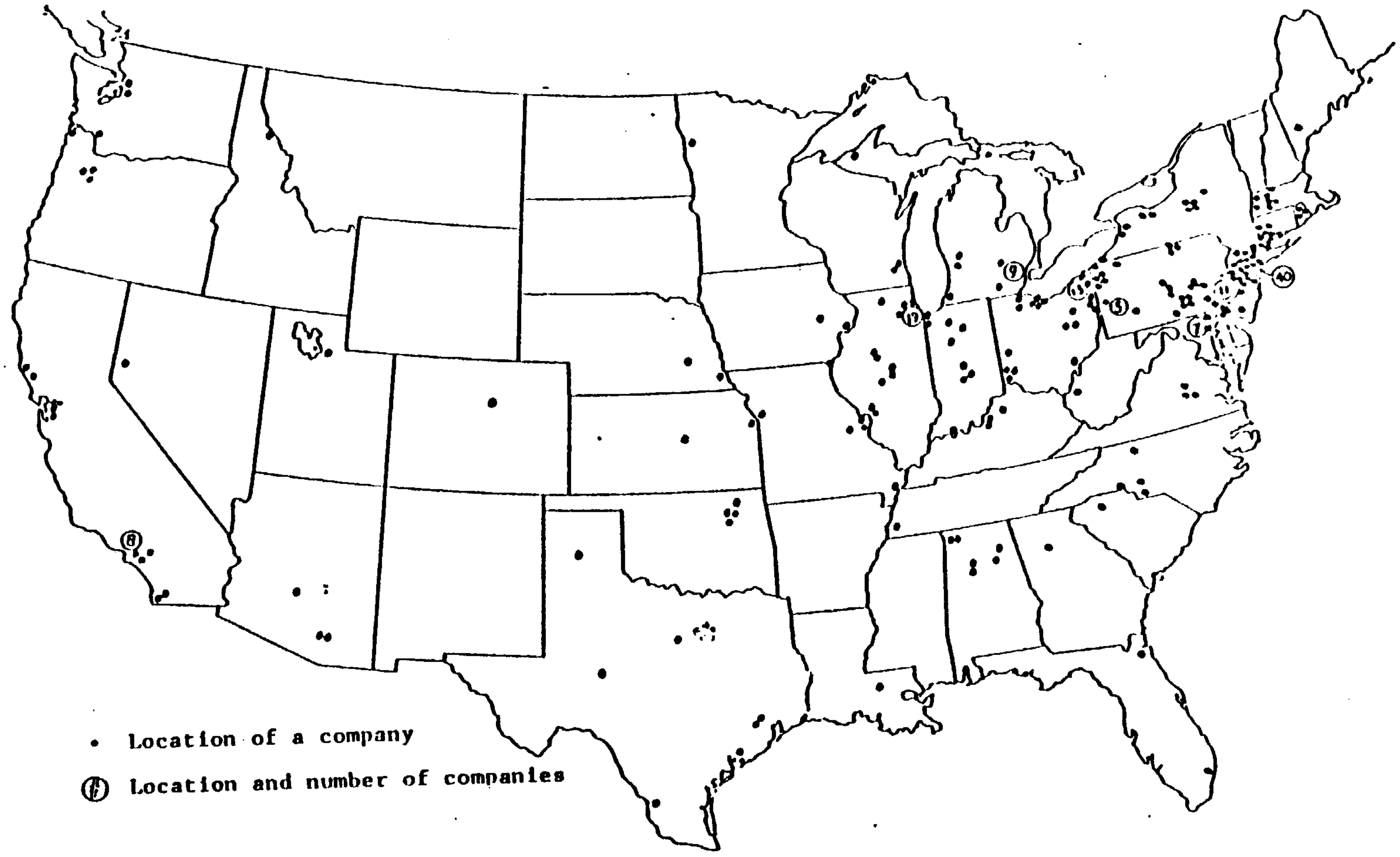

Figure 2.0-1. PLANT-LOCATION MAP FOR THE SECONDARY NONFERROUS METAL INDUSTRY

These segments are described in detail in Section 3 of this report.

The total production and the company populations of these segments are listed in Table 2.0-1. Because many companies produce more than one metal, the company population figures do not add up to 334. From this table, the four largest segments of the industry are (a) Aluminum, (b) Copper, Brass, and Bronze, (c) Lead/Antimony, and (d) Zinc, and these four segments account for 95 percent of the total industry production. From these production figures, it follows that the total amounts of emissions and effluents from these four major segments will be greater than those of the other fifteen segments. It should be emphasized, however, that these smaller segments can emit very hazardous pollutants and should be considered in characterizing the industry's emission sources.

Total utility requirements for the secondary nonferrous metal industry may also be estimated from 1971 data reported by the Bureau of Census (US-074). Purchased fuels and electrical energy amounted to 8.0 billion kilowatt-hours equivalent with the total cost being 23.1 million dollars. Purchased electrical energy represented 0.5 billion kilowatt-hours, costing 7.7 million dollars, while purchased fuels accounted for the remaining energy demands A breakdown of this latter category is shown in Table 2.0-2. These utility usage data indicate that the secondary nonferrous metal industry is mainly dependent on electricity and natural gas as an energy source. Fuel oil and coal are secondary. The high demands for natural gas could indicate that the future of the secondary nonferrous metal industry will be impacted by the decrease in natural gas supplies

Table 2.0-1. POPULATION AND PRODUCTION OF SEGMENTS WITHIN THE SECONDARY NONFERROUS METAL INDUSTRY

Segment	Population Number of companies	Production Metric tons (1975)
Aluminum	131	816,000
Copper, Brass, and Bronze	108	313,000
Lead/Antimony	130	520,000
Zinc	61	86,000
Beryllium	8	91
Cadmium	9	110[a]
Cobalt	14	120
Germanium	4	3.6[b]
Hafnium	4	–[c]
Indium	2	–[c]
Magnesium	15	18,000
Mercury	16	407
Nickel	36	53,000
Precious Metals	53	1,324
Selenium	4	9[d]
Tin	57	13,000
Titanium	18	7,600
Zirconium	7	–[c]

Source: Appendices D and E (Volume III), US-357

[a] Estimated based on 5% of total (primary and secondary) cadmium

[b] Year of data not reported

[c] Not reported

[d] Includes only secondary selenium produced from old scrap

Table 2.0-2. QUANTITIES AND COSTS OF FUELS PURCHASED BY THE SECONDARY NONFERROUS METAL INDUSTRY IN 1973

Fuel	Quantity	Cost, Million $
Distillate fuel oil	434,300 barrels	2.0
Residual fuel oil	145,100 barrels	0.6
Natural gas	14.0×10^9 cubic feet	7.7
Coal	3000 short tons	(<$50,000)
Coke and breeze	(not reported)	1.3
Other fuels	-	1.4
Fuels not specified by kind	-	2.5
Total:	7.5×10^9 kW-hr equivalents	15.5

Source: US-074

The industry currently is experiencing an upward growth trend (1 to 6% per year) with respect to production and particular industry segment. This can be expected to continue as interest in energy and raw material conservation continues. A second observation of industry trends forecasts a continuing decline in the number of companies as a result of consolidation, pollution control regulations, and technical obsolescence. In addition, the scrap producing facilities currently not considered within the secondary metal industry may intensify their efforts in secondary processing because of increasing transportation costs, efficiency expansion, or other incentives. Finally, a growing availability of municipal solid waste processing systems involving classification and various degrees of scrap pretreatment may constitute an additional expansion of the industry boundaries.

3.0 SECONDARY NONFERROUS METAL INDUSTRY SUMMARIES

In this section of the report, industry segment descriptions and environmental impact analysis results for each of the 18 secondary industry segments identified in Section 2.0 are presented. The four major industry segments (aluminum; copper, brass and bronze; lead/antimony; and zinc) are described in subsections 3.1 through 3.4. The remaining 14 minor metal recovery segments are discussed (in alphabetical order) in subsections 3.5 through 3.18.

The format which has been established for the presentation of industry data in this section involves (for each segment):

1) a segment description,
2) a segment analysis, and
3) a segment environment impact summary

Each segment description provides a brief overview of the companies comprising the segment, production data, raw materials, products and growth trends. The segment analysis section of each document contains a process flowsheet and a description of possible schemes for the flow of materials through the segment. Each process identified on the flowsheet is characterized with respect to its:

- function
- input materials
- operating parameters
- utilities
- waste streams
- EPA source classification code

The EPA Source Classification Code (SCC) is defined as a numerical coding to define point sources or processes that emit air pollutants.

In the environmental impact summary sections the major sources of environmental threat in each segment are discussed. Applicable control techniques for each emission source are also reported along with any available information on specific applications of those technologies in the industry.

3.1 Secondary Aluminum Segment

3.1.1 Segment Description - Secondary Aluminum

The aluminum segment of the secondary nonferrous metals industry recovers, processes, remelts, and refines aluminum-bearing scrap to produce metallic aluminum and aluminum alloys. Companies whose primary service is the collection, handling, and transport of scrap to the secondary aluminum plants are not considered under this definition.

This segment of the secondary nonferrous metals industry was established in 1904. It experienced major growth in the 1920's and again in the late 1940's and 1950's. While the total output of secondary aluminum has continued to increase in recent years, the number of companies in the population has decreased particularly in the last decade because of industry consolidation and technical obsolescence.

Total aluminum consumption (primary and secondary) as measured by shipments of aluminum ingot and mill products, increased 21 percent in 1973 (ST-328). The growing demand for aluminum is partially evidenced by the aluminum can recycling trend. Can collections in the first half of 1975 more than doubled the rate for the equivalent period in 1973 (CA-289). Both energy and environmental issues are responsible for this stimulated interest in recycling programs. The projected growth rate of this segment is approximately 6 percent per year (US-357).

According to the 1972 Census of Manufacturers there are 52 companies whose primary product is secondary aluminum ingot and 6 companies primarily engaged in manufacturing secondary aluminum billets. The total number of workers employed in these two groups of companies are 4000 and 300, respectively (US-276). However, 131 companies were identified in the Raw Material and Product/Company Listings in Appendices D and E (Vol. III).

The total 1975 domestic production of secondary aluminum was 816,000 metric tons (900,000 short tons), a decrease of nine percent compared to the 1974 production. Producers of secondary aluminum which are not considered to be a part of the secondary metals industry are primary producers, fabricators, foundries, and chemical producers.

Estimates of the number of secondary aluminum smelting plants in the United States range from 35 to 85 (EN-158, NA-182). Approximately 30 percent of the total production comes from the two largest companies, and another 30 percent comes from the next four largest establishments. It is obvious from these figures that the majority of the secondary aluminum produced in this country is accounted for by a small number of large plants.

Most secondary aluminum plants are located near heavily industrialized areas in order to be close to scrap suppliers and customers. Unlike primary aluminum producers, it is not essential for these plants to have access to major supplies of electricity and water. This industry is centered around Chicago and Cleveland in the Midwest, Los Angeles on the West Coast, and New York and Philadelphia in the East; there are no secondary aluminum smelters in the Rocky Mountains (EN-158).

Raw Materials

Raw materials costs represent approximately 75% of the total costs of a secondary aluminum plant. The major raw material is scrap aluminum which is purchased in competitive markets from scrap metal dealers and industrial plants. About 5% of the raw material cost is for alloying ingredients such as copper and silicon. Other process materials include degassing and demagging agents, fluxes and grain refining agents. These are specified more fully in the process descriptions presented in Section 3.1.2.

Raw materials purchased by secondary aluminum smelters include new and old scrap, sweated pig, and some primary aluminum. In 1973 the total consumption of scrap amounted to nearly 670,000 metric tons (ST-328). Table 3.1-1 presents a breakdown of the types of scrap consumed by secondary smelters. For comparison, the total consumption by other users of scrap aluminum (primary producers, foundries, fabricators, and chemical plants) is also shown.

Thirty distinct classifications for aluminum scrap have been established by the Aluminum Smelters Research Institute (ASRI), (now the Aluminum Recycling Association) based upon the copper, silicon, zinc, and iron content of the scrap. Magnesium is not specified since this more active contaminant can be removed with relative ease during processing. These scrap classifications are presented in Table 3.1-2.

New scrap results from semifabricating and fabricating operations while old scrap refers to products of obsolescence. Terms used to categorize new scrap are home (sometimes called revert or runaround) and prompt industrial scrap. Home scrap is recycled within the generating facility and thus does not enter the commercial scrap market. Prompt industrial scrap, on the other hand, is generated at facilities unequipped for recycling and is often sold to the secondary aluminum industry.

Table 3.1-1. U. S. CONSUMPTION OF ALUMINUM SCRAP AND SWEATED PIG IN 1973[a]

Class of consumer and type of scrap	Consumption, metric ton
Secondary smelters:[b]	
New scrap:	
Solids:	
Segregated low copper (Cu maximum, 0.4%)	136,909
Segregated high copper	8,730
Mixed low copper (Cu maximum, 0.4%)	88,200
High zinc (7000 series type)	6,073
Mixed clips	74,122
Borings and turnings:	
Low copper (Cu maximum, 0.4%)	25,799
Zinc, under 0.5%	10,191
Zinc, 0.5% to 1.0%	68,204
Foil, dross, skimmings	78,185
Other new scrap	20,306
Total new scrap	516,719
Old scrap (solids)	101,493
Sweated pig (purchased for own use)	50,673
Total all classes	668,885
Primary producers, foundries, fabricators, and chemical plants:	
New scrap:	
Solids:	
Segregated low copper (Cu maximum, 0.4%)	176,948
Segregated high copper	7,269
Mixed low copper (Cu maximum, 0.4%)	122,585
High zinc (7000 series type)	1,285
Mixed clips	4,520
Borings and turnings:	
Low copper (Cu maximum, 0.4%)	c
Zinc under 0.5%	c
Zinc, 0.5% to 1.0%	c
Foil, dross, skimmings	5,700
Other new scrap	72,549
Total new scrap[d]	391,411
Old scrap (solids)	58,645
Sweated pig (purchased for own use)	27,102
Total all classes	477,158
Total of all scrap consumed:	
New scrap:	
Solids:	
Segregated low copper (Cu maximum, 0.4%)	313,857
Segregated high copper	15,999
Mixed low copper (Cu maximum, 0.4%)	210,785
High zinc (7000 series type)	7,359
Mixed clips	78,642
Borings and turnings:	
Low copper (Cu maximum, 0.4%)	25,808
Zinc, under 0.5%	10,228
Zinc, 0.5% to 1.0%	68,710
Foil, dross, skimmings	83,885
Other new scrap	92,855
Total new scrap[d]	908,128
Old scrap (solids)	160,000
Sweated pig (purchased for own use)	77,776
Total all classes	1,146,042

[a] Includes imported scrap.
[b] Excludes secondary smelters owned by primary aluminum companies.
[c] Withheld to avoid disclosing individual company confidential data.
[d] Includes data withheld.

Source: ST-328

Table 3.1-2. A.S.R.I. ALUMINUM SCRAP CLASSIFICATIONS

1. **NEW PURE ALUMINUM CLIPPINGS:** Shall consist of new, clean, unalloyed sheet clippings and/or aluminum sheet cuttings, free from oil, grease, foil and any other foreign substance and from punchings less than one-half inch in size.
2. **NEW PURE ALUMINUM WIRE AND CABLE:** Shall consist of new, clean, unalloyed aluminum wire or cable free from hair wire, wire screen, copper, iron, insulation and any other foreign substance.
3. **OLD PURE ALUMINUM WIRE AND CABLE:** Shall consist of old, unalloyed aluminum wire or cable containing not over 1 per cent free oxide or dirt and free from hair wire, wire screen, copper, iron, insulation and any other foreign substance.
4. **SEGREGATED NEW ALUMINUM ALLOY CLIPPINGS:** Shall consist of new, clean, uncoated aluminum clippings of one specified aluminum alloy only, free from hair wire, wire screen, foil, can stock, stainless steel, iron, dirt, oil, grease and any other foreign substance, and from punchings less than one half inch in size.
5. **MIXED NEW ALUMINUM ALLOY CLIPPINGS:** Shall consist of new, clean, uncoated aluminum clippings of two or more alloys, none of which shall be alloys containing zinc in excess of .25% (such as 7,000 series), tin in excess of .30%, and/or magnesium in excess of 2.80%. To be free from hair wire, wire screen, foil, can stock, stainless steel, iron, dirt, oil, grease and/or any other foreign substance. Shall not contain punchings less than one half inch in size.
6. **MIXED LOW COPPER ALUMINUM ALLOY CLIPPINGS:** Shall consist of new, clean, uncoated aluminum clippings of two or more alloys, none of which shall exceed a maximum of .40% copper, .25% zinc, .30% tin, and 2.80% magnesium, and shall be free from tin-containing alloys, hair wire, wire screen, stainless steel, iron, dirt, oil, grease and/or any other foreign substance, and shall be free from punchings less than one half inch in size.
7. **SEGREGATED OLD ALUMINUM ALLOY SHEET:** Shall consist of clean, uncoated, old aluminum sheet of one specified alloy only, free from wrecked airplane sheet, hair wire, wire screen, foil, stainless steel, iron, dirt, oil, grease and any other foreign substance.
8. **MIXED OLD ALLOY SHEET:** Shall consist of clean, uncoated, old alloy sheet aluminum of two or more alloys not to contain wrecked airplane sheet and to be free from hair wire, wire screen, oil cans, foil, food or beverage containers, stainless steel, iron, dirt, oil, grease and all other foreign substances.
9. **SCRAP SHEET AND SHEET UTENSIL ALUMINUM:** Shall consist of clean, uncoated manufactured sheet aluminum, free from stainless steel, iron, dirt, or any other foreign substances and to be free from hub caps, radiator shells, airplane sheet, foil, food or beverage containers, pie plates, oil cans, bottle caps, and lawn furniture.
10. **SEGREGATED NEW ALUMINUM CASTINGS, FORGINGS, AND EXTRUSIONS:** Shall consist of new, clean, uncoated aluminum castings, forgings and extrusions of one specified alloy only and to be free from sawings, stainless steel, zinc, iron, dirt, oil, grease and any other foreign substances.
11. **MIXED NEW ALUMINUM FORGINGS AND EXTRUSIONS:** Shall consist of clean, new, uncoated aluminum forgings and extrusions of two or more alloys, none of which shall be alloys containing zinc in excess of .25% (such as 7,000 series), tin .30% and/or magnesium in excess of 2.80%. Shall also be free from sawings, stainless steel, zinc, iron, dirt, oil, grease and any other foreign substance.
12. **MIXED NEW ALUMINUM CASTINGS:** Shall consist of clean, new, uncoated aluminum castings of two or more alloys, none of which shall exceed 3% zinc, .50% tin, and/or magnesium in excess of 2.80%. Shall be free of sawings, stainless steel, iron, dirt, oil, grease, and any other foreign substances.
13. **ALUMINUM AUTO CASTINGS.** Shall consist of all clean automobile aluminum castings of sufficient size to be readily identified and to be free from iron, dirt, brass, babbitt bushings, brass bushings and any other foreign materials. Oil and grease not to exceed 2%.
14. **ALUMINUM AIRPLANE CASTINGS:** Shall consist of clean aluminum castings from airplanes and to be free from iron, dirt, brass, babbitt bushings, brass bushings and any other foreign materials. Oil and grease not to exceed 2%
15. **MIXED ALUMINUM CASTINGS:** Shall consist of all clean aluminum castings which may or may not contain auto and airplane castings, but no ingots, and to be free from iron, dirt, brass, babbitt and any other foreign materials. Oil and grease not to exceed 2%.
16. **ALUMINUM PISTONS:**
    - (a) **CLEAN ALUMINUM PISTONS:** Shall consist of clean aluminum pistons to be free from struts, bushings, shafts, iron rings and any other foreign materials. Oil and grease not to exceed 2%.
    - (b) **ALUMINUM PISTONS WITH STRUTS:** Shall consist of clean whole aluminum pistons with struts to be free from bushings, shafts, iron rings and any other foreign materials. Oil and grease not to exceed 2%.
    - (c) **IRONY ALUMINUM PISTONS:** Should be sold on recovery basis, or by special arrangements with purchaser.
17. **WRECKED AIRPLANE SHEET AND/OR BREAKAGE ALUMINUM:** Should be sold on recovery basis, or by special arrangements with purchaser.
18. **NEW ALUMINUM FOIL:** Shall consist of clean, new, pure, uncoated, unalloyed aluminum foil, free from etched radar foil, paper, dirt, lead, stainless steel, iron, tin, solder, plastic or any other foreign materials. Should not be packed in hydraulic briquettes.
19. **OLD ALUMINUM FOIL:** Shall consist of clean, old, uncoated, pure, unalloyed aluminum foil, free from etched and radar foil, paper, dirt, lead, stainless steel, iron, tin, solder, plastic or any other foreign materials. Should not be packed in hydraulic briquettes.
20. **ALL OTHER ALUMINUM BASE FOILS INCLUDING ETCHED FOIL, RADAR FOIL AND CHAFF** Should be sold by special arrangements with purchaser.
21. **SEGREGATED ALUMINUM BORINGS AND TURNINGS.** Shall consist of clean, uncorroded aluminum borings and turnings of one specified alloy only and subject to deductions for fines in excess of 3% through a 20 mesh screen and dirt, free iron, oil, moisture and all other foreign materials. Material containing iron in excess of 10% and/or any free magnesium or stainless steel or containing highly flammable cutting compounds, will not constitute good delivery.
22. **MIXED ALUMINUM BORINGS AND TURNINGS** Shall consist of clean, uncorroded aluminum borings and turnings of two or more alloys and subject to deductions for fines in excess of 3% through a 20 mesh screen and dirt, free iron, oil, moisture and all other foreign materials. Material containing iron in excess of 10% and/or any free magnesium or stainless steel or containing highly flammable cutting compounds, will not constitute good delivery. To avoid dispute should be sold on basis of definite maximum zinc, tin and magnesium content.
23. **SWEATED ALUMINUM:** Shall consist of aluminum scrap which has been sweated or melted into a form or shape such as an ingot, pig or slab for convenience in shipping; to be free from corrosion, drosses or any foreign materials. Should be sold subject to sample or analysis.
24. **ALUMINUM GRINDINGS** Should be sold on recovery basis, or by special arrangements with purchaser.
25. **ALUMINUM DROSSES, SPATTERS, SPILLINGS, SKIMMINGS AND SWEEPINGS.** Should be sold on recovery basis, or by special arrangements with purchaser.
26. **ALUMINUM HAIR WIRE:** Should be sold by special arrangements with purchaser.
27. **ALUMINUM WIRE SCREEN** Should be sold by special arrangements with purchaser.
28. **COATED ALUMINUM (PAINTED OR PLASTIC COATED, ETC.):** Should be sold by special arrangements with purchaser. Siding, awnings, and venetian blinds should each be packaged separately
29. **CONTAINERS OF ALL TYPES (OIL, FOOD, BEVERAGE, AEROSOL):** Should be sold by special arrangements with the purchaser, and should each be packaged separately.
30. **ITEMS NOT COVERED SPECIFICALLY BY ABOVE CLASSIFICATIONS.** Any new item which might appear and which is not covered specifically by above classifications should be discussed and sold by special arrangements with the purchaser.

Source: EN-158

New clippings, forgings, and other solids are purchased from the aircraft industry, fabricators, and industry and government manufacturing plants. Borings and turnings originate mainly from the machining of castings, rods, and forgings by the aircraft and automobile industries. Residues from melting operations at primary production plants, secondary smelting operations, casting plants, and other foundries include dross, skimmings, and slag.

Old scrap enters the market through scrap collectors and dealers who collect, sort, and sometimes physically process the scrap materials before delivering them to the secondary smelters. Old scrap includes such items as automobile parts, household items, and dismantled airplanes. High iron aluminum scrap is often considered a distinct scrap because it requires special pretreatment. Sweated pig refers to scrap which has been treated in a pyrometallurgical process to separate aluminum from higher melting constituents, such as iron. Although sweating is considered to be a secondary aluminum industry process, in some cases it is carried out by the scrap dealer.

Products

Listed below are the chief products of the secondary aluminum segment:

- Specification alloy ingots
- Billets
- Notched bars
- Shot
- Hot metal
- Hardeners
- Fines

The most important of these products are specification alloy ingots which are generally cast in pigs (15 to 50 pounds) or sows (500 to 1000 pounds). One-thousand-pound billet logs of secondary aluminum for use in the extrusion industry are also cast. Four standard grades of deoxidant for use in the iron and steel industry are manufactured. These may be in the form of notched bars or shot. Other products include hot metal, hardeners, and fines.

Approximately ninety percent of the products from the secondary aluminum industry are sold to foundries (EN-158). A breakdown of the 1973 production of secondary aluminum alloys by independent smelters is shown in Table 3.1-3.

3.1.2 Segment Analysis - Secondary Aluminum

The aluminum segment of the secondary nonferrous metals industry is involved with the cleaning, melting, refining, and pouring of scrap aluminum. An industry flowsheet showing the processes used to convert scrap aluminum to secondary aluminum products, 90 percent of which are sold to the foundry industry, is presented in Figure 3.1-1. Because of variations in quality of scrap received, product line specifications, equipment design, and operating size, a general flowsheet is presented to show the possible operations carried out at aluminum plants. Based on the industry definition used in the present study, production of secondary aluminum involves two general classes of operations: (1) scrap pretreatment and (2) smelting/refining.

Scrap pretreatment involves receiving, sorting, and processing scrap to remove contaminants and to physically prepare the material for smelting. Processes based on mechanical, pyrometallurgical, and hydrometallurgical techniques are used. Those actually employed at a specific facility are selected on the basis of the type of scrap processed.

Table 3.1-3. PRODUCTION OF SECONDARY ALUMINUM ALLOYS BY INDEPENDENT SMELTERS IN 1973

Alloy	Production[a,b] Metric tons	Short tons
Pure aluminum (Al minimum, 97.0%)	109,769	121,020
Aluminum-silicon:		
95/5 Al-Si, 356, etc. (Cu maximum, 0.6%)	17,759	19,579
13% Si, 360, etc. (Cu maximum, 0.6%)	51,609	56,899
Aluminum-silicon (Cu 0.6% to 2%)	3,611	3,981
No. 12 and variations	9,439	10,407
Aluminum-copper (Si maximum 1.5%)	4,200	4,630
No. 319 and variations	56,550	62,347
Nos. 122 and 138	48	53
380 and variations	367,878	405,585
Aluminum-silicon-copper-nickel	4,238	4,672
Deoxidizing and other destructive uses:		
Grades 1 and 2	21,389	23,580
Grades 3 and 4	5,887	6,491
Aluminum-base hardeners	6,667	7,351
Aluminum-magnesium	3,198	3,526
Aluminum-zinc	10,128	11,166
Miscellaneous	18,874	20,809
Total	691,244	762,096

[a] Gross weight, including copper, silicon, and other alloying elements. Secondary smelters used 14,800 and 31,600 metric tons of primary aluminum in 1972 and 1973, respectively, in producing secondary aluminum-based alloys.

[b] No allowance was made for consumption or receipts by producing plants.

Source: ST-328

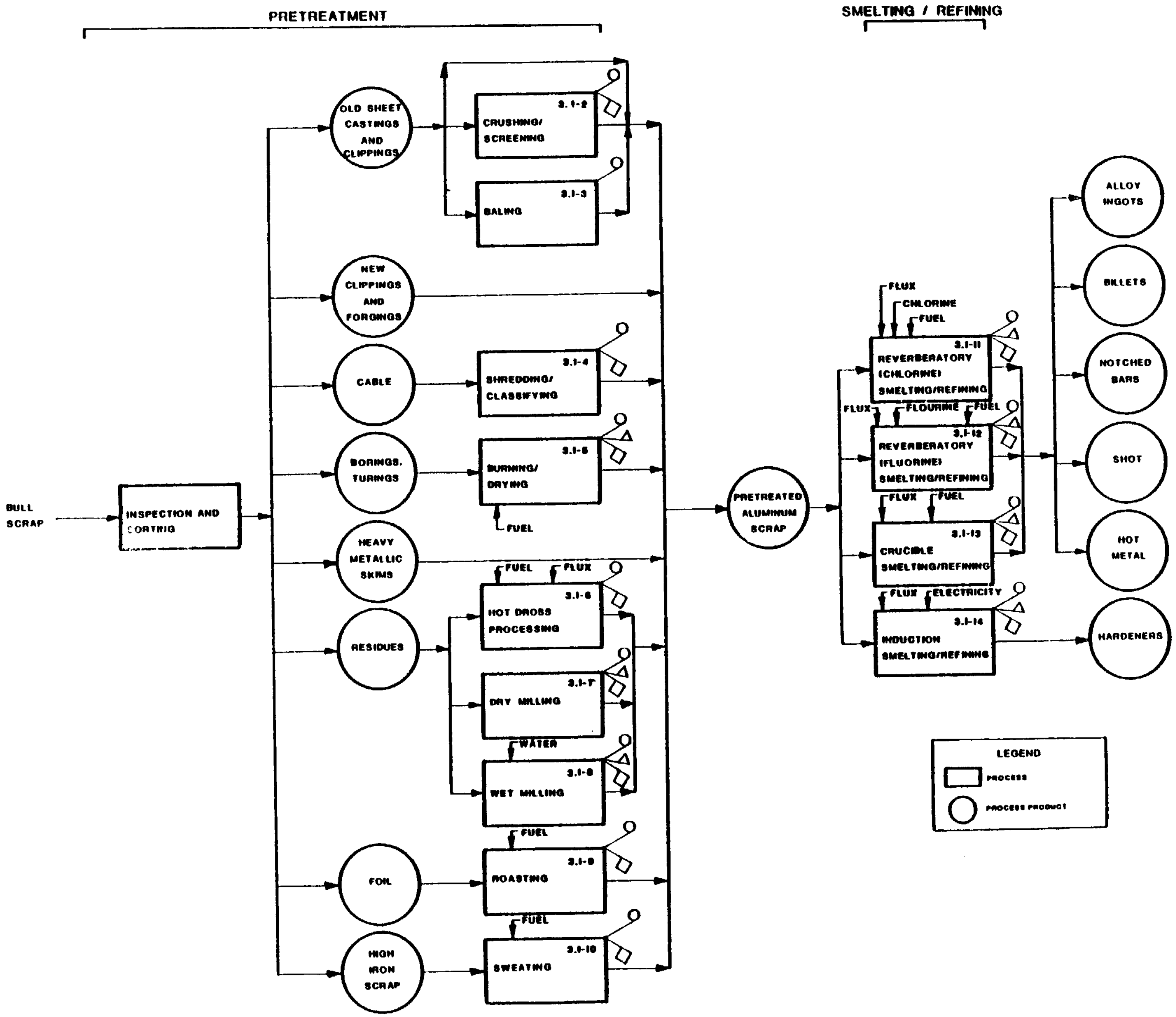

FIGURE 3.1-1 PROCESS FLOW DIAGRAM FOR THE ALUMINUM SEGMENT OF THE SECONDARY NONFERROUS METAL INDUSTRY

The smelting/refining operation generally involves the following steps:

- charging
- melting
- fluxing
- alloying
- mixing
- demagging
- degassing
- skimming
- pouring

All the above steps may be involved in each process, with process distinctions being based mainly on furnace type and emission characteristics. As with scrap pretreatment, however, not all of these steps are necessarily incorporated into the operations carried out at a particular plant. Also, some steps may be combined or reordered, depending on furnace design, scrap quality, process inputs, and product specifications.

Individual process descriptions for each scrap pretreatment and smelting/refining process follow this general discussion. Information on utility requirements and operating parameters were not available or were very incomplete in many instances. Another area in which many data were unclear or incomplete was the waste streams characterization area. Particulate emission factors have been defined for reverberatory and crucible smelting/refining processes, chlorinating stations, and sweating operations; however, neither particulate matter nor gaseous emissions (specifically, hydrocarbons and gas phase inorganics) have been adequately characterized with respect to their compositions. Scrap quality variations (types and relative amounts of feed impurities) can complicate the emission source characterization problem significantly.

Inspection and Sorting

Function - The purchased aluminum scrap undergoes inspection upon delivery. Clean scrap requiring no pretreatment is transported to storage or is charged directly into the smelting furnace. The bulk of the scrap, however, must be manually sorted as it passes along a steel belt conveyor. Free iron, stainless steel, zinc, brass, and over-sized materials are removed. If the scrap has not yet been sorted according to physical form, the following separations may also be made:

- Old castings and sheet
- Bulky sheet, clippings, and castings
- New clippings and forgings
- High-iron castings and sheet
- Aluminum cable
- Insulated cable
- Borings and turnings
- Skimmings, drosses, and slags
- Heavy metallic skim chunks
- Foil contaminated with paper, gutta-percha, or insulation

The sorted scrap then goes to appropriate scrap treating processes. If the scrap is already clean or if pretreating facilities are not available, it may be charged directly to the smelting furnace.

Input Materials - Aluminum scrap and contaminants.

Operating Parameters - Not available.

Utilities - Power to operate conveyors.

Waste Streams - Free iron, stainless steel, zinc, brass, and over-sized scrap.

EPA Source Classification Code - None

Crushing/Screening

Function - Sorted scrap is conveyed to a ring crusher or hammer mill where the material is shredded and crushed, and the iron is torn away from the aluminum. The crushed material is passed over vibrating screens to remove dirt and fines. Tramp iron is removed by magnetic drums and/or belt separators. The clean aluminum then falls directly into tote boxes.

Input Materials - Old scrap, especially castings and sheet, contaminated with iron.

Operating Parameters - Not available.

Utilities - Power to drive equipment (conveyors, ring crusher or hammer mill, vibrating screens, magnetic separators).

Waste Streams -

- (Minor amounts of metallic and non-metallic dust are produced in this step.)
- The quantity of solid waste (mostly tramp iron) is expected to be low since the majority of the iron should have been removed in the sorting process.

EPA Source Classification Code - None

Baling Process

Function - Specially designed baling equipment is used to compact bulky aluminum scrap. The bales produced are generally 1 x 2 meter (3 x 6 foot).

Input Materials - Scrap sheet, castings, and clippings.

Operating Parameters - Not available

Utilities - Electricity required to drive baling equipment.

Waste Streams -

- Particulate emissions consisting primarily of dirt and alumina dust resulting from aluminum oxidation.

EPA Source Classification Code - None

Shredding/Classifying

Function - Pure aluminum cable with steel reinforcement or insulation is cut by alligator type shears, then granulated or further reduced in hammer mills to separate the iron core and the plastic coating from the aluminum. Magnetic processing accomplishes iron removal, and air classification separates the insulation.

Input Materials - Aluminum cable with steel reinforcement and/or neoprene or plastic insulation.

Operating Parameters - Not available.

Utilities - Energy requirements are those needed to drive the equipment.

Waste Streams -

- Minor air emissions (principally dust) are produced in this process.
- Significant solid wastes are generated. The scrap iron can be recycled. The plastic insulation is generally disposed of in landfills.

EPA Source Classification Code - None

Burning/Drying

Function - In most cases, borings and turnings are pretreated in order to remove cutting oils, greases, moisture, and free iron. The processing steps involved are (a) crushing in hammer mills or ring crushers, (b) volatilizing the moisture and organics in a gas- or oil-fired rotary dryer, (c) screening the dried chips to remove aluminum fines, (d) magnetically treating the remainder for iron removal, and (e) storing the clean dried borings in tote boxes.

Input Materials -Borings, turnings, and other contaminated scrap.

Operating Parameters - Not available.

Utilities - Gas or fuel oil is required to fire the rotary dryer, and additional power is needed to drive the other equipment involved such as afterburners, motors, etc.

Waste Streams -

- Atmospheric emissions constitute a significant air pollution problem. Afterburners are generally used to convert volatilized hydrocarbons to CO_2 and H_2O. Other gases potentially present, depending on the composition of the organic contaminants, include chlorides, fluorides, and sulfur oxides. Since fuel combustion products are also emitted, oil firing produces higher emissions than natural gas firing.

Oxidized aluminum fines blown out of the dryer by the combustion gases constitute a source of particulate emissions.

- Wet scrubbers are now used in some facilities to control these emissions in place of afterburners. This control measure may result in a significant aqueous waste stream.
- The solid waste stream is chiefly composed of tramp iron removed during the magnetic processing step.

EPA Source Classification Code - None

Hot Dross Processing

Function - Aluminum can be recovered from the hot dross discharged from the refining furnace by batch fluxing with a salt-cryolite mixture. This process is carried out in a mechanically rotated, refractory lined barrel. The metal is tapped periodically through a hole in the base of the barrel.

Input Materials - Hot dross from smelting/refining operations and salt-cryolite flux.

Operating Parameters - Not available.

Utilities - Energy required to operate equipment.

Waste Streams -

- Mechanically generated dust from the rotating barrel constitutes the main air emission. Some fumes are also produced as a result of the fluxing reactions. Both of these problems can be controlled by enclosing the barrel in a hood system and ducting the stream to a baghouse. No afterburner is required.
- Dry dross remaining in the barrel and baghouse dust are the major solid wastes produced.

EPA Source Classification Code - None

Dry Milling

Function - In the dry milling process, (cold aluminum-laden dross and other residues are processed by milling, screening, and concentrating to obtain a product containing a minimum aluminum content of 60-70%. Ball mills, rod mills, or hammer mills can be used to reduce the oxides and nonmetallics to fine powders. Separation of dirt and other non-recoverables from the metal is achieved by screening, air classification, and/or magnetic separation.)

Input Materials - Residues (particularly low-aluminum residues), drosses, skimmings, and slags.

Operating Parameters - Not available.

Utilities - Power required to drive the milling equipment.

Waste Streams -

- (Large amounts of dust are generated as a result of the crushing, milling, screening, air classification and materials transfer steps.) These emissions can be contained by using hoods vented to baghouses. Wet dust collection is used at a few facilities.

- Aqueous effluents are generated when wet dust collectors are used. The aqueous waste stream will contain suspended solids such as aluminum oxide and hydrated alumina, and soluble chlorides. Milling drosses may also generate ammonia when hydrolyzed by water. Slag processing generally leads to higher levels of soluble potassium, sodium chloride, and fluoride salts than the processing of drosses or skimmings.

- Solid wastes consisting of alumina dust, dirt and iron containing residues are generally disposed of on-site. Attempts are being made to develop a market for this waste because of its high alumina content.

<u>EPA Source Classification Code</u> - None

Wet Milling

Function - (Leaching involves (a) wet milling, (b) screening, (c) drying, and (d) magnetic separation to remove fluxing salts and other nonrecoverables from drosses, skimmings, and slags. First, the raw material is fed into a long rotating drum or an attrition or ball mill where soluble contaminants are leached out. The washed material is then screened to remove fines and dissolved salts, dried, and passed through a magnetic separator to remove ferrous materials. The nonmagnetics are then stored or charged directly to the smelting furnace.)

Input Materials - Input materials are the residues from various smelting/refining operations such as slags, drosses, and skimmings. A chemical analysis of a slag from a rotary-type furnace is given below. In general, slags contain higher levels of chlorides and fluorides than drosses or skimmings, while drosses often contain aluminum nitride.

Table 3.1-4. CHEMICAL ANALYSIS OF A TYPICAL ROTARY ALUMINUM FURNACE SLAG

Constituent	Composition, percent
Aluminum	5-15
Aluminum oxide	25-35
Sodium chloride	25-33
Potassium chloride	25-33
Other	3-7

(Source: CA-307)

Process water is also required. Of eight plants surveyed, only two reported that they recycled water in their residue treatment processes (EN-158). Quantities of wastewater generated are discussed below.

Operating Parameters - Not available.

Utilities - Electrical energy is required for driving the equipment and drying the screened material.

Waste Streams -

- There are no significant sources of atmospheric emissions from this process with the possible exception of the drying step where ammonia may be emitted. No specific information was available on this topic.

- Significant quantities of wastewater are generated by this process. According to one survey, the wastewater volumes generated in wet milling of residues ranged from 16,700 to 218,000 liters per metric ton of aluminum recovered (EN-158). These effluents are typically very saline, with high levels of suspended solids (aluminum and alumina fines). Suspended solids levels of up to 30 wt. percent have been reported. Chemical analyses (loadings and/or concentrations) of milling wastewaters from four different plants are presented in Table 3.1-5. The differences which are observed are accounted for by variations in residue and makeup water quality (e.g., fume scrubbing liquor, pond recycle liquor, or fresh water. In all of the eight plants surveyed which use wet milling processes, the wastewater is sent to a settling pond and, in several cases, chemically treated before discharge.

- Solid wastes include the undersized materials from the screening step and the settled wastewater solids. These are generally disposed of in landfills.

<u>EPA Source Classification Code</u> - None

Table 3.1-5. TYPICAL ANALYSES OF SETTLED WASTEWATERS FROM ALUMINUM RESIDUE LEACHING OPERATIONS

	Plants					
	1 [a]	2 [b]	3 [c]		4 [d]	
Parameter	Loading (kg/MT Al)	Conc. (mg/ℓ)	Conc. (mg/ℓ)	Loading (kg/MT) [e]	Conc. (mg/ℓ)	Loading (kg/MT) [e]
Alkalinity	6.47	314	586	102	500	-7.5 [f]
COD	0.97	2,045			29	0.17
Total solids			24,264	5,144	17,800	326
Total dissolved solids	13.51	12,920			17,400	324
Total suspended solids	0.121	4,961	15	1.5	159	-5.6
Sulfate		1,100	47	1.5	151	1.8
Chloride	0.319	6,492	15,465	3,264	8,903	150
Cyanide		0.04			0.05	0
Fluoride	0.129	2.9	8.7	1.81	16.5	0.38
Ammonia	0.33	0.75	350	73	0.30	-0.03
Aluminum	0.002	0.3	16.4	3.5	28	-1.49
Calcium		58.8	23	-7.4	48	0.17
Copper	<0.001	0.174	0.070	0.008	0.137	0.003
Magnesium		32.5	6	3.9	76	1.39
Nickel		1.2	0.240	0.009	0.20	0
Sodium		2,560	11,600	2,528	3,103	46.2
Potassium		1,087	6,470	1,407	4,802	102
Zinc	0	0.015	0.10	0	0.198	-9.1
Cadmium		0.05	0.002	0	0.005	-0.001
Lead		0.20	0.020	0.004	0.028	-0.001
Manganese		0.16	0.045	0.002	0.060	0
Chlorine residue			--	--	--	--
Oils and grease	0.053	55.4	0	0	0.5	0
Phenols (ppb)		--	--	--	0.03	0
pH	8.68	8.3	9.09		9.2	
Nitrates	0.032					

[a] Calculated from U. S. Corps. of Engineers, concentration data not given.

[b] From residue milling solid waste washing, tonnage values of residue waste processed not available - loading cannot be calculated. Water flow is 151 ℓpm.

[c] Data from 7 month and 9 month average and verification data from state: metals verified composite of 18 samples collected over a period of 6 days.

[d] Represents composite of 9 samples collected over 3 days. Milling waste stream is blended with scrubber waste stream.

[e] Loading calculated as:

$$[\text{conc. effluent (mg/}\ell) - \text{conc. intake (mg/}\ell)] \times \frac{\text{quantity of water used } (\ell)}{\text{quantity of Al recovered from residue (MT)}}$$

[f] Negative values indicate that the process reduced the concentration of this parameter and are derived from reported analytical values.

(Source: EN-158)

Roasting

Function - In the roasting process, carbonaceous materials associated with aluminum foil are charred and then separated from the metal product.

Input Materials - Aluminum foil backed with paper, gutta-percha, or insulation.

Operating Parameters - Not available.

Utilities - Fuel for roasting and power required by auxiliary equipment.

Waste Streams -

- Although no specific information was found, it is expected that atmospheric emissions result from this process.
- Charred scrap materials constitute the major solid waste stream generated by the roasting process.

EPA Source Classification Code - None

Aluminum Sweating

Function - Sweating is a pyrometallurgical process which is used to recover aluminum from high iron content scrap. Open-flame reverberatory furnaces with sloping hearths are generally employed, although grate-type furnaces are also in use. Separation is accomplished as aluminum and other low melting constituents melt out and trickle down the hearth, through a grate and into air-cooled molds or collecting pots. The product is termed "sweated pig". The higher melting materials including iron, brass, and oxidation products formed during the sweating process are periodically removed from the furnace.

Input Materials - High-iron aluminum scrap, particularly old sheet, castings, and dross.

Operating Parameters - Operating temperatures range from 680-760°C (1250-1400°F).

Utilities - Sweating furnaces are fired by either gas or oil. Additional energy is required to power auxiliary equipment.

Waste Streams -

- Atmospheric emissions are a function of the feed scrap composition. Smoke may result from incomplete combustion of organic contaminants (e.g., rubber, oil, and grease, plastics, paint, cardboard, paper) which may be present.

Fumes can result from oxidation of magnesium and zinc contaminants. Sweating of drosses and skims containing fluxes may create fumes. Residual aluminum chloride flux sublimes at 178°C (352°F) and is extremely hygroscopic; subsequent hydrolysis results in HCl formation.

Chemical characterizations of atmospheric emissions were not available; however, particulate emissions are known to consist chiefly of aluminum trioxide. The particulate emission factor for an aluminum sweating furnaces is 7.25 kg/MT (14.5 lb/ton) of metal processed (EN-030). For baghouse-controlled processes, the factor is 1.65 kg/MT (3.3 lb/ton) of metal processed (EN-030). Particle size data from an aluminum sweating reverberatory furnace with a capacity of 345 kg/hr (760 lb/hr) are given in Table 3.1-6.

Table 3.1-6. PARTICLE SIZE DATA - ALUMINUM SWEATING FURNACE EMISSIONS

Particle Diameter μ	Cumulative Weight %
1.79	4.8
2.38	10.8
3.57	24.3
4.76	37.3
7.10	55.6
8.90	65.8
10.10	70.2
11.90	76.4
14.30	82.9
21.40	88.9
39.30	95.5
71.40	99.0

(Source: DA-069)

Reduction of atmospheric emissions can be achieved by (1) installation of adequate hooding systems to capture emissions generated during residue removal and charging, (2) proper burner operation, and (3) removing magnesium and combustible contaminants from the scrap before charging. An afterburner followed by a baghouse is recommended to control emissions.

- The major solid wastes stream from this process is an iron-containing residue contaminated with aluminum and other nonferrous metals such as zinc, magnesium, and lead.

<u>EPA Source Classification Code</u> - 3-04-001-01

Reverberatory Smelting-Refining with Chlorine Demagging

(Function - Reverberatory furnaces are commonly used to convert clean sorted scrap, sweated pigs, or in some cases untreated scrap to specification alloy ingots, shot, and hot metal. The steps described below may be reordered or even excluded from a particular smelter's operation, depending on the type of scrap processed, product specifications, and facilities available.

The scrap is charged to the furnace by some mechanical means, often through charging wells designed to permit introduction of chips and light scrap below the surface of a previously melted charge ("heel"). Batch processing is generally practiced for alloy ingot production. Continuous feeding and pouring are generally used to produce products having less restrictive specifications.)

(Cover fluxes are used to prevent contact with and subsequent oxidation of the melt by air. Solvent fluxes react with nonmetallics such as residues from burned coatings and dirt to form insolubles which float to the surface as part of the slag.)

(Alloying agents are charged through the forewell in amounts determined by product specifications. Injection of nitrogen or other inert gases can be used to promote and to aid in raising dissolved gases, typically hydrogen, and intermixed solids to the surface.)

Demagging reduces the magnesium content of the molten charge from approximately 0.3 - 0.5% (typical scrap value) to about 0.1% (typical product line alloys specification). When demagging with chlorine gas, chlorine, injected under pressure through carbon tubes or lances, reacts with magnesium and aluminum as it bubbles to the surface. Recently, chlorination chambers have been designed as an improved feature of reverberatory furnaces. Other chlorinating agents, or fluxes, such as anhydrous aluminum chloride or chlorinated organics are sometimes used.

The melt is typically degassed with nitrogen, chlorine, or nitrogen/chlorine mixtures. In some cases solid degassing fluxes may be used. Other degassing techniques available include vibration, high vacuum, and solidification with remelting. This step is necessary to remove dissolved hydrogen, oxygen, and moisture from the melt.

In the skimming step, contaminated semisolid fluxes (dross, slag, or skimmings) are ladled from the surface of the melt and removed through the forewell. The melt is then precooled before pouring according to one of the following methods:

- Alloy ingots, billets, and notched bars are poured into molds and cooled by direct or indirect water cooling, water or mist/air sprays, or air cooling.

- Aluminum shot is produced by pouring molten aluminum onto a vibrating feeder and quenching with water.

- Hot metal is obtained by pouring the aluminum into heated crucibles having capacities ranging up to 6800 kg (15,000 lb.).

Input Materials - The input materials to this process include treated or untreated scrap, sweated pigs, fluxes, alloying agents, chlorinating agents, and degassing agents. Commonly used chemicals are:

Cover flux: sodium chloride
potassium chloride
calcium chloride
calcium fluoride
aluminum fluroide
common mixture: 47.5% NaCl
47.5% KCl
5% cryolite

Solvent flux:
aluminum chloride
ammonium chloride
zinc chloride
cryolite
other fluorides
borax

Alloying
agents: copper
silicon
manganese
magnesium
zinc

Mixing and/or degassing agents:

nitrogen
chlorine
nitrogen/chlorine mixture (90:10%)
helium
argon
metallic chlorides (solid)

Chlorinating agents:

chlorine
anhydrous aluminum chloride
chlorinated organics

The quantity of cover flux added is a function of the surface area of scrap. Generally the flux is 10-33% by weight of the total material charged (flux plus scrap).

The theoretical demagging agent requirement is 3.5 kg chlorine per kg Mg removed; however, in practice this may run as high as 15 kg Cℓ/Kg Mg (or 5 to 6 150-lb chlorine cylinders/50 ton furnace) (EN-158, LA-186).

Operating Parameters - Typical operating parameters are:

- Furnace capacity: 15-90 tons
- Typical chlorination chamber dimensions: 1.2m x 3.0m
- Charging time: 4-75 hours (avg. 24)
- Length of heating cycle: variable
- Temperature (chlorination step): 760-820°C (1400-1500°F)
- Temperature (pouring): 732°C (1350°F)

Utilities - Reverberatory furnaces are directly fired on either natural gas or fuel oil. Heat input per kilogram of alloy may range from 1100-1400 kcal (2000-2500 Btu/lb). Additional energy requirements are those needed to operate auxiliary equipment.

The total energy requirement for the entire remelting process for aluminum can recycling, including transportation and delacquering, is 0.11 kWhr (or 1900 kcal), per kilogram of molten metal (0.05 kWhr or 3420 Btu per lb) (AT-060).

Water usage in this process varies widely depending on the extent to which water is used for ingot cooling. Reported water usage for five plants (all using once through cooling water) ranged from 250 to 11,500 liters per metric ton of metal cooled. One plant reported that it used 60,000 liters per metric ton for shot quenching. No data were available for plants which recycle their cooling water (EN-158).

Waste Streams -

Atmospheric emissions from this processing step represent a significant fraction of the total particulate and gaseous effluents generated in the secondary aluminum industry. Typical furnace effluent gases will contain combustion products, chlorine, hydrogen chloride, metal chlorides (e.g., zinc, magnesium, and aluminum), aluminum oxide, and various metals and metal compounds depending on the quality of scrap consumed.

The particulate emission factor for the reverberatory smelting process, exclusive of the demagging step, is 2.15 kg/metric ton of metal processed (4.3 lb/short ton).

Baghouses or electrostatic precipitators reduce this factor to 0.65 kg/metric ton (1.3 .g/short ton) (EN-030). Particulate control efficiencies of these devices can be as high as 90+%. It has been estimated that approximately 60% of the reverberatory smelters in the secondary aluminum industry employ some form of particulate control device.

The uncontrolled particulate emission factor for the chlorination step (a major potential pollution source), is 500 kg/metric ton of chlorine used (1000 lb/short ton). The controlled emission factor (baghouse) is 25 kg of particulate per ton (50 lb/short ton) (EN-030).

The compositions of the atmospheric emissions from various process steps vary widely depending on such things as quality of scrap, fluxes used, operating parameters, degassing and demagging agents, and furnace type. Air emissions from a typical reverberatory (chlorine) smelting refining process include combustion products; chlorine; hydrogen chloride; chlorides of aluminum, zinc, and magnesium; aluminum oxide; and various metallic species depending on scrap quality. Qualitative descriptions of the air emissions resulting from each processing step are summarized in the first two columns of Table 3.1-7.

Application of air pollution control equipment to this process in part depends on the furnace configuration. If a charging well (forewell) or separate chlorinating station is present,more efficient use can be made of gas cleaning systems because this configuration generally allows

Table 3.1-7. WASTE STREAMS FROM REVERBERATORY (CHLORINE) SMELTING-REFINING PROCESS

Process Step	Atmospheric Emissions		Wastewater Emissions		Solid Waste Emissions	
	Composition	Remarks	Composition	Remarks	Composition	Remarks
Charging	Fumes and smoke from volatization and/or combustion of scrap contaminants.					
Fluxing, alloying, and mixing (N_2)	Gases: Nitrogen, hydrogen fluoride, hydrogen chloride, combustion gases, and other volatile components Particulate: Major constituent when fluxing with salt-cryolite mixture is sodium chloride with minor amounts of aluminum and magnesium compounds. Additional compounds of Na, Al, Mg, Co, Fe, Pb, Mn, K, Cr, Zn, and Ni may also be present	Fluxing fume samples collected by thermal precipitation were found to contain particles smaller than 2 microns with most of the particles <0.1 micron. The fumes were characterized as corrosive, particularly when collected wet. These emissions are converted to air pollution control residuals (either wastewater, sludge, or solid waste) at plants where such systems are implemented. See gas cleaning processes below.				
Demagging	Gases: Chlorine, hydrogen halides, volatile metal chlorides, combustion gases (if there is not a separate chlorination chamber). Particulate: Aluminum chloride, aluminum fluoride, aluminum oxide, magnesium chloride, magnesium fluoride, magnesium oxide, calcium chloride, calcium fluoride, sodium chloride, zinc oxide, zinc chloride, plus additional compounds of Cu, Ni, Cd, and other metals.	The parameters which determine quantities of emissions from demagging are · metal temperature chlorine flow rate magnesium content of alloy depth of chlorine injection · thickness and composition of dross Air pollution control systems are usually used to process demagging effluent gases. See below.				
Degassing (N_2, Cl_2, or N_2-Cl_2 mixture)	Severe fuming results only with Cl_2 or N_2-Cl_2 mixtures. Emissions are similar to those from demagging	The results of one study showed that all fume particles from degassing with chlorine were under 2 microns and 90-95% were less than 1 micron. Mean particle size appeared to be 0.7 microns. Refer to gas cleaning processes below.				
Skimming	Minor fugitive emissions	Can be controlled by hood			Slag, skimmings, or dross	These solids are often reprocessed for their aluminum values
Pouring	Minor atmospheric emissions	Can be controlled by hood				
Metal cooling	Minor atmospheric emissions	Can be controlled by hood	Data on cooling water are scarce, but indications are that pollutant levels are low with the exception of oil and grease. Chemical analysis of effluents from three plants are given in Table 3.1-10.	The following distribution of cooling water discharge practices is based on a survey of secondary aluminum plants (EN-150): · evaporation 2 plants · direct discharge to municipal sewer } 24 plants · direct discharge to stream · ponding 4 plants · continuous recycle (discharge semiannually) 13 plants · discharge after some recycling 7 plants	Sludge buildup, especially from shot quenching, must be periodically removed	
Slag cooling and storage	Emissions of hydrocarbons and ammonia result if water allowed to contact carbides and nitrides present in slag.		Runoff from open storage of slag is characterized by soluble salts (NaCl, KCl, $MgCl_2$) and possibly ammonia.			
Gas cleaning fume scrubbing	See above	Residual particulate concentrations in outlet gas will generally range from 10-50% of their inlet gas values. Removal of gaseous components will range from 0-90+% particular removal efficiency depending upon contactor type and sorbent	Untreated wastewater from fume scrubbers at two plants have been analyzed; results are presented in Table 3.1-11. In general untreated water is characterized by low pH (~1-2) and high levels of chlorides, aluminum, magnesium, zinc, manganese, cadmium, copper, nickel, and lead. Neutralization results in pH's ranging from 9-11, and high levels of sodium, potassium, and calcium, with reduced quantities of aluminum, magnesium, and heavy metals	Based on 26 plants employing wet air pollution control methods for Cl_2-based demagging the following distribution of wastewater discharge was found (EN-150) . with no recycling 12 . with limited recycling 6 . continuous recycle, zero discharge 0 . to evaporation pond 3 . with neutralization 17 . with solids removal 17	Neutralization of wastewater, if practiced, may generate some solid waste in the form of sludge	
Gas cleaning baghouse or electrostatic precipitator					Collected particulate emissions are described in atmospheric emission column	These solids are generally disposed of in landfills. The potential for groundwater contamination by leachate exists

separation of combustion gases from emissions from fluxing, demagging and degassing. Furnace combustion gases and charging emissions are generally vented directly to the atmosphere. Fumes from the chlorinating station can be captured by a submerged hood and ducted to a gas cleaning system. Hazardous gaseous components and some particulates can be removed by alkaline or aqueous scrubbing, often followed by a particulate control device such as a baghouse or electrostatic precipitator. Coated baghouses are also used to some extent for halogenated gas absorption. Efficiencies of various scrubbing systems applied to demagging fumes are compared in Table 3.1-8, and efficiencies of several particulate control devices are shown in Table 3.1-9.

- Wastewater effluents from the Reverberatory Smelting-Refining Process with chlorine demagging include metal cooling water and fume scrubbing effluent. Quantities of each, particularly cooling water, are extremely variable from plant to plant and, in addition, water usage in general is not well defined. For example, reported water usage for ingot cooling at five plants ranged from 250 to 11,500 liters per metric ton of metal cooled (60-2760 gal/short ton) (EN-158). Quantities discharged were not given. Wastewater flow from wet scrubbing of chlorination fumes is approximately 95 to 190 liters per kg of Mg removed (11-23 gal/lb) (EN-158). Compositions and disposal practices for both of these wastewater effluents are summarized in Tables 3.1-7, 3.1-10, and 3.1-11.

Table 3.1-8. SCRUBBER COLLECTION EFFICIENCIES FOR EMISSIONS FROM SECONDARY ALUMINUM REVERBERATORY SMELTERS WITH CHLORINE DEMAGGING

	Scrubber collection efficiencies, %[a]			
	Slot scrubber		Packed-column scrubber	
Contaminants	Water	10% caustic solution	Water	10% caustic solution
HCl	90 to 95	95 to 99	95 to 98	99 to 100
Cl_2	30 to 50	50 to 60	75 to 85	90 to 95
Particulates	30 to 50	50 to 60	70 to 80	80 to 90

[a] Collection efficiency depends mainly upon the L/G ratio, the velocity of gas in the scrubber, and other aspects of the scrubber design. These values are typical efficiencies obtained by actual tests but do not reflect the entire range of possible results.

Source: DA-069

Table 3.1-9. AVERAGE PARTICULATE COLLECTION EFFICIENCY OBTAINED BY USING VARIOUS DEVICES ON EMISSIONS FROM SECONDARY ALUMINUM REVERBERATORY SMELTERS WITH CHLORINE DEMAGGING

Type of device	Efficiency, %
Horizontal multipass wet cyclone	65 to 75
Single-pass wet dynamic collector	70 to 80
Packed-column water scrubber with limestone packing	75 to 85
Ultrasonic agglomerator followed by a multitube dry cyclone	85 to 98
Electrical precipitator	90 to 99

Source: Jenny, 1951, as cited in DA-069

Table 3.1-10. CHARACTER OF COOLING WASTEWATER FROM ALUMINUM REVERBERATORY FURNACES WITH CHLORINE DEMAGGING

Parameter	Plant 1[a]		Plant 2[b]		Plant 3[c]	
	Concentration mg/ℓ	Net Loading g/MT product	Concentration mg/ℓ	Net Loading g/MT product	Concentration mg/ℓ	Net Loading g/MT product
Alkalinity	7.3	—	237	—	95	—
COD	1206	815	244	138	15	172
Total solids	1215	766	1146	545	198	69
Total dissolved solids	248	119	989	465	180	—
Total suspended solids	929	626	157	80	18	182
Sulfate	15.3	6.3	24	7	—	—
Chloride	143	93.0	310	174	29	46
Cyanide	0.03	0.006	.004	.002	—	—
Fluoride	0.78	—	2.3	—	0.9	—
Ammonia	—	—	—	—		
Nitrate	—	—	—	—		
Aluminum	10.07	7.26	1.7	—	0.7	0.008
Calcium	2.26	—	18.4	0.33	—	—
Copper	0.133	0.065	0.026	0.015	—	—
Magnesium	1.17	—	4.05	1.61	—	—
Nickel	0.03	0.007	0.26	0.10	—	—
Sodium	3.59	0.271	733	420	—	—
Zinc	0.61	0.393	0.013	0.006	—	—
Cadmium	0.015	0.004	0.01	0.006	—	—
Lead	0.46	0.261	0.10	—	—	—
Manganese	0.10	0.061	0.30	0.17	—	—
Chlorine residue	0.02	0	—	—	5 (?)	86
Oils and grease	1833	1240	259	147	—	—
Phenols (ppb)	99.3	0.043	ND	—	—	—
pH	5.5	5.5	6.4	—	4.5 - 6.5	—

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[a] Water usage at this plant is 39,700 ℓ/day (avg.) and metric tons poured is 58.5 MT/day.

[b] Water flow is 30 gpm for 260 min. per day (avg.) and 51 MT of metal are poured daily.

[c] Water usage is 302,800 ℓ/day and 23-30 MT of metal are poured daily.

[d] $\frac{\{\text{Conc effluent} - \text{conc intake (mg/l)}\} \times \text{liters/day}}{\text{Avg. amount of metal cooled, mtons/day}} \times 10^{-3}$ gram/mg = loading, gram/mton

Source: EN-158

Table 3.1-11. CHARACTER OF UNTREATED WASTEWATER FROM CHLORINATION FUME SCRUBBING

Parameter	Plant C-7 [a]		Plant D-6 [b]	
	Conc., mg/ℓ	Loading, grams/kg Mg [c]	Conc., mg/ℓ	Loading, grams/kg Mg [c]
COD	123	12.1	536	95.8
Total solids	2910	301		
Total dissolved solids	1885	194	10,500	1856
Total suspended solids	225	22.3	480	83.0
Sulfate	11	0.51	481	84.4
Chloride	4420	446	8,671	1560
Cyanide	<0.02	0	—	—
Fluoride	0.24	-0.08 (d)	0.7	-0.324
Aluminum	472	50.9	6.12	0.615
Calcium	0.12	-0.215	990	176
Copper	0.25	0.02	1.31	0.236
Magnesium	41.2	3.86	55.8	9.81
Nickel	0.050	0.003	0.74	0.106
Sodium	3.11	-0.007	770	32.7
Potassium	—	—	206	37.1
Zinc	0.952	0.091	3.58	0.64
Cadmium	0.066	0.006	0.30	0.054
Lead	0.061	0.004	0.24	0.025
Manganese	0.449	0.049	2.34	0.349
Chlorine residue	0.257	0.027		
Oils and grease	13.9	0.590	6.24	0.403
Phenols (ppb)	20.7	-0.002	—	
pH	2.1	—	1.0	—

a Average of three composite samples.

b Average of five composite samples.

c Loading calculated as:

$$\left(\text{conc. effluent (mg/ℓ)} - \text{Conc. intake (mg/ℓ)}\right) \times \frac{\text{quantity of water used (ℓ)}}{\text{quantity of Mg removed (kg)}}$$

d Negative numbers indicate that the process apparently reduced the concentration of this parameter, and are derived from the reports of analytical results as shown above.

Source: EN-158

- The solid wastes generated in this process are: (1) drosses and skimmings which are usually recycled (Processes 3.1-6 through 3.1-8), (2) particulate control residuals, typically disposed of by landfill, and (3) sludge from wastewater treatment. Characteristics of these emissions are summarized in Table 3.1-7.

<u>EPA Source Classification Code</u> -

3-04-001-03	Smelting - reverberatory furnace
3-04-001-04	Chlorinating station

Reverberatory Smelting-Refining with Fluorine Demagging

Function - This process is similar to the Reverberatory Smelting-Refining Process with chlorine demagging except that aluminum fluoride rather than chlorine is employed in the demagging step. The AlF_3 reacts with magnesium to produce metallic aluminum and magnesium fluoride, which then floats to the surface and is skimmed off.

Input Materials - The raw materials charged to this process are treated or untreated scrap, fluxes, alloying agents, aluminum fluoride, and nitrogen or other degassing agents.

The weight of aluminum fluoride required for magnesium removal is approximately 4.3 kg/kg Mg (EN-158). In some cases as much as one ton of AlF may be required when charging a 40- to 50-ton furnace.

The types and amounts of other input materials are described in Process No. 3.1-11.

Operating Parameters - Refer to Process No. 3.1-11.

Utilities - The utility requirements for this process include:

- Natural gas or fuel oil
- Energy to drive auxiliary equipment
- Cooling water

Refer to Process No. 3.1-11 for further information.

Waste Streams -

- The use of AlF_3 rather than chlorine in the demagging step results in reduced atmospheric emissions. Fluorides emitted as gaseous fluorides (hydrogen fluoride, aluminum and magnesium fluoride vapors, and silicon tetrafluoride) or as dusts require control to prevent significant environmental impact. Atmospheric emissions from other process steps are similar to those emitted from reverberatory (chlorine) smelting-refining (Process No. 3.1-11).

  Of the 14 secondary aluminum plants surveyed which use AlF_3 for demagging, 7 used fabric filters, 2 had wet scrubbers, and 5 were uncontrolled (EN-158). Venturi wet scrubbers are usually used for fluoride emission control.

- Aqueous waste streams result from metal cooling and fume scrubbing. Cooling water effluents were discussed under Process 3.1-11.

  Fluoride-containing scrubbing liquors do not constitute a significant wastewater stream. Neutralization effects the precipitation of fluorides, which are generally sparingly soluble compounds. This allows recirculation of the supernatant to the scrubber. Recycled scrubber liquor contains residual fluorides of magnesium, aluminum, and possibly cryolite.

- Settled solids from neutralization of fluoride scrubber liquors constitute a solid waste stream. This sludge is normally dewatered and disposed of as landfill.

Other solid wastes from this process are air pollution control residuals from dry collection systems and dross, slag, or skimmings from the skimming step. These were discussed under Process No. 3.1-11.

EPA Source Classification Code - 3-04-001-03

Crucible Smelting-Refining

Function - The crucible smelting-refining process is used to remelt small batches of aluminum scrap; this type of furnace is generally limited to 500 kg (1000 lb) capacities or less. The process steps are essentially the same as those of reverberatory furnaces.

Small crucibles are lifted out of the furnace and used as ladles for pouring. Larger ones are usually of the tilting type, where metal is transferred to smaller capacity ladles before pouring into molds.

Input Materials - Refer to Process 3.1-11.

Operating Parameters - Not available

Utilities - Crucible furnaces are fired indirectly with either gas or fuel oil. In general, efficiency of fuel usage with this furnace type is extremely low, in some cases 5 percent or less (DA-069). Electricity is sometimes used as a heat source.

Waste Streams - This process creates wastes similar to the reverberatory processes; the quantities produced, however, are much less due to the size of the operation.

EPA Source Classification Code - 3-04-001-02

Induction Smelting-Refining

Function - (This process is designed to produce hardeners by blending superpure aluminum and hardening agents in an electric induction furnace. The process steps involved include (a) charging scrap to the furnace, (b) melting, (c) adding and blending the hardening agent, (d) skimming, (e) pouring, and (f) casting. The hardened product is cast in the form of notched bars.)

Input Materials - Electrical conductor scrap (superpure aluminum) and hardening agents (titanium, boron and/or chromium) are the feeds to this process.

Operating Parameters - The capacities of induction furnaces used for melting aluminum are much smaller than reverberatory furnaces. This furnace type offers higher efficiencies, closer temperature control, less oxidation, and improved melt homogeneity.

Utilities - Electricity requirements are those needed to melt the scrap and to operate auxiliary equipment.

Waste Streams -

- Small quantities of atmospheric emissions containing aluminum, alloying agents, and other metals are generated in all process steps. Combustion products are not present in emissions from induction furnaces.

- The only potential source of aqueous waste from this process is the furnace and metal cooling water.

- Drosses from the skimming step are the only solid wastes.

- Further details of these waste effluents are presented in Process 3.1-11.

<u>EPA Source Classification Code</u> - None

3.1.3 Environmental Impact - Secondary Aluminum

The aluminum segment of the secondary nonferrous metal industry is a source of fine particulate matter and gaseous atmospheric emissions, wastewater, and solid wastes. These emissions can represent significant health and environmental hazards if not properly controlled.

The most serious air pollution problem associated with this industry segment which occurs during smelting-refining is the fuming produced during the demagging step. These fumes may consist of halogenated volatiles and/or particulates, metallic species, and combustion gases. Significant particulate and gaseous emissions can also be generated during scrap pretreatment processes such as aluminum sweating, dross processing, and burning/drying. Control measures are available to reduce the most serious of these air emissions. Dry processes (fabric filters) are usually employed for particulate control, while wet scrubbing techniques or coated fabric filters are necessary for gaseous halide removal. Alternate demagging processes which minimize fuming are under development. Fugitive emissions are also present due to material transfer and storage.

Chloride fume scrubbing liquors constitute a significant wastewater problem, while fluoride liquors can be recycled after neutralization and solids removal. Another wastewater effluent is metal cooling water. This stream, which does not normally contain significant quantities of hazardous components is typically discharged to ponds, streams, or municipal sewer systems. Leaching of dross and skimmings from the smelting-refining operation creates considerable wastewater effluents containing high saline and suspended solids levels. The best practicable control technologies currently available for treating these four types of wastewater are (EN-158):

- Chloride fume scrubbing effluents - pH adjustment and settling
- Fluoride fume scrubbing liquors - pH adjustment, settling; (total recycle usually possible)
- Metal cooling wastewater - air cooling or continuous recycle with periodic removal, dewatering, and disposal of sludge
- Dross wet milling - pH adjustment and settling with some recycling to minimize discharge

Effluent limitations for chloride fume scrubber effluent and wet dross milling discharges which must be met by existing sources by 1 July 1977 are presented in Tables 3.1-12 and 3.1-13.

Solid wastes from secondary aluminum production include dross and skimmings from smelting/refining operations, air pollution control residuals, wastewater neutralization sludge, and discarded scrap contaminants from sorting and classifying and sweating processes. Drosses can be recycled or disposed of with the other solid waste streams, which typically wind up in landfills.

For 1974, the total scrubber sludge and furnace slag disposal from the Aluminum Segment was 101,100 and 245,000 MT, respectively (EN-399). These solid wastes contain hazardous constituents and represent a significant hazard to health and the environment.

Several of the emissions identified in this section constitute significant health and environmental hazards. These effects are summarized in the Preliminary Pollutant Health and Environmental Impact Table presented in Section 5. Table 3.1-14 illustrates the process, emissions, and control technology for the Aluminum Segment.

Table 3.1-12. EFFLUENT LIMITATIONS FOR TREATED FUME SCRUBBER WASTEWATER GENERATED DURING CHLORINE DEMAGGING TO BE ACHIEVED BY JULY 1, 1977, BASED ON THE BEST PRACTICABLE CONTROL TECHNOLOGY CURRENTLY AVAILABLE

Effluent Characteristic	Effluent Limitation[a] (kg per 1000 kg Mg removed)
TSS	175
COD	6.5
pH	7.5-9.0

[a] Average of daily values for 30 consecutive days shall not exceed the limitation values.

Source: EN-158

Table 3.1-13. EFFLUENT LIMITATIONS FOR TREATED WASTEWATER FROM RESIDUE MILLING TO BE ACHIEVED BY JULY 1, 1977, BASED ON THE BEST PRACTICABLE CONTROL TECHNOLOGY CURRENTLY AVAILABLE

Effluent Characteristic	Effluent Limitations[a] (kg per 1000 kg product)
TSS	1.5
Fluoride	.4
Ammonia (as N)	.01
Aluminum	1.0
Copper	.003
COD	1.0
pH	Within the range of 7.5 to 9.0

[a] Average of daily values for 30 consecutive days shall not exceed limitation value.

Source: EN-158

Table 3.1-14. PROCESS POLLUTANT AND CONTROL SUMMARY - ALUMINUM SEGMENT

Process & Pollution Control	Air Emissions	Aqueous Effluents	Solid Wastes
3.1-1 Inspection and Sorting EPA SCC: None	None Reported	None Reported	Free iron, stainless steel, zinc, brass and over-sized scrap
Pollution Control	None Reported	None Reported	None Reported
3.1-2 Crushing/Screening EPA SCC: None	Particulates Low amounts of dust	None Reported	Tramp iron
Pollution Control	None Reported	None Reported	None Reported
3.1-3 Baling EPA SCC: None	Particulates Dirt and alumina dust	None Reported	None Reported
Pollution Control	None Reported	None Reported	None Reported
3.1-4 Shredding/Classifying EPA SCC: None	Particulates Low amounts of dust and other particulate matter	None Reported	Scrap iron and plastic insulation
Pollution Control	None Reported	None Reported	Recycling or landfill
3.1-5 Burning/Drying EPA SCC: None	Gases Combustion products such as CO, CO_2, N_2, H_2O, chlorides, fluorides, sulfur oxides Particulates Aluminum oxides and ash from fuel combustion	Wet scrubber effluent containing chlorides, fluorides, sulfur oxides, and aluminum oxides	Tramp iron
Pollution Control	Afterburners Wet scrubbers	None Reported	None Reported

Table 3.1-14. (CONTINUED)

Process & Pollution Control	Air Emissions	Aqueous Effluents	Solid Wastes
3.1-6 Hot Dross Processing EPA SCC: None	Particulates Dusts and fumes produced by fluxing	None Reported	Dry dross and collected particulates
Pollution Control	Baghouses		Landfill
3.1-7 Dry Milling EPA SCC: None	Particulates Large amounts of dust, aluminum oxides Gases Ammonia	Wet scrubber effluent which contains aluminum oxides, hydrated alumina, and soluble chloride, fluoride and potassium salts	Collected particulates that are high in alumina
Pollution Control	Baghouses Wet Scrubbers	Settling Ponds	Landfill
3.1-8 Wet Milling EPA SCC: None	Particulates Possibility of particulate emissions from drying	High volumes of waste-water containing salts, alumina, aluminum sulfates, chlorides, cyanides, fluorides, ammonia, calcium, copper, magnesium, nickel, sodium, potassium, zinc, cadmium, lead, maganese, oils, grease, phenols and nitrates	Alumina and aluminum fines and particulates from the settling ponds
Pollution Control	None Reported	Settling ponds followed by chemical treatment	Landfill
3.1-9 Roasting EPA SCC: None	Particulates Particulates from charring carbonaceous materials	None Reported	Charred scrap
Pollution Control	None Reported		Landfill

Table 3.1-14. (CONTINUED)

Process & Pollution Control	Air Emissions	Aqueous Effluents	Solid Wastes
3.1-10 Aluminum Sweating EPA SCC: 3-04-001-01	Gases HCl resulting from hydrolysis of aluminum chloride flux, combustion products Particulates Smoke from incomplete combustion of organics, Fumes of magnesium and zinc oxides and aluminum chloride, Aluminum trioxide particulates	None Reported	Iron containing aluminum and nonferrous metals such as zinc, magnesium, and lead
Pollution Control	Afterburners Baghouses		Landfill
3.1-11 Reverberatory (Chlorine) Smelting-Refining EPA SCC: 3-04-001-03 (Furnace) 3-04-001-04 (Chlorination)	Gases Chlorine, hydrogen chloride, combustion products, and aluminum zinc, and magnesium chlorides Particulates Aluminum oxide and other metals	Metal cooling water and wet scrubber effluent. Wastewater contains sulfates, chlorides, cyanides, fluorides, aluminum, calcium, copper, magnesium, nickel, sodium, zinc, cadmium, lead, manganese, phenols, oils and greases.	Drosses and skimmings, particulate control residuals, and wastewater sludge. Solid waste have components similar to the aqueous wastes.
Pollution Control	Wet Scrubbing Baghouses Electrostatic precipitators Coated baghouses	Settling Ponds	Landfill

Table 3.1-14. (CONTINUED)

Process & Pollution Control	Air Emissions	Aqueous Effluents	Solid Wastes
3.1-12 Reverbertory (Fluorine) Smelting-Refining EPA SCC: 3-04-001-03	Gases Hydrogen fluoride, aluminum fluoride, magnesium fluoride, silicon, tetrafluoride, and combustion products Particulates Dusts containing aluminum oxide and other metals	Metal cooling water and wet scrubbing. Wastewater constituents are similar to Process 3.1-11.	Drosses and skimmings, particulate control residuals, and wastewater sludge. Solid waste constituents are similar to those in Process 3.1-11.
Pollution Control	Wet Scrubbers Baghouses	Settling Ponds Chemical treatment	Landfill
3.1-13 Crucible Smelting-Refining EPA SCC: 3-04-001-02	Air emission constituents are similar to Process 3.1-11. However, they are much less.	Aqueous emission constituents are similar to Process 3.1-11	Solid emission constituents are similar to Process 3.1-11.
Pollution Control	Wet Scrubbers Baghouses	Settling Ponds Chemical treatment	Landfill
3.1-14 Induction Smelting-Refining EPA SCC: None	Air emissions constituents are similar to Process 3.1-11 with the exception of combustion products	Process cooling water having constituents similar to Process 3.1-11	Drosses and skimmings having constituents similar to Process 3.1-11
Pollution Control	Baghouses	None Reported	Landfill

3.2 Secondary Copper, Brass and Bronze Segment

3.2.1 Segment Description - Secondary Copper, Brass and Bronze

These industries are grouped together for purposes of this profile because a considerable overlap exists between the population of companies producing secondary copper and those processing bronze and brass. Differences which do exist in these operations are associated mainly with the quality of the raw materials used and the degree of processing required. Generally, the secondary copper industry deals with less pure raw materials and produces a more refined, pure copper product, whereas brass and bronze processors take cleaner scrap and primarily remelt, modify and cast alloys which involve less purification and refining. However, the basic processing steps and the fundamental material, copper, remain the same.

According to Appendices D and E (Volume III), there are 108 companies in the secondary copper, bronze and brass segment. The majority of this industry's production is concentrated in the northeast quadrant of the country. Other areas of concentration are the Upper Midwest and the more urban and industrial East, North Central and Middle Atlantic regions.

The 1972 Census of Manufacturers (US-276) reports that the total number of employees in the secondary copper industry is 4900, of which 3500 are production workers. The total value of shipments is given as $692.6 million, representing about one-third of the total value of the secondary nonferrous metals industry.

The total secondary copper production in 1972 was 543,600 metric tons (599,300 short tons) (US-276). Another source (CA-305) gives 532,000 metric tons (587,000 short tons) for 1972, increasing from 346,000 metric tons (381,000 short tons) in 1961, with projected copper recoveries of 800,000 metric tons (900,000 short tons) by the year 2000. The 1975 estimate given in the Commodity Data Summaries 1976 (US-357) was 313,000 metric tons. Those variations in production values probably reflect the different bases used in classifying this industry segment.

Another set of total figures which undoubtedly reflect the use of different classification criteria has been reported. The information summarized below represents the quantities of copper recovered from scrap by various industries in 1973 (SC-303):

	Metric Tons	Short Tons
Secondary smelters	260,821	287,555
Brass mills	550,377	606,791
Primary copper industry	296,563	326,961
Total	1,107,761	1,221,307

A breakdown of copper-base scrap consumption and copper recovery from scrap by these three industries is presented in Table 3.2-1.

The combined pressures of an increasing price of primary copper and environmental concerns have stimulated an interest in this industry in a variety of lower-grade raw materials. New recovery technology is being continually developed; e.g., recovery of copper from junked automobiles (DE-187). It has been reported that 9 to 15 kg (20-30 lb) of copper can be recovered per automobile (CA-305).

Table 3.2-1. DOMESTIC CONSUMPTION OF AND RECOVERY FROM PURCHASED NEW AND OLD COPPER-BASE SCRAP IN 1971 THROUGH 1973

Period	Consumption, metric tons (short tons)						
	Primary Producers		Secondary Smelters		Brass Mills		Total
	New Scrap	Old Scrap	New Scrap	Old Scrap	New Scrap	Old Scrap	
1971	214,291 (236,263)	253,784 (279,806)	106,583 (117,512)	277,520 (305,976)	568,792 (627,114)	24,513 (27,026)	1,445,483 (1,593,697)
1972	237,348 (261,685)	246,744 (272,044)	100,959 (111,311)	288,218 (317,771)	645,784 (712,000)	31,531 (34,764)	1,550,584 (1,709,575)
1973	281,429 (310,275)	266,263 (293,555)	100,603 (110,915)	264,134 (291,208)	662,138 (730,007)	42,365 (46,707)	1,616,932 (1,782,667)
	(Copper recovered in unalloyed and alloyed form from purchased scrap)						
1972	192,022 (211,711)	132,909 (146,537)	58,170 (64,135)	207,995 (229,322)	485,828 (535,643)	29,419 (32,435)	1,106,343 (1,219,783)
1973	185,130 (204,106)	111,433 (122,855)	62,269 (68,652)	198,551 (218,903)	510,014 (562,291)	40,363 (44,500)	1,107,760 (1,221,307)

Source: SC-303

No specific information was available on variations in the sizes of copper, bronze and brass processing facilities; however, this segment is probably typical of the secondary industry as a whole. The largest group of companies in the secondary industry is the 100-249 employee class, with the next largest groups being those in the 50-99 and 20-49 employee classifications (US-276).

Raw Materials

The copper scrap comprising the great bulk of the raw materials used by this industry can be first classified ad new (61 percent), i.e., produced in the fabrication of finished products, or old (39 percent), from obsolete, worn out or salvaged articles (US-357). Old scrap sources include wire, plumbing fixtures, electrical machinery, automobiles and domestic appliances. Other materials with copper values include slags, drosses, foundry ashes and sweepings from smelters and copper processing industries. A detailed classification adopted by the National Association of Secondary Materials Industries is given in Table 3.2-2 and definitions for each classification are given in Section 3.2-4. The major single source of copper scrap (47 percent) comes from copper wire and tubing (FI-103).

A tabulation of the compositions of various standard brasses and bronzes is given in Table 3.2-3. This table gives the compositions of both raw materials and products for secondary brass and bronze processors. Although specifications for scrap impurities such as wire insulation, oil, grease, and paint are not given, these associated materials are often significant contributors to the pollution potential of the scrap.

In addition to the scrap, other raw materials necessary for secondary copper processing include fluxes of boron minerals, old glass and salt; minor alloying components such as phosphorus, tin, and lead (if required); and leaching or reaction agents such as sulfuric acid and ammonium carbonate.

TABLE 3.2-2

NATIONAL ASSOCIATION OF SECONDARY MATERIALS INDUSTRIES CLASSIFICATIONS FOR COPPER-BEARING SCRAP MATERIALS

No.	Designation
1.	No. 1 copper wire
2.	No. 2 copper wire
3.	No. 1 heavy copper
4.	No. 2 copper
5.	Light copper
6.	Refinery brass
7.	Copper-bearing scrap
8.	Composition or red brass
9.	Red brass composition turnings
10.	Genuine babbitt-lined brass bushings
11.	High-grade - low-lead bronze solids
12.	Bronze paper mill wire cloth
13.	High-lead bronze solids and borings
14.	Machinery or hard brass solids
15.	Machinery or hard brass borings
16.	Unlined standard red car boxes (clean journals)
17.	Lined standard red car boxes (lined journals)
18.	Cocks and faucets
19.	Mixed brass screens
20.	Yellow brass scrap
21.	Yellow brass castings
22.	Old rolled brass
23.	New brass clippings
24.	Brass shell cases without primers
25.	Brass shell cases with primers
26.	Brass small arms and rifle shells, clean fired
27.	Brass small arms and rifle shells, clean muffled (popped)
28.	Yellow brass primer
29.	Brass pipe
30.	Yellow brass rod turnings
31.	New yellow brass rod ends
32.	Yellow brass turnings
33.	Mixed unsweated auto radiators
34.	Admiralty brass condenser tubes
35.	Aluminum brass condenser tubes
36.	Muntz metal tubes
37.	Plated rolled brass
38.	Manganese bronze solids

Source: NA-182

TABLE 3.2-3 NOMINAL CHEMICAL SPECIFICATIONS FOR BRASS AND BRONZE INGOT INSTITUTE STANDARD ALLOYS

Alloy No.	Classification	Cu,%	Sn,%	Pb,%	Zn,%	Fe,%	Al,%	Ni,%	Si,%	Mn,%
1A	Tin bronze	88.0	10.0		2.0					
1B	Tin bronze	88.0	8.0		4.0					
2A	Leaded tin bronze	88.0	6.0	1.5	4.0					
2B	Leaded tin bronze	87.0	8.0	1.0	4.0					
2C	Leaded tin bronze	87.0	10.0	1.0	2.0					
3A	High-lead tin bronze	80.0	10.0	10.0						
3B	High-lead tin bronze	83.0	7.0	7.0	3.0					
3C	High-lead tin bronze	85.0	5.0	9.0	1.0					
3D	High-lead tin bronze	78.0	7.0	15.0						
3E	High-lead tin bronze	71.0	5.0	24.0						
4A	Leaded red brass	85.0	5.0	5.0	5.0					
4B	Leaded red brass	83.0	4.0	6.0	7.0					
5A	Leaded semi-red brass	81.0	3.0	7.0	9.0					
5B	Leaded semi-red brass	76.0	2.5	6.5	15.0					
6A	Leaded yellow brass	72.0	1.0	3.0	24.0					
6B	Leaded yellow brass	67.0	1.0	3.0	29.0					
6C	Leaded yellow brass	61.0	1.0	1.0	37.0					
7A	Manganese bronze	59.0	1.0	1.0	37.0	1.0	0.6			0.5
8A	Hi-strength mang. bronze	57.5			39.0	1.0	1.0			1.5
8B	Hi-strength mang. bronze	64.0			24.0	3.0	5.0			3.5
8C	Hi-strength mang. bronze	64.0			24.0	3.0	5.0			3.5
9A	Aluminum bronze	88.0				3.0	9.0			
9B	Aluminum bronze	89.0				1.0	10.0			
9C	Aluminum bronze	85.0				4.0	11.0	2.0		0.5
9D	Aluminum bronze	81.0				4.0	11.0	4.0		3.0
10A	Leaded nickel brass	57.0	2.0	9.0	20.0			12.0		
10B	Leaded nickel brass	60.0	3.0	5.0	16.0			16.0		
11A	Leaded nickel bronze	64.0	4.0	4.0	8.0			20.0		
11B	Leaded nickel bronze	66.5	5.0	1.5	2.0			25.0		
12A	Silicon bronze	88.0			5.0	1.5			4.0	1.5
12B	Silicon brass	82.0			14.0				4.0	

Source: HA-182

Products

The classification system used to describe the various grades of recovered copper roughly corresponds to the various stages of the secondary refining process. In order of increasing copper purity, these grades of recovered copper are (NA-182):

1) "White metals" (babbit, lead, and solder) from sweating process. These may be used internally or sold to another processor.
2) Copper powder
3) Copper shot
4) Fire-refined copper
5) Electrolytic-refined copper

These products will be discussed in more detail as outputs from the various processes.

Brass and bronze product specifications have been established by the Brass and Bronze Ingot Institute (Table 3.2-3). Brass is a copper-base alloy with zinc while bronze is a copper-tin alloy; additional alloying agents may include lead, iron, aluminum, nickel, silicon, and manganese. These alloys are marketed as hardeners, generally in the form of ingots.

Copper consumption including brass and bronze in 1970 has been characterized as follows (CA-305):

Use	Percent of Market
Wire mills	42.2
Sheet (copper and brass)	15.3
Rod and mechanical wire (brass)	13.9
Foundries (brass and bronze)	10.5
Plumbing tube (copper)	6.6
Commercial tube (copper and brass)	7.8
Other	3.5

A breakdown by market category is as follows:

Category	Percent
Electrical and electronics	29.0
Building construction	22.0
Consumer and general	20.8
Industrial machinery and equipment	16.7
Transportation	11.5

A more complete characterization of products, raw materials, and companies is given in Appendices, A, B, and C.

3.2.2 Segment Analysis - Secondary Copper

The secondary copper, bronze and brass industry is typical of the secondary nonferrous metals industry as a whole in that it is fragmented and difficult to characterize. Qualitatively, the various processes making up the industry are well known but hard data on process operating parameters and pollutant emission characteristics are very limited. Consequently, the process descriptions in this section include many information gaps. In cases where process data was available, an attempt has been made to assess that information in terms of its consistency with known physical and chemical data and principles.

A process flow sheet for the segment as a whole is given in Figure 3.2-1. In some cases, processes with similar characteristics have been combined, with differences noted in the text of the description.

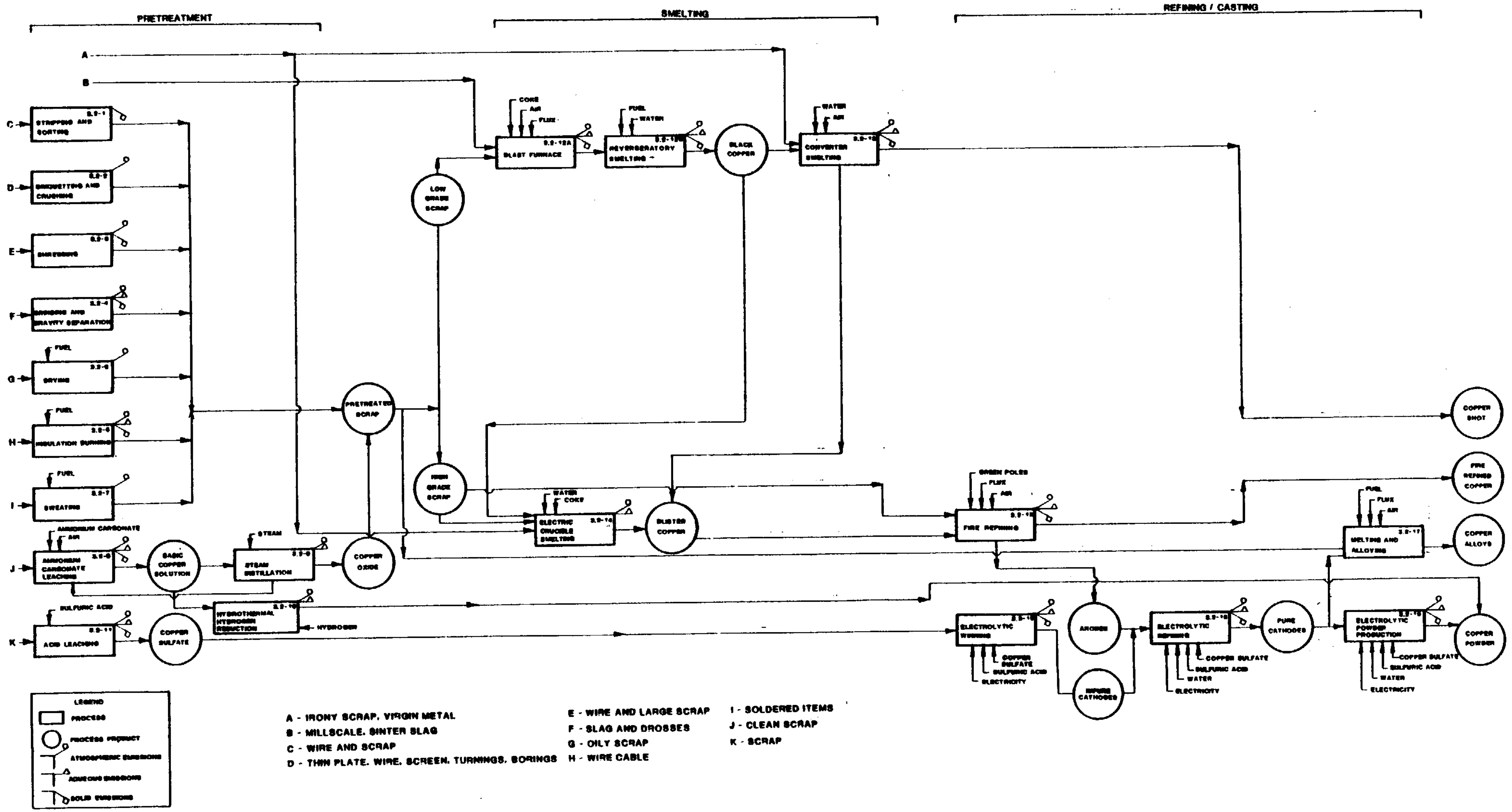

FIGURE 3.2-1
PROCESS FLOW DIAGRAM FOR THE COPPER, BRASS AND BRONZE SEGMENT OF THE SECONDARY NONFERROUS METAL INDUSTRY

Stripping and Sorting

Function - Feed scrap is segregated for further treatment by a variety of processes adapted to the considerable number of input materials. Generally, scrap is sorted on the bases of its copper content and cleanliness. Clean brass and bronze scrap may be manually separated for charging directly to a melting and alloying furnace. Ferrous components can be separated magnetically. Insulation and lead cable coverings are stripped by hand or by specially designed machines. As part of the hand sorting process, large items may be broken apart by desoldering.

Input Materials - Insulated and lead-covered cable and wire; miscellaneous scrap.

Operating Parameters - Not applicable.

Utilities - Energy to drive wire strippers, conveyors and magnets.

Waste Streams -

- Solid waste is the only waste stream produced. These wastes include plastic and fiber insulation, lead cable sheathing and ferrous scrap rejections. Control practices include landfill disposal, incineration of combustibles and sale of scrap metals to other processors if they cannot be used in-house.
- Atmospheric emissions would result from the incineration of combustibles.

EPA Source Classification Code - None

Briquetting and Crushing

Function - Varieties of relatively clean scrap are compacted for easier handling in the smelting step. The machinery used in this process includes hydraulic baling presses, hammer mills and ball mills.

Input Materials - Clean wire, thin plate, wire screen, borings, turnings, and chips.

Operating Parameters - Not available.

Utilities - Energy required to drive the equipment.

Waste Streams - There may be some dust emissions consisting of dirt, organic compounds and metal particles. These can be collected in hoods for conveyance to the plant particulate control system.

EPA Source Classification Code - None

Shredding

Function - In this step, the separation of copper wire from insulation and other materials is accomplished by reducing the size of the entire mixture. The pulverized material is then sorted by air or hydraulic classification with magnetic separation of any ferrous materials. Copper oxidation and the pollution problems resulting from insulation burning (Process No. 3.2-6) are thus avoided. The process steps are: (a) cutting into a 20-40 mm (3/4 - 1-1/2") random length in a knife-type primary granulator, (b) reduction to 5-7 mm (3/16 - 1/4") particles in a secondary granulator, (c) screening to separate fine copper, unliberated wire and insulation chunks, and (d) gravity separation into clean copper, insulation and recyclable middle fractions (ST-339).

Input Materials - This process is designed primarily for cleaning insulated wire. More heterogenous wires such as grease-filled cable and bimetallic wire were not within the state-of-the-art in 1971 (SI-108). A more detailed process separating copper and aluminum was proposed in 1972 (ST-339), but the present state-of-the-art is poorly defined.

Operating Parameters - Not readily definable.

Utilities - Energy to drive granulators, shaking screens, and fans.

Waste Streams -

- Particulate matter containing significant amounts of both insulation and metal appears in the air used in classification. Cyclones or baghouses may be used to collect this particulate matter. Recycling of the air in a closed system is also practiced (ST-339).
- Noise pollution is a possibility if proper acoustic shielding is not provided, since shredding system dBa levels may reach 100-110 (ST-339).
- Shredded insulation material is the major solid waste produced. This material can be disposed of in a landfill or reclaimed, either as various plastic fractions or other materials such as HCl from polyvinyl chloride insulation (ST-339).

EPA Source Classification Code - None

Grinding and Gravity Separation

Function - This process accomplishes the same function as Process No. 3.2-3, Shredding, but uses an aqueous separation medium and different input materials. The unit operations involved in this process are grinding, screening and gravity separation. Their purpose is the concentration of the metal value in the scrap so that subsequent thermal refining steps will not be overburdened with waste material.

Input Materials - A wide variety of materials with metal values are processed: (a) slags, (b) drosses, (c) skimmings, (d) foundry ashes, (e) spills, (f) sweepings and (g) baghouse dust. These materials may be supplied by either an outside source or other processes at the secondary smelter.

Operating Parameters - Equipment used includes size reduction machines (hammer and ball mills), screening devices and floatation cells. Specific operating conditions for these equipment items were not found.

Utilities - Power is required to operate the size reduction equipment, shaking screens and pumps. Water makeup is required in the floatation media preparation step.

Waste Streams -

- Particulate emissions resulting from grinding and screening include fluxing materials, dirt and small amounts of metals. No quantitative industry-wide emission factors are available. Conventional baghouses or cyclones should be effective in reducing these particulate emissions.

- The liquid waste stream would contain any soluble constituents of the gangue material, which encompasses a great variety of possibilities. Even if the water in the gravity separation step is recycled, there will be a blowdown/sludge stream requirement which will create disposal problems. Examples of waste water compositions are presented in Table 3.2-4.

- Solid wastes from the screening step also are present. No information is available on waste amounts and compositions.

<u>EPA Source Classification Code</u> - None

Table 3.2-4. CHARACTER OF WASTEWATER FROM SLAG QUENCHING AND GRANULATION OR SLAG MILLING AFTER SETTLING

	Plant 9 - Net Loading[a]				Plant 11 - Gross Loading[b]				Plant 38 - Net Loading[b]				Plant 39 - Net Loading[b]			
	Intake	Discharge			Intake	Discharge			Intake	Discharge			Intake	Discharge		
			Loading				Loading				Loading				Loading	
	Conc., mg/l	Conc., mg/l	kg/MT	(lb/ton)	Conc., mg/l	Conc., mg/l	kg/MT	(lb/ton)	Conc., mg/l	Conc., mg/l	kg/MT	(lb/ton)	Conc., mg/l	Conc., mg/l	kg/MT	(lb/ton)
Product MT/day (ton/day)		Copper 45.3 (50)				Alloy 108 (119)				Alloy 9.7 (10.7)				Alloy 43.5 (48)		
Water flow l/day (gal/day)		3,000,000[c] (792,000)				545,400 (144,100)				72,670 (19,200)			662,400 (175,000)	617,000 (163,000)		
Constituent																
Alkalinity	170	190	1.325	(2.650)	--	2965	14.976	(29.95)	71.33	104.67	0.250	(0.50)	685	733	0.681	(1.36)
COD	23.2	25.3	0.139	(0.278)	--				18.333	22.67	0.032	(0.064)				
Solids, Total	1294	1620	21.589	(43.18)	--	3900	19.695	(39.39)	421.3	6456	45.210	(90.42)				
Solids, diss.	64	336	18.013	(36.03)	--				387.67	2953.7	19.224	(38.45)	1,754	1,852	1.39	(2.78)
Solids, susp.	1231	1284	3.510	(7.020)	--	630	3.182	(6.364)	33.67	3502.3	25.986	(51.97)	21,405	22,980	326	(652)
TOC									63.3	268.67	1.539	(3.078)				
Phosphorus	0.029	0.031	0.0001	(0.0002)					0.293	0.403	0.001	(0.002)	1.0	1.0	NLC	
Cyanide	0.005	0.004	NLC[e]		--	NF[d]	--		0.053	0.163	0.001	(0.001)				
Antimony	0.142	0.111	NLC						<0.0	2.867	0.021	(0.042)				
Arsenic	0.001	0.001	NLC						<0.02	<0.02	NLC					
Boron	2.46	2.60	0.001	(0.001)					0.667	6.0	0.040	(0.080)				
Cadmium	0.111	0.067	NLC		--	0.11	0.0006	(0.0012)	0.067	1.683	0.012	(0.012)				
Copper	0.093	0.071	NLC		--	19.78	0.100	(0.20)	12	1250	9.275	(18.55)	0.10	0.11	0.00014	(0.00028)
Chromium						0.120	0.001	(0.002)								
Iron	0.005	0.007	NLC		--	13.0	0.066	(0.132)	1.833	163.667	1.212	(2.424)	13	14	0.0142	(0.0284)
Lead	0.297	0.192	NLC		--	23.0	0.116	(0.232)	5.333	916.67	6.835	(13.67)	0.9	1.0	0.0014	(0.0028)
Manganese	0.325	0.399	0.0005	(0.001)					0.467	43.33	0.321	(0.642)	0.05	0.05	NLC	
Mercury	0.0004	0.0003	NLC						<0.001	0.002	0.001	(0.002)				
Nickel	0.024	0.030	NLC		--	0.35	0.002	(0.004)	0.133	18.0	0.134	(0.268)				
Zinc	1.492	0.622	NLC		--	80.35	0.631	(1.262)	6.0	983.33	7.322	(14.64)	0.16	0.17	0.00014	(0.00028)
Oil and grease	1	1	NLC						11.0	23.333	0.092	(0.184)	0	0	NLC	
pH		8.32				9.8			7.4	8.53			9.35	9.35		

---

[a] Slag granulation.

[b] Slag milling.

[c] Estimated time for granulation 6 hr/day.

[d] NF = not found.

[e] NLC = no loading calculable.

Source: EN-462

Drying

Function - Here volatile organic contaminants including cutting fluids, oils and greases are removed. This process is distinguished from wire burning (No. 3.2-6) in that the contaminants are not burned. Various types of heating equipment are used, such as rotary kilns, ovens, and muffle furnaces. This process is similar to the Burning/Drying Process in the Aluminum Segment.

Input Materials - Organic contaminated scrap such as borings, turnings and chips are fed to this process.

Operating Parameters - A heating temperature which is high enough to drive off or decompose the organic contaminants is used. The length of the drying period will vary according to the contaminant volatility and type of scrap. Specific data for this operation were not found.

Utilities - Oil or gas to fire the drying furnaces.

Waste Streams - Only atmospheric emissions are produced, but they can be significant. Depending on the organic matter, the gases may contain chlorides, sulfur oxides, flourides and hydrocarbons. Particulate matter could include metals, soot and condensed heavy organics. Quantitative emission factors are not available. An afterburner is almost mandatory to control the organic emissions. HCl and HF can be removed by alkaline wet scrubbing. Non-combustible particulates can be removed by scrubbers or baghouses.

EPA Source Classification Code - None

Insulation Burning

Function - This process is intended to separate insulation and other coatings from copper wire by burning these materials in furnaces. The wire scrap is charged in batches to a primary ignition chamber. Combustion is started with auxiliary fuel and air. Volatile combustion products are then passed to a secondary combustion chamber or afterburner. Further treatment of combustion gases in a scrubber or baghouse is desirable if significant quantities of particulates or hazardous vapors are generated in this process. In most cases, the insulation burning is self-sustaining, but there can be problems with wire coated with polyvinyl chloride, fluorocarbon polymers or other flame resistant plastic formulations. If non-combustible inorganic materials such as fiberglass or ceramics are present they must be removed separately, either before or after burning.

Although the shredding method of wire treatment (Process No. 3.2-3) has been proposed as a relatively non-polluting replacement for this process, new developments in wire burning equipment promise considerable improvements over older designs (CO-368). It is claimed that a properly designed wire burner with full pollution control capabilities can recover copper from wire scrap for about 1½¢ lb. Data on pollutant removal efficiencies for various wire and insulation types were not found.

Input Materials - The total combustible content of the wire scrap can vary up to 50 percent by weight. Most commercial wire contains 20-35 percent combustibles. Wire smaller than 14 gauge is not usually burned since excessive copper oxidation losses are sustained with small wires. Wire and cable larger than about one inch in diameter is also not burned but stripped by hand or machine. The combustible portion of the wire scrap may include a considerable variety of materials, such as rubber, paper, natural and/or artificial fibers and fabrics, asphaltic materials or plastics such as polyethylene and polyvinyl chloride. Metallic and/or non-metallic inorganic fillers may also be present. Plastics formulated for flame resistance may have bromine, phosphorus and antimony compounds up to levels of several weight percent.

Operating Parameters - The size of the wire batches charged to the furnace varies from approximately 20 kg (50 lb) to 450 kg (1000 lb) or more, with 110 kb (250 lb) being typical (DA-069). A representative set of wire incineration furnace operating parameters are given in Table 3.2-5.

Table 3.2-5. WIRE INCINERATION FURNACE OPERATING PARAMETERS

Feature	Recommended Value
Gas velocities	9.1 m/sec (30 ft/sec)
Primary chamber outlet temperature	700°C (1300°F)
Afterburner final temperature	870°C (1600°F)
Residence time in stack @ maximum temperature	0.50 sec
Combustion air	
Primary	100% excess
Secondary	100% of theoretical

Source: DA-069

Utilities - The major requirements are primary fuel for initial charge heating during primary combustion and secondary fuel in the afterburner to insure complete combustion. A typical value for natural gas fuel usage in secondary burning is $0.445 m^3/kg$ ($7.13 ft^3/lb$). The amount of primary fuel required will vary widely depending upon the type of wire burned and furnace design.

Electrical power is required to operate scrubber pumps and exhaust fans; makeup water and scrubbing reagents are required if wet effluent gas scrubbers are employed.

Waste Streams - Air pollution is the principal problem, with liquid wastewater from scrubbers (if used) and solid non-combustible insulation residues being the only possibilities for liquid and solid pollutants.

> It is not possible to accurately characterize wire-burning process air emissions since the present extent of pollution control technology application is not known. It was estimated in 1971 that wire burning was essentially completely uncontrolled. An uncontrolled particulate emission factor of 137 kg/metric ton of scrap wire processed (274 lb/short ton) has been estimated to be representative of the wire burning process (SH-106).
>
> Proper design and operation of the incineration system is essential if pollutant emissions are to be minimized. This is particularly true of the secondary burning step. The data shown in Table 3.2-6 clearly indicate that wire burning emissions vary significantly depending upon whether secondary burning is used. Even with efficient secondary combustion however, the problems

Table 3.2-6. WIRE INCINERATOR EFFLUENTS (TYPICAL RUBBER-COVERED WIRE CHARGE)

Parameter or Effluent	Secondary Burners Off	Secondary Burners On
Charge wt, kg (lb)	100 (220)	106 (234)
Combustibles in charge, wt %	35	16
Ash in charge, wt %	6	6
Smoke opacity, %	Constant 100% black	0-25%
Particulates at 12% CO_2, gm/Nm^3 (gr/ft^3)	66 (29)	.59 (.26)
Particulates, kg/metric ton combustible (lb/short ton)	178 (350)	17.5 (35)
Mixing chamber temp., °C (°F)	416 (781)	1027 (1881)
Aldehydes, ppm	105	5
Hydrocarbons, ppm	640	8
Nitrogen oxides, ppm	11	25
Sulfur compounds as SO_2, ppm	.012	.0039

Source: DA-069

of HCl from polyvinyl chloride, HF from fluorocarbon plastics, and inorganic particulates from non-combustible fillers remain. These emissions can be controlled by conventional alkaline wet scrubbers and baghouses. However, wet scrubbers have been shown to be poor substitutes for complete combustion (LA-186).

- Liquid waste from this process consists of scrubber blowdown liquid. The nature of this material and hence the water treatment options required will be determined by the contaminants present in the furnace effluent gas stream.

- Solid wastes result from baghouse residues and possibly scrubber sludges.

EPA Source Classification Code - None

Sweating

Function - The removal of low-melting components from scrap is accomplished in this process by heating the scrap to a controlled temperature which is just above the melting point of the metals to be sweated out (usually solder). In this industry segment, the primary metal, copper, is generally not the melted component. This is in contrast to aluminum and lead sweating, where these primary metals are usually melted to recover them from scrap containing still higher melting impurities (principally iron).

The copper sweating process is carried out in various types of furnaces according to the type of scrap and the difficulty of removal of the low-melting impurities. There are four basic types of furnaces (NA-182).

Sloping hearth - The scrap is charged to a preheated furnace, heated to the desired tempature, raked over the hearth and discharged. Solder, lead, and other low-melting constituents are collected in a pit.

Reverberatory - Scrap which is more difficult to sweat may be charged to this type of furnace which is usually equipped with a shaking grate. The molten solder falls through the grate to a collecting sump.

Pot - The scrap is dipped in a pot of molten alloy and removed after its low-melting constituents are released.

Tunnel - The scrap passes continuously on a conveyer through the tunnel furnace. At the furnace exit, the hot scrap is dumped on tilting screen to remove solder not lost in the furnace proper.

Input Materials - Typical scrap to be sweated includes automobile radiators, plumbing fixtures, gas meter boxes and radio chassis. The material to be sweated out of the scrap is usually a relatively small constituent of the total scrap.

Operating Parameters - Most copper sweating furnaces are operated in the temperature range 340-370°C (650-700°F). In this temperature range, tin and lead are melted but not zinc and aluminum. Higher temperatures are avoided to minimize losses of valuable metals through melting and/or oxidation and to avoid fume formation problems.

Utilities - The principal utility requirement is fuel to heat the scrap. The amount of fuel required is a function of furnace design, operating procedure, scrap type, and product quality specifications.

Waste Streams - The principal emissions are atmospheric, consisting of metal and metal oxide dusts and fumes, and partly oxidized organic material from scrap contaminants such as antifreeze, oil, grease and paint. The metals and metal oxides present in the furnace effluent gas are mainly the volatile compounds such as lead, tin, and zinc, a common constituent of copper and its alloys. There is no firm data available, but particulate emissions from automobile radiators sweating operations have been estimated at 7.5 kg/metric ton of scrap processed (15 lb/short ton) (SH-106). These emissions may be controlled by baghouses, wet scrubbers or electrostatic precipitators.

EPA Source Classification Code - None

Ammonium Carbonate Leaching

Function - Copper values can be recovered from relatively clean scrap by leaching and dissolution in a basic ammonium carbonate solution. Cupric ions in an ammonia solution will react with metallic copper to produce cuprous ions, which can be reoxidized to the cupric state by air oxidation. After the crude solution is separated from the leach residue, the copper is recovered (in the oxide form) by steam distillation (Process No. 3.2-9). Although this process has not been widely used in the past, it represents an attractive alternative to traditional thermal processes with their associated atmospheric emission problems.

A recent study has been made to define important process parameters and possible improvements in this process (ST-343). Increased efficiency was obtained by (1) more agitation and flow during leaching, and (2) the use of elemental sulfur to convert the cuprous ion in solution to the sulfide precipitate. In this form it can be further processed by primary copper ore techniques.

Input Materials - Scrap with copper values which are difficult to separate (such as starters, electric motors and transformers) can be treated with this process. Feed material should be relatively clean of dirt, grease and other foreign matter. Ammonium carbonate and air are used for leaching and oxidizing.

Operating Parameters - The leaching is conducted in the temperature range of 30-40°C (86-104°F). The maximum copper dissolution rate occurs in the range of 10-30 gm/liter of cupric ion. The best ratio of NH_3 to CO_2 in solution is 4 to 1 (ST-343).

Utilities - Energy is required only for solution heating and recirculation (pumping).

Waste Streams -

- The only gaseous emissions from this process are ammonia and carbon dioxide escaping from the solutions. NH_3 losses can be minimized by exercising proper control over the leaching solution pH.

- Solid wastes include residual scrap containing unleached metals which can be sold or processed further and leach residues which must be disposed of.

- Since the leaching liquor is recycled there should be little chance for liquid wastes, except for intermittent recharging and disposal.

EPA Source Classification Code - None

Steam Distillation

Function - Copper is recovered from the leaching liquor of the ammonium carbonate process (No. 3.2-8) by steam distillation and precipitation as copper oxide. Boiling the solution precipitates the copper as the oxide. This material is dried before it is sent to other processes such as hydrogen reduction (No. 3.2-10) or blast furnace/reverberatory smelting (No. 3.2-12) for copper recovery.

Input Materials - Copper as cupric ion in an ammonium carbonate solution from the leaching process (No. 3.2-8).

Operating Parameters - The steam distillation may take place at either atmospheric or higher pressures.

Utilities - Steam to heat the solutions and drier fuel.

Waste Streams -

- Atmospheric emissions may include ammonia and carbon dioxide (see Process No. 3.2-8) and also copper oxide particulates in the drier offgases.
- If the liquid waste is recycled to the leaching process, there is little potential for water pollution from this step.

EPA Source Classification Code - None

Hydrothermal Hydrogen Reduction

Function - As an alternative to the steam distillation (Process No. 3.2-9), the copper may be recovered from the solution of Process No. 3.2-8 by hydrothermal hydrogen reduction. The heating of the liquor under hydrogen pressure precipitates the copper as a powder. The copper is filtered, washed, dried and sintered under a hydrogen atmosphere. The powder is then ground and screened. The spent liquor is recycled to the leaching process (No. 3.2-8).

Both the steam distillation and hydrogen reduction processes have the disadvantages of expensive equipment and complex operation (ST-343). Thus a search has been made for alternative methods of recovery from the leaching liquor such as reaction with elemental sulfur to produce copper sulfide, as noted in Process No. 3.2-8.

Input Materials - Copper-containing ammonium carbonate solution from Process No. 3.2-8, containing 10-30 g/liter of copper.

Operating Parameters - The hydrogen reduction is carried out at a temperature of 160 - 205°C (325-400°F) and 3.58 megapascals (500 psig).

Utilities - Energy is required for heating, drying, pulverizing and screening.

Waste Streams

- The gaseous emissions contain ammonia and carbon dioxide as for Processes 3.2-8 and 3.2-9, plus hydrogen. Additional metallic particulate emissions resulting from the copper powder processing steps can be controlled by baghouses. The amounts of all of these components are expected to be minor but no data are available.

- The spent liquor is a possible liquid pollutant, but it is mostly recycled to the leaching process.

Sulfuric Acid Leaching

Function - Scrap copper is dissolved in hot sulfuric acid to form a copper sulfate solution for feed to the electrowinning process (No. 3.2-18). An alternative product is crystalline copper sulfate. After digestion in a hot aerated sulfuric acid solution, the undissolved residue is filtered off. Lead and tin impurities precipitate and are carried off with the residue. Other metallic impurities are best controlled by scrap selection and/or pretreatment.

Input Materials - Various kinds of heavy and light scrap can be digested by this method. Another common type of feed is shot obtained by quenching of molten copper from a refining furnace.

Operating Parameters - Temperatures are usually maintained around 90°C (200°F). The reaction is considered complete when the pH has fallen to 1 or 2 (0.1 - 0.01 eq H^+/l), indicating excess acid. Sparging air is maintained at a volumetric rate per minute equal to the volume of the material in the digestion tank.

Utilities - Data on heat and power requirements for this process were not found.

Waste Streams -

- The spent or bleed-off acid will contain a wide range of metallic and nonmetallic contaminants.

- The undissolved residues which are usually disposed of via landfill could result in a secondary pollution problem.

- Sulfuric acid mist from the digester is usually controlled by using demisters similar to those developed for use in sulfuric acid manufacturing operations.

<u>EPA Source Classification Code</u> - None

Blast Furnace/Reverberatory Smelting

Function - This process uses equipment and techniques similar to primary copper ore smelting to produce black copper containing 70-80 percent copper for further refining. The feed is scrap of lower grade than that input to other secondary refining processes. The overall chemical process in the blast furnace is based on the reduction of copper by the coke fuel and the carbon monoxide formed from it. Impurities such as iron combine to form a slag which separates from the molten copper. The slag and metal mixture is tapped to a reverberatory furnace for separation.

The scrap is charged at the top of the blast furnace and proceeds downward, meeting reducing gases from the fuel at the bottom. The oxides of the base metals either dissolve in the slag, fume off, or are reduced and dissolve in the copper. The black copper product may contain zinc, lead, tin, bismuth, antimony, iron, silver, nickel, or other metals contained in the scrap. Sulfur in the coke or other feed materials reacts with the copper to form copper sulfide; this reaction can be largely avoided by using low-sulfur coke. The molten product may be cast into ingots or transferred in the molten state to the converter (Process No. 3.2-13) for further purification (SP-058, NA-182).

Input Materials - The scrap types normally charged to a blast furnace include high iron content copper and brasses, motor armatures, foundry sweepings, slags, drosses, and skimmings. It was estimated in 1961 that the minimum profitable copper content was about 30 percent (SP-058). In 1973, it was reported that feeds containing as little as 10 percent copper can be processed economically (BU-184). Lower grade output of previous scrap preparation processes are used as inputs to the blast furnace.

The coke used as a fuel and reducing agent comprises about 10 percent of the charge. Limestone and millscale (iron oxides) are added to form an iron silicate slag for fluxing purposes.

Operating Parameters - The copper is maintained somewhat above its melting point of 1083°C (1981°F), usually in the range of 1090-1150°C (2000-2100°F). The slag leaves the furnace at about 1040°C (1900°F) (DA-069). A typical secondary blast furnace has a maximum diameter of 1.3 meters (50 inches), tapering to 1 meter (40 inches) at the top, with a water jacketed section 3 meters (10 feet) high. Air flow required is 38-46 cubic meters/min per sq meter of area at the bottom (125-150 $ft^3/min/ft^2$). The nominal capacity of such a unit would be in the range of 55-65 metric tons/day (60-70 short tons/day).

Utilities - The coke charge supplies both process heat and acts as a reducing agent. Cooling water is also required by the furnace, and in the ingot casting, and shot quenching operations.

Waste Streams -

- Pollutants in the blast furnace effluent gases may include carbon monoxide, sulfur oxides, nitrogen oxides, and possibly halogens and hydrocarbons if these components are present as scrap contaminants. No quantitative information on these emissions is available.

  The particulate emissions consist of fly ash, soot, and metal and metal oxide fumes. Total particulate emissions have been estimated to be 25 kg/metric ton (50 lbs/short ton) (SH-106). One set of analytical data for collected baghouse dust has been cited (NA-182):

CONSTITUENT	PERCENT
Zinc	58-61
Lead	2-8
Tin	5-15
Copper	0.5
Antimony	0.1
Chlorine	0.1-0.5

Pollution control equipment usually includes settling chambers, baghouses, and possibly electrostatic precipitators and wet scrubbers.

- The amount of slag formed is typically 5 percent of the total charge. A typical slag analysis is given below (SP-058):

CONSTITUENT	PERCENT
Iron oxide (FeO)	29
Calcium oxide (CaO)	19
Silica (SiO_2)	39
Zinc (Zn)	10
Copper (Cu)	0.8
Tin (Sn)	0.7

- Liquid wastewater will result from furnace cooling, ingot casting and slag quenching operations. Discharge rates can be minimized by recycling this water.

<u>EPA Source Classification Code</u> - 3-04-002-01

Converter Smelting

Function - The black copper from Process No. 3.2-12 (blast furnace/reverberatory smelting) can be further refined to increase the copper content from 70-80 percent to 90-99 percent. Most of the product, called blister copper, is poured and cast or transferred molten to Process No. 3.2-15 (Fire Refining). A lesser amount of direct product is produced in the form of copper shot by water quenching.

The process steps involved in converter smelting are (a) charging with molten black copper, (b) blowing with air to oxidize copper sulfides and other metals, (c) deslagging, (d) secondary blowing, and (e) final slag skimming. Most of the reactions are exothermic; thus no external heat is required. In fact, if the iron content of the black copper feed is too high, pure copper scrap may have to be added to the charge to help keep the temperature under control. A flux containing silica (e.g., sand or glass) is usually added to react with iron oxides. This forms an iron silicate phase which is removed as slag.

Converters are pear-shaped or cylindrical steel shells lined with ceramic bricks of calcined magnesite. Openings (tuyeres) are provided for blowing air into the molten charge when the converter is tilted to the blow position.

Input Materials - Black copper of 70-80 percent purity, air, and silica flux are the feed materials. The impurities in the black copper may be iron or copper sulfides, and various other metals and metal oxides such as tin, lead, antimony and zinc.

Operating Parameters - The temperature is probably maintained a few hundred degrees above the melting point of copper, as in previous molten copper processes.

Utilities - No energy is required except incidental equipment motor power if the copper is supplied in the molten state.

Waste Streams -

- The major sources of particulate emissions are the charging/melting and blowing steps, which are estimated to each have emission factors on the order of 23 kg/metric ton of copper charged (50 lb/short ton) (VA-091). The composition of these particulates is not known, however, these solids are expected to contain significant quantities of volatile metals such as zinc, tin, and lead. The usual form of control device is a baghouse.
- The baghouse dust constitutes a solid waste stream, which may have sufficient metal value to warrant recycling to a previous purification process. The slag represents another solid waste stream, which contains mainly iron and other metals in a silica matrix. Slag may either be recycled or disposed of in a landfill if metal values are not sufficient.
- Wastewater from ingot cooling and slag quenching is also generated. Typical effluent water quality data for a metal cooling operation is given in Table 3.2-7.

EPA Source Classification - None

Table 3.2-7. CHARACTER OF WASTEWATER FROM MOLTEN METAL COOLING AND QUENCHING

Plant 9 - Net Loading			
Intake	Discharge		
Conc., mg/l	Conc., mg/l	Loading kg/MT	(lb/ton)
	Copper		
	45.3		
	(50)		
	3,000,000[a]		
	(792,000)		
170	182	0.795	(1.59)
23.2	11.2	NLC	
1294	1238	NLC	
64	31	NLC	
1231	1208	NLC	
0.029	0.023	NLC	
0.005	0.005	NLC	
0.142	0.126	NLC	
<0.001	<0.001	NLC	
2.46	2.35	NLC	
0.111	0.098	NLC	
0.098	0.069	NLC	
<0.005	<0.007	NLC	
0.297	0.223	NLC	
0.325	0.372	0.003	(0.006)
<0.0004	<0.0002	NLC	
0.024	0.019	NLC	
1.492	0.821	NLC	
<1	<1	0	
8.3	8.3		

[a] Casting time estimated at 4 hours.

Source: EN-462

Electric Crucible Smelting

Function - Feed containing low copper values can also be refined by using electric heating and pure oxygen in place of air for oxidation. The same sequence of charging, melting, blowing and skimming used in the previous two processes is also used here. An advantage of electric heating is the fact that it gives better control over the exothermic portions of the process.

Input Materials - Feed can be either pretreated scrap, raw scrap or black copper from Process No. 3.2-12 (Blast furnace/reverberatory smelting).

Operating Parameters - Temperatures which are closer to the melting point of copper are possible. Volumes of gases will be about one-fifth of those required by processes using air blowing.

Utilities - Electric power is used for heating, but data concerning the amount used and the efficiency of using electric power rather than coke or natural gas fuels are not available.

Waste Streams -

- Gaseous emissions of sulfur and nitrogen oxides will be present, but in reduced volume in comparison to other smelting processes. Soot and carbon monoxide will be absent. Particulate emissions may also be lower but not data are available.

- Liquid wastes will be similar to the analogous coke-fueled process.

- Slag removed represents a solid waste stream, which may be recycled or disposed of in a landfill.

<u>EPA Source Classification Code</u> - None.

Fire Refining

Function - In this process, the blister copper from Processes 3.2-13 and -14 is further refined to the 99.9 percent purity level. Clean, high grade copper scrap can also be charged directly to this process, which is very similar to the refining process used in the primary copper refining industry. In the fire refining process, copper may be either partially refined to a grade suitable for electrolytic purification (Process No. 3.2-16) or further refined to the practical limit in order to achieve a commercially salable product. About 14 percent of the total primary and secondary copper produced in this country is marketed as fire-refined copper (KI-048).

Fire refining can be accomplished in either a reverberatory or a cylindrical tilting furnace. The latter type is generally used with molten copper feed to cast anodes for electrolytic refining. The production of ingot and bar or the melting of blister copper ingots is usually done in a reverberatory furnace.

Both oxidation of impurities and reduction of residuals are done in this process. The process steps are (a) charging the furnace; (b) melting in an oxidizing atmosphere; (c) skimming the slag; (d) blowing with air or oxygen until the melt is about 10 percent Cu_2O (1 percent total oxygen); (e) adding a reducing agent and surface cover of charcoal or coke; (f) reducing the oxygen content to 0.03-0.05 percent by forcing green maple or birch logs beneath the surface of the melt, agitating the melt with reducing gases such as hydrogen, hydrocarbons, and carbon monoxide formed during the "poling" process; (g) reskimming the slag, and (h) casting the melt into ingots, wire bars, and other products.

An innovation recently introduced is the use of natural gas as a reducing agent. Fluxes may be added to extract impurities, e.g., sodium carbonate for arsenic and antimony. A variety of specialized reagents and procedures are available for copper material of special composition (SP-058). The control, sampling, and entire course of the process is still very much an art based on long experience.

Input Materials - The blister copper from Processes 3.2-13 and -14, which is the main feed material, has a copper content in the range of 90-99 percent. Scrap charge must be clean and relatively impurity-free. A green pole requirement of 50 kg/metric ton of copper processed (100 lb/short ton) has been cited (NA-182). Fluxing agents are also inputs to this process.

Operating Parameters - The capacities of furnaces used for this operation usually range from 90-360 metric tons (100-400 short tons).

Utilities - Heat is necessary to keep the charge molten, but no specific data on fuel or cooling water requirements were found.

Waste Streams -

- Atmospheric emissions include sulfur oxides in the oxidation phase and hydrocarbons in the reducing phase. Particulates should include carbon from the flux cover and metal oxides. No data for these emission sources were found.

- Solid wastes include the slag and skimmings which could present a disposal problem if not recycled or sold for recovery of other metal values. Arsenic, antimony, magnesium and aluminum may be present.

- The usual liquid wastes for cooling and quenching operations are produced.

EPA Source Classification Code - None

Electrolytic Refining

Function - Copper cathodes of 99.9+ percent purity may be produced as the output of the fire refining process (No. 3.2-15). Oxygen is the major impurity in the product, usually at the 0.03-0.05 percent level. As the anodes dissolve in the electrolysis process, impurities either dissolve in the electrolyte or fall to the bottom of the containing cell to be collected as slime. The cathodes produced are melted and cast in subsequent processes.

The electrolyte accumulates both soluble anode impurities (antimony, bismuth, lead, nickel, iron and zinc) and copper. Other metals collect on the cathode as scale or fall to the bottom as sludge.

A replacement rate of up to 75 percent a month of the electrolyte is circulated to liberator cells with insoluble lead anodes and copper starter sheets as cathodes. The copper content is reduced in two stages to 0.1-0.2 g/l. The copper produced is recycled to the appropriate process, depending on its purity. The effluent liquid may be concentrated and processed for further metal recovery, e.g., nickel as nickel sulfate.

The slime from both the primary electrolysis and the electrolyte purification step is filtered or centrifuged. This material may either be processed further for precious metal recovery or discarded.

Input Materials - Feed materials other than copper anodes which are required are sulfuric acid and copper sulfate for electrolyte solution makeup. Various additives, mainly glue (0.02-0.06 kg/metric ton of cathodes or 0.04-0.12 lb/short ton), are used to suppress coarse crystal growth and entrapment of impurities in the cathode material.

Operating Parameters - Typical values are given in Table 3.2-8.

TABLE 3.2-8. TYPICAL ELECTROLYTIC COPPER REFINING PARAMETERS

Parameter	Value
Anode weight, kg (lb)	275 (600)
Slimes fall, kg/metric ton (lb/short ton)	6 (12)
Cathode life, days	13
Temperature, °C (°F)	60 (140)
kWh/metric ton cathode (kWh/short ton)	220 (200)

Source: KI-048

Utilities - Electric power usage figures are given above.

Waste Streams -

- The only atmospheric emissions reported are arsine gas (AsH_3) which results from reduction of arsenic at the cathode. Arsine can also be formed in electrolyte regeneration, but in neither case are any quantitative data reported. The usual control practice involves the use of exhaust hoods over the electrolysis cells which vent to the outside of the building. If the copper feed contains phosphorus, there is also the possibility of the formation of phosphene, PH_3.
- The solid streams generated by dewatering slimes may be processed or sold for their precious metal content, recycled, or discarded if their quality is insufficient. Data are lacking on compositions and disposal practices.

Much or all of the wastewater may be treated and recirculated. One available analysis of electrolytic process wastewater is given in Table 3.2-9.

<u>EPA Source Classification Code</u> - None

TABLE 3.2-9. CHARACTER OF WASTEWATER FROM ELECTROLYTIC REFINING

Pollutant Parameters	Loading, kg/Kkg metal produced[a]
Suspended solids	0.0048
Cadmium	NLC[b]
Copper	3×10^{-8}
Lead	1.7×10^{-7}
Mercury	NLC[b]
Nickel	1.7×10^{-7}
Zinc	3×10^{-7}
Oil & grease	NLC[b]
pH	8.0

[a] Discharge would be outflow from treatment plant of excess wash-down water in event of breakdown and is not continuous.

[b] NLC - no loadings calculable.

Source: EN-462

Melting and Alloying

Function - Clean scrap is melted and reformulated, if necessary, to produce the desired alloy. A minimum of purification is assumed in this process. The major process steps are charging, melting, fluxing, alloying, pouring, and casting.

This process is used almost exclusively in the brass and bronze production area. Its emissions are markedly different from melting essentially pure copper. Brass melting in particular has higher particulate emissions from volatile constituents, zinc and lead, while bronzes, which contain tin as the chief additive, are more akin to pure copper. A table of standard alloy compositions was given in Table 3.2-3.

A number of different types of furnaces are used for this process, depending mainly on the desired batch size and total throughput. Large tonnages of standard alloys are most practically handled by stationary reverberatory furnaces, while the more flexible rotary furnace is limited to moderate tonnages. Small quantities of special alloy compositions are often produced in gas- or electric-fired crucible furnaces. The use of more closely controlled electric induction furnaces for special high-grade alloys is increasing in some plants.

Input Materials - Clean, selected bronze and brass scrap is charged to the furnace along with fluxes and alloys to bring the resulting mixture to the final composition desired. Fluxes both protect the melt from atmospheric oxidation and react with and dissolve impurities. Fluxing materials used include sodium chloride, charcoal, boron-containing minerals, lime, glass and sand. Sometimes an additive is both a flux and alloying constituent, such as a 10-15 percent phosphorus-copper alloy. The phosphorus reacts with oxygen in the melt to form the volatile P_4O_{10}. Gases such as nitrogen are sometimes bubbled up through the melt to remove some solid impurities by entrainment and to sweep out gaseous impurities.

Operating Parameters - Although operating conditions vary widely depending primarily on the desired product, the values noted below for a large reverberatory furnace are typical (SP-058).

Overall dimensions:	3.7 x 8.1 m (12 x 26.5 ft)
Molten metal depth:	1.0 m (3 ft)
Total weight of scrap charged:	86,000 kg (190,000 lb)
Average charge composition, weight percent:	82 Cu, 4 Sn, 5.26 Pb, 0.6 Ni, 0.6 Fe, 0.18 Sb, 0.07 S, 0.0-0.05 Al, nil As, 7.25 Zn.
Product composition, weight percent:	84.5 Cu, 4.4 Sn, 5.25 Pb, 5.4 Zn, 0.15 Fe, 0.22 Sb.
Flux composition:	230 kg (500 lb) broken window glass, removed after melting; 230 kg (500 lb) again added, plus sand as long as it dissolves freely. Total flux of 1800 kg (4000 lb).
Slag weight:	4500 kg (10,000 lb)
Slag composition, percent	20 zinc oxide, 20 iron oxides, 35 silicon oxides, 20 copper prills, 5-8 copper oxide, small amounts of cadmium oxide, magnesium oxide, and aluminum oxide.
Time cycle:	
Charging and melting	30 hours
Refining	10 hours
Pouring	8 hours
Metal recovery	93 percent
Pouring temperatures	1090-1200°C (2000-2200°F) (DA-069)

Utilities - For the above large reverberatory furnace the natural gas fuel usage over the entire 48 hour cycle is 0.319 Nm^3/kg of charge (5.11 ft^3/lb) (SP-058).

Waste Streams -

- Atmospheric emissions include fuel combustion products, organic scrap contaminants and particulate matter such as fly ash, soot and metal oxides. The most hazardous of these emissions in most cases would be the oxides of the volatile metals, lead and zinc; thus, the severity of this problem depends somewhat on the lead and zinc content of the melt. For typical red and yellow brass furnaces, the zinc oxide content of the particulate fume averages about 60 percent, and lead oxide 15 percent (DA-069). Lesser constituents include tin, copper, cadmium, and silicon.

Overall emissions have been cited for various types of furnaces (SI-106):

	PARTICULATE EMISSIONS	
FURNACE	lb/metric ton	lb/short ton
Blast	9	18
Crucible	6	12
Cupola	36.5	73
Electric induction	1	2
Reverberatory	35	70
Rotary	30	60

However, other parameters such as pouring temperature, collection hood design, and furnace details can affect emissions.

The typical particulate collection device is the baghouse, which has been operated routinely at collection efficiencies of about 95% (DA-069). Electrostatic precipitators have been tried but have been unsatisfactory on lead and zinc particulate fumes. Wet scrubbers also have efficiency problems when compared to baghouses, collecting only 50-65% in some tests cited (DA-069).

- Solid wastes include slags (discussed under Operating Parameters) and baghouse dusts. If not recycled to recover their metal values, these are normally disposed of in a landfill.

- Liquid wastes are produced as a result of ingot cooling. An example of a wastewater analysis has been given in Table 3.2-7.

EPA Source Classification Code -

Crucible furnace	3-04-002-02
Cupola furnace	3-04-002-03
Electric induction furnace	3-04-002-04

Electrolytic Winning

Function - Copper is recovered as impure cathodes from a copper sulfate solution which usually comes from Process No. 3.2-11, Sulfuric Acid Leaching. The copper produced must be further treated (by Process No. 3.2-16) to attain the purity of regular electrolytic copper.

In this process, spent electrolyte is continuously bled from the system, regenerated, and recycled. The process steps are: (a) preparing the electrolyte, (b) electrolyzing copper or starter sheet cathodes (c) removing the cathodes, (d) cleaning the cathodes, (e) replacing the starter strips, and (f) regenerating the electrolyte (NA-182).

Input Materials - Copper sulfate solution from acid leaching or other sources and copper starter sheets for initial cathodes are required.

Operating Parameters - Basically the same as Process No. 3.2-16.

Utilities - Basically the same as Process No. 3.2-16.

Waste Streams - There will be spent electrolyte residues similar to those of Process No. 3.2-16. There will also be slimes formed from other metals. The amount of slimes formed will depend on the type of scrap originally leached with sulfuric acid (NA-182).

EPA Source Classification Code - None.

Electrolytic Powder Production

Function - Pure copper powder is produced by electrolysis from the copper cathodes from Process No. 3.2-16. The process steps are (a) use pure copper from Process No. 3.2-16 as anodes, (b) deposit copper powder, (c) filter the powder from the cell electrolyte, (d) recycle the electrolyte, (e) rinse the powder, (f) dry the powder in a reducing atmosphere of hydrogen and carbon monoxide, and (g) classify, blend and package the powder.

Input Materials - Cathode copper from Process No. 3.2-16.

Utilities - Electricity is required as the driving force for the electrolytic reaction, and heat is required to dry the powder.

Waste Streams -

- Atmospheric emissions include gaseous emissions of carbon monoxide, hydrogen, and possibly arsine and unburned fuel, and particulate emissions consisting of dusts from the drying and powder handling steps. No quantitative data are available.
- Liquid wastes similar to the spent electrolyte solutions generated in Processes 3.2-16 and 3.2-18 are produced.

EPA Source Classification Code - None

3.2.3 Environmental Impact - Secondary Copper, Bronze and Brass

The secondary copper, bronze, and brass segment of the secondary nonferrous metals industry is a source of nearly all known types of pollutants. These include (a) particulates, (b) organic and inorganic gases, (c) metal-contaminated liquid wastes, and (d) solid wastes.

A major pollutant is the metal and metal oxide dusts emitted in the gases from sweating furnaces, converters, and crucibles. These particulates are primarily zinc and lead oxides, since these are the most volatile elements present in appreciable amounts. The emission levels depend on the lead and zinc contents of the scrap as well as the operating temperature of the equipment used. These dusts are usually controlled with baghouses.

Organic pollutant emissions come from the burning of wire insulation and the volatilization of any solvents, grease, or paint contaminating the original scrap. Properly designed and operated afterburners can usually minimize these emissions.

Emissions of inorganic gases such as sulfur dioxide, hydrogen chloride, arsine, and nitrogen oxides result from the various combustion processes used in this segment. Sulfur dioxide emissions are generally lower than those of the primary metal industry because the raw materials used contain less sulfur. The sulfur in the coke used in the blast furnaces as fuel and reducing agent is the major source of the sulfur dioxide emissions. No information was found to make a general assessment of the magnitude of the nitrogen oxides emissions. The results of an industry survey of air pollution control practices are presented in Table 3.2-10.

TABLE 3.2-10.

AIR POLLUTION CONTROL PROCESSES USED BY SMELTERS AND REFINERS OF SECONDARY BRASS AND BRONZE AND SECONDARY COPPER

	NUMBER OF PLANTS (PERCENT)		
CONTROL PROCESS	Brass and Bronze	Copper	Combined
Plants surveyed	37	7	44
Only dry air pollution control (electrostatic)	21 (57)	2 (29)	23 (52)
Only wet air pollution control	7 (21)	1 (14)	8 (20)
Both types of air pollution control	1 (3)	4 (57)	5 (11)
No air pollution control	4 (11)	1 (14)	5 (11)
No data supplied	3	0	3

Source: EN-378

Aqueous waste streams from from three main sources: (1) liquid wastes from acidic or basic scrap leaching and dissolution processes, (2) waste cooling water from pouring and casting operations, and (3) liquid wastes and slimes from electrolytic refining. Much of the wastewater is either recycled or disposed of rather than being extensively treated. There should not be a serious problem if the ultimate long-term disposal is non-polluting. The results of a survey of industry practices is given in Table 3.2-11.

The solid wastes include sludges and slimes from electrolytic and gravity separation processes, as well as fluxes, drosses, and skimmings from the various metal purification furnaces. As with liquid wastes, those solids not recycled can be disposed of safely, but there are no data on current disposal practices. Disposal methods which formerly were acceptable, such as deep ocean dumping or landfills, may in many cases no longer be allowed.

TABLE 3.2-11

SUMMARY OF WASTEWATER HANDLING PRACTICE AND DISPOSITION
USED BY SECONDARY COPPER INDUSTRY

CONTROL PROCESS	NUMBER OF PLANTS (PERCENT) Brass and Bronze	Copper	Combined
No water use	1 (3)	0	1 (2)
No treatment, discharge to			
Stream	2 (6)	1 (14)	3 (7)
Sewer	8 (24)	0	8 (18)
Treat, discharge to			
Stream	1 (3)	1 (14)	2 (5)
Sewer	4 (11)	0	4 (9)
Recycled, no discharge	10 (29)	1 (14)	11 (25)
Recycled, some discharge to stream			
Periodic	3 (9)	2 (29)	5 (11)
Continuous	1 (3)	1 (14)	2 (5)
Recycled, some discharge to sewer			
Periodic	5 (14)	0	5 (11)
Continuous	2 (6)	1 (14)	3 (7)

Source: EN-378

Table 3.2-13 lists the air, aqueous and solid emissions from each process in this segment and the reported control equipment for each type of emission from the processes. The health and environmental effects of thse emissions are summarized in Section 5 of this volume. Since the emissions from this segment are similar in many respects as the emissions from the lead segments, there is sufficient health data (ON-020) to warrent control of these multimedia emissions by the best available control technology.

Table 3.2-12. PROCESS POLLUTANT AND CONTROL SUMMARY

COPPER, BRASS, AND BRONZE SEGMENT

Process & Pollution Control	Air Emissions	Aqueous Effluents	Solid Wastes
3.2-1 Stripping and Sorting	Particulates Incineration of solid waste combustibles	None Reported	Plastic and fiber insulation, lead cable sheathing, and iron scrap
EPA SCC: None			
Pollution Control	None Reported		Landfills Incineration of combustibles Recycle metal values
3.2-2 Briquetting and Crushing	Minor amounts of dirt, organic compounds, and metallic particles	None Reported	None Reported
EPA SCC: None			
Pollution Control	Baghouses		
3.2-3 Shredding	Insulation and metallic particulate matter	None Reported	Insulation
EPA SCC: None			
Pollution Control	Baghouses		Landfills Reclaimed
3.2-4 Grinding and Gravity Separation	Particulate matter consisting of fluxes, dirt, and metals	Spent gravity separation water consisting of P, Cn, Sb, As, B, Cd, Cu, Fe, Pb, Mn, Ni, Zn, grease and oil	Screening residues consisting of dirt, fluxes, and metals
EPA SCC: None			
Pollution Control	Baghouses	None Reported	None Reported
3.2-5 Drying	Gases Chlorides, fluorides, sulfur oxides, hydrocarbons Particulates Soot and heavy organics	Wet Scrubber effluent	Collected particulates
EPA SCC: None			
Pollution Control	Afterburners Wet Scrubbing Baghouses	Settling Pond	Landfills

Table 3.2-12 (CONTINUED)

Process & Pollution Control	Air Emissions	Aqueous Effluents	Solid Wastes
3.2-6 Insulation Burning EPA SCC: None	Gases HCl, HF, chlorides, fluorides, hydrocarbons, aldehydes, and sulfur oxides Particulates Noncombustible fillers	Scrubber effluent	Collected particulates
Pollution Control	Wet scrubbing Baghouses Afterburners	Neutralizing	Landfills
3.2-7 Sweating EPA SCC: None	Particulates consisting of metals and metal oxides, partially oxidized oil, grease, and paint and zinc oxide	Wet scrubber effluent	Collected particulates
Pollution Control	Baghouses Wet scrubbers Electrostatic precipitators	Settling ponds	Landfills
3.2-8 Ammonium Carbonate Leaching EPA SCC: None	Ammonia, and carbon dioxide	Blow-down leaching liquor	Leaching residues
Pollution Control	None Reported	None Reported	Recycled Landfills
3.2-9 Steam Distillation EPA SCC: None	Ammonia, carbon dioxide, and minor amounts of copper	Blow-down leaching liquor	None Reported
Pollution Control	None Reported	None Reported	

Table 3.2-12 (CONTINUED)

Process & Pollution Control	Air Emissions	Aqueous Effluents	Solid Wastes
3.2-10 Hydrothermal Hydrogen Reduction	Gases Ammonia, carbon dioxide Particulates Copper Powder	None Reported	Collected particulates
EPA SCC: None			
Pollution Control	Baghouses		Recycled
3.2-11 Sulfuric Acid Leaching	Sulfuric acid mist	Blow down acid	Undissolved residues
EPA SCC: None			
Pollution Control	Mist eliminators	None Reported	Landfills
3.2-12 Blast Furnace/Reverberatory Smelting	Gases Carbon monoxide, sulfur oxides, halogens (chlorine) and hydrocarbons Particulates Fly ash, soot, and metal and metal oxide fumes consisting of Zn, Pb, Sn, Cu, and Sb	Scrubber effluent process cooling water and ingot casting spray and slag quenching water	Collected particulates and slag consisting if iron oxide, calcium oxide, silica, zinc, copper, and tin
EPA SCC: 3-04-002-01			
Pollution Control	Settling chamber Baghouses Electrostatic precipitators Wet scrubbers	Settling ponds for scrubber effluent None reported for aqueous emissions	Landfills

Table 3.2-12 (CONTINUED)

Process & Pollution Control	Air Emissions	Aqueous Effluents	Solid Wastes
3.2-13 Converter Smelting	Metallic particulates of zinc, tin, and lead	Water from ingot cooling and slag quenching consisting of P, Cn, Sb, As, B, Cd, Cr, Cu, Fe, Pb, Mn, Hg, Ni, Zn, oil, and grease	Collected particulates
EPA SCC: None			
Pollution Control	Baghouses	None Reported	Recycled
3.2-14 Electric Crucible Smelting	Sulfur oxides and nitrogen oxides	Refer to Process No. 3.2-13	None Reported
EPA SCC: None			
Pollution Control	None Reported	None Reported	
3.2-15 Fire Refining	<u>Gases</u> Sulfur oxides and hydrocarbons <u>Particulates</u> Fluxes and metallic oxides	Refer to Process No. 3.2-12	Slag and skimmings containing As, Sb, Mg, and Al
EPA SCC: None			
Pollution Control	None Reported	None Reported	Recycled Landfills
3.2-16 Electrolytic Refining	Arsine and possibly phosphine	Blow-down water containing nitrates, sulfates, sulfites chlorides, Al, Sb, As, Cd, Ca, Cr, Cu, Fe, Pb, Mg, Mn, Hg, Ni, K, Ag, Na, Zn, oil and grease.	Slimes
EPA SCC: None			
Pollution Control	None Reported	None Reported	Sold for precious metal content Recycled Landfills

Table 3.2-12 (CONTINUED)

Process & Pollution Control	Air Emissions	Aqueous Effluents	Solid Wastes
3.2-17 Melting and Alloying EPA SCC: Crucible Furnace: 3-04-002-02 Cupola Furnace: 3-04-002-03 Electric Induction Furnace: 3-04-002-04	Gases Combustion products and hydrocarbons Particulates Organic scrap, fly ash, soot, metal oxides, such as zinc and lead oxides, tin, copper, cadmium, and silcon	Refer to Process No. 3.2-13	Slags and collected particulates
Pollution Control	Baghouses	Refer to Process No. 3.2-13	Recycled Landfills
3.2-18 Electrolytic Winning EPA SCC: None	Refer to Process No. 3.2-16	Refer to Process No. 3.2-16	Refer to Process No. 3.2-16
3.2-19 Electrolytic Powder Production EPA SCC: None	Gases Carbon monoxide, hydrogen and arsine. Particulates Copper powder	Refer to Process No. 3.2-16	Refer to Process No. 3.2-16
Pollution Control	None Reported		

3.2-4 Copper-bearing scrap definitions (SP-058)

No. 1 copper wire shall consist of clean, untinned, uncoated, unalloyed copper wire and cable, not smaller than No. 16 B & S wire gage, free of burnt wire which is brittle. Hydraulically briquetted copper subject to agreement.

No. 2 copper wire shall consist of miscellaneous, unalloyed copper wire having a nominal 96 percent copper content (minimum 94 percent) as determined by electrolytic assay. Should be free of the following: Excessively leaded, tinned, soldered copper wire; brass and bronze wire; excessive oil content, iron, and nonmetallics; copper wire from burning, containing insulation; hair wire; burnt wire which is brittle; and should be reasonably free of ash. Hydraulically briquetted copper wire subject to agreement.

No. 1 heavy copper shall consist of clean, unalloyed, uncoated, copper clippings, punchings, bus bars, commutator segments, and wire not less than one-sixteenth of an inch thick, free of burnt wire which is brittle; but it may include clean copper tubing. Hydraulically briquetted copper subject to agreement.

No. 2 copper shall consist of miscellaneous, unalloyed copper scrap having a nominal 96 percent copper content (minimum 94 percent) as determined by electrolytic assay. Should be free of the following: Excessively leaded, tinned, soldered copper scrap; brasses and bronzes; excessive oil content, iron and nonmetallics; copper tubing with other than copper connections or with sediment; copper wire from burning, containing insulation; hair wire; burnt wire which is brittle; and should be reasonably free of ash. Hydraulically briquetted copper subject to agreement.

Light copper shall consist of miscellaneous, unalloyed copper scrap having a nominal 92 percent copper content (minimum 88 percent) as determined by electrolytic assay and shall consist of sheet copper, gutters, downspouts, kettles, boilers, and similar scrap. Should be free of the following: burnt hair wire; copper clad; plating racks, grindings, copper wire from burning, containing insulation; radiators; fire extinguishers; refrigerator units; electrotype shells; screening; excessively leaded, tinned, soldered scrap; brasses and bronzes; excessive oil, iron, and non-metallics; and should be reasonably free of ash. Hydraulically briquetted copper subject to agreement. Any items excluded in this grade are also excluded in the higher grades above.

Refinery brass shall contain a minimum of 61.3 percent copper and maximum 5 percent iron and to consist of brass and bronze solids and turnings, and alloyed and contaminated copper scrap. Shall be free of insulated wire, grindings, electrotype shells and nonmetallics. Hydraulically briquetted material subject to agreement.

Copper-bearing scrap shall consist of miscellaneous copper-containing skimmings, grindings, ashes, irony brass and copper, residues and slags. Free of insulated wires; copper chlorides; unprepared tangled material; large motors; pyrophoric material; asbestos brake linings; furnace bottoms; high lead materials; graphite crucibles; and noxious and explosive materials. Fine-powdered material by agreement. Hydraulically briquetted material subject to agreement.

Composition or red brass shall consist of red brass scrap, valves, machinery bearings and other machinery parts, including miscellaneous castings made of copper, tin, zinc, and/or lead. Should be free of semired brass castings (78 to 81 percent copper); railroad car boxes and other similar high-lead alloys; cocks and faucets; gates; pot pieces; ingots and burned brass; aluminum and manganese bronzes; iron and nonmetallics. No piece to measure more than 12 inches any one part of weight more than 100 pounds.

Red brass composition turnings shall consist of turnings from red brass composition material and should be sold subject to sample or analysis.

Genuine babbitt-lined brass bushings shall consist of red brass bushings and bearings from automobiles and other machinery, shall contain not less than 12 percent high tin base babbitt, and shall be free of iron-backed bearings.

High-grade - low-lead bronze solids. It is recommended these materials be sold by analysis.

Bronze paper mill wire cloth shall consist of clean genuine Fourdrinier wire cloth and screen having a minimum copper content of 87 percent, minimum tin content of 3 percent, and a maximum lead content of 1 percent, free of stainless steel and Monel metal stranding.

High-lead bronze solids and borings. It is recommended that these materials be sold on sample or analysis.

Machinery or hard brass solids shall have a copper content of not less than 75 percent, a tin content of not less than 6 percent, and a lead content of not less than 6 percent - nor more than 11 percent, and total impurities, exclusive of zinc, antimony, and nickel of not more than 0.75 percent; the antimony content not to exceed 0.50 percent. Shall be free of lined and unlined standard red car boxes.

Machinery or hard brass borings shall have a copper content of not less than 75 percent, a tin content of not less than 6 percent, and a lead content of not less than 6 percent - nor more than 11 percent, and the total impurities, exclusive of zinc, antimony, and nickel of not more than 0.75 percent; the antimony content not to exceed 0.50 percent.

Unlined standard red car boxes (clean journals) shall consist of standard unlined and/or sweated railroad boxes and unlined and/or sweated car journal bearings, free of yellow boxes and iron-backed boxes.

Lined standard red car boxes (lined journals shall consist of standard babbitt-lined railroad boxes and/or babbitt-lined car journal bearings, free of yellow boxes and iron-backed boxes.

Cocks and faucets shall consist of mixed clean red and yellow brass, including chrome or nickel-plated, free of gas cocks, beer faucets, and aluminum and zinc-base die-cast material, and contain a minimum of 35 percent semired.

Mixed brass screens to consist of clean mixed-copper, brass, and bronze screens and to be free of excessively dirty and painted material.

Yellow brass scrap shall consist of brass castings, rolled brass, rod brass, tubing and miscellaneous yellow brasses, including plated brass. Must be free of manganese-bronze, aluminum-bronze, unsweated radiators or radiator parts, iron, excessively dirty and corroded materials.

Yellow brass castings shall consist of yellow brass castings in crucible shape, no piece to measure more than 12 inches over any one part; and shall be free of brass forgings, silicon bronze, aluminum bronze and manganese bronze, and not to contain more than 15 percent nickel plated material.

Old rolled brass shall consist of old pieces of yellow sheet brass and yellow light tubing brass, free from solder, tinned, and nickel-plated material, iron, paint and corrosion, rod brass and condenser tubes.

New brass clippings shall consist of the cuttings of new unleaded yellow brass sheet or plate, to be clean and free of foreign substances, and not to contain more than 10 percent of clean brass punchings under one-fourth inch. To be free of Muntz metal and naval brass.

Brass shell cases without primers shall consist of clean-fired 70/30 brass shell cases free of primers and any other foreign material.

Brass shell cases with primers shall consist of clean-fired 70/30 brass shell cases containing the brass primers and which contain no other foreign material.

Brass small arms and rifle shells, clean-fired shall consist of clean-fired 70/30 brass shells free of bullets, iron, and any other foreign material.

Brass small arms and rifle shells, clean muffled (popped) shall consist of clean muffled (popped) 70/30 brass shells free of bullets, iron, and any other foreign material.

Yellow brass primer shall consist of clean yellow brass primers, burnt or unburnt. Free of iron, excessive dirt, corrosion, and any other foreign material.

Brass pipe shall consist of brass pipe free of plated and soldered materials or pipes with cast brass connections. To be sound, clean pipes free of sediment and condenser tubes.

Yellow brass rod turnings shall consist of strictly rod turnings, free of aluminum, manganese, composition, and Tobin and Muntz metal turnings; not to contain over 3 percent free iron, oil, or other moisture; to be free of grindings and babbitts; to contain not more than 0.30 percent tin and not more than 0.15 percent alloyed iron.

New yellow brass rod ends shall consist of new, clean rod ends from free-turning brass rods or forging rods, not to contain more than 0.30 percent tin and not more than 0.15 percent alloyed iron. To be free of Muntz metal and naval brass or any other alloys. To be in pieces not larger than 12 inches and free of foreign matter.

Yellow brass turnings shall consist of yellow brass turnings, free of aluminum, manganese, and composition turnings; not to contain over 3 percent of free iron, oil, or other moisture; to be free of grindings and babbitts. To avoid dispute, to be sold subject to sample or analysis.

Mixed unsweated auto radiators shall consist of mixed automobile radiators, to be free of aluminum radiators, and iron finned radiators. All radiators to be subject to deduction of actual iron. The tonnage specification should cover the gross weight of the radiators, unless otherwise specified.

Admiralty brass condenser tubes shall consist of clean sound Admiralty condenser tubing which may be plated or unplated, free of nickel alloy, aluminum alloy, and corroded material.

Aluminum brass condenser tubes shall consist of clean sound condenser tubing which may be plated or unplated, free of ncikel alloy, and corroded material.

Muntz metal tubes shall consist of clean sound Muntz metal tubing which may be plated or unplated, free of nickel alloy, aluminum alloy, and corroded material.

Plated rolled brass shall consist of plated brass sheet, pipe, tubing and reflectors, free of soldered, tinned, corroded, and aluminum-painted material, Muntz metal and Admiralty tubing, and material with cast brass connections.

Manganese bronze solids shall have a copper content of not less than 55 percent, a lead content of not more than 1 percent, and shall be free of aluminum bronze and silicon bronze.