PB 212 730

A STUDY TO IDENTIFY OPPORTUNITIES FOR INCREASED SOLID WASTE UTILIZATION. VOLUMES II TO VII

National Association of Secondary Material Industries, Incorporated
New York, New York

1972

DISTRIBUTED BY:

NTIS
National Technical Information Service
U. S. DEPARTMENT OF COMMERCE
5285 Port Royal Road, Springfield Va. 22151

PB 212 730

OC# 1576460

BIBLIOGRAPHIC DATA SHEET	1. Report No. EPA-SW-40D.2-72	2.
4. Title and Subtitle: A Study to Identify Opportunities for Increased Solid Waste Utilization. Volumes II to VII.		5. Report Date: 1972
		6.
7. Author(s): Battelle Memorial Institute, Columbus Laboratories		8. Performing Organization Rept. No.
9. Performing Organization Name and Address: National Association of Secondary Material Industries, Inc. New York, New York 10017		10. Project/Task/Work Unit No.
		11. ~~Contract~~/Grant No. G06-EC-00282
12. Sponsoring Organization Name and Address: U.S. Environmental Protection Agency, Office of Solid Waste Management Programs, Washington, D.C. 20460		13. Type of Report & Period Covered: Final
		14.
15. Supplementary Notes		

16. Abstracts

This study concerns the development of greater solid waste utilization through analysis of the secondary materials industry, its sources of supply, its consuming markets, and its economic and technological problems. Eight separate materials and a general report are included. The materials examined are aluminum, copper, lead, zinc, nickel and stainless steel, precious metals, paper, and textiles. Problems inhibiting increased recycling of these materials are identified, and recommended actions are proposed. A survey of the secondary materials industry was the basis for many of the identified problems and also provided numerous statistics on the scrap industry.

17. Key Words and Document Analysis. 17a. Descriptors

*Refuse, *Recycling, *Markets, Industrial wastes, Salvage, *Metal scrap

17b. Identifiers/Open-Ended Terms

*Solid waste, *Resource recovery, *Secondary materials, *Secondary materials industry, Scrap industry, Paper, Textiles, Aluminum, Copper, Zinc, Lead, Precious metals, Nickel, Stainless steel

17c. COSATI Field/Group 13B

18. Availability Statement: Release to public	19. Security Class (This Report) UNCLASSIFIED	21. No. of Pages ~~621~~ 608
	20. Security Class (This Page) UNCLASSIFIED	22. Price $9.00

FORM NTIS-35 (REV. 3-72) USCOMM-DC 14952-P72

As an aid to the reader, the U.S. Environmental Protection Agency has included the master bibliography for the entire nine-volume work at the back of this book.

A STUDY TO IDENTIFY OPPORTUNITIES

FOR INCREASED SOLID WASTE UTILIZATION

Volume II: Aluminum Report
Volume III: Copper Report
Volume IV: Lead Report
Volume V: Zinc Report
Volume VI: Nickel and Stainless Steel Report
Volume VII: Precious Metals Report

This report (SW-40d.2) on work performed under solid waste management demonstration grant no. G06-EC-00282 to the National Association of Secondary Material Industries, Inc., was written by BATTELLE MEMORIAL INSTITUTE, COLUMBUS LABORATORIES *and is reproduced as received from the grantee.*

Book 1, which consists of Volume I — *General Report* (SW-40d.1) is available from the Department of Commerce, National Technical Information Service, Springfield, Virginia.

Book 3, which consists of Volumes VIII and IX — *Paper Report* and *Textile Report* (SW-40d.3) is available from the Department of Commerce, National Technical Information Service, Springfield, Virginia.

U.S. ENVIRONMENTAL PROTECTION AGENCY

1972

ACKNOWLEDGEMENTS

This report and the others in the series were made possible by the cooperation of a large number of people. Those who gave this help include:

- The owners and managers of a large number of recycling companies who discussed the industry with Battelle researchers
- The people at hundreds of recycling companies who completed and returned the Industry Census questionnaires
- The managers and specialists of many users of materials--both primary and recycled--and generators of scrap who discussed recycling from their individual points of view
- The personnel of trade associations, trade publishers, and other service groups who advised the researchers
- The staff members of NASMI who provided guidance, criticism, and encouragement to the research team
- The members of the NASMI commodity committees who provided insight and information without which meaningful results would have been difficult or impossible
- The staff of World Wide Information Service, Inc., who interviewed a large number of recycling companies for the industry census.

NOTICE

This report is part of a series of 9 volumes on the recycling of solid waste materials:

Volume	Materials Covered
I	General Report
II	Aluminum
III	Copper
IV	Lead
V	Zinc
VI	Nickel and Stainless Steel
VII	Precious Metals
VIII	Paper
IX	Textiles

The reader should read Volume I as well as the volumes covering materials of specific interest. Volume I provides a brief summary of the other 8 volumes, plus an analysis of activities and recycling problems common to all of the commodities. Areas of commonality include such matters as legislation and its effect on recycling, and a description of the equipment used in processing secondary materials. It also presents a statistical profile of that portion of the secondary materials industry studied.

VOLUME II

ALUMINUM REPORT

TABLE OF CONTENTS

TABLE OF CONTENTS
(Continued)

TABLE OF CONTENTS
(Continued)

LIST OF TABLES

LIST OF TABLES
(Continued)

LIST OF FIGURES

SUMMARY

The economic recycling of waste materials is desirable because (1) it aids in the conservation of natural resources and (2) reduces dependence on foreign ores. Recycling is not a new concept, having been practiced for many decades. Recycling, therefore, is of interest to the Office of Solid Waste Management whose responsibility it is to formulate and recommend solid waste programs for the United States. This report on the recycling of aluminum provides information and analyses to be used as a basis for program planning. The report was prepared by Battelle-Columbus with the guidance and help of the National Association of Secondary Material Industries (NASMI). It is based on a 12-month study of aluminum recycling.

The report reviews briefly the demand and supply for aluminum scrap in the United States. It analyzes the recycling of aluminum, the operations of scrap processors and smelters, sources of aluminum scrap, markets for secondary aluminum, and recycling rates by types of scrap. Based on this analysis the report presents the problems faced by the aluminum recycling industry. Finally, it evaluates these problems to determine priorities, and recommends courses of action to solve or reduce these problems - with the emphasis on increasing recycling of aluminum in order to reduce solid waste disposal problems.

Aluminum has a relatively high scrap value, and therefore, the scrap is reclaimed under conditions where lower value scrap materials (such as steel, and lead) would not be reclaimed. Yet, in terms of maintaining an environment free of solid waste, the major problem in aluminum is the collection of old aluminum scrap, especially that scrap in the form of cans, or packaging foil, or in the form of a part on a complex piece of equipment such as an automobile.

Aluminum Recycling Industry

The importance of recycled aluminum in the total aluminum market is unknown because statistics on aluminum scrap consumption are available only for scrap which is actually purchased. On the basis of purchased scrap only, recycled aluminum accounted for 18.6 percent of the aluminum supply in 1969 and the aluminum recycled is 48 percent of aluminum calculated to be available for recycling.

Consumers of aluminum scrap, that is, the secondary smelters, primary producers, and nonintegrated fabricators all buy and use new scrap. Although definitive data are not available, nearly all of the new aluminum scrap produced is recycled. On the other hand, old aluminum scrap (generated when articles containing aluminum become obsolete) is consumed by essentially only one element of the recycling industry, the secondary smelter.[(1)] Although only rough estimates are possible, this report shows that only about 13 percent of the old aluminum scrap theoretically available is recovered. Figure I presents a flow diagram showing the data and estimated statistics of aluminum recycling in 1969. Examination of this figure shows that an estimated 2.2 million tons[(2)] of aluminum were theoretically available for recycling in 1969. Of this amount, about 1 million ton was recycled - about 74 percent of this went into casting alloys and other secondary smelter products, while about 25 percent went into wrought aluminum products.

If increased recycling of old aluminum scrap is stimulated, there is a limited market available. This market is the secondary smelter, which in turn has

(1) The aluminum can recycling programs qualify the primary aluminum companies as recyclers of old scrap. The quantities of aluminum recycled are very small compared to those quantities recycled by the secondary smelters.

(2) Does not include new scrap that was not purchased.

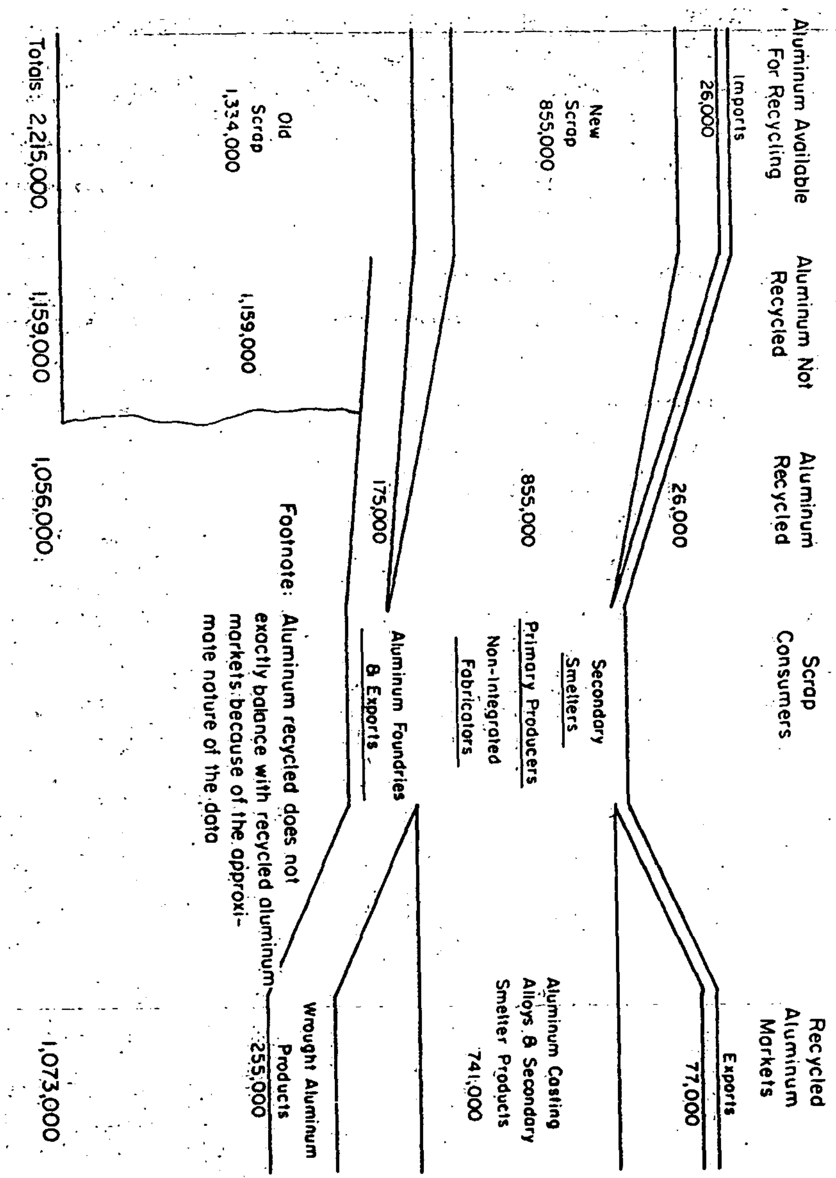

FIGURE I. FLOW DIAGRAM OF RECYCLING ALUMINUM - 1969, SHORT TONS
Source: U.S. Bureau of Mines, Minerals Yearbook, 1969, Preprint on Aluminum, and Battelle Estimates.

a limited product line, mainly aluminum casting alloys, and therefore, limited markets. Although the use of aluminum casting alloys is growing rapidly, increases in the old aluminum scrap supply at greater rates would necessitate action to maintain a supply/demand balance. The possible actions are:

(1) Increased use of old scrap, relative to new scrap by the secondary smelter

(2) Development of new secondary alloys and/or products

(3) Development, by the primary producers, of methods of utilizing old scrap (in much the same way that old can scrap is recycled).

Aluminum Recycling Problems and Recommended Actions

Aluminum recycling problems were outlined based on interviews with members of the industry. The problems were assigned priorities based on three factors:

- Potential for improvement of the environment
- Potential for conservation of natural resources
- Possibilities for realistic solutions.

Based on the above, the three problem areas that can be considered high priority are:

(1) Reclamation of old aluminum scrap from "Container and Packaging" sources

(2) Air pollution control

(3) Reclamation of old aluminum scrap from "Transportation" sources.

The detailed definition and analysis of these problems, along with recommended actions, are given in Table I.

TABLE 1. ALUMINUM RECYCLING - MAJOR PROBLEMS AND RECOMMENDED ACTIONS

Problem	Reclamation of Aluminum Scrap From Container and Packaging Sources	Air Pollution Control	Reclamation of Old Aluminum Scrap From Transportation Sources
Problem Definition	1. Scrap is widely disseminated. 2. Foil, caps, closures, and containers are found in household and industrial refuse. 3. In addition, aluminum containers are often discarded as litter.	1. Costs of equipment are very high compared to total investment of most scrap dealers and secondary smelters. 2. Reliability of present equipment is rated as poor. 3. Lack of uniform standards and enforcement penalize those that control emissions. 4. Continual changing of standards penalize those that have purchased control equipment.	1. Not all aluminum on a salvaged auto is utilized. 2. Aircraft scrap is an obvious source and is recovered if economical. 3. Other sources include trucks, trailers, buses, boats, etc.
Problem Analysis	1. Collection is a major part of the problem. 2. Segregation of refuse within the household may aid in utilization. 3. Recovery from municipal refuse may provide a solution. 4. Legislation aimed at segregation and collection problems may help.	1. Air pollution laws and enforcement are not uniform throughout country. 2. Pollution control equipment financing is difficult for the small smelters. 3. There appears to be a lack of reliable air pollution control equipment capable of attaining some air pollution standards.	1. Better utilization of aluminum in the nonferrous fraction of auto shredder scrap is needed. 2. Improved collection of abandoned autos is needed. 3. Some old scrap is not recoverable because an item such as an airplane may be exported or become obsolete overseas. 4. Even though large quantities of aluminum are now being recycled, transportation items represent a promising area in which to increase recycling of aluminum.
Action Recommended	1. Continue current can reclamation programs. 2. Utilize current collection systems to obtain scrap, i.e., local refuse collectors. 3. Promote segregation of aluminum from refuse at the source by law or other incentives, and/or 4. Develop an economic system for recycling aluminum from municipal refuse.	1. Push passage of realistic federal air pollution laws with strong provision for equal enforcement. 2. Provide financial aid in the form of low cost loans or rapid tax writeoffs to companies purchasing needed equipment. 3. Initiate research and development on more dependable and maintenance-free air pollution control equipment.	1. Learn to better utilize aluminum from auto shredder scrap. 2. Continue research being performed by industry and the USBM, EPA, and NASMI on removal of aluminum from auto shredder scrap. 3. Improve collection of abandoned automobiles, especially in remote areas.
By Whom (1)(2)(3)	EPA, NASMI, USBM, Aluminum and Aluminum Can Producers, Council on Environmental Quality	EPA, NASMI, ASRI, and Equipment Manufacturers	EPA, NASMI, and USBM and Legal Action - Auto Wreckers' Association
Specific Steps	1. Intensify current USBM and other studies on utilization of urban refuse. 2. Promote and/or sponsor pilot studies on the segregation of aluminum scrap from other refuse at the source. 3. Aluminum and aluminum can producers should continue can reclamation programs, especially as an effective way of removing can litter.	1. The recommended air pollution laws and financial aid can be provided through contact with legislators. 2. Concerned organizations should present specific air pollution control equipment needs before manufacturers and pressure for development of needed equipment.	1. Continuation and intensification of research and development by industry and the USBM. 2. An EPA/NASMI/USBM team could monitor progress and point out areas where further research is needed.

(1) The responsibility for recommended actions shown in this table are based on importance of the action, benefit to the taxpayers, and opportunities for NASMI. They are the best judgments of Battelle.

(2) Recommended actions were distributed between high priority and lower priority based on the evaluation with three criteria.

(3) It is suggested that NASMI continue its leading role in recycling, recognizing that other organizations such as the Bureau of Mines, Department of Commerce, Council of Environmental Quality, HEW Office of Information, and State, Local, and Federal Legislatures must be involved.

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INTRODUCTION

In June, 1970, Battelle-Columbus undertook a research program for the National Association of Secondary Material Industries, Inc. (NASMI). This work was carried out under a subcontract from an Office of Solid Waste Management grant to NASMI. This report on aluminum is one of a series of eight commodity reports plus a general or summary report.

Background

The Office of Solid Waste Management is responsible for formulating and recommending Federal Government policies in the area of solid waste pollution. This includes pursuing appropriate research to determine the status and problems of solid waste activities, and to develop programs to reduce solid waste pollution.

One approach to the reduction of solid waste pollution is to reclaim waste materials for reuse - the recycling concept. A well established industry--the secondary materials industry--exists to accomplish this recycling. NASMI is the trade association representing the nonferrous metals, paper, and textiles portion of this industry.

The scrap processors, secondary smelters, and other companies that make up the secondary materials industry have developed effective channels and methods for recycling nearly all waste materials of economic value. These companies have performed their difficult and essential functions well in the traditional economic environment.

More recently, additional dimensions have been added to this traditional economic environment. These new dimensions are (1) improvement of the environment in which we live, and (2) increased need for conservation of natural resources. No longer is economic gain the sole driving force for recycling of waste materials. Social gain has been added in the forms of improved living conditions and preservation of resources for future generations. In an economics-based nation this creates problems of interpretation and evaluation of noneconomics-based goals and activities.

The purpose of this series of reports is to identify obstacles to the recycling of nonferrous solid wastes, and to recommend directions for investigation and research to overcome these obstacles.

Objectives

The objective of the study on which this report is based was to identify opportunities for the increased utilization of solid waste. The major sub-objectives were:

(1) To determine the structure and functions of the secondary materials industry, and its relationships to sources of supply and markets

(2) To identify and evaluate problems of recycling - materials, sources, industry, and markets

(3) To determine opportunities for increased recycling.

Scope

The major subjects included in the scope of the study are the secondary materials industry, the materials it recycles, the sources of solid wastes, and the markets for recycled materials. Activities peripheral to these major subjects are considered where pertinent to recycling.

The materials included in the study are:

Aluminum	Nickel and Nickel Alloys
Copper and Copper Alloys	Precious Metals (Silver and Gold)
Lead	Paper
Zinc	Textiles

Research Methods

The methods and procedures used in the study are discussed under four types of activities. They include (1) literature search, (2) extensive survey, (3) in-depth survey, and (4) analysis and synthesis.

Literature Search

The literature search included reviewing and studying books, Government reports, industry reports, and trade journals covering solid waste handling and problems, recovery and market data, and recycling of valuable materials.

The results of this effort included the accumulation of data and descriptive material, and an organized bibliography dealing with each of the commodities covered in the scope of the study.

Extensive Survey

The extensive survey of the secondary materials industry consisted of a mail survey and personal interviews with management personnel of companies involved with the collection, processing, and sale of secondary materials. About 600 responses were received.

The information developed through the extensive survey included dollar sales, tons of major materials handled, types of solid waste processed, sources of materials, investment, equipment and facilities, number of employees, the amount of space used, and the grades and quantities of secondary materials produced.

The data from the extensive survey provided statistical tabulations of the regional distribution of the secondary materials industries by type of commodity in terms of numbers of establishments, volume of business, and numbers of employees.

In-Depth Survey

The in-depth survey of selected members of the secondary materials industries, their suppliers, and the users of their products served to identify the major technical and economic problems facing those companies involved with secondary material utilization. About 200 interviews were completed. Battelle-Columbus and NASMI commodity specialists jointly selected the companies to be interviewed in depth.

Interview guides for each of the commodities were prepared. The problems and potential solutions for greatest recycling and waste utilization that were developed from the literature search and prior Office of Solid Waste Management work plus the knowledge of the NASMI commodity specialists provided the basis for designing the interview guide.

Analysis and Synthesis

The analysis and synthesis step was concerned with the collation and analysis of data and information derived from both the literature, extensive survey, and in-depth survey. The analysis and synthesis activity covered the following tasks:

(1) Economic Data on the Secondary Materials Industries. The economic data developed through the extensive survey of the secondary materials industries were tabulated and analyzed as to the amount and type of solid waste handled and as to operational data such as number of employees, amount of space required, capitalization, and geographic locations.

(2) Flow Diagrams and Life Cycles. Flow diagrams were developed to indicate the flow of materials from primary production and scrap sources through fabrication. Life cycle estimates of various products were used to develop data on quantities available for possible recycling.

(3) Demand-Supply Relationships. Estimates were made of future demand and supply levels for secondary materials. The relationship between these data provide an indication of potential surpluses or shortages of recycled materials through 1980.

(4) Stability of Flow and Consumption. This analysis is closely related to the supply-demand analysis described above and identifies the ability of the various secondary materials to compete as source materials for manufacturers. A number of factors were examined such as price changes in the secondary materials, the availability of materials, and the effect of sudden changes in the magnitude of demand.

(5) Direct Impacts of Technological Change. Direct technical and technological factors were examined to determine their effect on rates of processing and recycling. Potential changes that could take place in technology that could decrease or increase the rate of solid waste recovery were examined. This included the identification of potentially recoverable solid wastes, the problems limiting the recovery to current levels, and the possibilities of technical advances through the use of known technology or through added scientific and engineering research.

(6) Constraints on Expansion of the Secondary Materials Industries. This analysis included consideration of elements critical to expansion of recycling - labor and management availability, laws and regulations, equipment availability, nature of solid waste materials, market needs, etc.

(7) Potentials for Expansion of the Secondary Materials Industries. Based on the constraints identified in the above task, plus examination of various methods for overcoming constraints, this task determined the ability of the secondary materials industries to meet new opportunities for recycling.

(8) Indirect Technological Change. The broad overall technological trends indirectly affecting the secondary materials industries were examined, and their probable impacts determined.

THE ALUMINUM INDUSTRY

In order to better understand the aluminum recycling industry, it is important to know the makeup of the entire aluminum industry and its products.

Characteristics of Aluminum

Aluminum is the "newest" of the metals covered in this series of reports, and in terms of production volume, is by far the most important. The properties responsible for the widespread use of aluminum are its low density, high strength-to-weight ratio, and good electrical and thermal conductivity. Also, the metal and many of its alloys may be formed or cast easily, and it is resistant to many forms of corrosion. The unit volume costs of aluminum are relatively low, although not as low as steel.

Wrought Alloys

Wrought alloys are generally those which are rolled, drawn, extruded, or formed by some fabricating method other than casting. These alloys are designated by an identification system devised by the Aluminum Association. (See Appendix A, Table A-1, for details of the identification system.) Permissible impurity levels for wrought aluminum alloys are given in Appendix A, Table A-2. Because of the very low impurity levels specified, the use of scrap in preparing heats is usually limited to new scrap that is well segregated.

Casting Alloys

Aluminum casting alloys are used in die, permanent mold, and sand casting. Aluminum Association designations for casting alloys are given in Appendix A, Table A-3; while former commercial designations and chemical specifications of selected alloys are given in Appendix A, Table A-4. Other designations and specifications for aluminum casting alloys have been issued by the Society of Automotive Engineers (SAE), the American Society for Testing Materials (ASTM), and various agencies of the Federal Government. In addition, some aluminum producers have their own designations.

The specifications for many of the casting alloys permit more than trace amounts of iron, zinc, and manganese. The use of scrap in preparation of these alloys is not as critical as in the case of wrought alloys. In fact, casting alloys are prepared from old scrap and new scrap that has not been highly segregated.

Some casting alloy specifications are, however, highly restrictive in terms of chemistry; and preparation using little or no scrap is dictated by the specification.

Other Forms of Aluminum

Relatively low purity aluminum is used for deoxidizing iron and steel. Specifications for "deox" along with the ASTM and commercial specifications are given in Appendix A, Table A-5. Deox is essentially a low purity form of aluminum, and in most cases can be prepared readily from scrap. Aluminum in metal, alloy, or scrap form may be used in the reduction of certain ferroalloys, in iron, zinc, and copper-base alloys, in the production of aluminum chloride, explosives, pryotechnics, exothermics, etc.

Characteristics of the Aluminum Industry

The aluminum industry, for the purposes of this report, is viewed as including the following types of companies.

(1) Primary Producers are those companies which produce aluminum metal from alumina. Some of the primary producers are fully integrated, in that they own their own bauxite* source and alumina plants. Most are integrated forward in that they own their own facilities for producing aluminum shapes from primary ingot.

(2) Nonintegrated Fabricators are those companies which buy aluminum ingot, billet, and/or scrap, melt and fabricate into a wrought form by rolling, extrusion, etc.

(3) Secondary Smelters are those companies which purchase aluminum scrap and process it into secondary aluminum alloys.

(4) Scrap Processors are those companies which collect, sort, process, and sell aluminum scrap. Most aluminum scrap processors handle other scrap materials as well.

Materials Sources

Bauxite ore is used in the production of alumina, from which aluminum is eventually derived. Bauxite comes from foreign sources. The major suppliers in 1969 were Jamaica, Surinam, and the Dominican Republic. In some instances alumina is imported directly, the major sources being Australia and Surinam. Bauxite, and other aluminum containing minerals are plentiful, and large deposits exist. There appears to be no problem with future supply.

* (See Material Sources.)

Figure 1 gives a graphical representation of the various aluminum sources and markets in the year 1969. The market for aluminum is given by product form and by end use categories. This figure shows domestic primary production accounts for 69 percent of the total aluminum supply, while secondary recovery accounts for 19 percent, or about 1/5 of the supply of aluminum.

Aluminum Producers

Production of primary aluminum in the U. S. is dominated by the so-called "Big Three"--Alcoa, Reynolds, and Kaiser. These companies accounted for 73 percent of primary aluminum capacity existing in 1970. The companies producing primary aluminum and their size in terms of production capacity are given in Table 1. Since power is a significant portion of production costs the primary producers tend to locate near sources of low cost electricity. Thus, they have located generally in TVA and Bonneville power areas, or where cheap coal-based power is available. Despite an over supply situation, starting in the last quarter of 1970, new reduction facilities are under construction and others have been announced for future construction.

The secondary aluminum smelters are much smaller and more widely scattered than primary producers. According to the Aluminum Smelters Research Institute (ASRI), about 35 companies actually prepare specification ingot for direct sale to the end user. Table 2 presents the estimated capacities and location of the large secondary smelters. The eight companies listed are active in 18 locations and have nearly enough capacity to produce as much secondary ingot as was shipped in 1969. The secondary smelters tend to locate near sources of scrap and markets. Thus, much of the production capacity is in the Ohio, Indiana, Illinois, Michigan, and Wisconsin areas. On the West Coast, the Los Angeles area is a popular site for smelter location because of the abundance of aircraft scrap.

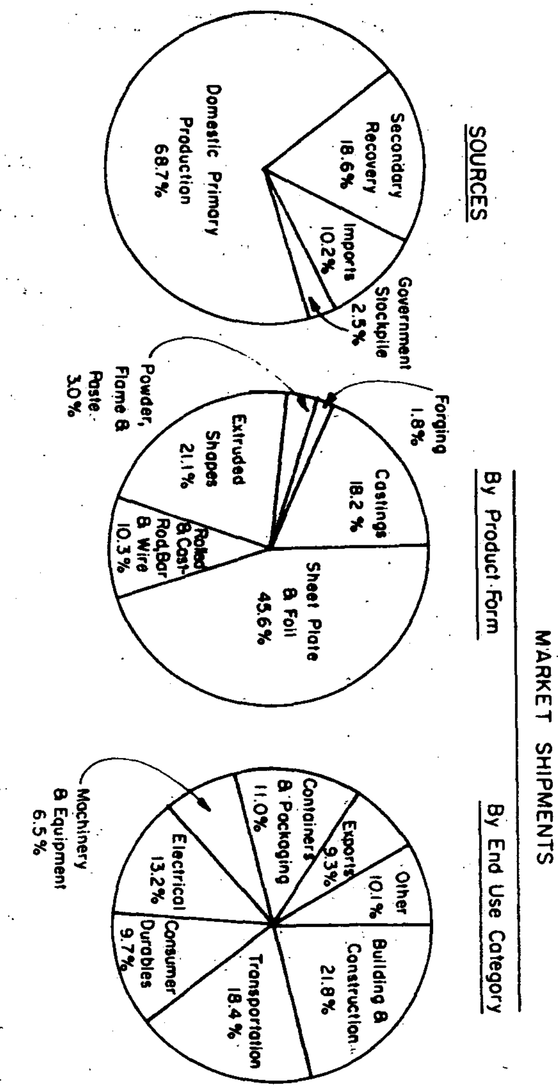


FIGURE 1. SOURCES AND MARKETS FOR ALUMINUM, 1969

Source: The Aluminum Association, Aluminum Statistical Review, 1969

TABLE 1. PRIMARY ALUMINUM CAPACITY, BY COMPANY

Company and Location	Installed Capacity, Tons*
Aluminum Company of America:	
Alcoa, Tennessee	200,000
Badin, North Carolina	100,000
Massena, New York	125,000
Point Comfort, Texas	175,000
Rockdale, Texas	275,000
Vancouver, Washington	100,000
Warrick, Indiana	175,000
Wenatchee, Washington	175,000
Totals	1,325,000
Anaconda Aluminum Company:	
Columbia-Falls, Montana	175,000
Consolidated Aluminum Company:	
New Johnsonville, Tennessee	140,000
Eastalco Aluminum Company	
Frederick, Maryland	90,000
Harvey Aluminum (Incorporated):	
The Dalles, Oregon	90,000
Intalco Aluminum Corporation:	
Bellingham, Washington	265,000
Kaiser Aluminum and Chemical Corporation:	
Chalmette, Louisiana	260,000
Mead, Washington	206,000
Ravenswood, West Virginia	163,000
Tacoma, Washington	81,000
Totals	710,000
National-Southwire Aluminum Company:	
Hawesville, Kentucky	90,000
Ormet Corporation	
Hannibal, Ohio	240,000
Reynolds Metals Company:	
Arkadelphia, Arkansas	63,000
Jones Mills, Arkansas	122,000
Listerhill, Alabama	200,000
Longview, Washington	190,000
Massena, New York	128,000
San Patricio, Texas	111,000
Troutdale, Oregon	100,000
Totals	945,000
Grand Total	4,070,000

* As of September, 1970.

Source: American Metal Market, December 14, 1970, p. 12.

TABLE 2. ESTIMATED CAPACITIES AND LOCATIONS OF LARGER SECONDARY ALUMINUM SMELTERS

Parent Company	Division	Location	Estimated 1969 Capacity, Tons/Yr.	
U. S. Reduction Company	------	East Chicago, Indiana	45,000	
		Alton, Illinois	30,000	
		Russellville, Alabama	23,000	
		Toledo, Ohio	21,000	
		Aurora, Illinois	15,600	
		Ontario California	9,600	160,000*
Vulcan Materials Company	A. & M. Division	Oak Creek, Wisconsin	48,000	
		Sandusky, Ohio	40,000	
		Corona, California	25,000	
		Hot Springs, Arkansas	25,000	138,000
American Metal Climax	Apex Smelting Co.	Chicago, Illinois	44,000	
		Cleveland, Ohio	44,000	
		Long Beach, California	22,000	110,000
Ogden Corporation	Wabash Smelting, Inc.	Wabash, Indiana	70,000	70,000
Rio Tinto Zinc	Alloys & Chemicals	Cleveland, Ohio	70,000	70,000
Michigan Standard Alloys	------	Benton Harbor, Michigan	42,000	42,000
Diversified Metals Corp.	George Sall Metals	Philadelphia, Pa.	38,000	38,000
Aluminum Smelting & Refining	------	Maple Heights, Ohio	38,000	38,000
Total				666,000

* Includes expansion in several facilities not accounted for on an individual basis.

Source: "Aluminum: Profile of an Industry", pp 44-46, Published by Metals Week, 1969, and Battelle Estimates.

28

Table 3 gives the latest available Bureau of Census Data (1967) on the primary aluminum industry and the secondary aluminum smelters. Several important differences between these two types of producers are indicated. For the secondary smelters the cost of materials is 80 percent of the value of their shipments. For the primary ingot producer, this ratio is only 52-53 percent, due to the necessary greater value added in starting from bauxite.

Table 3 is also useful because it shows the relative difference in size of the primary industry as compared to the secondary smelters. For example, the value of ingot shipments by the primary producers is almost four times that of the secondary smelters.

Production

The supply of aluminum in the U.S. is given in Table 4 for 1968 and 1969. In 1969 primary production of 3,793,000 tons was supplemented by secondary recovery of 1,030,000 tons.

TABLE 4. SUPPLY OF ALUMINUM, THOUSANDS OF TONS

	1968	1969
Domestic Production (Primary Ingot)	3,255	3,793
Domestic Secondary Recovery	997	1,030
Recovery From Imported Scrap	34	26
Unwrought Imports	675.5	468.5
Imports of Mill Products	70	66
Shipments from GSA Stockpile	56.5	139.5
Total Supply	5,098	5,523

Source: The Aluminum Association, Aluminum Statistical Review, 1969, p 13.

TABLE 3. GENERAL STATISTICS FOR ESTABLISHMENTS, BY INDUSTRY SPECIALIZATION AND PRIMARY PRODUCT CLASS SPECIALIZATION: 1967

Industry or Product Class Code	Industry or Product Class By Percent of Specialization	Establishments	All Employees		Production Workers			Value Added by Manufacture	Cost of Materials	Value of Shipments	Capital Expenditures, New
			Number	Payroll	Number	Man-hours	Wages				
		(number)	(1,000)	(million dollars)	(1,000)	(millions)	(million dollars)	(million dollars)	(million dollars)	(million dollars)	(million dollars)
3334	Primary Aluminum										
	Entire Industry	25	23.8	190.9	19.2	38.4	145.2	811.8	341.6	1,608.7	151.7
33347	Aluminum Ingot, Primary Aluminum Reduction Plants (Primary Product Class of Establishment)	22	22.5	180.4	18.1	36.4	137.0	782.0	793.0	1,531.7	128.8
	Establishments With 75% or More Specilization	18	17.5	141.3	14.2	28.6	108.7	604.2	641.6	1,211.3	121.5
33417	Aluminum Ingot, Produced by Secondary Smelters (Primary Product Class of Establishment)	54	4.8	34.5	3.7	8.0	23.5	71.5	289.4	362.6	8.3
	Establishments With 75% or More Specilization	48	4.1	29.7	3.2	6.9	20.5	61.8	247.8	311.6	7.3
33418	Aluminum Extrusion Billet, Secondary Smelters (Primary Product Class of Establishment)	9	0.5	3.0	0.4	0.9	2.2	9.6	37.2	46.8	1.1

Note: Detailed figures may not add to totals because of independent rounding or independent dropping of fractions of thousands (rather than rounding) in computer operations.

Source: Bureau of Census, "1967 Census of Manufactures", Major Group 33, Primary Metal Industries, Report MC 67(2)-33C, issued September, 1970, p 33C-33.

TABLE 1. PRIMARY ALUMINUM CAPACITY, BY COMPANY

Company and Location	Installed Capacity, Tons*
Aluminum Company of America:	
Alcoa, Tennessee	200,000
Badin, North Carolina	100,000
Massena, New York	125,000
Point Comfort, Texas	175,000
Rockdale, Texas	275,000
Vancouver, Washington	100,000
Warrick, Indiana	175,000
Wenatchee, Washington	175,000
Totals	1,325,000
Anaconda Aluminum Company:	
Columbia-Falls, Montana	175,000
Consolidated Aluminum Company:	
New Johnsonville, Tennessee	140,000
Eastalco Aluminum Company	
Frederick, Maryland	90,000
Harvey Aluminum (Incorporated):	
The Dalles, Oregon	90,000
Intalco Aluminum Corporation:	
Bellingham, Washington	265,000
Kaiser Aluminum and Chemical Corporation:	
Chalmette, Louisiana	260,000
Mead, Washington	206,000
Ravenswood, West Virginia	163,000
Tacoma, Washington	81,000
Totals	710,000
National-Southwire Aluminum Company:	
Hawesville, Kentucky	90,000
Ormet Corporation	
Hannibal, Ohio	240,000
Reynolds Metals Company:	
Arkadelphia, Arkansas	63,000
Jones Mills, Arkansas	122,000
Listerhill, Alabama	200,000
Longview, Washington	190,000
Massena, New York	128,000
San Patricio, Texas	111,000
Troutdale, Oregon	100,000
Totals	945,000
Grand Total	4,070,000

* As of September, 1970.

Source: American Metal Market, December 14, 1970, p. 12.

TABLE 2. ESTIMATED CAPACITIES AND LOCATIONS OF LARGER SECONDARY ALUMINUM SMELTERS

Parent Company	Division	Location	Estimated 1969 Capacity, Tons/Yr.	
U. S. Reduction Company	------	East Chicago, Indiana	45,000	
		Alton, Illinois	30,000	
		Russellville, Alabama	23,000	
		Toledo, Ohio	21,000	
		Aurora, Illinois	15,600	
		Ontario California	9,600	
				160,000*
Vulcan Materials Company	A. & M. Division	Oak Creek, Wisconsin	48,000	
		Sandusky, Ohio	40,000	
		Corona, California	25,000	
		Hot Springs, Arkansas	25,000	
				138,000
American Metal Climax	Apex Smelting Co.	Chicago, Illinois	44,000	
		Cleveland, Ohio	44,000	
		Long Beach, California	22,000	
				110,000
Ogden Corporation	Wabash Smelting, Inc.	Wabash, Indiana	70,000	70,000
Rio Tinto Zinc	Alloys & Chemicals	Cleveland, Ohio	70,000	70,000
Michigan Standard Alloys	------	Benton Harbor, Michigan	42,000	42,000
Diversified Metals Corp.	George Sall Metals	Philadelphia, Pa.	38,000	38,000
Aluminum Smelting & Refining	------	Maple Heights, Ohio	38,000	38,000
Total				666,000

* Includes expansion in several facilities not accounted for on an individual basis.

Source: "Aluminum: Profile of an Industry", pp 44-46, Published by Metals Week, 1969, and Battelle Estimates.

Table 3 gives the latest available Bureau of Census Data (1967) on the primary aluminum industry and the secondary aluminum smelters. Several important differences between these two types of producers are indicated. For the secondary smelters the cost of materials is 80 percent of the value of their shipments. For the primary ingot producer, this ratio is only 52-53 percent, due to the necessary greater value added in starting from bauxite.

Table 3 is also useful because it shows the relative difference in size of the primary industry as compared to the secondary smelters. For example, the value of ingot shipments by the primary producers is almost four times that of the secondary smelters.

Production

The supply of aluminum in the U.S. is given in Table 4 for 1968 and 1969. In 1969 primary production of 3,793,000 tons was supplemented by secondary recovery of 1,030,000 tons.

TABLE 4. SUPPLY OF ALUMINUM, THOUSANDS OF TONS

	1968	1969
Domestic Production (Primary Ingot)	3,255	3,793
Domestic Secondary Recovery	997	1,030
Recovery From Imported Scrap	34	26
Unwrought Imports	675.5	468.5
Imports of Mill Products	70	66
Shipments from GSA Stockpile	56.5	139.5
Total Supply	5,098	5,523

Source: The Aluminum Association, Aluminum Statistical Review, 1969, p 13.

TABLE 3. GENERAL STATISTICS FOR ESTABLISHMENTS, BY INDUSTRY SPECIALIZATION AND PRIMARY PRODUCT CLASS SPECIALIZATION: 1967

Industry or Product Class Code	Industry or Product Class By Percent of Specialization	Establishments	All Employees		Production Workers			Value Added by Manufacture	Cost of Materials	Value of Shipments	Capital Expenditures, New
			Number	Payroll	Number	Man-hours	Wages				
		(number)	(1,000)	(million dollars)	(1,000)	(millions)	(million dollars)	(million dollars)	(million dollars)	(million dollars)	(million dollars)
3334	Primary Aluminum										
	Entire Industry	25	23.8	190.9	19.2	38.4	145.2	811.8	341.6	1,608.7	151.7
33347	Aluminum Ingot, Primary Aluminum Reduction Plants (Primary Product Class of Establishment).	22	22.5	180.4	18.1	36.4	137.0	782.0	793.0	1,531.7	128.8
	Establishments With 75% or More Specilization . . .	18	17.5	141.3	14.2	28.6	108.7	604.2	641.6	1,211.3	121.5
33417	Aluminum Ingot, Produced by Secondary Smelters (Primary Product Class of Establishment).	54	4.8	34.5	3.7	8.0	23.5	71.5	289.4	362.6	8.3
	Establishments With 75% or More Specilization . . .	48	4.1	29.7	3.2	6.9	20.5	61.8	247.8	311.6	7.3
33418	Aluminum Extrusion Billet, Secondary Smelters (Primary Product Class of Establishment).	9	0.5	3.0	0.4	0.9	2.2	9.6	37.2	46.8	1.1

Note: Detailed figures may not add to totals because of independent rounding or independent dropping of fractions of thousands (rather than rounding) in computer operations.

Source: Bureau of Census, "1967 Census of Manufactures", Major Group 33, Primary Metal Industries, Report MC 67(2)-33C, issued September, 1970, p 33C-33.

Markets for Aluminum

The markets for aluminum have been outlined in Figure 1, both by product form and general end use. The shipments of aluminum, by major end use markets, are given in Table 5 for the years 1960 and 1969. Total aluminum shipments have grown from 2,366,000 tons in 1960 to 5,409,000 tons in 1969. This is equivalent to a compound growth rate of 9.6 percent per year, much faster than the rate for lead or zinc. As can be seen in Figure 1, the two largest end use categories are "Building and Construction" which accounted for 21.8 percent and "Transportation" which accounted for 18.4 percent of the aluminum market in 1969. The fastest rate of growth, however, is exhibited by the "Containers and Packaging" market. From 1960 to 1969 shipments of aluminum to this market increased at the compound growth rate of 15.7 percent per year.

TABLE 5. ALUMINUM SHIPMENTS, 1960 AND 1969, BY END-USE CATEGORY, THOUSANDS OF TONS

End-Use Category	1960	1969
Building and Construction	608.5	1,179.0
Transportation	427.5	994.0
Consumer Durables	256.5	527.5
Electrical	264.0	713.0
Machinery and Equipment	166.5	349.5
Containers and Packaging	160.5*	596.5**
Exports	308.5	503.5
Other	174.0	546.0
Total	2,366.0	5,409.0

* Metal and composite cans accounted for 47 thousand tons of this category.

** Metal and composite cans accounted for 333 thousand tons of this category.

Source: The Aluminum Association, Aluminum Statistical Review, 1969, pp 34 and 35.

Secondary Aluminum Markets

Scrap is utilized by primary producers and nonintegrated producers of wrought alloy products. The scrap utilized is generally new (prompt industrial scrap) and well identified with regard to alloy content. It is usually only a portion of a furnace charge, the remainder being primary aluminum ingot. The product, although it is made using scrap aluminum, is essentially indistinguishable from a primary aluminum alloy made to the same specifications. The markets for such a product are the same as for primary aluminum alloys and were covered above.

Very important, however, are the markets for secondary aluminum alloys, which are produced to specification by the secondary aluminum smelter. The smelter utilizes both old and new scrap to produce mainly aluminum casting alloys, although some deox, aluminum pig, and master alloys are also produced. In 1969 an estimated 741,000 tons of secondary products were produced by the secondary smelters. Further information on secondary smelter production is given later in the section titled The Aluminum Recycling Industry.

Market Outlook

The growth of the primary aluminum industry, based on shipments, has been at the compound rate of 9.6 percent per year from 1960 to 1969. Growth in shipments from 1970 to 2000 are expected to slow somewhat, dropping to 6.4 percent per year.[(1)] At least one producer has estimated that the 1966-1975 rate will probably be 3 percent compounded annually, considerably lower than the optimistic forecast above.

(1) S. P. Wimpfen, "Nonferrous Scrap Availability as Viewed by a Materials Supply Specialist", Presented at the NASMI-Bureau of Mines Recycling Workshops, Washington, D.C., January 7, 1971.

Secondary smelter shipments grew 9.4 percent per year from 1960 to 1969. During the same period, shipments of aluminum die castings (the major secondary market) grew at a rate of 11.1 percent per year. Future growth in secondary aluminum is expected to average 8.5 percent per year from 1970 to 2000.(1)

THE ALUMINUM RECYCLING INDUSTRY

The aluminum recycling industry includes the organizations involved in getting aluminum scrap from its point of non-use, processing it, and transferring it to a point of use. The types of organizations and their functions include:

Type	Recycling Function
Scrap Processors or Dealers	Purchase, collect, sort, process, and sell aluminum scrap
Scrap Brokers	Buy and sell aluminum scrap
Secondary Aluminum Smelters	Prepare and consume new and old aluminum scrap in the preparation of secondary alloys
Primary Aluminum Producers and Nonintegrated Fabricators	Consume new scrap in preparation of primary alloys in ingot and wrought forms
Other Consumers	Consume scrap in preparation of alloys, deox, chemicals, etc.

Characteristics of Aluminum Materials

Primary Aluminum Alloys

Primary aluminum producers and nonintegrated fabricators are a part of the aluminum recycling industry in the sense that they utilize aluminum scrap in

(1) S. P. Wimpfen, op.cit.

the preparation of alloys. Even though the scrap content of these alloys might be sizable, the materials produced are generally referred to as primary aluminum alloys.

Secondary Aluminum Alloys

Secondary aluminum alloys are alloys produced almost entirely from scrap. These alloys are usually aluminum casting alloys or deox and are essentially equivalent to similar primary alloys made to the same specifications.

Scrap Drosses

Table 6 provides definitions for standard grades of aluminum scrap and for dross. The definitions are those of the National Association of Secondary Material Industries.

Characteristics of the Aluminum Recycling Industry

A diagram showing the components of the aluminum recycling industry is given in Figure 2. The scrap flows from its sources to a consumer; it may or may not pass through a scrap dealer. Another diagram presenting the flow of aluminum scrap is presented in Figure 3 and is self-explanatory.

Scrap Sources

Before discussing scrap sources in detail it is appropriate to discuss the difference between new scrap and old scrap. New scrap is taken to be scrap that is generated in the production of aluminum metal or in the production of aluminum parts or a finished article made from aluminum. Old scrap is generally scrap from aluminum containing articles which have been removed from service at the end of their usable life.

TABLE 6. GRADES OF ALUMINUM SCRAP AND DROSS

NEW PURE ALUMINUM CLIPPINGS

Shall consist of new, clean, unalloyed sheet clippings and/or aluminum sheet cuttings, free from oil and grease, foil and any other foreign substances and from punchings less than 1/2 inch in size.

MIXED LOW COPPER ALUMINUM CLIPPINGS AND SOLIDS

Shall consist of new, clean, uncoated and unpainted low copper aluminum scrap of two or more alloys and to be free of foil, hair wire, wire screen, dirt, and other foreign substances. Grease and oil not to total more than 1 percent. Also free from punchings less than 1/2 inch in size. New can stock subject to arrangement between buyer and seller.

MIXED ALLOY SHEET ALUMINUM

Shall consist of clean old alloy sheet aluminum of two or more alloys and to be free of 70S (7000) series, foil, Venetian blinds, castings, hair wire, screen wire, food or beverage containers, pie plates, dirt, and other foreign substances. Oil and grease not to total more than 1 percent. Up to 10 percent painted sidings and awnings are permitted.

SCRAP SHEET AND SHEET UTENSIL ALUMINUM

Shall consist of clean, unpainted old 2S (1100) or 3S (3003) aluminum sheet and sheet utensils, free from hub caps, radiator shells, airplane sheet, foil, food or beverage containers, pie plates, oil cans and bottle caps, dirt, and other foreign substances. Oil and greast not to total more than 1 percent.

NEW PURE ALUMINUM WIRE AND CABLE

Shall consist of new, clean, unalloyed aluminum wire or cable free from hair wire, wire screen, iron, insulation and any other foreign substance.

OLD PURE ALUMINUM WIRE AND CABLE

Shall consist of old, unalloyed aluminum wire or cable containing not over 1 percent free oxide or dirt and free from hair wire, wire screen, iron, insulation and any other foreign substance.

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 greast not to exceed 2 percent.
(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 greast not to exceed 2 percent.
(c) Irony Aluminum Pistons. Should be sold on recovery basis, or by special arrangements with purchaser.

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 percent through a 20 mesh screen and dirt, free iron, oil, moisture and all other foreign materials. Material containing iron in excess of 10 percent and/or free magnesium or stainless steel or containing highly flammable cutting compounds will not constitute good delivery.

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 percent through a 20 mesh screen and dirt, free iron, oil, moisture and all other foreign materials. Material containing iron in excess of 10 percent and/or 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.

MIXED ALUMINUM CASTINGS

Shall consist of all clean aluminum castings which may contain auto and airplane castings but no ingots, and to be free of iron, dirt, brass, babbit, and any other foreign materials. Oil and grease not to total more than 2 percent.

TABLE 6. GRADES OF ALUMINUM SCRAP AND DROSS (Continued)

WRECKED AIRPLANE SHEET ALUMINUM

Should be sold on recovery basis or by special arrangements with purchaser.

NEW ALUMINUM FOIL

Shall consist of clean, new, pure, uncoated, unalloyed aluminum foil, free from anodized foil, radar foil and chaff, paper, plastics, or any other foreign materials. Hydraulically briquetted material by arrangement only.

OLD ALUMINUM FOIL

Shall consist of clean, old, pure, uncoated, unalloyed aluminum foil, free from anodized foil, radar foil and chaff, paper, plastics, or any other foreign materials. Hydraulically briquetted material by arrangement only.

ALUMINUM GRINDINGS

Should be sold on recovery basis or by special arrangements with purchaser.

ALUMINUM DROSSES, SPATTERS, SPILLINGS, SKIMMINGS, AND SWEEPINGS

Should be sold on recovery basis or by special arrangements with purchaser.

SWEATED ALUMINUM

Shall consist of aluminum scrap which has been sweated or melted into a form or shape such as an ingot, pit, or slab for convenience in shipping; to be free from corrosion, drosses or any foreign materials. Should be sold subject to sample or analysis.

SEGREGATED NEW ALUMINUM ALLOY CLIPPINGS AND SOLIDS

Shall consist of new, clean, uncoated and unpainted aluminum scrap of one specified aluminum alloy only and to be free of foil, hair wire, wire screen, dirt, and other foreign substances. Oil and grease not to total more than 1 percent. Also free from punchings less than 1/2 inch in size. New can stock subject to arrangement between buyer and seller.

MIXED NEW ALUMINUM ALLOY CLIPPINGS AND SOLIDS

Shall consist of new, clean, uncoated and unpainted aluminum scrap of two or more alloys free of 70S (7000) series and to be free of foil, hair wire, wire screen, dirt, and other foreign substances. Oil and grease not to total more than 1 percent. Also free from punchings less than 1/2 inch in size.

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 other foreign substances.

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, babbit bushings, brass bushings, and any other foreign materials. Oil and grease not to total more than 2 percent.

ALUMINUM AIRPLANE CASTINGS

Shall consist of clean aluminum castings from airplanes and to be free from iron, dirt, brass, babbit bushings, brass bushings, and any other foreign materials. Oil and grease not to total more than 2 percent.

Source: "The Nonferrous Scrap Metal Industry—Its Operations, Procedures, Techniques", pp 116-117, published by the National Association of Secondary Material Industries, Inc., 1967.

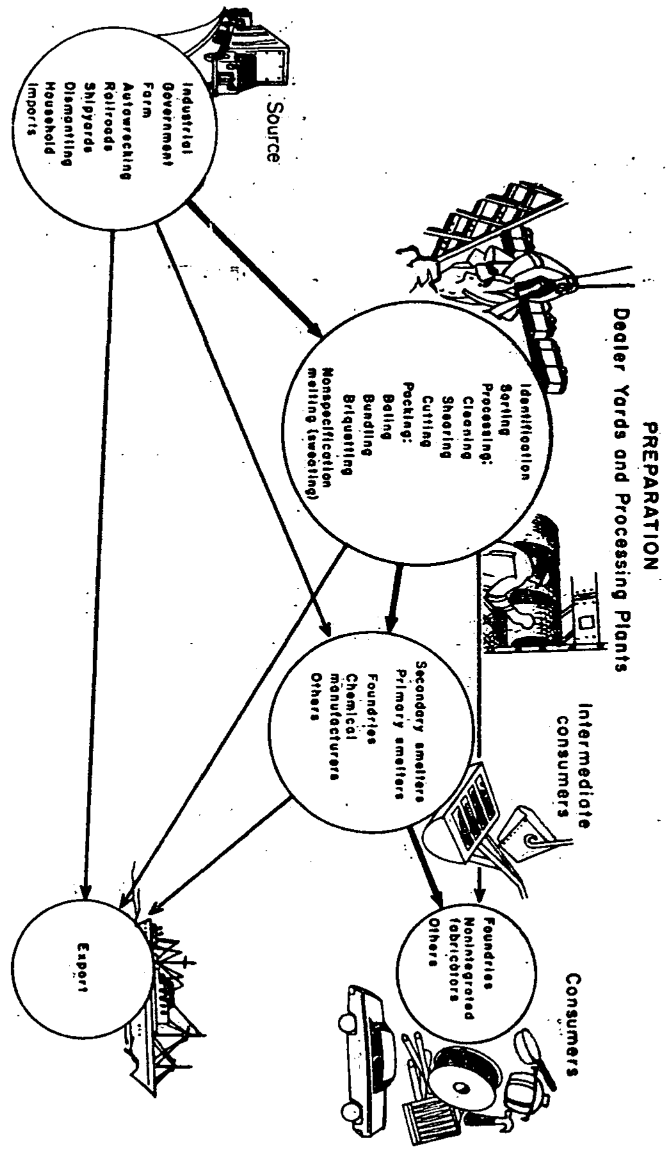
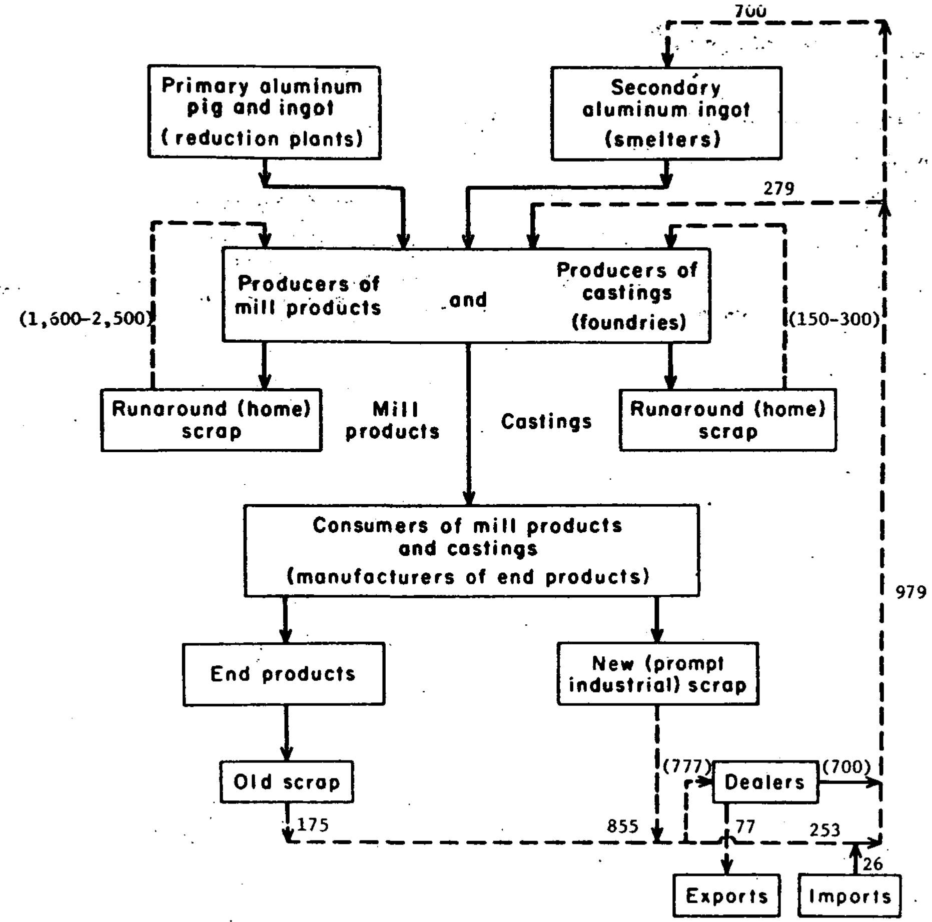


FIGURE 2. - Flow of Material in the Commercial Secondary Aluminum Industry.

Source: National Association of Secondary Materials Industries



Scrap Flow is indicated by dashed line.
Numbers give estimated scrap flow in thousands of tons for 1969.

FIGURE 3. FLOW OF ALUMINUM SCRAP

Source: D. L. Siebert, "Impact of Technology on the Commercial Secondary Alum Industry", U.S. Bureau of Mines, Report IC-8445, 1970, p 5, and Batte Estimates.

TABLE 8. NEW AND OLD ALUMINUM SCRAP CONSUMPTION, AS REPORTED BY TYPE, 1969

Type of Scrap		Percent of Total Reported Consumption
New Scrap:		
Solids:		
Segregated low copper(1)	26.77	
Segregated high copper	3.20	
Mixed low copper(1)	12.32	
High zinc (7000 series type)	1.12	
Mixed clips	7.32	
Borings and Turnings:		
Low copper(1)	1.60	
Zinc, under 0.5 percent	2.44	
Zinc, 0.5 to 1.0 percent	5.84	
Other	7.68	
Foil, Dross, Skimmings, and Other	13.94	
Total New Scrap		82.23
Old Scrap:		
Solids	11.26	
Sweated pig(2)	6.49	
Total Old Scrap		17.75
Grand Total		100.00

(1) Copper maximum 0.4 percent.
(2) Purchased for own use.

Source: Derived from U. S. Bureau of Mines, Minerals Yearbook, 1969, Preprint on Aluminum, p 4.

Scrap Prices. Aluminum scrap prices vary depending on location and type of scrap. Prices are somewhat volatile, that is, they are subject to rapid change. Table 9 gives smelters' wholesale buying prices, and Table 10 gives scrap dealers' buying prices as of March, 1971. At that time, an official aluminum ingot price of $0.29 per pound was in effect, but price discounts of as much as $0.04 to $0.05 per pound were reported by industry sources. Recently, one company has officially reduced its price to $0.23 per pound.

TABLE 9. ALUMINUM SCRAP WHOLESALE BUYING PRICES, CARLOAD LOTS, DELIVERED TO BUYER'S WORKS, MARCH, 1971

Types of Scrap	Price, Cents Per Pound
Aluminum Clips 3003, 6061, 1100, 5052	16.75-17.25
Aluminum Clips 2014, 2017, 2024	15.50-16.00
Aluminum Clips 7075	12.25-12.75
Aluminum Clips Mixed	14.50-15.00
Old Aluminum Sheet	13.00-13.50
Aluminum Cast*	13.00-13.50
Aluminum borings, turnings, clean dry basis, less than 1% zinc and less than 1% iron	13.25-13.75

* Including clean crankcases and pistons.

Source: American Metal Market, March 10, 1971, p 23.

TABLE 10. NONFERROUS SCRAP DEALERS' BUYING PRICES FOR ALUMINUM, MARCH, 1971

Location	Type of Scrap	Alloy	Price, Cents Per Pound
New York	Aluminum Clips	1100 & 3003	8.50-9.00
	Aluminum Sheet and Cast		7.50-8.00
	Aluminum Clips	7075	6.00-7.00
	Mixed Low Copper Clips		8.50-9.50
	Aluminum Turnings & Borings, as is		4.00-4.50
	Aluminum Turnings & Borings	7075	3.25-3.75
Los Angeles	Aluminum Clips, Segregated, Low Copper		8.50
	Aluminum Clips	7075	7.50
	Aluminum Clips, Mixed		7.50
	Aluminum Sheet and Cast		6.00
	Aluminum Borings and Turnings, as is		4.00
	Aluminum Borings and Turnings, as is	7075	3.00
Chicago	Aluminum Clips, Mixed		9.00-10.00
	Aluminum Sheet and Cast		7.00-8.00
	Aluminum Borings, as is		5.50-6.00
Pittsburgh	Aluminum Clips, Mixed		10.00-10.50
	Aluminum Crankcase		6.00-7.00
	Aluminum Cast, Sheet		6.00-7.00
	Aluminum Siding Scrap		9.00-9.50
	Aluminum Borings, as is		6.00-7.00

Source: American Metal Market, March 10, 1971, pp 17-18.

Description of the Activities of the Organizations That Make Up the Aluminum Recycling Industry

Scrap Processors or Dealers. The scrap processors handling aluminum usually also process other nonferrous materials, and in some cases also handle ferrous materials. The scrap processor's functions are given in Figure 2. It has been estimated that approximately 70 percent[(1)] of the aluminum scrap sold is handled by scrap processors.

Scrap processing is a local business in the sense that transportation costs limit the distances over which low unit value materials can be shipped. Thus, scrap dealers tend to locate in industrial areas close to both scrap generators and scrap consumers. A large portion of the scrap collected comes from the immediate location of the processor; however, purchases from as far away as 200 miles are not unusual. Overland freight transportation costs severely limit purchases from sources that are over 200-300 miles from the processor

Scrap processors have periods of imbalance to contend with due to the fact that the supply of scrap is much greater than demand. This surplus is sometimes exported to foreign countries as required by their own supply and demand situation. Obviously foreign markets can be served more economically from coastal sources than from inland sources.

The flow of scrap at a processing facility consists of the following general steps: collection, identification, sorting, processing, including the use of sweat furnaces, packing, storing, and shipping.

(1) "Economic Study of Salvage Markets for Commodities Entering the Solid Waste Stream", by Midwest Research Institute, December, 1970, Chapter VI, p 5-6.

In some cases scrap will have been sorted by the seller, or perhaps all the scrap from one source will be one alloy. At times, new scrap will have retained the original alloy identification markings put on the wrought product by the primary producer. In such a case, identification by specific alloy is possible. If none of the above conditions exist, a general knowledge of the use of alloys in the manufacture of various mill products and end products is useful in sorting by general alloy type. The most prominent series of alloys in use today are 1000, 3000, 6000, and 7000. Obviously, the scrap dealer must keep abreast of current aluminum industry practice to know what alloys or series of alloys are likely to reach the market and in what forms. Alloys and types change too rapidly to be specific. For instance, aluminum beverage can bodies are now almost exclusively produced from the 3004 or 1100 alloy for deep drawing. The tops, however, are 5182.

If the above avenues of identification fail, chemical and spectrographic tests are used to classify the alloys into general categories.

After proper identification and sorting, the aluminum may be processed in a number of different ways. Some scrap processors may shred or crush sheet, castings, cans, and other aluminum solids, and remove iron contamination by magnetic separation. The resulting fragments, generally smaller than fist size, can be shipped in appropriate containers. Another processing step of great importance is the removal of insulation from aluminum cable. The insulation is removed by mechanical means. One way is a cable stripper, wherein a length of cable is run through the stripper which longitudinally slits the insulation, and the insulation is then removed by hand. A new method now utilized by many processors is an expensive and sophisticated piece of equipment called a "chopper". The chopper cuts insulated cable and wire into very small pieces. The chopped insulation is separated by air elutriation, and the product is then passed

over magnets to remove any iron or steel contamination. The chopped aluminum is then shipped to consumers as a relatively pure aluminum.

The other important function of the scrap dealer is packaging of scrap. Scrap may be baled or briquetted for ease of shipment and handling.

The secondary smelter buys scrap, both old and new, from scrap dealers. In some cases, secondary smelters will also buy scrap directly from an industrial source. In this latter case, however, usually only several large sources are utilized.

The scrap preparation functions which might be performed by the secondary smelter have been described in a U. S. Bureau of Mines report.(1) The following is taken from that report.

> "Approximately 85 percent of the total scrap purchased by secondary smelters is from mill products, and 15 percent is from castings. Each smelter segregates the scrap into four general classes:
>
> (1) Sheet and castings
> (2) Clippings and other solids
> (3) Borings and turnings
> (4) Residues (dross, slag, and skimmings) and sweated pit.
>
> Each class of scrap has its specific mix of such factors as chemical composition, metallic recovery, and physical form, which determines not only its value but also the manner in which it must be processed. Figure 5 shows the flow of each class of scrap material through a secondary aluminum smelter. It is well to point out, however, that not all smelters can process all four classes of scrap. Indeed it is quite rare if they do because the necessity of processing each class in a different manner calls for specialized equipment. Since not all secondary smelters have the specialized equipment, they are limited in what scrap they can process. Some smelters purchase all classes of scrap, including the cheap low-grade material, and refine it in a complicated processing circuit. Other smelters are limited to specific classes of higher priced material that can be refined in a short, simple processing circuit."

(1) D. L. Siebert, "Impact of Technology on the Commercial Secondary Aluminum Industry", IC 8445, p 12. U.S. Bureau of Mines Report.

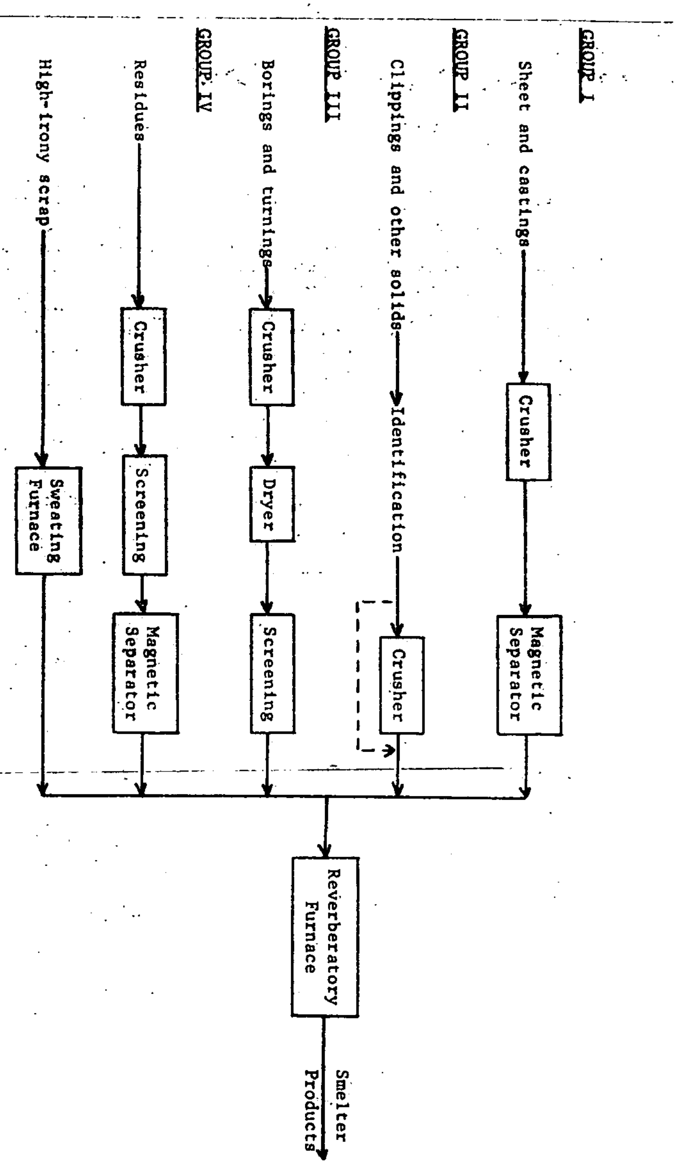


FIGURE 5. DIAGRAM OF SCRAP MATERIAL FLOW IN SECONDARY ALUMINUM SMELTER

Source: D. L. Siebert, "Impact of Technology on the Commercial Secondary Aluminum Industry", U.S. Bureau of Mines Report IC 8445, p 14.

49

The secondary aluminum producers are an important part of the aluminum recycling industry because they are essentially the only volume users of old aluminum scrap. However, with the growth in reclamation of aluminum cans, some of the primary producers are now in the old scrap reclamation business. Volumes to date, however, are minute compared to total industry use of old scrap.

Primary Producers. Recycling by the primary producers is generally limited to new scrap utilization. Major sources of scrap are the producers own plants, their customers, and scrap dealers.

Primary producers generally purchase "pedigreed" scrap. That is, new scrap which is well identified as to alloy type, clean, bare, and prepared in a readily usable form. Borings, turnings, and other finely divided or contaminated forms of scrap are usually not purchased. The need for only "pedigreed" scrap is justified because of the low impurity levels and narrow alloy specifications in force for wrought alloys. A mislabled or contaminated scrap charge could be extremely expensive if a "heat" is ruined.

Much of the new scrap obtained by the primary producers is obtained on conversion agreements. There are two kinds of conversion agreements: (1) direct toll, and (2) sale and purchase agreements. In a toll agreement the primary producer agrees to take a given amount of scrap from a customer and return an equivalent amount of mill products, charging the customer the difference between the value of the mill product and the scrap. Because this procedure is difficult to administer, it is seldom used.

Today, most scrap purchased on a conversion agreement is on a sales and purchase basis. Under this arrangement, the primary producers buy scrap outright from their customers at a predetermined price. Generally, the primary producer will buy back all the scrap generated from the products sold to a customer. This scrap is used within the primary producer's company or may be sold. If the scrap is in an undesirable form (such as borings and turnings) the primary producer may sell the scrap to a dealer or a secondary smelter.

Although the primary producers generally purchase "pedigreed" scrap, because of their extensive operations, they are not equipped to handle less desirable forms of scrap that arise within their company or are returned in conversion deals. Therefore, foil, dross, some forms of painted or coated scrap, etc., are usually sold to the secondary industry.

When primary ingot is short in relation to demand, the primary producers tend to substitute scrap for primary metal. Because the primary producers purchase the better grades of scrap, while secondary smelters are not as particular, they do not usually compete directly. However, in periods when scrap is short, competition occurs.

Nonintegrated Producers. The nonintegrated producers are aluminum fabricators that do not have primary aluminum reduction capabilities. A large number of the nonintegrated producers specialize in extrusions. They must purchase all of their aluminum requirements from outside sources. Clean alloy scrap of the variety needed is therefore in great demand as long as it is a low cost substitute for primary ingot.

The scrap needs of the nonintegrated producer are similar to those of the primary producer, in that they purchase mainly "pedigreed" scrap. Because most of the nonintegrated producers are extruders, their scrap purchases are mainly of the 6061 and 6063 alloys, which are extrusion alloys.

Aluminum Scrap and Secondary Aluminum Markets

There are really two markets to consider when discussing recycling of aluminum. The scrap market and the market for secondary aluminum products.

Scrap Markets

About 90 percent of the aluminum scrap generated goes to aluminum producers (primary, secondary, and nonintegrated). However, there are several other aluminum scrap markets worthy of mention. Such include steel deoxidation, reducing agent in the manufacture of ferroalloys, steel alloying, zinc-base alloys, copper-base alloys, and aluminum chloride. These "destructive" uses consumed 15,457 tons of scrap (gross weight) and 9,823 tons of dross (recoverable weight) in 1965.(1)

The consumption of purchased scrap in 1969, as reported by the U. S. Bureau of Mines breaks down as follows:

	Percent
Independent Secondary Smelters	67.0
Primary Producers	18.5
Nonintegrated Fabricators	7.0
Foundries	7.5
	100.0

Slightly over 1 million ton of purchased scrap was estimated to have been consumed. Scrap consumption for destructive uses, although not recorded by the U. S. Bureau of Mines, probably amounted to less than 3 percent of total aluminum scrap consumption in 1969. About 175,000 tons, or 17.5 percent of the purchased aluminum scrap consumed was old scrap, with the secondary smelter being essentially the only consumer.

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(1) U.S. Department of Commerce/Business and Defense Services Administration, Aluminum and Magnesium Division, "Aluminum Ingot and Scrap in Non-Aluminum Uses 1965", p. 2, June, 1967.

The marketing department of a leading aluminum producer has forecast purchased aluminum scrap consumption for 1971 through 1980, based presumably on current technology and practice. Selected data from the forecast are given in Table 11.

TABLE 11. ESTIMATED DEMAND FOR ALUMINUM SCRAP, 1971-1980

Year	Estimated Demand for Aluminum Scrap Thousands of Tons Total	From New Scrap	From Old Scrap
1971	1,050	875	175
1974	1,375	1,100	275
1979	1,910	1,550	360

Source: S. T. Abbate, Presentation to NASMI Seminar, University of Wisconsin, Madison, Wisconsin, August 13, 1970.

Secondary Aluminum Markets

As explained earlier, certain so-called primary aluminum products are made from scrap, but usually only "pedigreed" scrap is used to make these alloys. Essentially the only volume consumers of old scrap, and contaminated or nonsegregated new scrap, are the secondary smelters.

No data are available on secondary aluminum markets by segments. The best available information is a breakdown by products produced, as given in Table 12. Based on the product breakdown for 1969, it appears that approximately 85 percent of the reported production is casting alloys. Another 7.5 percent is relatively pure aluminum (usually sold to nonintegrated fabricators) and 4.9 percent is deox. Die casting alloys are the major single product of the secondary smelter, and they account for about 60 percent of reported production.

TABLE 12. PRODUCTION OF SECONDARY ALUMINUM ALLOYS, BY INDEPENDENT SMELTERS, 1969

Alloy	Production Short Tons
Pure aluminum (Al minimum, 97.0 percent)	47,641
Aluminum-silicon:	
95/5 Al-Si, 356, etc. (maximum Cu, 0.6 percent)	17,285
13 percent Si, 360, etc. (maximum Cu, 0.6 percent)	46,082
Aluminum-silicon (Cu, 0.6 to 2 percent)	7,770
No. 12 and variations	6,208
Aluminum-copper (maximum Si, 1.5 percent)	779
No. 319 and variations	50,883
Nos. 112, 138	363
No. 380 and variations	356,444
Aluminum-silicon-copper-nickel	25,223
Deoxidizing and other descructive uses:	
Grades 1 and 2	19,579
Grades 3 and 4	12,093
Aluminum-base hardeners	6,679
Aluminum-magnesium	905
Aluminum-zinc	6,440
Miscellaneous	29,623
Total Reported	633,997
Estimate Based on Full Coverage	741,000

Source: U. S. Bureau of Mines, Minerals Yearbook, 1969, Preprint on Aluminum.

Major markets for die cast aluminum products are: automotive (over 50 percent), home appliances, and industrial and commercial machinery and tools.

The secondary smelters compete with primary aluminum producers for markets in only one major product, casting alloys. In 1969, 849,000 tons of aluminum castings were shipped.[1] Thus, based on U. S. Bureau of Mines figures cited earlier, roughly 75 percent of the casting alloy in these shipments was made by secondary smelters. The remainder was supplied by the primary producers. Most of the casting alloys supplied by the primary industry are in the form of molten metal, and most of this is supplied to automobile makers. Some of the casting alloys supplied by the primary industry are made to chemistry specifications, which cannot usually be met by the secondary smelter.

The deox market is estimated to be approximately 50,000 tons annually. It appears that the secondary producers have 60 percent of this market, while primary producers and scrap dealers have the remaining 40 percent. Although the primaries and secondaries compete in this market, it is relatively unimportant.

In all of the other aluminum markets, there is essentially no competition between the secondary smelter and the primary producer.

Secondary Aluminum Prices. Secondary aluminum alloys usually sell for a slightly lower price than primary aluminum ingot, because the alloys are produced easily from scrap. For instance, in March, 1971, the popular 380 secondary alloy (with 1 percent maximum zinc) was quoted at 28 cents per pound, versus 29 cents per pound for primary aluminum ingot.[2] This price differential will fluctuate depending on many factors, the most important of which appears to be the price of scrap. In times of high scrap prices, the 380 secondary alloy might be quoted at prices higher than primary ingot.

(1) The Aluminum Association, Aluminum Statistical Review, 1969, p 28.
(2) American Metal Market, March 10, 1971, p 23.

If primary alloy prices dropped sufficiently, primary alloys could conceivably capture all of the secondary alloy market (about 740,000 tons in terms of 1969 results). On the other hand, if secondary alloy prices dropped sufficiently the additional market captured would amount to about 210,000 tons in terms of 1969 results.

Industry Data

A survey of the recycling industry developed data to afford profiles of the industry and the companies making up the industry. Volume I, General Report, in this series gives many of these data. A few data concerning aluminum are given here.

The average recycler of aluminum compares with the average recycler of all commodities as follows:[1]

	Investment in Plant and Equipment	Number of Employees	Investment Per Employee
Aluminum	$1,739,000	66	$26,200
All Commodities	$1,480,000	71	$20,800

Figure 6 shows the variation in annual volume of aluminum handled, by census region, for (1) aluminum scrap processors, and (2) aluminum scrap consumers. This figure shows that in 1969 the average amount of aluminum processed by scrap dealers which handle aluminum was 1,230 tons; while the average amount consumed by the various consumers was 6,300 tons. The average volume of aluminum scrap handled by scrap processors does not vary widely from region to region. On the other hand, there are some significant region differences in the average volume of aluminum scrap consumed. Three regions have particularly low average consumption per consumer; they are the Pacific, New England, and West South Central regions. It is believed that the unusually low annual consumption of aluminum scrap in these areas is the result of data obtained from sweaters, that consider themselves to be consumers.

(1) Data from extensive survey.

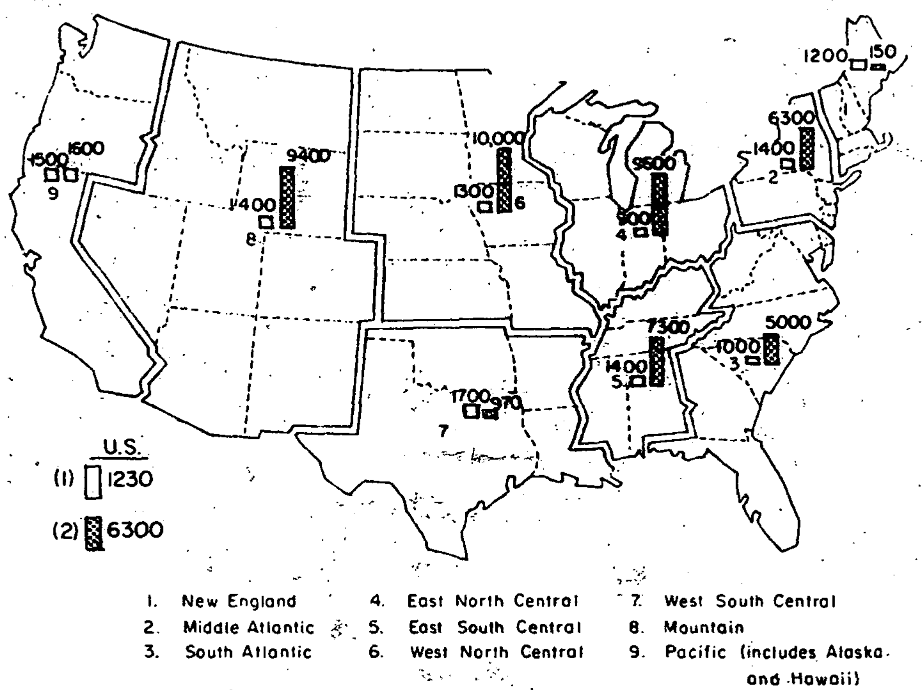

FIGURE 6. AVERAGE VOLUME IN TONS PER YEAR OF (1) ALUMINUM SCRAP PROCESSORS, AND (2) ALUMINUM SCRAP CONSUMERS, BY REGION, 1969
Source: Extensive survey

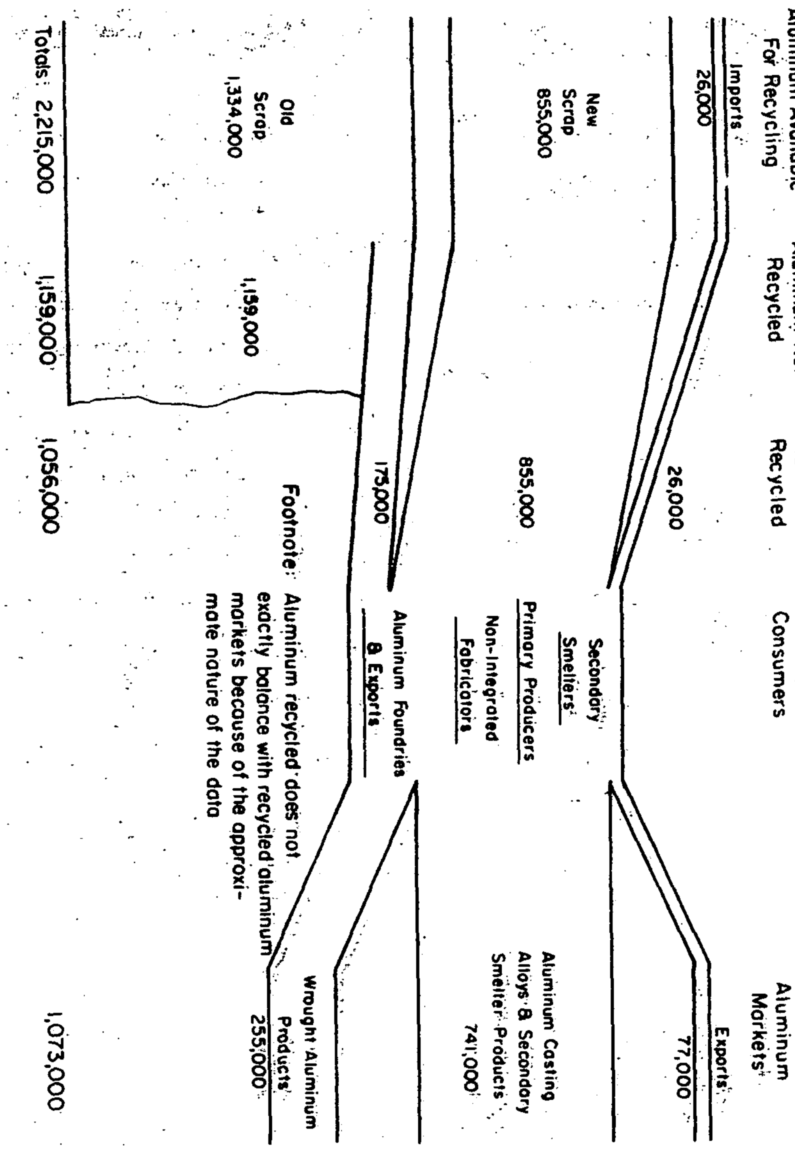

FIGURE 7 FLOW DIAGRAM OF RECYCLING ALUMINUM - 1969, SHORT TONS
Source: U.S. Bureau of Mines, Minerals Yearbook, 1969, Preprint on Aluminum, and Battelle estimates.

Materials Flow Pattern for Aluminum Recycling

A diagramatic table, representing the quantitative flow of aluminum scrap to its various consumers, and to ultimate markets is given in Figure 7. In the flow pattern shown, the widths of the various channels are proportional to the quantities involved. The first column of Figure 7 shows the estimated amount of aluminum available for recycling, by source, was 2,215,000 tons in 1969. The import source is simply aluminum scrap imports.(1)

The new scrap available for recycling was estimated to be essentially the quantity that was reported as consumed. This presumes a 100 percent recycling rate on new scrap. This is not precisely true, because some new aluminum scrap is lost in the form of low aluminum drosses, and recovery rates are less than unity. According to industry sources, well over 90 percent of the new aluminum scrap is recycled. The 855,000 tons of new aluminum scrap shown as available for recycling in 1969 represents only that scrap which was available for sale. A much greater tonnage is likely to have been recycled within the primary aluminum companies, and was never available for sale.

The amount of old scrap available for recycling had to be calculated using various assumptions. Table 13 presents Battelle-Columbus' estimate of the old scrap available, by source, and the percent of recycling of the scrap from each source. The 1969 "crop" of old aluminum scrap was based on expected life cycles of various aluminum containing products. Details of the estimates are given in Appendix B, Table B-1.

Of the estimated 1.3 million tons of aluminum becoming obsolete, only 175,000 tons of aluminum were reclaimed in 1969, or in other words, only 13 percent of the aluminum becoming obsolete was recycled. However, it is likely that the

(1) Some scrap imports might be primary ingot, broken into pieces and assigned to the scrap category.

TABLE 13. OLD ALUMINUM SCRAP RECYCLING, 1969

Scrap Source	Estimated Aluminum Becoming Obsolete, Tons	Estimated Old Aluminum Recycled, Tons	Estimated Percent Recycled	Estimated Aluminum Not Recycled, Tons
Building and Construction	71,000	9,000	13.0	62,000
Transportation	329,000	100,000	30.0	229,000
Consumer Durables	197,000	25,000	13.0	172,000
Electrical	7,000	6,500	93.0	500
Machinery and Equipment	61,000	15,000	25.0	46,000
Containers and Packaging	486,000	2,000	0.4	484,000
Other	183,000	17,500	9.2	5,500
Totals	1,334,000	175,000*	13.1	1,159,000

* Imports are ignored because it is believed that the old scrap component of imports is not significant.

Source: U. S. Bureau of Mines, Minerals Yearbook, 1969, Preprint for Aluminum, and Appendix B, Table B-1.

amount of old aluminum scrap readily available to the recycling industry is actually much smaller because:

(1) Some items, especially aircraft, are exported and are then not scrapped in the United States

(2) Some items such as aluminum cans and other packaging items are widely disseminated and usually are not collected

(3) Some obsolete items such as certain military aircraft are being stored (for use during emergencies) rather than being scrapped

(4) The data are not corrected for recovery yields.

Demand/Supply Analysis

A brief analysis of the expected future demand for old aluminum scrap and the expected availability of old aluminum scrap is presented in Table 14. New aluminum scrap supply and demand are not considered because, under current and likely future conditions, there is sufficient demand for all that is available.

TABLE 14. DEMAND/SUPPLY ANALYSIS FOR OLD ALUMINUM SCRAP, 1969, 1974, and 1979*

Year	Estimated Demand for Old Aluminum Scrap, Tons	Estimated Supply of Old Aluminum Scrap, Tons	Estimated Aluminum Scrap Becoming Obsolete, Tons
1969	175,000	175,000	1,334,000
1974	275,000	324,000	1,970,000
1979	360,000	451,000	2,989,000

* The 1974 and 1979 demand for old scrap is based on estimates of aluminum recovered from old scrap as given in Table 11. The estimated supply or crop of old scrap was estimated in the same fashion as the 1969 figures (see Table B-1, Appendix B). No change in technology was presumed, i.e., the percentage of recycling in each category was presumed to exhibit no change from that given in Table B-1. Further, to estimate the old scrap "crop" for 1974 and 1979, shipments of aluminum for the Containers and Packaging category had to be estimated. For this purpose, the figures 574,000 and 1,148,000 tons, respectively, were used for 1974 and 1979.

The data in Table 14 indicate a potential surplus of old aluminum scrap amounting to 49,000 tons in 1974 and 91,000 tons in 1979, an indication that future development of new markets for old aluminum scrap is needed. If the technology of the recovery of aluminum from obsolete articles improves, then an even greater excess of supply over demand can be expected.

How can such an excess of supply over demand be handled? To answer this question is difficult. First, it should be noted that the data in Table 14 were derived assuming that there was a balance in supply and demand in 1969. This may not be true, in fact industry sources claim a shortage in the supply of old scrap. Quantification of the degree of under supply of old scrap in 1969 is not possible when one considers the various types of scrap and alloys involved. Therefore, at best, one can only make general statements. It appears likely that the secondary smelters may be able to utilize the supply of old scrap forecast in Table 14. However, it is also likely that future additions to the old scrap supply by way of improved collection and recovery methods could not be absorbed by the secondary smelters producing current product lines. Therefore, new markets for old scrap and new products made from old scrap may be needed. This can be accomplished by product and market research and development; and by expanding the use of old scrap by the primary aluminum industry.

ALUMINUM SCRAP RECYCLING PROBLEMS

There are several major problem areas that directly reduce the amount of aluminum that is recycled. In this section a quantitative approach has been taken in an effort to evaluate the effect of the problems on recycling aluminum.

New Scrap

New, or prompt industrial scrap is recognized as valuable and consequently nearly all is recycled. Aluminum melting dross is treated and reclaimed. Drosses containing as little as 10 to 15 percent aluminum are treated to reclaim the aluminum. There are no data to indicate the degree to which new scrap and dross are recycled. Industry officials claim that well over 90 percent of the new scrap generated is recycled.

Old Scrap

Table 15 presents the seven categories of old aluminum scrap generators along with estimates of the quantities of old scrap that are not being recycled. The definition and analysis of problems associated with recycling of aluminum for each end use category are given. In terms of estimated quantities of aluminum not recycled, the Containers and Packaging, Transportation, and Consumer Durables categories are the most important, and are discussed more fully in the section entitled "Courses of Action Concerning Recycling of Aluminum".

ALUMINUM RECYCLING INDUSTRY PROBLEMS

As a result of field interviews several problem areas emerged as significant factors in the aluminum recycling industry. These are:

- Air pollution control
- Composite aluminum scrap
- Need for new methods of upgrading aluminum scrap
- Solid wastes

These problems are defined and analyzed in Table 16.

Air Pollution Control

The most often mentioned problem confronting the aluminum recycling industry is the improved control of air pollution. This is especially true in the case of the secondary smelters.[1] Proper control of emissions is very expensive and difficult to achieve with present equipment. An analysis of pollution control problem is given in Table 16. The increased recycling costs resulting from strict air pollution control might lead to a slight decrease in recycling painted, coated, or composite aluminum scrap which produce smoke when melted directly.

Composite Aluminum Scrap

All segments of the aluminum recycling industry are faced with the continual problem of learning to process aluminum scrap contained in a never ending parade of new (aluminum containing) products. Of particular difficulty is the processing of composite scrap. Examples are such items as paper and vinyl coated aluminum; painted, lacquered or enameled aluminum; and metal-metal composites

(1) For a review of the emission problems of the secondary smelter see "Impact of Technology on the Commercial Secondary Aluminum Industry", U.S. Bureau of Mines publication, 1C8445.

TABLE 15. IDENTIFICATION AND ANALYSIS OF PROBLEMS CONCERNING OLD ALUMINUM THAT WAS NOT RECYCLED IN 1969

	Building and Construction Sources	Transportation Sources	Consumer Durable Sources
Problem Definition	1. Aluminum items are used for a myriad of items in the building and construction category. 2. Small items that become obsolete are usually discarded. 3. Demolition of old structures yields negligible amounts of aluminum per structure.	1. Not all aluminum on a salvaged auto is utilized. 2. Aircraft scrap is an obvious source and is recovered if economical. 3. Other sources include trucks, trailers, buses, boats, etc.	1. Scrap is widely disseminated. 2. Most items have small amounts of aluminum.
Estimate of Old Aluminum Scrap Not Recycled, tons	62,000	229,000	172,000
Estimate of Percent of Available Old Aluminum Not Recycled	87	70	87
Problem Analysis	1. Better collection needed. 2. Much of the scrap is heavily painted, vinyl coated, etc. Therefore, the additional steps needed for coating removal makes scrap recycling less economical. 3. Yield of aluminum scrap per building is low. Future yields will increase. 4. This area has limited possibilities for increased recycling of aluminum.	1. Better utilization of aluminum in the nonferrous fraction of auto shredder scrap is needed. 2. Improved collection of abandoned autos is needed. 3. Some old scrap is not recoverable because an item, for instance an airplane, may be exported or become obsolete overseas. 4. Even though large quantities of aluminum are now being recycled, transportation items represent a very promising area in which to increase recycling of aluminum.	1. Items except cooking utensils and lawn furniture are not recycled to a high degree. 2. Part of problem is learning to economically recycle small amounts of aluminum that are in old refrigerators, washing machines, air conditioners 3. This is a promising area in which to increase the recycling of aluminum.

TABLE 15. IDENTIFICATION AND ANALYSIS OF PROBLEMS CONCERNING OLD ALUMINUM THAT WAS NOT RECYCLED IN 1969 (Continued)

	Electrical Sources	Machinery and Equipment Sources
Problem Definition	1. Electrical transmission lines are not a significant recycling problem. 2. Electrical machinery, lighting fixtures and large conduit, etc., represent a small portion of electrical sources, but are widely disseminated and not recycled.	1. Scrap is widely disseminated in a myriad of machines and equipment such as special industrial equipment, agricultural machinery, materials handling equipment, irrigation pipe, process industries.
Estimate of Old Aluminum Scrap Not Recycled, tons	500	46,000
Estimate of Percent of Available Old Aluminum Not Recycled	7	75
Problem Analysis	1. Electrical transmission lines are normally recycled. 2. Other electrical items are recycled on a very limited basis. 3. Based on the above estimate, this area has very limited possibilities for increased recycling of aluminum.	1. Better collection needed. 2. Based on the above estimate, this area has limited possibilities for increased recycling of aluminum

TABLE 15. IDENTIFICATION AND ANALYSIS OF PROBLEMS CONCERNING OLD ALUMINUM THAT WAS NOT RECYCLED IN 1969 (Continued)

	Packaging Sources	Other Sources
Problem Definition	1. Scrap is extremely widely disseminated. 2. Foil, caps, closures, and containers are found in household and industrial refuse. 3. In addition, aluminum containers occur as litter.	1. The "other" category consists mainly of defense items. 2. Some items become obsolete outside of the U.S. and may not be recycled in the U.S.
Estimate of Old Aluminum Scrap Not Recycled, tons	484,000	165,500
Estimate of Percent of Available Old Aluminum Not Recycled	99.6	89.8
Problem Analysis	1. Collection is a major part of the problem. Current collection programs return a very small fraction of the aluminum available. 2. Segregation of refuse within the household may aid in utilization. 3. Recovery from municipal refuse may provide a solution. 4. Legislation aimed at segregation and collection problems may aid. 5. This area holds the most promise for the increased recycling of aluminum.	1. Much defense scrap is sold on a bid basis. However, much is not being recycled due to lack of minimum bids. 2. A small tonnage is destructively consumed and therefore, not available for recycling. 3. This area has limited possibilities for increased recycling of aluminum.

TABLE 16. IDENTIFICATION AND ANALYSIS OF OTHER ALUMINUM RECYCLING PROBLEMS

Title	Air Pollution Control	Composite Aluminum Scrap	Need for New Methods of Upgrading Aluminum Scrap	Recycling Wastes
Problem Definitions	1. Costs of equipment very high compared to total capital investment of most scrap dealers and secondary smelters. 2. Reliability of present equipment rates as poor. 3. Lack of uniform standards and enforcement penalize those that control emissions. 4. Continual changing of standards penalize those that have purchased control equipment.	1. Composites of aluminum are difficult to recycle. 2. Composites which combine aluminum with paper, vinyl, paint, and other coatings create air pollution problems on recycling. 3. Composites such as copper coated aluminum wire or aluminum coated steel wire or steel cans with aluminum ends may only be recycled under special conditions.	1. If old scrap could be refined economically, it could be utilized in making wrought alloys. 2. Improved sorting of old aluminum scrap from other aluminum scrap or other nonferrous scrap is needed.	1. Operation of the secondary smelter produces waste such as spent fluxes and drosses. 2. Magnesium chloride wastes are generated. 3. Processing of aluminum cable gives rise to small amounts of cable insulation wastes.
Effect on Recycle Rate	Strict control of air emissions will <u>tend</u> to increase recycling costs and lower recycling rates.	The use of various aluminum composites tends to lower the recovery rate or make recycling uneconomical.	Improved upgrading techniques should increase recycling.	Essentially no effect.
Problem Analysis	1. Air pollution laws and enforcement are not uniform throughout the country. 2. Financing of pollution control equipment is difficult for the small smelter. 3. There appears to be a lack of reliable equipment capable of attaining some air pollution standards.	1. Manufacturers and designers produce products without special regard to recycling problems. 2. Specific composites may be recycled if a method and/or market is found.	1. Development of improved, economic refining techniques is a difficult technical problem. 2. Scrap sorting problems may be attacked by many methods. Solutions are likely to be highly specific.	1. Industry has learned to process drosses and spent fluxes for aluminum content. Low aluminum content material is a disposal problem. 3. Cable insulation wastes are a disposal problem.

of aluminum with copper or steel or another aluminum alloy. These composites either present recycling problems, or cannot be recycled economically.

The recycling problems created by composites have to be attacked on an individual basis. Prevention of some of the recycling problems associated with aluminum composites could be solved or eased if manufacturers gave some thought to recycling in the design stage. For example, the steel beverage can with an "easy open" aluminum top is not readily recycled either for the aluminum ends or the steel body. Perhaps the can industry could have made a more "recycleable" can, such as an all steel or all aluminum can, with the "easy open" feature.

Need for New Methods of Upgrading Aluminum Scrap

The need for new methods of upgrading aluminum scrap can be attacked by dividing the problem into three parts. In one, consideration is given to conversion of a group of mixed aluminum scrap to pure aluminum or a usable alloy. In the second, consideration is given to separation or sorting of a mixed group of aluminum alloys. The third has to do with separation of aluminum alloys from other nonferrous alloys.

Conversion of Mixed Aluminum Scrap to Pure Metal or a Practical Alloy

As mentioned earlier, magnesium is the only element that the secondary smelters find practical to remove from aluminum. Electrolytic molten salt methods of refining aluminum alloys are available but are too costly. Long range technical research in the area of refining aluminum alloys is indicated, but likelihood of complete technical and economic success is not considered good.

Sorting of Mixed Aluminum Alloy

The value of a mixed group of aluminum alloys can be improved if the alloys are sorted by type. To date, various chemical spot tests or emission spectrograph tests have been used. Faster and more economical methods are needed.

Sorting of Aluminum from Nonferrous Scrap

Much of the sorting of aluminum from nonferrous scrap can be done by sight and feel. This "hand picking" can be accomplished economically if large pieces are involved. With the advent of the auto shredder, the need for separation of metals from the nonferrous fraction of the shredder output arose. The separation of aluminum from this nonferrous fraction is being accomplished and is under investigation. Prominent methods of separation include heavy media separation and air elutriation methods.

Recycling Wastes

Solid wastes resulting from recycling aluminum include wastes generated by the secondary smelter such as dross, slag and magnesium chloride, and wastes generated by the scrap processor such as cable insulation. The problem of solid-wastes generated by the aluminum recycling industry is basically an environmental problem, rather than an industry problem. Recycling of these wastes would not be expected to improve the recycling rate for aluminum.

Secondary Smelter Residues

The secondary smelter generates dross, slag (spent flux), and magnesium chloride in the course of melting and removing magnesium from aluminum.

The drosses containing mainly Al_2O_3, aluminum, and some salts and dirt are treated to recover the aluminum. Drosses containing as little as 10 to 15 percent aluminum can be treated for aluminum recovery. Leaner drosses are a disposal problem. A portion of the drosses "produced" are sold or consumed in making exothermic or "hot top" materials for the steel industry.

Fluxes are used to protect the molten aluminum from oxidation and gas absorption. The spent flux or slag is a solid waste which is reprocessed for aluminum content. These fluxes may contain 10 to 20 percent aluminum and can be upgraded by wet milling to 65 percent aluminum. The waste salts (containing a mixture of NaCl, KCl, and a fluoride bearing salt such as cryolite) are brought into solution in the wet milling operation, and at this point are liquid wastes, which must be treated in some fashion.

In the chlorine treatment of molten aluminum for magnesium removal, the compound $MgCl_2$ is formed. This compound may be slightly contaminated with $AlCl_3$ and other impurities. Today, little use is made of this compound, and it represents a disposal problem to most secondary smelters.

Scrap Processing Residues

The major solid waste generated in the processing of aluminum scrap is cable insulation. Insulation could be paper, any of a number of various plastics, rubber, or even glass. The insulation may be in small pieces (as from a chopper) or in long lengths (as from a cable stripper). The amount of insulation waste generated from aluminum wire insulation is very small compared to the insulation waste from copper wire. To date, no significant use for these wastes has been found.

COURSES OF ACTION CONCERNING RECYCLING OF ALUMINUM

Having identified the major problems concerning the recycling of aluminum, it is necessary to evaluate them and select those that are amenable to solutions. Then, courses of action can be developed to lead to solutions for the problems.

Evaluation of Problems

The problem areas that have been identified as significant cover a wide range of importance and possibilities for solutions. It is necessary to evaluate the differences in order to assign priorities for action.

Four of the problem areas can be assigned low priorities immediately.

Four problem areas dealing with old scrap generation: (1) Electrical, (2) Machinery and Equipment, (3) Building and Construction, and (4) Other Categories were assigned low priorities because the amount of old aluminum scrap not recycled is estimated to be comparatively small. Thus, the above four problem areas will not be given further attention.

To evaluate the remaining problems relating to the recycling of aluminum, three criteria for judging the severity of the problems were developed. These same criteria were also used in the other commodity reports in this series. The three judgment criteria were based on the following questions:

(1) Will solution of the problem improve the environment? (Possible Score 0-10)

(2) Will solution of the problem conserve natural resources? (Possible Score 0-5)

(3) Can realistic solutions be found? (Possible Score 0-5)

Table 17 presents the problems enumerated in the previous section and shows the scores assigned to each problem by Battelle-Columbus. By this method it is shown that the three major problem areas are:

(1) Reclamation of old aluminum scrap from Container and Packaging sources

(2) Air Pollution Control

(3) Reclamation of old aluminum scrap from Transportation sources.

Recommended Actions

The recommendations of what to do about the seven major problems of the aluminum recycling industry are covered in two parts:

(1) High Priority Actions

(2) Lower Priority Actions.

The high priority actions should be dealt with before attention is given to the lower priority actions.

High Priority Actions

The high priority actions recommended here are important and far-reaching enough to be in the public interest. Thus, participation by EPA is desirable. Participation by NASMI and its members is also desirable, since the problems and suggested actions to be taken are predominately within the range of activities of the present aluminum recycling industry.

Table 18 presents the recommended action programs for the high priority aluminum recycling problems. These programs are discussed below.

TABLE 17. EVALUATION OF SEVEN PROBLEMS RELATED TO RECYCLING ALUMINUM

Problems	Criteria and Scores			Total Scores
	Solution of Problem Will Improve Environment (10)	Solution of Problem Will Conserve Natural Reources (5)	Realistic Solutions Can Be Found (5)	
Reclamation of old aluminum from:				
Transportation Sources	7	4	3	14
Consumer Durables Sources	5	3	3	11
Containers and Packaging Sources	8	5	4	17
Air Pollution Control	10	0	5	15
Composite Aluminum Scrap	4	2	3	9
Need New Methods of Upgrading Old Scrap	6	4	2	12
Recycling Wastes	8	1	2	11

TABLE 18. RECOMMENDED ACTIONS, HIGH PRIORITY ALUMINUM RECYCLING PROBLEMS

Title	Reclamation of Old Aluminum Scrap From Container and Packaging Sources	Air Pollution Control	Reclamation of Old Aluminum Scrap From Transportation Sources
Actions Recommended	1. Continue current can reclamation programs. 2. Utilize current collection systems to obtain scrap, i.e., local refuse collectors. 3. Promote segregation of aluminum from refuse at the source by law or other incentives, and/or 4. Develop an economic system for recycling aluminum from municipal refuse.	1. Push passage of realistic Federal air pollution laws with strong provision for equal enforcement. 2. Provide financial aid, in the form of low cost loans or rapid tax write-offs to companies for purchasing needed equipment. 3. Initiate research and development on more dependable and maintenance-free air pollution control equipment.	1. Learn to better utilize aluminum from auto shredder scrap. 2. Continue research being performed by industry and the USBM, EPA, and NASMI.
By Whom(1)(2)(3)	EPA, NASMI, USBM, CEQ, Aluminum Producers and Aluminum Can Producers	EPA, NASMI, ASRI, CEQ and Equipment Manufacturers	EPA/NASMI and U. S. Bureau of Mines
Specific Steps	1. Intensify current USBM and other studies on utilization of urban refuse. 2. Promote and/or sponsor pilot studies on segregation of aluminum scrap from other refuse at the source. 3. Aluminum and aluminum can producers should continue can reclamation programs. Especially as an effective way of removing litter.	1. The recommended air pollution laws and financial aid can be promoted through contact with legislators. 2. Concerned organizations should present specific air pollution control equipment needs before manufacturers and pressure for development of needed equipment.	1. Continuation and intensification of research and development by industry and USBM. 2. An EPA/NASMI/USBM team could monitor progress and point out areas where further research is needed.

(1) The responsibility for recommended actions shown in this table are based on importance of the action, benefit to the taxpayers, and opportunities for NASMI. They are the best judgments of Battelle.
(2) Recommended actions were distributed between high priority and lower priority based on the evaluation with three criteria.
(3) It is suggested that NASMI continue its leading role in recycling, recognizing that other organizations such as the Bureau of Mines, Department of Commerce, Council of Environmental Quality, HEW Office of Information, and State, Local, and Federal Legislatures must be involved.

Reclamation of Old Aluminum Scrap from Container and Packaging Sources. The problem of reclaiming aluminum from cans, foil, and other containers and packages is mainly one of collection. The wide public dissemination of these items makes collection uneconomical.

Current Can Reclamation Programs. The aluminum can reclamation programs sponsored by the major primary aluminum producers, and others are becoming more and more successful. However, the 10 cents per pound payment plus handling, processing, and transportation costs appear to exceed the actual value of the cans. Thus, it is the opinion of many that the can reclamation programs are, in fact, subsidized.

Collection of aluminum cans is made by interested individuals, or civic, charitable, environmental or other groups. The cans are taken to a collection center which may be operated by a primary aluminum company, a brewer or his distributor or other interests. Subsequently, the cans are processed by shredding and magnetic separation operations.

The processed can scrap is then shipped to primary aluminum plants for recycling into can stock alloy. Because the lid of the aluminum can is made from a different alloy than the body, there are limits on the amount of can scrap which can be used in preparing a can alloy melt. Currently, only two plants are equipped for charging aluminum can scrap into can stock melts. These plants are located in Warrick, Indiana, and Lister Hill, Alabama. Thus, can scrap generated on the West Coast must be shipped long distances to be recycled.

Can reclamation has operated outside the traditional scrap gathering channels, with one exception. One major aluminum company is utilizing scrap processors to process and ship can scrap to their can stock plant. It is believed that the dealer receives 5 cents per pound for this function, giving a total direct cost of 15 cents per pound. Other companies from time to time may utilize scrap processors for the shredding and magnetic separation operation.

One might expect that the normal channels for aluminum can reclamation would include the scrap dealer-processor and the secondary aluminum producer. This system did not and does not operate because of the high cost of collection and the undesirable alloying elements in the cans. Aluminum cans (lid and body) contain about 2.25 percent magnesium and 1 percent manganese on the average. Both elements are usually undesirable in secondary alloys. The magnesium may be removed, at some cost, while the manganese content can be lowered only by dilution.

In 1970, aluminum cans returned for recycling amounted to 2,875 tons out of approximately 226,000 tons of aluminum shipments for making all aluminum cans.[(1)(2)] This amounts to less than a 2 percent recycle. Even though a higher rate of can recycling is expected in 1971, it is unlikely that a significant fraction of shipments will be recycled. The continuation of both the subsidy and group interest in collection is open to some doubt. The can collection programs do little in the way of reclaiming all the other aluminum used in containers and packaging.

Other Collection Methods. In light of the above, it is obvious that other means of collection old aluminum cans, foil, etc., are also needed.

Perhaps the best way to collect this old scrap is to utilize a collection system that is in use, the local garbage or refuse system. To utilize these existing collection systems, two types of action are obvious.

First, household and industrial wastes might be segregated so that all aluminum cans, foil, etc., are kept separate all through the collection phase. The aluminum once collected might then be recycled. To promote segregation by the householder and other municipal waste contributors, either a law or other incentive is needed.

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(1) Aluminum Association Press Release (no date)
(2) American Metal Market, March 19, 1971, p 10.

A second and perhaps better long range action would be to develop methods of reclaiming aluminum from municipal wastes. Other novel methods of collection might also be the subject of pilot programs. EPA, CEQ, NASMI, and the U. S. Bureau of Mines would be logical participants in the above programs.

Air Pollution Control. The coming of more stringent air pollution control regulations is viewed with apprehension by most secondary smelters. The typical smelter may be faced with a large capital outlay[(1)] for equipment which may not be capable of satisfying air pollution regulations that are subject to change. In addition, a secondary smelter that is eminently equipped to control emissions is at a disadvantage in competing with one that isn't or only has to meet less stringent regulations in some other location.

Most of the secondary smelters in Los Angeles County have survived the strict air pollution laws in force there. They have managed to make the large capital investment required and have learned to live with equipment that is difficult to maintain.

Actions recommended include quick passage of realistic Federal air pollution laws with strong provision for equal enforcement and financial aid in the form of low cost loans or rapid tax write offs for purchasing needed equipment. Both recommendations can be pursued by EPA, CEQ, and NASMI through contact with legislators.

Research and development aimed at improving the reliability of air pollution control equipment used or needed by the secondary aluminum smelter should be performed. NASMI and/or ASRI and the equipment manufacturers should meet and determine specific needs. Research should be funded by the equipment manufacturers and the potential users.

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(1) Large compared to total plant investment.

<u>Reclamation of Old Aluminum Scrap from Transportation Sources</u>. More efficient utilization of the aluminum in the nonferrous fraction of auto shredder scrap is needed. The auto shredder has provided a source of aluminum scrap not previously available. In order to make the auto shredding operation more viable, methods of reclaiming aluminum and other nonferrous metals have been and are being investigated. Methods such as hand picking, heavy media separation, and air elutriation are used or being tried in the recovery of aluminum. Recovery ratios can be improved. Further research by industry and government is recommended. Since the future reclamation of not only aluminum, but other metals is tied to utilization of auto shredder scrap, and since shredders play an important role in the removal of old auto hulks and even old appliances, an EPA/NASMI/USBM team should monitor industry/government progress in the area.

Lower Priority Actions

The lower priority actions that are recommended are neither important enough, nor far-reaching enough to warrant high priority action.

The low priority problems are:

(1) Need for New Methods of Upgrading Old Scrap

(2) Reclamation of Aluminum from Consumer Durables Sources

(3) Recycling Wastes

(4) Composite Aluminum Scrap.

These are presented in Table 19, along with suggested actions.

Other Actions

Additional actions are recommended in the general report of this series. Some of these relate to the recycling of aluminum. Refer to the general report for additional information.

TABLE 19. RECOMMENDED ACTIONS, LOW PRIORITY ALUMINUM RECYCLING PROBLEMS

Title	Need for New Methods of Upgrading Old Scrap	Reclamation of Old Aluminum Scrap From Consumer Durables Sources	Recycling Wastes	Composite Aluminum Scrap
Actions Recommended	1. Initiate research to find economic methods of refining aluminum. 2. Conduct research in the areas of sorting aluminum scrap. 3. Continue research on recovery of aluminum from low grade scrap.	1. Determine which consumer durables contain the most aluminum. 2. Determine the usual disposal method(s). 3. Recommend collection and reclamation methods.	1. Push research on the recovery of aluminum from low grade drosses and spent flux being undertaken by USBM. 2. Initiate research on products/markets for magnesium chloride and cable insulation waste as recommended.	1. Educate manufacturers and designers on the merits of products designed for recycling. 2. Perform technical and market studies aimed at utilizing metal composites.
By Whom(1)(2)(3)	EPA/NASMI/USBM and Industry	NASMI/EPA	USBM/EPA/Industry	EPA/NASMI
Specific Steps	1. Funding long term efforts to accomplish the above aims is necessary. A look at unconventional techniques is needed.	1. Sponsor research to determine the usual or average content of important consumer durables, their average life, and normal disposal methods. 2. Initiate action depending on results of above	1. Product and market research aimed at finding products and markets for magnesium chloride and cable insulation waste should be performed by sponsorship of any of the above.	1. Start broad education program that could be carried out by NASMI. Could include points on design for recycling. 2. Upon identification of a large amount of aluminum metal composites which are not being recycled, EPA/NASMI could sponsor a technical-economic study aimed at finding new uses for the scrap. 3. EPA/NASMI could pressure can makers away from the steel-aluminum can.

(1) The responsibility for recommended actions shown in this table are based on importance of the action, benefit to the taxpayers, and opportunities for NASMI. They are the best judgments of Battelle.

(2) Recommended actions were distributed between high priority and lower priority based on the evaluation with three criteria.

(3) It is suggested that NASMI continue its leading role in recycling, recognizing that other organizations such as the Bureau of Mines, Department of Commerce, Council of Environmental Quality, HEW Office of Information, and State, Local, and Federal Legislatures must be involved.

APPENDIX A

ALUMINUM ALLOY SPECIFICATIONS

TABLE A-1. ALUMINUM ASSOCIATION ALLOY DESIGNATION SYSTEM FOR WROUGHT ALLOYS*

	Alloy Number
Aluminum - 99.00 percent minimum or greater aluminum alloys grouped by major alloying elements	1XXX
Copper	2XXX
Manganese	3XXX
Silicon	4XXX
Magnesium	5XXX
Magnesium and silicon	6XXX
Zinc	7XXX
Other Elements	8XXX

* In the 1XXX group for minimum purities of 99.00 percent and greater, the last two of the four digits in the designation indicate the minimum aluminum percentage. These digits are the same as the two digits to the right of the decimal point when the minimum aluminum percentage is expressed to the nearest 0.01 percent. For instance, a 1050 alloy would contain a minimum of 99.50 percent aluminum. The second digit in the designation indicates modifications in impurity limits. In the 2XXX to 8XXX alloy groups the last two of the four digits in the designation have no special significance. The second digit in the alloy designation indicates alloy modifications.

Source: "Handbook of Aluminum", 3rd Edition, Published by Alcan Aluminum Corporation, Cleveland, Ohio, 1970, p 225.

TABLE A-2. CHEMICAL COMPOSITION LIMITS OF SELECTED WROUGHT ALUMINUM ALLOYS (PERCENT)

Alloy	Silicon	Iron	Copper	Manganese	Magnesium	Chromium	Zinc	Titanium	Other Elements Each	Other Elements Total	Aluminum, Minimum
1060	0.25 max	0.35 max	0.05 max	0.03 max	0.03 max	--	0.05 max	0.03 max	0.03 max	--	99.60
1100	1.0 Si+ Fe max		0.05-0.20	0.05 max	--	--	0.10 max	--	0.05 max	0.15 max	99.00
2024	0.50 max	0.50 max	3.8-4.9	0.30-0.90	1.2-1.8	0.10 max	0.25 max	--	0.05 max	0.15 max	Remainder
3004	0.30 max	0.7 max	0.25 max	1.0-1.5	0.8-1.3	--	0.25 max	--	0.05 max	0.15 max	Remainder
5052	0.45 Si+ Fe max		0.10 max	0.10 max	0.10 max	0.15-0.35	0.10 max	--	0.05 max	0.15 max	Remainder
6061	0.40-0.8	0.7 max	0.15 - 0.40	0.15 max	0.8-1.2	0.04-0.35	0.25 max	0.15 max	0.05 max	0.15 max	Remainder
7075	0.4 max	0.5 max	1.2-2.0	0.30 max	2.1-2.9	0.18-0.35	5.1-6.1	0.20 max	0.05 max	0.15 max	Remainder

Source: "Handbook of Aluminum", 3rd Edition, Published by Alcan Aluminum Corporation, Cleveland, Ohio, 1970, pp 148-149.

TABLE A-3. ALUMINUM ASSOCIATION DESIGNATION FOR FOUNDRY (CASTING) ALLOYS*

	Designation Number
Aluminum - 99.00 percent minimum and greater aluminum alloys grouped by major alloying elements	1XX.X
Copper	2XX.X
Silicon, with added copper and/or magnesium	3XX.X
Silicon	4XX.X
Magnesium	5XX.X
Unused series	6XX.X
Zinc	7XX.X
Tin	8XX.X
Other major alloying elements	9XX.X

* The 1XX.X series indicates aluminum in the form of ingot or castings having a minimum aluminum percent of 99.00. The second two digits indicate the minimum aluminum content and are the same as the two digits to the right of the decimal in the minimum aluminum percentage when it is expressed to the nearest 0.01 percent. Special control of one or more individual elements is indicated by a letter prefix to the basic four-digit designation. In the 2XX.X to 8XX.X designations the first digit identifies the alloy group. The second two digits are assigned when the alloy is registered--a modification of the original alloy is indicated by a letter prefix to the numerical designation.

A zero in the fourth place, XXX.0, is used when referring to compositions of castings; and a one or a two in the fourth place, XXX.1 or XXX.2, is used when referring to compositions of ingot. The compositional limits of XXX.1 ingot differ from those of castings by prescribed amounts in respect to iron, magnesium, and, in the case of die castings, zinc. When the limits for ingot are closer than those prescribed for XXX.1 ingot the designation XXX.2 applies.

Source: "Handbook of Aluminum", 3rd Edition, Published by Alcan Aluminum Corporation, Cleveland, Ohio, 1970, p 226.

TABLE A-4. CHEMICAL COMPOSITION SPECIFICATION FOR SELECTED ALUMINUM CASTING ALLOYS
(Percent)

Aluminum Association Alloy Number	Former Commercial Designation	Copper	Silicon	Magnesium	Zinc	Iron	Manganese	Nickel	Titanium	Chromium	Others Each
					Die Casting Alloys						
A413.0	A13	0.6	11.0-13.0	1.10 max	0.5 max	1.0 max	0.35 max	0.50 max	--	--	0.20 max
A360.0	A360	0.6	9.0-10.0	0.45-0.6	0.35 max	1.0 max	0.35 max	0.50 max	--	--	0.15 max
B380.0	380	3.0-4.0	8.5- 9.5	0.10 max	1.0 max	1.0 max	0.5 max	0.50 max	0.25 max	--	0.20 max
A380.0	A380	3.0-4.0	8.5- 9.5	0.10 max	2.0-3.0	1.0 max	0.5 max	0.50 max	0.25 max	--	0.20 max
					Permanent Mold Castings						
F332.0	F132	2.0-4.0	8.5-10.5	0.6-1.5	1.0 max	0.9 max	0.50 max	0.50 max	0.25 max	--	0.20 max
319.0*	319	3.0-4.0	5.5- 6.5	0.1 max	1.0 max	1.0 max	0.50 max	0.35 max	0.25 max	--	0.20 max
356.0*	356	0.2 max	6.5- 7.5	0.25-0.40	0.30 max	0.5 max	0.35 max	--	0.25 max	--	0.05 max
					Sand Castings						
208.0	108	3.5-4.5	2.5- 3.5	0.10 max	1.0 max	1.0 max	0.50 max	--	0.25 max	--	0.20 max
308.0**	A108	3.5-4.5	5.5- 6.5	0.10 max	1.0 max	1.0 max	0.50 max	--	0.25 max	--	0.20 max
213.0	113	6.0-7.0	2.0- 3.0	0.10 max	1.5-2.5	1.2 max	0.6 max	0.35 max	0.25 max	--	0.20 max

* Might also be used to produce sand castings.

** Might also be used to produce permanent mold castings.

Source: "The Alloy Data Book" published by Apex Smelting Company, Division of AMAX Aluminum Company, Inc., pp 28-34

TABLE A-5. DESIGNATIONS AND CHEMICAL SPECIFICATIONS FOR ALUMINUM ALLOYS FOR DEOXIDATION IN IRON AND STEEL MANUFACTURE

ASTM Designations	Commercial Designation	Aluminum	Copper	Zinc	Magnesium	Total of All Impurities, Maximum
980A	Special	98 min	0.2 max	0.2 max	0.5 max	2.0
950A	Grade 1	95-97.5	1.5 max	1.5 max	1.0 max	5.0
920A	Grade 2	92-95	4.0 max	1.5 max	1.0 max	8.0
900A	Grade 3	90-92	4.5 max	3.0 max	2.0 max	10.0
850A	Grade 4	85-90	5.0 max	5.5 max	2.5 max	15.0

Source: "The Alloy Databook", published by Apex Smelting Company, Division of AMAX Aluminum Company, Inc., p 34.

APPENDIX B

CALCULATIONS OF ESTIMATED AVAILABILITY OF OLD ALUMINUM SCRAP

TABLE B-1. CALCULATION OF ESTIMATED AVAILABILITY OF OLD ALUMINUM SCRAP, 1969

Source	Estimated Life Cycle, Years	Year or Years Interest	Aluminum Shipments in Year of Interest, Tons	Estimated Fraction of Shipments to Source	Estimated Shipments to Source Corrected for New Scrap Return	Aluminum Scrap 1969, Tons
Building and Construction	30	1939	(350,000)[(a)]	0.250	0.816	71,000
Transportation	10	1958-1960	2,237,000 avg.	0.180	0.816	329,000
Consumer Durables	10	1958-1960	2,237,000 avg.	0.108	0.816	197,000
Electrical	50	1919	64,500[(b)]	0.125	0.816	7,000
Machinery and Equipment	20	1948-1950	1,066,000 avg.	0.070	0.816	61,000
Containers and Packaging	<1	1969	5,409,000	0.110[(c)]	0.816	486,000
Other	10	1958-1960	2,237,000 avg.	0.100	0.816	183,000
					Total	1,334,000

(a) Estimated Based on Primary Ingot Production.
(b) Primary Ingot Production.
(c) Actual

Sources: U.S. Bureau of Mines, <u>Minerals Yearbook</u>, Volume I-II, Chapter on Aluminum for 1958, 1959, and 1960, and The Aluminum Association; <u>Aluminum Statistical Review</u>, 1969 and Battelle Estimates. Life cycle data obtained from "Resources in America's Future - Patterns of Requirements and Availabilities 1960-2000", by H. H. Landsberg, L. L. Fischman, and J. L. Fisher, Published for Resources for the Future, Inc. by The John Hopkins Press.

TABLE OF CONTENTS

TABLE OF CONTENTS (Continued)

LIST OF TABLES

TABLE OF CONTENTS (Continued)

LIST OF TABLES (Continued)

LIST OF FIGURES

TABLE OF CONTENTS (Continued)

LIST OF APPENDIXES

SUMMARY

The economic recycling of waste materials is a desirable approach to the disposal of solid wastes. Recycling, therefore, is of interest to the Office of Solid Waste Management whose responsibility it is to formulate and recommend solid waste programs for the United States. This report on recycling of copper and copper alloys provides information and analyses to be used as a basis for program planning. The report was prepared by Battelle-Columbus with the guidance and help of the National Association of Secondary Material Industries (NASMI). It is based on a 12-month study of copper recycling.

The report reviews briefly the demand and supply for copper in the United States--both primary and secondary. It analyzes the recycling of copper--the operations of scrap processors and secondary smelters, ingot makers and other consumers--sources of copper scrap, markets for recycled copper, and recycled rates by types of scrap. Based on this analysis the report presents the problems faced by the copper recycling industry. Finally, it evaluates these problems to determine priorities, and recommends courses of actions to solve or reduce these problems--with the emphasis on increasing recycling of copper in order to reduce solid waste disposal problems.

The Recycling Industry

The task of the procurement, identification and sorting, smelting, refining, and sale of copper and copper-base alloy scrap for use by refineries, brass mills, and ingot makers are functions of the copper recycling industry. Scrap processors, brokers, secondary smelters, and ingot makers have developed efficient and economic means of recycling the many different types and forms of copper scrap.

Recycled copper makes up a significant proportion of total copper consumption as seen below:

Source of Copper	Percent of Total Consumption
Recycled copper	42.1
Foreign ores	8.4
Domestic ores	45.1
Other	4.4
TOTAL	100.0

Problems

Estimates of percentage recycling for the major identifiable markets for copper were made to outline those channels where there was some obstacle to recycling. Figure I is a schematic diagram of recycled copper flow. It shows estimates of total amounts available for recycling in 1969, total amounts recycled and total amounts not recycled for the major identifiable scrap forms. About 61 percent of the total copper available for recycling is returned to some copper use. The principal markets for recycled copper are wire and cable, brass mill products, and cast brass and bronze products.

Table I shows identification and analysis of those problems concerning copper that was not recycled in 1969. Table II shows identification and analysis of those problems that do not directly reduce the amount of copper recycled. Thes are problems that might have economic effects on an individual company or on the industry, or make operations more difficult.

Recommendations

In order to identify those problems having the highest priority for attention, evaluations based on several criteria were made of each problem. The highest priority ideas are those that are so important that the public, as well

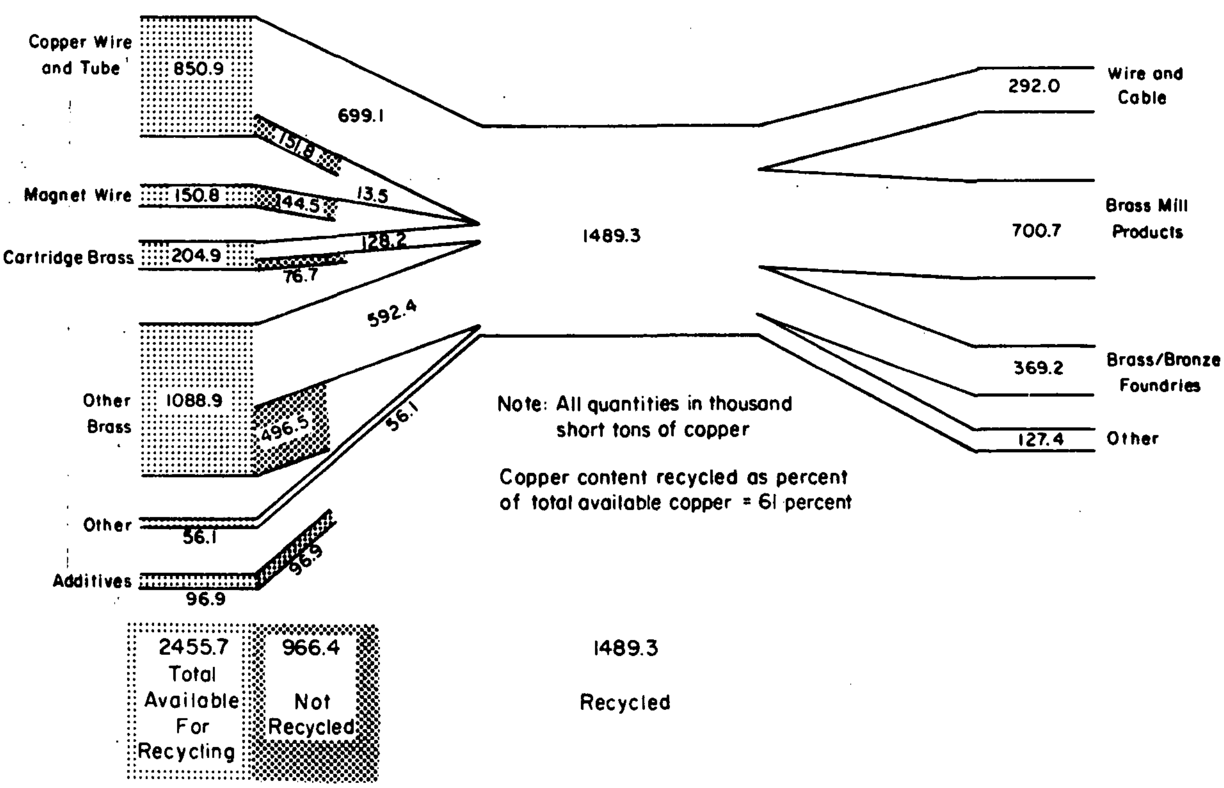


FIGURE I. RECYCLED COPPER FLOW, 1969

Source: Battelle estimates, U.S. Department of the Interior, Bureau of Mines, Minerals Yearbook, "Copper" chapter.

1x

TABLE I. IDENTIFICATION AND ANALYSIS OF PROBLEMS CONCERNING COPPER THAT WAS NOT RECYCLED IN 1969

Title	Scrap Categories Where Some Copper Was Not Recycled		
	Copper Wire and Tube	Magnet Wire	Cartridge Brass
PROBLEM DEFINITION	1. Copper wire is used for the following: a) insulated communication wire and cable b) power wire and cable c) coated magnet wire for transformer and motor windings d) other types of insulated wire and cable for building, automobile, airframe, and shipboard applications e) insulated appliance wire and flexible cord sets f) wire for large transformer and motor windings. 2. Of the above, magnet wire is not included (it is under magnet wire problem). 3. Copper tube is used for the following typical end-products: a) plumbing tube b) air conditioning and refrigeration c) heavy industrial equipment. 4. At the end of their useful lives, communication cable, power cable, bare wire from large transformers and generators, and plumbing tube from larger buildings are collected, processed, and recycled.	1. Magnet wire is used for windings in motors and generators. 2. Motors range in size from common fractional horsepower motors for household appliances to common generators and larger fractional horsepower motors for automobiles, small pumps, and machines, to less common large horsepower motors. 3. In short, the most common motors contain small amounts of copper individually but large amounts in aggregate. The larger common motors contain large amounts of copper but these don't consume much in aggregate. 4. In addition, copper windings are generally surrounded by iron making simple recovery difficult.	1. Cartridge brass is used for small arms and ammunition artillery shells. 2. Small arms and artillery rounds are fired mostly either at domestic military bases or in battlefields. 3. Small arms and artillery shells can be 100 percent recycled from military training bases. 4. However, small arms shells are often scattered in small quantities over many square miles of land, but shells are easily recognized and are valuable. 5. Artillery shells are often scattered in larger quantities--over many square miles of land--but these are easily recognized as being valuable.
THOUSAND SHORT TONS OF COPPER NOT RECYCLED	151.8	144.5	76.7
PERCENT OF AVAILABLE COPPER <u>NOT</u> RECYCLED	18	91	37
PROBLEM ANALYSIS	1. After a usable service life of up to 30 years, copper cable is about 100 percent recycled as scrap by utilities and phone companies after being replaced. 2. Plumbing tube, which is generally in place for the entire life of the building, can have a life up to 60 to 65 years. When building is torn down, copper is segregated and recycled. 3. Nearly all of the above is economically recyclable except those applications in which the copper item is a small fraction in a widely dispersed consumer product, e.g., (a) air conditioning and refrigeration tube and (b) appliance wire. 4. Thus perhaps 5 to 10 percent should not be recycled. 5. Yet 18 percent is not recycled. 6. This area appears to be a promising one in which to increase recycling of copper.	1. After an average useful service life of 6 years for magnet wire in a consumer appliance to 10 or more years for larger fractional horsepower motor applications intended for industrial or farm use, the motor is scrapped. 2. If economically recyclable, material returned, on average should equal magnet wire use about 8 to 10 years ago. 3. However, recycling rate is just 9 percent. 4. This area appears to be a promising one in which to increase recycling of copper.	1. Cartridge brass scrap sells for about 30 cents per pound in the United States. 2. Items, like glass bottles, etc., with lower value <u>are</u> being recycled in the United States. 3. Logic would indicate that most cartridge brass, at market conditions, should be recycled. 4. Yet only 63 percent of cartridge brass <u>is</u> recycled. 5. This appears to be a promising area in which to increase the recycling of copper.

NOT RECYCLED IN 1969 (Continued)

<table>
<tr><th rowspan="2">Title</th><th colspan="2">Scrap Categories Where Some Copper Was Not Recycled</th></tr>
<tr><th>Other Brass</th><th>Copper Used As Additive</th></tr>
<tr><td>PROBLEM DEFINITION</td><td>1. a) This category includes all brass mill products except those considered in other categories:
• cartridge brass
• copper (unalloyed) wire, tube, and strip.
b) This category includes all brass/bronze foundry products.
c) Two brass mill products which have been included in this category, strip for automobile radiators and railroad car boxes, are analysed separately in Table 13 in the text. Each product is about 90 percent recycled.

2. Brass mill products included are used in a myraid of different applications, e.g., plumbing and heating, hardware, fasteners and closures, watches, screw machine products, etc.

3. Brass/bronze cast products are used in pumps and valves, ship propellors, plumbing fittings, etc.</td><td>1. This category includes all copper powders, many of which are used to strengthen iron-based P/M parts.

2. This category includes all copper used by the steel, chemical, aluminum, and other industries as an alloying additive.

3. In the above applications copper is a minor part of a much larger system. For example, copper contents for low-alloy steels range from 0.20 to 3.00 percent. Steels and other copper-containing alloys are uneconomical to segregate and use over for copper content. Consequently, the copper content is sufficiently diluted to be determined as lost.</td></tr>
<tr><td>THOUSAND SHORT TONS OF COPPER NOT RECYCLED</td><td>496.5</td><td>96.9</td></tr>
<tr><td>PERCENT OF AVAILABLE COPPER NOT RECYCLED</td><td>45.6</td><td>100.0</td></tr>
<tr><td>PROBLEM ANALYSIS</td><td>1. Due to the lack of statistical information, it is not known what types of products are being recycled except strip for automobile radiators and railroad car boxes. Since the latter are tabulated separately, recycling rates for these can be calculated. As shown in Table 13 in the text, automobile radiators and railroad car boxes are each about 90 percent recycled.

The brass mill and brass foundry industries sell products to a number of different market segments. Some of these are:
a) alloy copper tube
b) brass/bronze valves
c) coinage
d) brass/bronze plumbing fittings
e) tube for heat exchangers.
Due to the lack of data concerning the above and other large markets for brass mill or brass foundry products, it isn't known to what extend these products are being recycled.

3. This appears to be a promising area in which to increase recycling.</td><td>1. Copper, as an alloying element in either aluminum or steel is usually present in quantities under 1 percent.

2. In many cases, copper containing alloys are produced in relatively small tonnages.

3. It is practically impossible to do either of the following:
a) separate copper from alloy
b) segregate low copper alloys from similar alloys containing no copper for the purposes of reusing copper content. Result: copper is usually diluted.

4. This is not a promising area in which to increase the recycling of copper.</td></tr>
</table>

TABLE II. IDENTIFICATION AND ANALYSIS OF PROBLEMS WHICH DO NOT DIRECTLY REDUCE THE AMOUNT OF COPPER THAT IS RECYCLED (1)

Title	Wire Insulation Removal	Declining Secondary Copper Markets
PROBLEM DEFINITION	1. Most cable and wire has been insulated or covered with either lead, polyethylene, PVC, rubber, asbestos or paper and cloth. 2. To be recyclable, the insulation must be removed. 3. However, due to stringency of air pollution regulations, processors must use either incineration equipment with suitable pollution abatement equipment, or mechanical methods such as cable stripping or fragmentizing. 4. There is a trend toward fragmentizing most ordinary insulated wires and separating copper from insulation with air blowers or other suitable techniques. However, the process is difficult with armored or greased cables.	1. Brass/bronze foundries have lost the new railroad car journal bearing market to roller bearings, and the repair railroad journal segment is expected to decline to zero within 10 to 15 years. Other brass/bronze application markets, e.g., plumbing fittings, are also expected to see reduction in share of market due to competition from plastic materials. 2. Increasing competition from aluminum in such areas as service drop cable, bus bars, and power cable--where less serious design constraints exist is expected. However, in some magnet wire applications, e.g., consumer appliances--where design is more constraining--might become a future problem. 3. Use of some brass mill products, especially those used in construction, e.g., plumbing tube, copper/brass trim, etc., will decline relative to plastics, aluminum, etc.
EFFECT ON RECYCLING RATE	No significant effect on recycling. Some economic effect because of increased investment for equipment.	No significant effect on rate (2) of recycling. Some effect on amount of recycling for particular applications on a long-term basis.
PROBLEM ANALYSIS	1. The stringency of air pollution laws is forcing processors into higher cost equipment. 2. This is creating need for larger processing operations to justify higher cost equipment. 3. Development of cheaper and more versatile equipment methods would be of great help.	1. It is unlikely that continued decline of those markets where some other product has been found superior can be slowed or averted. 2. New products and alloys should be developed to utilize properties possessed by copper as compared with its substitutes.

(1) Problems adversely affect economics or practice of recycling but the effect in terms of amount cannot be measured. This situation is considered an indirect effect.

(2) Rate of recycling = $\frac{\text{Material recycled}}{\text{Total available to be recycled}}$

TABLE II. IDENTIFICATION AND ANALYSIS OF PROBLEMS WHICH DO NOT DIRECTLY REDUCE THE AMOUNT OF COPPER THAT IS RECYCLED (Continued)

Title	Air Pollution Control	Customer Prejudice
PROBLEM DEFINITION	1. During melting of brass at a foundry, ingot maker, or secondary smelter, small quantities of zinc and other materials are oxidized and expelled from the melt as flue dust. 2. Nothing can be done to solve particulate pollution by melters except by purchasing pollution abatement equipment. 3. Efforts to combat this problem in many cases may entail higher costs.	1. Two charges often made against the recycling industry are: (a) Recycling materials industry is often the most important reason for fluctuations in price of refined copper. (b) Users of refined copper wire bar not made entirely from ore sources sometimes claim that such material is inferior to that made entirely from ore sources.
EFFECT ON RECYCLING RATE	No significant effect on the amount of copper recycled. Some economic effect on smaller foundries because of increased investment cost.	No significant effect on the amount of copper recycled. Little or no economic effect.
PROBLEM ANALYSIS	1. This will probably result in fewer, but larger foundries and ingot makers. 2. Development of cheaper and better pollution control equipment would be of great help.	1. Consumers and large producers of copper find a small secondary copper source a convenient target when copper prices are rising. Swings in refined or other copper prices are not primarily due to the recycling industry, but due to a combination of causes. Some of these are: sharp increases/decreases in demand by copper users, sharp decreases/increases in supply by all copper suppliers including changes in governmental stockpile levels. 2. Consumers find a small secondary copper source a convenient target when they have processing difficulties. Refined copper wire bar made to specification from some scrap sources is equivalent to that made completely from ore in price and maximum impurity levels. Yet, many consumers of copper will purchase refined copper made only from ore sources. 3. Making secondary copper products equivalent to primary copper products in reputation, in addition to specification, would be of great help.

as the copper/copper recycling industry, would have interest in their solution. Consequently, these problems are important enough to be acted upon by EPA. These problems with their recommended actions are shown in Table III. Lower priority ideas are those which are important for the recycling industry to solve, but which are not important enough for full-scale participation by the public. Consequently, these problems are not important enough to be acted upon by EPA. The problems with their recommended actions are shown in Table IV.

TABLE III. RECOMMENDED ACTION, HIGH PRIORITY COPPER PROBLEMS

Title	Copper Wire and Tube*	Copper Magnet Wire	Brass Products**
ACTIONS RECOMMENDED	1. R&D should be undertaken to develop economical techniques and technology for the mechanical separation of copper wire and tube from aluminum, steel, plastics, and insulations of various kinds.	1. R&D should be undertaken to develop an economic process for recovery of copper magnet wire from small motors.	1. An investigation should be undertaken to determine why 496,500 short tons of copper contained in brass products were not recycled in 1969.
BY WHOM (1)(2)(3)	EPA/NASMI	EPA/NASMI	EPA/NASMI
	1. NASMI form a committee of three copper smelters and three major scrap processors. 2. Committee discuss problem with several of each of the following: • electric utilities • cable manufacturers • manufacturers of: consumer durables and durable goods that employ copper wire and tube. 3. Survey the following organizations to find out where copper wire and tube are going when discarded: • scrap processors • building dismantlers • secondary smelters • municipal waste handlers. 4. Analyze the results of 2 and 3 above to determine if recycle rate is indeed low; if so, analyze how to increase it. 5. Take appropriate actions on feasible ideas generated by analysis.	1. NASMI form a committee of three copper smelters and three major scrap processors. 2. Committee discuss problem with several of each of the following companies: • manufacturers of fractional horsepower motors • manufacturers of magnet wire. 3. Survey the following organizations to find out where magnet wire products are going when discarded. • scrap processors • secondary smelters • municipal waste handlers • other. 4. Analyze the results of 2 and 3 above to determine if recycle rate is indeed low; if so, analyze how to increase it. 5. Take appropriate actions on feasible ideas generated by analysis.	1. NASMI form a committee of two copper smelters, two major scrap processors, and two ingot makers. 2. Committee analyze why there is a low recycle rate for brass products. 3. Committee discuss problem with U.S. Bureau of Mines, Department of Commerce, and Copper Development Association to find possible reporting errors. 4. Committee discuss problem with original equipment manufacturers and other final users of brass products to find out where and how much brass goes into various major markets. 5. Survey the following organizations to find out where brass products are going when discarded: • scrap processors • secondary smelters • municipal waste handlers • other. 6. Analyze the results of 3, 4, and 5 above to determine if recycle rate is indeed low, and if it is, how to increase it. 7. Take appropriate actions on feasible ideas generated by analysis.

Notes: * Except copper magnet wire.
** Except the following:
(a) cartridge brass
(b) unalloyed copper wire and tube.
(1) The responsibility for recommended actions shown in this table are based on importance of the action, benefit to the taxpayers, and opportunities for NASMI. They are the best judgments of Battelle.
(2) Recommended actions were distributed between high priority and lower priority based on the evaluation with three criteria.
(3) It is suggested that NASMI continue its leading role in recycling, recognizing that other organizations such as the Bureau of Mines, Department of Commerce, Council of Environmental Quality, HEW Office of Information, and State, Local, and Federal Legislatures must be involved.

TABLE IV. RECOMMENDED ACTIONS, LOWER PRIORITY PROBLEMS

Title	Cartridge Brass	Legislative Problems
ACTIONS RECOMMENDED	An investigation should be made. Find out why 76,000 short tons of copper contained in cartridge brass were not re-cycled in 1969. A good portion of this may be ex-plainable by errors of reporting or by exports of copper contained in cartridge brass from Southeast Asia to countries other than the United States.	An investigation should be initiated to determine what steps can be taken to amend various legislation practices which aren't in the best interest of the recycling industry and the public. These problems are: • Sale of emergency stockpiles • Restrictions on the expor-tation of certain types of scrap.
BY WHOM [1] [2] [3]	NASMI	NASMI
RECOMMENDED STEPS	1. Form a committee representing • major scrap processors and • major export/import dealers 2. Committee analyze why there is a low recycle rate for obsolete cartridge brass. 3. Committee discuss this prob-lem with U.S. Bureau of Mines, Department of Commerce, Depart-ment of Defense, and Copper Development Association. 4. Committee discuss this prob-lem with several of each of the following: • Brass mills • Cartridge and artillery shell producers	1. Form a committee representing • NASMI, • major scrap processors, • and smelters. 2. Inform pertinent committees in Congress on the effects of various legislation on the recycling of copper materials.

(1) The responsibility for recommended actions shown in this table are based on importance of the action, benefit to the taxpayers, and opportunities for NASMI. They are the best judgments of Battelle.

(2) Recommended actions were distributed between high priority and lower priority based on the evaluation with three criteria.

(3) It is suggested that NASMI continue its leading role in recycling, recognizing that other organizations such as the Bureau of Mines, Department of Commerce, Council of Environmental Quality, HEW Office of Information, and State, Local, and Federal Legislatures must be involved.

TABLE IV. RECOMMENDED ACTIONS, LOWER PRIORITY PROBLEMS (Continued)

Title	Wire Insulation Removal	Declining Markets
ACTIONS RECOMMENDED	An investigation should be undertaken to develop more effective methods of wire insulation removal.	Continue R&D efforts and initiate additional programs to find new uses for copper and brass products.
BY WHOM	NASMI	NASMI/COPPER DEVELOPMENT ASSOCIATION/ BRASS & BRONZE INGOT INSTITUTE, PRIMARY PRODUCERS
RECOMMENDED STEPS	1. Form a committee of major scrap pro-cessors. 2. Committee analyze pres-ent methods and problems of removing insulation. 3. Committee investigate methods and processes for removing armored steel and grease, etc., from cable. 4. If no acceptable methods are found, determine if it is feasible to carry on R&D to find out economic methods to remove the above.	1. All interested organizations cooperate in R&D programs to promote continued use of copper and develop new applications, supplementing efforts of copper and copper alloy producers.

TABLE IV. RECOMMENDED ACTIONS, LOWER PRIORITY PROBLEMS (Continued)

Title	Air Pollution Control	Customer Prejudices
ACTIONS RECOMMENDED	An investigation should be undertaken to determine the best present pollution abatement methods, and to find improved, cheaper methods.	A campaign should be undertaken to inform copper users of quality of secondary copper.
BY WHOM (1)(2)(3)	NASMI/INGOT MAKERS AND SECONDARY SMELTERS	NASMI
RECOMMENDED STEPS	1. Set up a committee of: • ingot makers and • secondary smelters. 2. Committee analyze present pollution abatement practices of industries with problems similar to it. 3. Committee should obtain advice from prominent pollution control equipment manufacturers concerning suitable equipment and cost.	1. Continue general publicity and educational programs including sponsorship of technical seminars. 2. Start advertising and educational program to publicize recycling of copper.

INTRODUCTION

In June 1970 Battelle undertook a research program for the National Association of Secondary Material Industries, Inc. (NASMI). This was under a subcontract of the Office of Solid Waste Management grant to NASMI. This repo on copper and copper alloys is one of a series of eight commodity reports plus general report.

Background

The Office of Solid Waste Management is responsible for formulatin and recommending Federal Government policies in the area of solid waste poll This includes pursuing appropriate research to determine the status and prob of solid waste activities, and to develop programs to reduce solid waste pol

One approach to the reduction of solid waste pollution is to recla waste materials for reuse - the recycling concept. A well established indust the secondary materials industry--exists to accomplish this recycling. NASM the trade association representing the nonferrous metals, paper, and textile portion of this industry.

The scrap processors, secondary smelters, ingot makers and other companies that make up the secondary materials industry have developed effective channels and methods for recycling nearly all waste materials of economic value. These companies have performed their difficult and essential functions well in the traditional economic environment.

More recently additional dimensions have been added to this traditional economic environment. These new dimensions are (1) improvement of the environment in which we live, and (2) increased need for conservation of natural resources. These new dimensions provide new challenges and opportunities for the recycling industry. No longer is economic gain the sole driving force for the recycling of waste materials. Social gain has been added in the forms of improved living conditions and preservation of resources for future generations. In an economics-based nation this creates problems of interpretation and evaluation of noneconomics-based goals and activities.

The purpose of this series of reports is to identify obstacles to the recycling of nonferrous solid wastes, and to recommend directions for investigation and research to overcome these obstacles.

Objectives

The objective of the study on which this report is based was to identify opportunities for the increased utilization of solid waste. The major sub-objectives were:

(1) To determine the structure and functions of the secondary materials industry, and its relationships to sources of supply and markets

(2) To identify and evaluate problems of recycling - materials, sources, industry, and markets, and

(3) To determine opportunities for increased recycling.

Scope

The major subjects included in the scope of the study are the secondary materials industry, the materials it recycles, the sources of solid wastes, and the markets for recycled materials. Activities peripheral to these major subjects are considered where pertinent to recycling.

The materials included in the study are:

Aluminum	Nickel and Nickel Alloys
Copper and Copper Alloys	Precious Metals (Silver, Gold, and Platinum)
Lead	Paper
Zinc	Textiles

Research Methods

The methods and procedures used in the study are discussed under four types of activities. They include (A) literature search, (B) extensive survey, (C) in-depth survey, and (D) analysis and synthesis.

Literature Search

The literature search included gathering and examining books, Government reports, industry reports, and trade journals covering solid waste handling and problems, recovery and market data, and recycling of valuable materials.

The results of this effort included the accumulation of data and descriptive material, and an organized bibliography dealing with each of the commodities covered in the scope of the study.

Extensive Survey

The extensive survey of the secondary materials industry consisted of a mail survey and personal interviews with management personnel of companies involved with the collection, processing, and sale of secondary materials. About 600 responses were received from the mail survey.

The information developed through the extensive survey included dollar sales, tons of major materials handled, types of solid waste processed, sources of materials, investment, equipment and facilities, number of employees, the amount of space used, and the grades and quantities of secondary materials produced.

The data from the extensive survey provided statistical tabulations of the regional distribution of the secondary materials industries by type of commodity in terms of numbers of establishments, volume of business, and numbers of employees.

In-depth Survey

The in-depth survey of selected members of the secondary materials industries, their suppliers, and the users of their products served to identify the major technical and economic problems facing those companies involved with secondary material utilization. About 200 interviews were completed. Battelle and NASMI commodity specialists jointly selected the companies to be interviewed in depth.

Interview guides for each of the commodities were prepared. The problems and potential solutions for greatest recycling and waste utilization that were developed from the literature search and prior Bureau of Mines work plus the knowledge of the NASMI commodity specialists provided the basis for designing the interview guide. Sample guides are reproduced in the Appendix of the General Report.

Analysis and Synthesis

The analysis and synthesis step was concerned with the collation and analysis of data and information derived from the literature, extensive survey, and in-depth survey. The analysis and synthesis activity covered the following tasks:

(1) Economic Data on the Secondary Materials Industries. The economic data developed through the extensive survey of the secondary material industries was tabulated and analyzed to determine the amount and type of solid waste handled, and to accumulate operational data such as number of employees, amount of space required, capitalization, and geographic locations.

(2) Flow Diagrams and Life Cycles. Flow diagrams were developed to indicate the flow of materials from primary production and scrap sources through fabrication. Life cycle estimates of various products were used to develop data on the amount of materials available for possible recycling.

(3) Demand-Supply Relationships. Estimates were made of future demand and supply levels for secondary materials. The relationships between these data provide an indication of potential surpluses or shortages of recycled materials through 1980.

(4) Stability of Flow and Consumption. This analysis is closely related to the supply-demand analysis described above and identifies the ability of the various secondary materials to compete as source materials for manufacturers. A number of factors were examined such as price changes in the secondary materials, the availability of materials, and the effect of sudden changes in the magnitude of demand.

(5) Direct Impacts of Technological Change. Direct technical and technological factors were examined to determine their effects on the rates of processing and recycling. Potential changes that could take place in technology that could decrease or increase the rate of solid waste recovery were examined. This included the identification of potentially recoverable solid wastes, the problems limiting the recovery to current levels, and the possibilities of technical advances through the use of known technology or through added scientific and engineering research.

(6) Constraints on Expansion of the Secondary Materials Industries. This analysis included consideration of the elements critical to expansion of recycling - labor and management availability, laws and regulations, equipment availability, nature of solid waste materials, market needs, etc.

(7) Potentials for Expansion of the Secondary Materials Industries. Based on the constraints identified in the above task, plus examination of various methods for overcoming constraints, this task determined the ability of the secondary materials industries to meet new opportunities for recycling.

(8) Indirect Technological Change. The broad overall technological trends indirectly affecting the secondary materials industries were examined, and their probable impacts determined.

THE COPPER INDUSTRY

For years copper has been used in essentially three basic intermediate product forms: copper wire and cable, brass mill products (including copper tube), and brass copper and copper alloy castings. The market segments that use these materials depend upon one or more of the outstanding physical properties of the metal, e.g., outstanding thermal and electrical conductivity, outstanding machinability, good corrosion resistance, and good ductility.

Characteristics of Copper and Copper Alloy Products

Copper and copper alloy products are produced in a wide range of different chemical compositions and shapes, cast and wrought.

Grades of Refined Copper

Refined copper metal is marketed in four basic types: (1) electrolytic cathode, (2) tough-pitch, (3) oxygen-free, and (4) deoxidized copper. Electrolytic cathode is the direct product of electrolytic refining and can be sold without further processing. Tough-pitch copper is refined either electrolytically or fire-refined and then cast into various shapes containing controlled amounts of oxygen in order to obtain adequate surface qualities on the casting. Oxygen-free copper is electrolytic copper that has been further processed under reducing conditions in an induction furnace to elmininate small cuprous oxide concentrations. Deoxidized coppers are those coppers that have been freed of oxygen by the addition of residual metallic deoxidizers, usually phosphorus and boron. See Table 1 for standard chemical composition limits for the most common refined copper materials.

Copper is supplied in six basic shapes: cathodes, cast wirebar, cast cakes, billets, ingots, and ingot bars and rod. Of the six, wirebar shapes and wire rod accounted for about 60 percent of the total consumption in 1969. The remaining consumption is almost equally divided among the other four shapes.

Grades of Brass Mill Products

There are hundreds of different brass mill products and compositions. These alloys are produced to a variety of industrial customer, military and standard (ASTM) specifications. Although not a brass product per se, even unalloyed products such as copper tube and strip are considered "brass mill products" since they can be produced on the same equipment. Other than unalloyed types, the following alloys are the most common brass mill compositions:

- Commercial bronze (90 percent copper, 10 percent zinc)
- Red brass (85 percent copper, 15 percent zinc)
- Cartridge brass (70 percent copper, 30 percent zinc)
- Yellow brass (65 percent copper, 35 percent zinc)
- Low-leaded brass (64.5 percent copper, 35 percent zinc, 0.5 percent lead)
- Admiralty metal (71 percent copper, 28 percent zinc, 1 percent tin).

Grades of Brass/Bronze Foundry Products

The brasses considered so far have been wrought brasses, that is, brasses that are used after being rolled or forged, etc. Brasses that are to be used in the cast condition must have, in addition to adequate strength and ductility, good machinability and good casting qualities. The following are the most common brass foundry alloys:

- Cast red brass (85 percent copper, 5 percent zinc, 5 percent tin, 5 percent lead)
- Cast yellow brass (60 percent copper, 38 percent zinc, 1 percent tin, 1 percent lead)
- Cast manganese bronze (58 percent copper, 39.7 percent zinc, 1 percent aluminum, 1 percent iron, 0.3 percent manganese.

TABLE 1. SPECIFICATIONS FOR MOST COMMON REFINED COPPER MATERIALS

Electrolytic Copper Wire Bars, Cakes, Slabs, Billets, Ingot and Ingot Bars
ASTM Designation: B 5-43

Chemical Composition--99.90 percent Cu, silver counted as copper.
Resistivity--Shall have resistivity not to exceed the following:

		Resistivity, max. international ohm
Wire Bars		0.15328
Other Shapes	when specified for electrical use	0.15328
	other uses	0.15694

Fire-Refined Copper for Wrought Products and Alloys
ASTM Designation: B 216-49

These specifications cover fire-refined copper for fabricating into wrought products not intended for electrical purposes, and for alloying in cast and wrought alloys.

The copper in all shapes shall conform to the following requirements as to chemical composition:

Copper plus silver, minimum percent	99.88	Nickel, maximum percent	0.05
Arsenic, maximum percent	0.012	Bismuth, maximum percent	0.003
Antimony, maximum percent	0.003	Lead, maximum percent	0.004
Selenium plus tellurium, maximum percent	0.025		

Source: American Society for Testing and Materials, 1916 Race Street, Philadelphia, Pa. 19103.

Characteristics of the Copper Industry

Copper is a relatively high-valued material and is marketed internationally as a concentrate, an ore, "blister", copper and copper alloy scrap, refined metal, and fabricated products. The United States is one of the few countries using the bulk of its mine output and its secondary copper in the production of fabricated goods in addition to importing relatively large quantities of ore and other copper-containing products. The U.S. copper industry is comprised of integrated primary producers, copper wire and brass fabricators, and the secondary copper industry. The major producers of refined copper and their capacities are shown in Appendix A.

Materials Sources

The United States depends on the following basic sources for copper bearing materials:

	1969 Consumption (thousand tons, copper content)
Domestic ores	1,469
Recycled scrap	1,375
Foreign ores	274
Stock change (refined and other)	60
Unaccounted	93

As seen above, most of the copper either is produced from domestic ores or recycled scrap. However, smaller, but significant, amounts of copper are derived from foreign ores.

Materials Flow

A diagram showing the materials flow from source of copper to fabricated product is shown in Figure 1. As shown, the major sources for copper are U.S. orebodies and recycled secondary materials. All of the ore, foreign or domestic, and some of the scrap is consumed and refined by one of the large, vertically integrated copper companies. The bulk of the refined products goes into copper wire or brass manufacture; some of it is exported and some of it is sold for foundry and other domestic use. Most of the scrap not made into refined products is recycled to either brass mills, ingot makers, or foundries in the form of scrap or secondary ingot; although some of it goes into steel or aluminum manufacture.

Copper Producers

Overall, the large producers of copper are usually vertically integrated from ore to fabricated product; American Metal Climax, American Smelting and Refining, Anaconda, Kennecott, and Phelps Dodge maintain the largest refining capacities. Furthermore, most of this capacity is in the form of electrolytic refining.

Many producers who convert refined shapes into fabricated shapes are divisions or subsidiaries of the copper refineries, e.g., Chase Copper and Brass (Kennecott Copper Corp.) and Anaconda American Brass (Anaconda Co.). However, major independents exist in each of the major fabrication fields; these companies purchase their copper from the major domestic or foreign producers of refined copper and domestic recyclers of copper and copper alloy scrap.

Other major producers of copper products are the recycling industry. In addition to segregation and recycling of scrap, the recycling industry produces a diversity of different alloys to be used as raw materials in the brass and foundry industries. The latter industries are discussed in detail in a subsequent section.

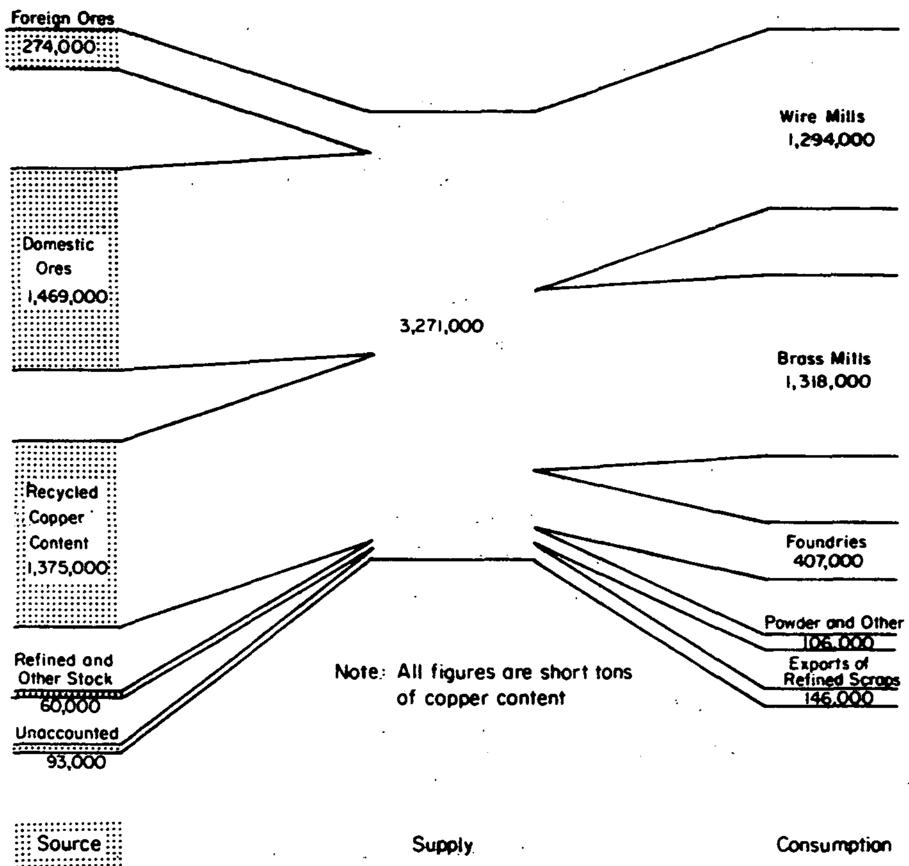


FIGURE I. MATERIALS FLOW FOR COPPER, 1969

Source: U.S. Department of Interior, Bureau of Mines, Minerals Yearbook, "Copper" chapter.

Table 2 gives the latest statistical information on primary and secondary copper smelters.

Production

Production of copper has increased from 2,236 thousand short tons in 1950 to 3,011 thousand short tons in 1965 and to 3,182.6 thousand short tons in 1969 (see Table 3). About 70 percent of this was refined copper from ore or scrap sources; the rest was processed or produced as segregated scrap or secondary ingot About 55 percent of the copper produced originated as ore; about 45 percent originated as scrap.

Markets for Copper

The main uses for primary and recycled copper are in brass mill products, wire and cable, cast foundry products, powder, and "other" miscellaneous uses. These uses for copper are described in this section and in further detail in Appendix B.

Historical Markets

Consumption of copper by main uses for the years 1950, 1955, and 1960 to 1969 is shown in Table 4. Copper consumption has grown slowly during the past 20 years in the brass mill products and wire and cable products. However, foundry products, among the large consumers of copper, have remained essentially constant during the same time period although there have been wide fluctuations year to year.

Prices

Producer prices for electrolytic copper in the United States for selected years are shown in Figure 2. However, due to shortages of refined copper in

TABLE 2. GENERAL STATISTICS FOR ESTABLISHMENTS, BY INDUSTRY SPECIALIZATION AND PRIMARY PRODUCT CLASS SPECIALIZATION: 1967

Industry of Product Class Code	Industry or Product Class	Establishments (number)	All Employees: Number (1,000)	All Employees: Payroll ($ million)	Value Added by Manufacture ($ million)	Cost of Materials ($ million)	Value of Shipments ($ million)	Capital Expenditures, new ($ million)
3331	<u>Primary Copper</u>							
	Entire industry	32	11.6	80.6	262.6	935.0	1,184.1	51.7
33412	<u>Secondary Copper</u> (pig, ingot, shot, etc.)							
	(Primary product class of establishment)	42	3.8	30.3	52.7	410.9	464.3	3.5

Source: U. S. Department of Commerce, Bureau of the Census, <u>1967 Census of Manufacturers</u>, "Smelting and Refining of Nonferrous Metals and Alloys".

TABLE 3. PRODUCTION OF COPPER IN THE UNITED STATES
(Copper content, thousand short tons)

Type/Source	1950	1955	1960	1965	1966	1967	1968	1969
Ore sources	1,239.9	1,342.4	1,518.9	1,711.8	1,711.0	1,133.0	1,437.4	1,742.8
Scrap sources	206.5	236.4	291.7	445.0	490.3	406.6	416.6	491.0
Total Refined	1,446.4	1,578.8	1,810.6	2,156.8	2,202.3	1,539.6	1,854.0	2,233.8
Secondary copper	790.0	786.4	601.1	855.1	910.5	805.5	853.5	948.8
Total Copper Produced	2,236.4	2,365.2	2,411.7	3,011.9	3,112.8	2,345.1	2,707.5	3,182.6

Source: U.S. Department of the Interior, Bureau of Mines, Minerals Yearbook, "Copper" chapter.
U.S. Department of Commerce, Business and Defense Services Administration, Copper Report.

TABLE 4. CONSUMPTION OF COPPER PRODUCTS BY TYPE
(thousand short tons)

	Copper Content											
	1950	1955	1960	1961	1962	1963	1964	1965	1966	1967	1968	1969(a)
Brass Mills												
Refined	675.1	647.0	486.5	599.8	636.1	673.9	690.4	739.9	928.5	650.4	652.5	796.7
Scrap	317.4	356.4	265.8	266.1	323.4	346.9	389.9	441.1	472.0	412.6	452.6	516.4
Recycled Ingot (1)	2.9	6.0	4.8	4.3	5.5	5.2	5.2	5.1	5.2	3.4	4.1	5.1
Total	995.4	1,009.4	757.1	870.2	965.0	1,026.0	1,085.5	1,186.1	1,405.7	1,066.4	1,109.2	1,318.2
Wire Mills (2)												
Refined	713.4	812.7	828.8	823.8	922.9	1,036.2	1,097.5	1,223.4	1,370.8	1,240.2	1,189.3	1,293.6
Foundries (3)												
Refined	34.2	24.5	22.7	23.9	26.7	22.4	25.3	28.1	42.9	35.4	31.0	44.0
Scrap	148.5	115.6	86.8	74.1	78.5	92.1	99.1	95.2	116.2	97.2	92.8	125.4
Recycled Ingot	277.5	250.4	203.8	201.6	206.9	216.1	232.7	251.3	262.8	233.9	241.1	237.8
Total	460.2	390.5	313.3	299.6	312.1	330.6	357.1	374.6	421.9	366.5	364.9	407.2
Powder Plants												
Refined	6.9	9.1	6.2	7.2	7.4	8.1	7.8	9.4	13.1	6.5	7.7	7.5
Scrap	5.3	10.9	9.7	7.6	8.9	8.2	14.1	15.1	17.0	16.0	17.5	17.5
Recycled Ingot	0.1	1.2	1.4	2.1	2.6	3.3	3.0	2.8	3.4	4.9	4.6	3.9
Total	12.3	21.2	17.3	16.9	18.9	19.6	24.9	27.3	33.5	27.4	29.8	28.9
Other Industries (4)												
Refined	46.4	23.0	28.9	29.1	24.4	23.8	26.5	21.2	25.3	19.9	19.4	27.7
Scrap	42.2	50.9	36.3	35.7	38.6	40.4	42.2	47.4	50.4	43.7	43.4	46.0
Recycled Ingot	2.3	1.8	0.7	1.2	2.7	2.4	3.2	3.6	3.2	2.8	3.8	3.5
Total	90.9	75.7	65.9	66.0	65.7	66.6	71.9	72.2	78.9	66.4	66.6	77.2
Copper Consumed												
Refined (5)	1,482.2	1,523.1	1,381.3	1,493.3	1,627.0	1,768.1	1,852.2	2,028.5	2,400.3	1,961.4	1,906.3	2,176.3
Scrap	790.0	786.4	601.1	583.2	657.6	710.9	784.7	855.1	910.5	805.5	853.5	948.8
TOTAL	2,272.2	2,309.5	1,982.4	2,076.5	2,284.6	2,479.0	2,636.9	2,883.6	3,310.8	2,766.9	2,759.8	3,125.1

(a) Preliminary.
(1) Ingot makers consume refined copper, scrap copper, and alloying metal and ship copper alloy ingots to brass mills, foundries, powder plants, and other industries. Their consumption of scrap and/or refined is included in copper consumption figures at bottom of Table.
(2) Wire mills consume refined copper only.
(3) Data adjusted by CDA.
(4) Chemical, steel, aluminum, and other industries.
(5) From scrap and ore sources.
Source: U.S. Department of the Interior, Bureau of Mines; Minerals Yearbook, "Copper" chapter; Copper Development Association, Annual Data 1970 Report

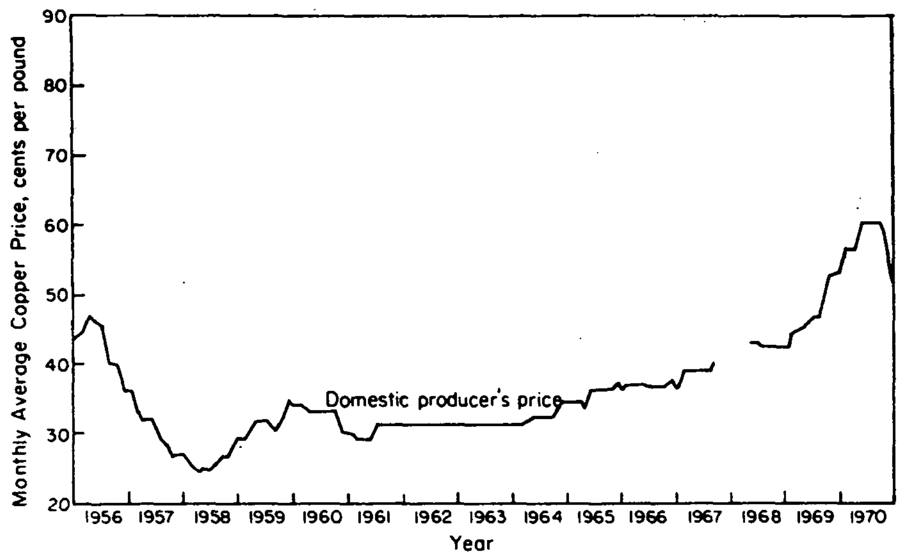


FIGURE 2. ELECTROLYTIC COPPER PRICES (PRODUCER) IN U.S.
Source: Metals Week (formerly E & MJ) average domestic delivered price. Suspended September 1, 1967. Resumed April 8, 1968.

the United States, some consumers have had, upon occasion, to purchase copper from the London Metal Exchange (LME). Consumers, however, who have had to purchase copper from the LME have done so at more widely fluctuating prices than those who purchase from domestic producers.

End Uses for Copper

Brass mills and wire mills each account for over 40 percent of the total copper consumption; foundry products account for about 13 percent of the total, and other uses, e.g., powder, chemicals, the remainder of copper consumption.

Brass. Brass mills are the largest consumer of copper raw materials, including scrap. Generally, copper, copper containing scrap, and alloying materials are melted and cast into billets, slabs, or cakes, then fabricated into tube, rod and wire, and sheet in subsequent processing steps. Brass mills perform the above operations on a number of different copper and copper-base alloys, e.g., pure copper, brass, phosphor bronze, nickel silver. Since brass mills do little refining during melting phases, they should be considered more like fabricators than as foundries.

Brass mills supply both copper and copper-base alloys in all wrought forms. On the average, about 35 to 40 percent of total brass mill production consists of pure copper shapes, sheet, rod and mechanical wire, and tube. In late years, especially, copper tube for plumbing and commercial tube applications has been the major portion of the copper fabricated by brass mills.

Generally, the largest end uses for brass mill products are for plumbing, heating, and architectural products in the construction industry; for automobile radiators; for copper bus bars and other current carrying devices in the electrical goods industry; and for use in a number of different applications in machinery

and industrial and construction equipment. Due to the Vietnam conflict, however, a far higher percentage of brass mill products have been used, since 1965, in small arms and other types of ammunition. Other significant, but smaller, end uses for brass mill products are in fasteners and fasteners, c...age and condenser tube.

Wire. Like brass mills, wire mills consume large amounts of copper raw materials. However, most of the copper consumed is in the form of a refinery shape; little purchased scrap or other recycled material is directly used by wire mills in wiremaking. However, recycled material reappearing as refined copper is used to some degree. Generally, wire is fabricated by hot rolling wirebars or by hot extrusion of billets into rods, which are then cold-drawn through various sizes into finished shapes. After the wire has been drawn to finished shape, it may be either shipped bare or receive one of the following treatments: enameling; tinning, stranding; and/or insulating with plastic, rubber, lead, paper, or other materials.

Wire mill products can be classified into three main categories: bare wire, insulated communication wire and cable, and other insulated wires and cable. Bare wire is used mostly as windings in many varieties of electrical machinery such as transformers, generators, communications equipment, and electronic components. Insulated communications wire and cable, as the classification denotes, includes all communications cable except that which is used as bare wire in equipment. Other insulated wires include magnet wire used as windings for small electrical equipment, power wire and cable, insulated cable used for appliance wire, and cable used for building and transportation.

Castings. As shown in Table 4, foundries are a large consumer of copper-base materials, including scrap. Foundries rely heavily on scrap and other recycled materials for their raw materials input. In 1969, for instance, about 90 percent of each pound of copper used by the foundry industry originated from recycled sources. Total copper contained in materials consumed by foundries has risen from about 313 thousand short tons in 1960 to 375 thousand short tons in 1965 and to 407 thousand short tons in 1969. Most of this was in the form of brass and bronze ingot, one of the major products of the copper recycling industry.

Sand castings represent the largest type of casting produced from copper-based alloy materials; other types produced in some quantity are permanent mold and die castings. These products are used in a wide variety of different applications, but the following are the most significant:

- Valves and fittings, excluding plumbing
- Metal plumbing fittings
- Plumbing valves
- Industrial pumps
- Railroad journal bearings
- Other bearings
- High voltage switching gear.

Powder. Consumption of copper raw materials in powder manufacture is not nearly so large as the three largest uses for copper: brassmaking, wiremaking, and foundry products. As seen from Table 4, secondary copper materials have been employed widely for powder production. In 1969, for instance, secondary materials accounted for about 75 percent of each pound of copper used in powder.

Other Uses. As shown in Table 4, consumption of copper in other products, e.g., chemical, steel, aluminum, etc., is minor.

Market Outlook

Due to recent shortages and price variances of copper raw materials, some customers have given serious thought to substituting some other material for copper. This has occurred in certain types of power and communications wire and cable, and in brass mill and foundry applications in plumbing. In addition, one major manufacturer of fractional horsepower tools has switched over to aluminum magnet wire instead of copper wire for motor windings. In short, the outlook for copper is not certain.

Battelle-Columbus estimates that annual growth rates for copper will be lower than the 4 to 4.5 percent per year commonly mentioned in the press literature, which is well above historical growth rates. Battelle-Columbus estimates that growth of total copper consumption will average about 2 percent annually through 1979.

THE COPPER RECYCLING INDUSTRY

The copper recycling industry's major functions include the purchase of scrap from industrial and public sources, upgrading it to a specification scrap form or ingot and marketing it to a potential user.[1] Main types of companies include:

Scrap processor/dealer or broker

Secondary smelter

Ingot maker.

Characteristics of Copper Materials

Recycled Smelter Copper

Blister and/or black copper, both nearly pure copper, are the main products of a secondary smelter. Low-grade scrap and residues, i.e., sweepings, foundry skimmings, armatures, etc., are feed material for conversion into blister copper. This blister copper may then be refined electrolytically by one of the large, integrated producers into a high grade copper.

Copper Scrap

Copper scrap includes new or obsolete scrap that is unalloyed. Although NASMI includes five different types of copper scrap in its classification circular,[2] the Bureau of Mines lists three distinctly different unalloyed copper scraps in its statistical data. They and their nominal compositions are all shown in Table 5. Also given are the main uses for each of the different types of unalloyed scrap. Brass mills can use unalloyed scrap for use as copper input in making brass or in making unalloyed, refined shapes for later fabrication into plumbing tube. Copper refineries, however, use unalloyed copper scrap to produce refinery shapes.

(1) For a discussion of the functions of the recycling industry, see Volume 1--General Report.
(2) For a complete discussion of these, see Table 6.

TABLE 5. MAIN TYPES OF UNALLOYED COPPER SCRAP

Type	Nominal Copper Content, percent	Where Used
No. 1 wire and heavy copper	99.9	Direct use in refined shapes or alloying agent in brassmaking.
No. 2 wire and heavy copper	96	Electrolytically refined, then fabricated into refined shapes or alloying agent in foundry products.
Light copper	92	Smelted, electrolytically refined, then fabricated into refined shapes.

Source: National Association of Secondary Material Industries, Circular NF-66.

TABLE 6. TYPES OF UNALLOYED COPPER SCRAP

NO. 1 COPPER WIRE

Shall consist of clean, untinned, uncoated, unalloyed copper wire and cable, not smaller than No. 16 B and S wire gauge, 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 1/16 of an inch thick, free of burnt wire which is brittle; but 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 91 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 nonmetallics; 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.

Source: National Association of Secondary Material Industries, Circular NF-66.

Copper-Base Scrap

Copper-base scrap includes new or obsolete scrap generated by users of brass mill products and obsolete copper-base castings.

As this scrap has not been changed in its original composition, most of it can be reused by itself or blended with other materials to produce products similar in composition to that of the scrap from which it originated. Due to the number of copper-base alloys, cast or wrought, there are a number of different scrap classifications. See Table 7 for a complete discussion of NASMI copper-base classifications. The Bureau of Mines, however, lists nine main categories of copper-base alloy scrap. These are shown in Table 8.

Skimmings, Spills, and Drosses

Skimmings, spills, and drosses are relatively low copper containing residues and scrap generated during melting or casting operations at brass mills or foundries. Other materials included under this category are grindings, irony brass, and other copper resulting from various machining operations. As the copper content of this material is generally too low for consumption in normal melting practices, this material is upgraded by smelting, either at a secondary or primary smelter, to a blister copper prior to subsequent electrolytic refining. Main scrap classifications for this category are shown in Table 9.

TABLE 7. TYPES OF COPPER BASE SCRAP

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 semi-red brass castings (78 percent 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" over any one part or weigh over 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.

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 to contain a minimum of 35 percent semi-red.

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, to be clean and free from foreign substances and not to contain more than 10 percent of clean brass punchings under 1/4". 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, 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 of tin and not more than 0.15 percent of 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" 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 nickel 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.

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 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.

Source: National Association of Secondary Material Industries. Circular NF-66.

TABLE 8. MAIN TYPES OF COPPER-BASE ALLOY SCRAP

Type	Approximate Copper Content
Composition or Red Brass	80 to 85
Railroad Car Boxes	72 to 75
Yellow Brass	65
Cartridge Cases and Brass	70
Auto Radiators (unsweated)	70
Bronze	55 to 60
Nickel Silver	65
Low Brass	80
Aluminum Bronze	78 to 90

TABLE 9. MAIN LOW GRADE SCRAP AND RESIDUES USED AS FEEDS FOR RECYCLED SMELTERS

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.

Source: National Association of Secondary Material Industries, Circular NF-66.

Characteristics of the Copper Recycling Industry

Scrap dealers collect, sort, and otherwise process the various grades of copper and copper-base scrap for potential use by smelters, ingot makers, or brass mills. Most of the major dealers handle both copper and copper-base alloy scrap but in addition also handle other materials, especially aluminum.

When processing copper scrap, usually insulated copper wire, dealers use either incineration or mechanical methods to separate copper from insulation. Due to air pollution laws, the latter technique, which chops or fragments the cable prior to gravity separation of insulation from copper, is increasingly used by the industry.

While brass mills commonly repurchase scrap from their large customers, thereby bypassing the secondary industry, dealers do perform an important function by processing the remaining portion. Segregation methods are mechanical, i.e., recognition of metals by filing, drilling, etc.

Consumers of copper and copper alloy scrap and residues are ingot makers (remelters), secondary smelters and refiners, brass mills, and foundries who convert scrap into useful products. Ingot makers purchase and melt down a wide variety of different types of scrap and make a specification ingot that is used by foundries as one of their prime raw materials. Secondary smelters take low copper containing residues and scraps and upgrade these to blister copper or prior to subsequent electrolytic refining.

Materials Sources

The main sources for copper or copper-base scrap are manufacturers of fabricated goods--as prompt industrial scrap--and end-users of various fabricated goods and products as obsolete scrap. Table 10 gives copper scrap consumption by type of scrap and source. As shown, the following four types of scrap represent about 75 percent of total consumption: No. 1 wire and heavy copper, No. 2 wire, mixed heavy and light copper, yellow brass, and low grade scrap and residues. Furthermore, obsolete scrap represents a significant proportion (about 43 percent) of total copper scrap consumption.

TABLE 10. CONSUMPTION OF COPPER AND COPPER BASED SCRAP BY TYPE AND SOURCE, 1969
(short tons of scrap)

Type of Scrap	Prompt Industrial	Obsolete	Total
No. 1 wire and heavy copper	192,158	146,137	338,295
No. 2 wire, mixed heavy and light copper	195,534	157,910	353,444
Composition or red brass	24,400	74,950	99,350
Railroad-car boxes	-	26,736	26,736
Yellow brass	335,816	65,829	401,645
Cartridge brass	110,444	21,655	132,099
Auto radiators (unsweated)	-	69,250	69,250
Bronze	12,254	28,821	41,075
Nickel silver	16,324	5,436	21,760
Low brass	53,323	1,243	54,566
Aluminum brass	783	387	1,170
Low grade scrap and residues	124,123	224,649	348,772
Mixed alloy scrap	3,143	-	3,143
Total	1,068,302	823,003	1,891,305

Source: U.S. Department of Interior, Bureau of Mines, Minerals Yearbook, "Copper" chapter.

Markets for Recycled Copper

Since most applications for copper can be satisfied equally well from either ore or recycled sources, scrap and other forms of secondary copper compete with ore as copper inputs to brass and other copper products. The question of which material is specified in a given product is generally one of price, the price for a given copper unit regardless of origin.

Historical Markets

Secondary copper in its broadest sense, i.e., all products made from scrap or similar origin, has historically represented a significant proportion of total copper used. Table 11 shows the extent of the role of secondary in total copper consumption. Secondary has consistently supplied between 41 and 46 percent of total copper consumption in the last two decades. In recent years, secondary copper has amounted to about 46 percent of total copper consumption.

Figure 3 describes the historical markets for copper and copper-base scrap. As shown, brass mills, ingot makers, and secondary copper producers, i.e., primary mills and secondary smelters, consume the bulk of the total scrap purchased each year. Foundries, chemical plants, and other manufacturers consume lesser amounts of scrap. Furthermore, Figure 3 shows that brass mill and refinery consumption of scrap has increased greatly over the past decade relative to other consumers.

Consumption of major types of copper bearing scrap by major consumers is shown in Table 12. Brass mills, foundries, and ingot makers consume mostly brass and other copper-base alloy scrap, products that they can melt with little difficulty. Primary producers, on the other hand, purchase unalloyed copper scrap to produce new refined shapes under controlled conditions, and along with secondary smelters, they purchase low-grade scrap and residues to upgrade into refined products.

TABLE 11. SECONDARY COPPER CONSUMPTION

(thousand short tons of copper content)

Year	As Refined Metal	As Scrap or Ingot	Total	Percent of Total Copper Consumption
1950	206.5	790.0	996.5	44
1955	236.4	786.4	1,022.8	44
1960	291.7	601.1	892.8	45
1961	281.7	583.2	864.9	42
1962	289.7	657.6	947.3	41
1963	302.1	710.9	1,013.0	41
1964	351.1	784.7	1,135.8	43
1965	445.0	855.1	1,300.1	45
1966	491.3	910.5	1,401.8	42
1967	406.6	805.5	1,212.1	44
1968	416.6	853.5	1,270.1	46
1969	491.0	948.8	1,439.8	46

Source: U.S. Department of Interior, Bureau of Mines, Minerals Yearbook, "Copper" chapter.

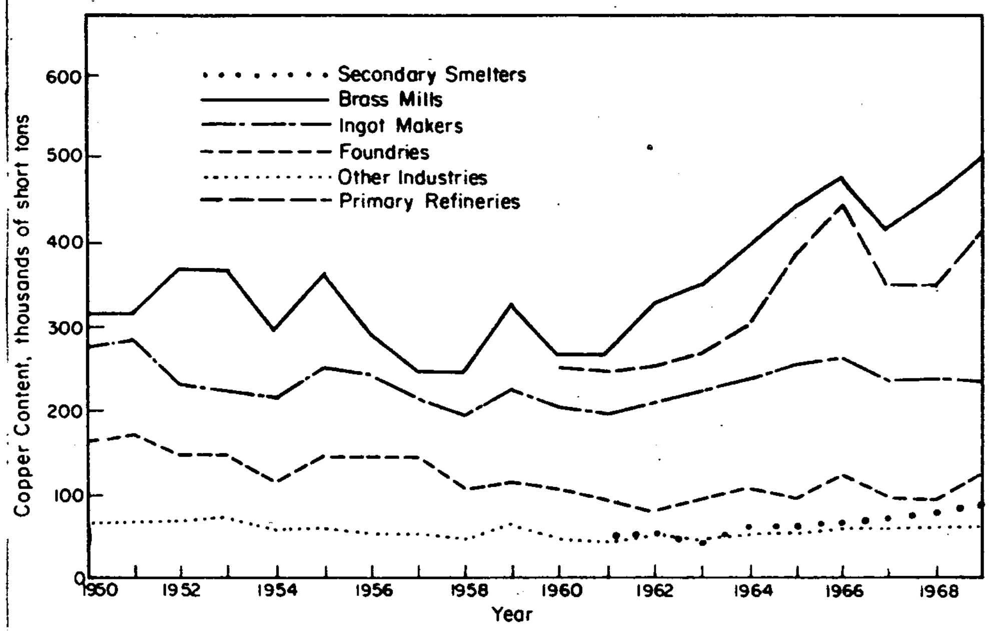


FIGURE 3. HISTORICAL MARKETS FOR COPPER AND COPPER-BASE SCRAP

Source: U.S. Department of the Interior, Bureau of Mines, Minerals Yearbook, "Copper" chapter.

TABLE 12. CONSUMPTION OF PURCHASED COPPER SCRAP BY USERS IN THE UNITED STATES IN 1969

(thousand short tons of copper content)

Type of Scrap	Brass Mills		Ingot Makers and Secondary Smelters		Primary Products		Foundries and Other	
	Quantity	Percent of Total	Quantity	Percent of Total	Quantity	Percent of Total	Quantity	Percent of Total
No. 1 wire and heavy copper	135.9	19.5	47.0	9.7	125.1	20.1	30.3	32.4
No. 2 wire, mixed heavy and light copper	33.7	4.8	92.6	19.2	214.2	34.5	13.0	13.8
Copper-base	525.4	75.7	280.1	58.1	3.0	0.5	45.4	48.6
Low-grade scrap and residues	0.0	0.0	62.2	13.0	278.7	44.9	4.9	5.2
Total	695.0	100.0	481.9	100.0	621.0	100.0	93.5	100.0

Source: U.S. Department of the Interior, Bureau of Mines, Minerals Yearbook, "Copper" chapter.

<u>Prices</u>

As world and domestic supplies of copper have been short in recent years, prices have risen and fluctuated greatly since 1960, a year of relative balance between supply and demand. Figure 4 shows prices for U.S. producers' copper and dealers' No. 2 copper scrap (buying prices). Note that during the copper shortage both prices moved upward, but the scrap price was actually higher than that for electrolytic copper.

<u>End-Use Patterns</u>

The major end-user markets for secondary copper, either as scrap or as refined copper, are shown in Table 13. Since copper refined from secondary smelting operations is generally made to ASTM specifications, the end-uses for refined secondary are essentially the same as for the total refined copper output. Consequently, wire mills are the largest consumers of secondary refined copper; brass mills are next. Also, since wire mills generally don't consume scrap except that generated internally, i.e., home scrap, brass mills and foundries consume most of the outside, purchased scrap. In total, then, brass mills are the largest consumer of secondary materials with about 49 percent of the total; foundries and wire mills trail with 26 and 20 percent of the total respectively.

Recycling Industry Data

A survey of the recycling industry developed data to provide a profile of the industry and the companies comprising the industry. The General Report, Volume I, gives many of these data. Information concerning the copper and copper alloy portion of the industry are given on page 39.

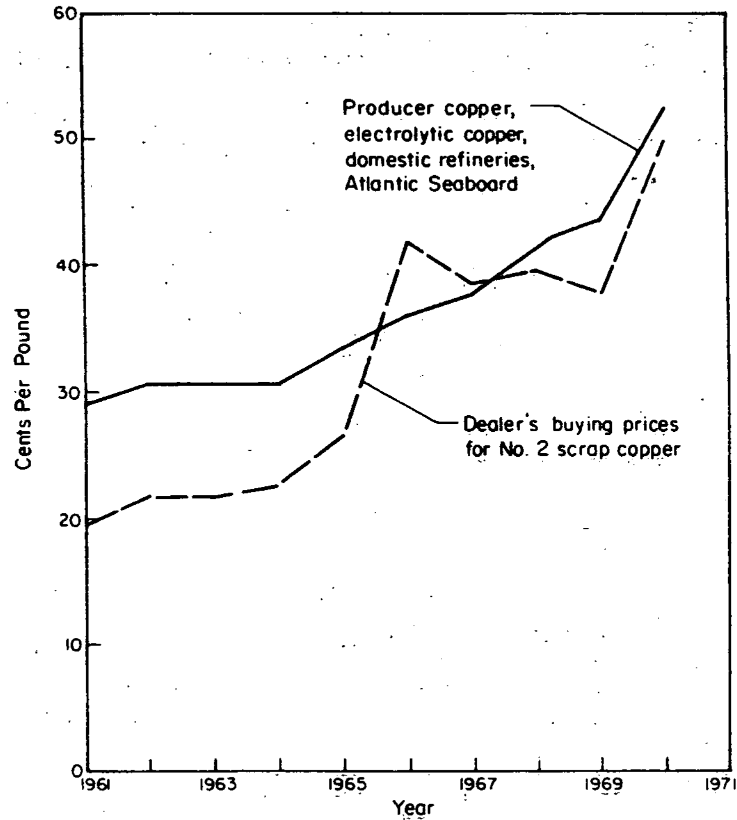


FIGURE 4. A COMPARISON BETWEEN PRODUCER AND NO. 2 DEALER COPPER PRICES

TABLE 13. MARKETS FOR SECONDARY COPPER, 1969

End User	Type of Secondary Product, (short tons) Refined[1]	Scrap or Ingot	Total	Percent of Total Secondary Copper
Wire and Cable	292.0	--	292.0	20
Brass Mill Products	179.8	520.9	700.7	49
Castings	11.5	357.7	369.2	26
Powders	1.7	21.0	22.7	1
Chemical Products	1.0	3.0[1]	4.0	Nil
Other Industries[2]	6.0	46.2	52.2	4

(1) Battelle estimates.
(2) Steel, aluminum, and other industries.

Source: U.S. Department of Interior, U.S. Bureau of Mines, Minerals Yearbook, "Copper" chapter; Copper Development Association, Annual Data 1970 Report.

The average recycler of copper compares with the average recycler of all commodities as follows:*

	Average Investment in Plant and Equipment	Average Number of Employees	Average Investment Per Employee
Copper	$1,863,000	98	$19,000
All Commodities	$1,480,000	71	$20,800

Figure 5 shows the variation in size by census region of copper and copper alloy processors and copper smelters. There is some correlation with population density, degree of industrialization, or other common regional indicators.

Materials Flow Diagram for Copper Recycling

Table 14 shows estimated percentages of copper recycled for several of the major identifiable articles. Recycling of obsolete electric wire and plumbing tube, automobile radiators, railroad car boxes, and low-grade scrap and residues (prompt industrial only) are all relatively high; however, cartridge and other brass are relatively low. Sources and methods for estimation, Table 14, are shown on page 41.

Figure 6 is a schematic diagram of the recycling estimates made in Table 14.

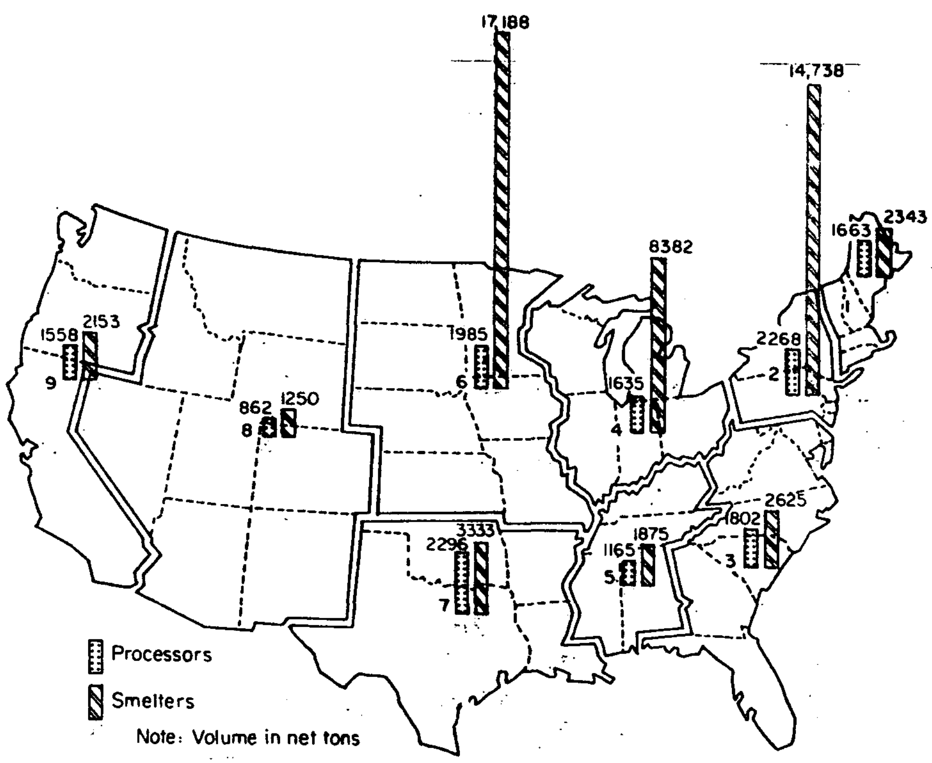
Demand/Supply Analysis

An analysis of the expected demand for copper inputs and their sources is necessary to identify opportunities for increased markets for recycled copper.

Demand for Recycled Copper

The demand for copper inputs in 1969 and the estimates for future years, 1974 and 1979, are shown in Table 15. As shown, the demand for copper is expected to increase at about 2 percent per year in the 1969-1979 period.

* Extensive survey data.



1. New England
2. Middle Atlantic
3. South Atlantic
4. East North Central
5. East South Central
6. West North Central
7. West South Central
8. Mountain
9. Pacific (includes Alaska and Hawaii)

FIGURE 5. VOLUME OF COPPER HANDLED BY TYPE OF RECYCLE, BY REGION

TABLE 14. ESTIMATED COPPER SCRAP RECYCLING, 1969

Kind and Type of Scrap[1]	Copper Content Available for Recycling[2] (thousand tons)	Copper Content Recycled[3] (thousand tons)	Percent Recycled	Copper Conten Not Recycle (thousand to
Electric Wire and Copper Tube				
Prompt Industrial	379.7	379.7[12]	100	--
Obsolete	471.2	319.4	68	151.8
TOTAL	850.9	699.1	82	151.8
Magnet Wire				
Prompt Industrial[4]	--	--	--	--
Obsolete[5]	158.0	13.5	9	144.5
TOTAL	158.0	13.5	9	144.5
Cartridge Brass				
Prompt Industrial	92.8	92.8	~100	--
Obsolete[6]	112.1	35.4	31	76.7
TOTAL	204.9	128.2	63	76.7
Automotive Radiators				
Prompt Industrial[7]	--	--	--	--
Obsolete	53.0	48.5	91	4.5
TOTAL	53.0	48.5	91	4.5
Railroad Car Boxes				
Prompt Industrial[8]	--	--	--	--
Obsolete	22.6	20.0	88	2.6
TOTAL	22.6	20.0	88	2.6
Other Brass, Cast and Wrought				
Prompt Industrial	310.0	310.0	~100	--
Obsolete	703.3	213.9[11]	30	489.4
TOTAL	1,013.3	523.9	52	489.4
Low Grade Scrap and Residues				
Prompt Industrial	37.2	37.2	~100	--
Obsolete[9]	--	--	--	--
TOTAL	37.2	37.2	~100	--
Other Scrap[10]				
Prompt Industrial	12.8	12.8	~100	--
Obsolete	6.1	6.1	--	--
TOTAL	18.9	18.9	100	--
Copper Alloying Additives[13]	96.9	--	00	96.9
TOTAL OBSOLETE	1,623.2	656.8	40	966.4
GRAND TOTAL	2,455.7	1,489.3	61	966.4

Notes: See following page.

Notes for Table 14.

(1) All scraps are separated into prompt industrial and obsolete scraps except automobile radiators and railroad car boxes, both obsolete scrap types. Obsolete low-grade scrap and residues, e.g., motor armatures and other contaminated copper scraps, were reclassified under other scraps so as to obtain as realistic a figure as possible for the amount of copper recycled.

(2) Calculated from estimated life cycles of various end-use products. Consumption for each end-use item was estimated using the following life cycles and consumption patterns:

Source	Life Cycle, (years)	Years of Copper Consumption Used to Calculate Copper Availability
Electric Wire and Copper Tube	45.0	1923-1931 average
Magnet Wire	10.0	1957-1958 average
Cartridge Brass	0.5	1968-1969 average
Automobile Radiators	12.0	1957-1958 average
Railroad Car Boxes	3.5	Battelle estimate of 1966
Brass, N.E.C.	30.0	1939-1942 average of brass mill shipments (50 percent scrap) plus 1941 - cast brass products
Low-Grade Scrap and Residues	0.5	1968
Copper Alloying Additives	14.0	1955

(3) a. Sources for Prompt Industrial Scrap estimates:
U.S. Department of Interior, Bureau of Mines, Minerals Yearbook, "Copper" chapter; Department of the Army; Battelle estimates.

b. Obsolete scrap was estimated in the following way:
1. Obsolete scrap for each end-use item, returning in the same form of scrap as the product was sold originally, was added a proportion of the obsolete low-grade scrap and residues using the following make-up of low-grade scrap and residues.

Type of Scrap	Proportions of Total
Ashes (incinerator)	12.5
Sweepings (warehouse)	12.5
Breakage (irony brass)	25.0
Armatures (generators, etc.)	20.0
Armored (fine insulated wire)	10.0
Large Contaminated Brass	5.0
Refinery Brass	15.0
	100.0

(4) Prompt industrial scrap generated during manufacture included under Electric Wire and Cable.

(5) Obsolete scrap returned to smelters as armatures in (3) above.

Notes for Table 13 (Continued)

(6) Source: Department of the Army.

(7) Prompt industrial scrap for radiators included under Other Brass, Cast or Wrought.

(8) Little prompt industrial scrap, other than drosses or residues, generated in manufacture of railroad car boxes; drosses and residues included separately under own type.

(9) Obsolete low-grade scrap proportioned using figures under (3) above.

(10) For simplicity, recycling assumed under this category to be 100 percent.

(11) Includes copper-base scrap exports.

(12) Includes unalloyed copper scrap exports.

(13) Includes copper used as copper or other additive to steel, aluminum, etc.

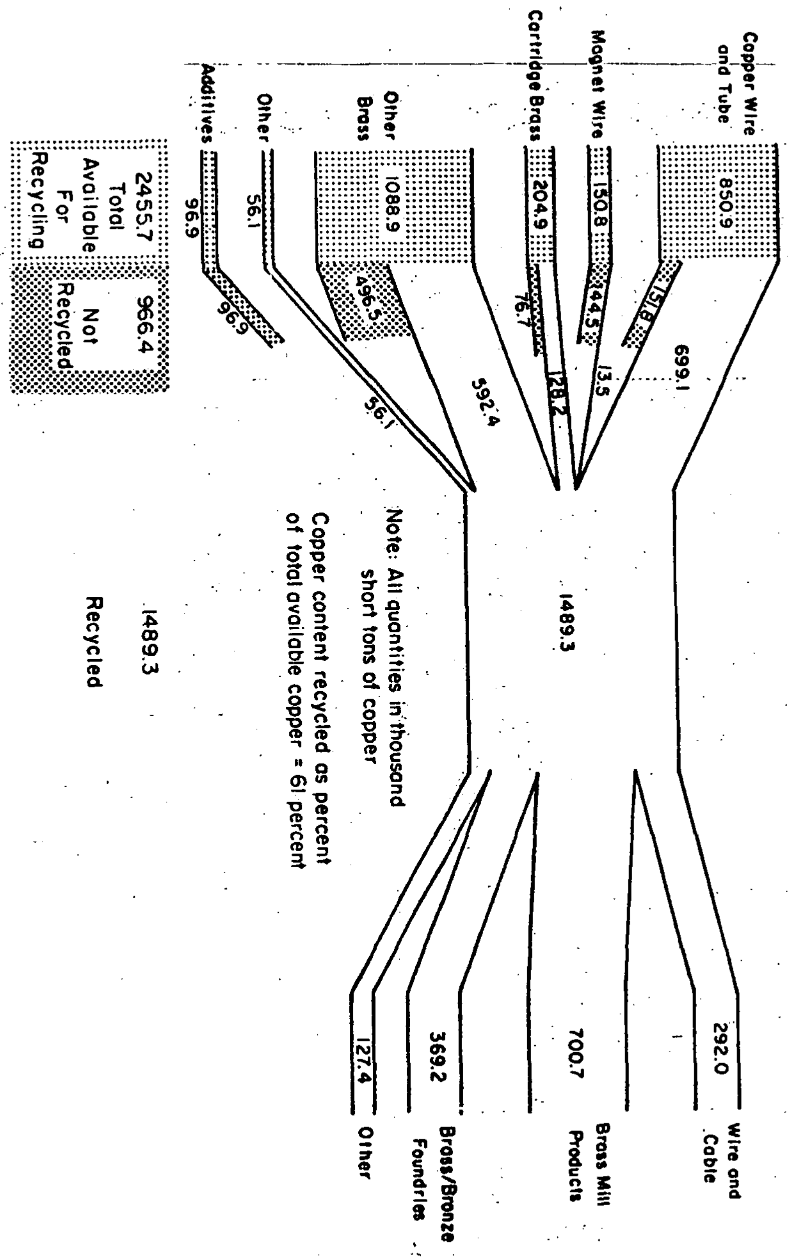


FIGURE 6. RECYCLED COPPER FLOW, 1969

Source: Battelle estimates, U.S. Department of the Interior, Bureau of Mines, Minerals Yearbook, "Copper" chapter.

TABLE 15. DEMAND FOR COPPER

Year	Thousand Short Tons of Copper Content: Recycled	Primary	Total	Recycled, Percent of Total Consumption
1969	1,439.8	1,685.3	3,125.1	46
1974	1,621.7	1,828.7	3,450.4	47
1979	1,828.6	1,980.9	3,809.5	48

Source: Battelle estimates.

Supply of Recycled Copper

Future availability of recycled copper, based on present recovery rates is shown in Table 16 (calculated by same method used to calculate 1969 availability); (see Table 14).

TABLE 16. SUPPLY OF RECYCLED COPPER

(thousand short tons, copper content)

Year	Recycled Copper Content
1969	1,439.8
1974	1,798.0
1979	1,781.9

Source: Battelle estimates.

Demand/Supply Balance in Future

In order to provide a view of what the future will be for the copper recycling industry, a demand/supply balance has been constructed using data from Tables 15 and 16 shown above. See Table 17.

TABLE 17. DEMAND/SUPPLY BALANCE FOR RECYCLED COPPER FOR 1974 AND 1979

(Thousand short tons, copper content)

Year	Demand	Supply	Apparent Balance
1974	1,621.7	1,798.0	176.3 (surplus)
1979	1,828.6	1,781.9	46.7 (deficit)

Source: Battelle estimates.

Since Table 17 assumes that the same incentives, i.e., price, cost, etc., are the same in 1974 and in 1979 as exist today, an apparent balance can be calculated based on (1) current recovery practices, (2) scrap availability forecasts, and (3) market forecasts. A moderate surplus and a moderate deficit of recycled copper is indicated for 1974 and 1979 respectively.

The major reason for the apparent future surplus and deficit for recycled copper are: (1) surplus of good obsolete scrap from products made during the period 1925 to 1930, (2) shortage of good obsolete scrap from products made during the period 1931 to 1939, and (3) slow growth of many copper markets (copper wire and cable, brass mill products, and foundry products). However, these balances do not show what will happen. In 1974, for instance, it is expected that recycled copper demand will increase relative to the supply at the expense of lower demand for primary copper. However, the indicated surplus for 1974 may cause downward price pressures and may discourage copper recycling.

Effect on Copper Industry

If different incentives, i.e., price, cost, etc., are different in 1974 as exist today, apparent balances calculated in Table 17 no longer apply. It is expected that an additional 329,000 tons of copper in copper and brass products can be recycled annually under ideal conditions(1). This additional amount represents about a 18 percent increase in the recycled copper supply in 1974. However, it represents only about 9 percent of total copper supply in 1974, or only about a 1.75 percent per year growth in total copper supply from 1969 to 1974. Since total supply fluctuates often by as much as 10 to 15 percent per year, the copper industry should have little trouble in absorbing this new supply.

(1) The 329,000 tons of copper was calculated based on the following changes in percent recycled.

	1969, percent	Goal, percent	Additional Recycled Copper Content (thousand tons)
Copper Wire and Tube	82	91	77
Magnet Wire	9	20	17
Cartridge Brass	63	90	55
Other Brass	52	70	180
		TOTAL	329

PROBLEMS THAT DIRECTLY REDUCE THE RECYCLING OF COPPER

There are several problems that directly reduce the rate of recycling of copper. These will be discussed in detail in the following paragraphs.

Industrial Scrap

As shown in Table 14 all industrial scrap generated, including ashes, sweepings, and other low-grade residues, are about 100 percent recycled. Some copper is lost during melt-down in brassmaking and in foundries and during smelting operations, but these losses are so small in proportion to the total copper containing industrial scrap recycled, i.e., a fraction of one percent, that they are not worth further study.

Obsolete Scrap

As shown in Table 14 recycling of copper in different categories varies from 91 and 88 percent respectively for automotive radiators and railroad car boxes to 82 percent for copper wire and tube to just 52 percent for other brass. The main problems that directly reduce the rate of recycling involve the following scrap materials:

Copper wire and tube

Copper magnet wire

Cartridge brass

Other brass.

Table 18 presents these problems along with a discussion of the problem definition, problem magnitude, and problem analysis.

TABLE 18. IDENTIFICATION AND ANALYSIS OF PROBLEMS CONCERNING COPPER THAT WAS NOT RECYCLED IN 1969

Title	Scrap Categories Where Some Copper Was Not Recycled Copper Wire and Tube	 Magnet Wire	 Cartridge Brass
PROBLEM DEFINITION	1. Copper wire is used for the following: a) insulated communication wire and cable b) power wire and cable c) coated magnet wire for transformer and motor windings d) other types of insulated wire and cable for building, automobile, airframe, and shipboard applications e) insulated appliance wire and flexible cord sets f) wire for large transformer and motor windings. 2. Of the above, magnet wire is not included (it is under magnet wire problem). 3. Copper tube is used for the following typical end-products: a) plumbing tube b) air conditioning and refrigeration c) heavy industrial equipment. 4. At the end of their useful lives, communication cable, power cable, bare wire from large transformers and generators, and plumbing tube from larger buildings are collected, processed, and recycled.	1. Magnet wire is used for windings in motors and generators. 2. Motors range in size from common fractional horsepower motors for household appliances to common generators and larger fractional horsepower motors for automobiles, small pumps, and machines, to less common large horsepower motors. 3. In short, the most common motors contain small amounts of copper individually but large amounts in aggregate. The larger common motors contain large amounts of copper but these don't consume much in aggregate. 4. In addition, copper windings are generally surrounded by iron making simple recovery difficult.	1. Cartridge brass is used for small arms and ammunition artillery shells. 2. Small arms and artillery rounds are fired mostly either at domestic military bases or in battlefields. 3. Small arms and artillery shells can be 100 percent recycled from military training bases. 4. However, small arms shells are often scattered in small quantities over many square miles of land, but shells are easily recognized and are valuable. 5. Artillery shells are often scattered in larger quantities--over many square miles of land--but these are easily recognized as being valuable.
THOUSAND SHORT TONS OF COPPER NOT RECYCLED	151.8	144.5	76.7
PERCENT OF AVAILABLE COPPER NOT RECYCLED	18	91	37
PROBLEM ANALYSIS	1. After a usable service life of up to 50 years, copper cable is about 100 percent recycled as scrap by utilities and phone companies after being replaced. 2. Plumbing tube, which is generally in place for the entire life of the building, can have a life up to 60 to 65 years. When building is torn down, copper is segregated and recycled. 3. Nearly all of the above is economically recyclable except those applications in which the copper item is a small fraction in a widely dispersed consumer product, e.g., (a) air conditioning and refrigeration tube and (b) appliance wire. 4. Thus perhaps 5 to 10 percent should not be recycled. 5. Yet 18 percent is not recycled. 6. This area appears to be a promising one in which to increase recycling of copper.	1. After an average useful service life of 6 years for magnet wire in a consumer appliance to 10 or more years for larger fractional horsepower motor applications intended for industrial or farm use, the motor is scrapped. 2. If economically recyclable, material returned, on average should equal magnet wire use about 8 to 10 years ago. 3. However, recycling rate is just 9 percent. 4. This area appears to be a promising one in which to increase recycling of copper.	1. Cartridge brass scrap sells for about 30 cents per pound in the United States. 2. Items, like glass bottles, etc., with lower value are being recycled in the United States. 3. Logic would indicate that most cartridge brass, at market conditions, should be recycled. 4. Yet only 63 percent of cartridge brass is recycled. 5. This appears to be a promising area in which to increase the recycling of copper.

TABLE 18. IDENTIFICATION AND ANALYSIS OF PROBLEMS CONCERNING COPPER THAT WAS NOT RECYCLED IN 1969 (Continued)

Title	Scrap Categories Where Some Copper Was Not Recycled: Other Brass	Scrap Categories Where Some Copper Was Not Recycled: Copper Used As Additive
PROBLEM DEFINITION	1. a) This category includes all brass mill products except those considered in other categories: • cartridge brass • copper (unalloyed) wire, tube, and strip. b) This category includes all brass/bronze foundry products. c) Two brass mill products which have been included in this category, strip for automobile radiators and railroad car boxes, are analyzed separately in Table 13 in the text. Each product is about 90 percent recycled. 2. Brass mill products included are used in a myraid of different applications, e.g., plumbing and heating, hardware, fasteners and closures, watches, screw machine products, etc. 3. Brass/bronze cast products are used in pumps and valves, ship propellors, plumbing fittings, etc.	1. This category includes all copper powders, many of which are used to strengthen iron-based P/M parts. 2. This category includes all copper used by the steel, chemical, aluminum, and other industries as an alloying additive. 3. In the above applications copper is a minor part of a much larger system. For example, copper contents for low-alloy steels range from 0.20 to 3.00 percent. Steels and other copper-containing alloys are uneconomical to segregate and use over for copper content. Consequently, the copper content is sufficiently diluted to be determined as lost.
THOUSAND SHORT TONS OF COPPER NOT RECYCLED	496.5	96.9
PERCENT OF AVAILABLE COPPER <u>NOT</u> RECYCLED	45.6	100.0
PROBLEM ANALYSIS	1. Due to the lack of statistical information, it is not known what types of products are being recycled except strip for automobile radiators and railroad car boxes. Since the latter are tabulated separately, recycling rates for these can be calculated. As shown in Table 13 in the text, automobile radiators and railroad car boxes are each about 90 percent recycled. The brass mill and brass foundry industries sell products to a number of different market segments. Some of these are: a) alloy copper tube b) brass/bronze valves c) coinage d) brass/bronze plumbing fittings e) tube for heat exchangers. Due to the lack of data concerning the above and other large markets for brass mill or brass foundry products, it isn't known to what extend these products are being recycled. 3. This appears to be a promising area in which to increase recycling.	1. Copper, as an alloying element in either aluminum or steel is usually present in quantities under 1 percent. 2. In many cases, copper containing alloys are produced in relatively small tonnages. 3. It is practically impossible to do either of the following: a) separate copper from alloy b) segregate low copper alloys from similar alloys containing no copper for the purposes of reusing copper content. Result: copper is usually diluted. 4. This is not a promising area in which to increase the recycling of copper.

Other Direct Problems

Other problems that directly reduce the amount of recycling, but which cannot be measured quantitatively, are those problems caused by legislative action. They are as follows:

(1) Sale of emergency copper stockpile

(2) Restrictions on the exportation of certain types of scrap

(3) Subsidies allowed to primary industries, but not to recycling industries, in the form of ore depletion allowances.

All of the above actions will decrease, everything else being equal, the price for copper scrap. Since lowered prices might decrease collection and segregation of copper scraps in those areas where it had been economic to do so, a lowered recovery rate will probably result.

PROBLEMS THAT DO NOT DIRECTLY REDUCE RECYCLING OF COPPER

These are problems that might have economic effects on an individual company or on the industry, or make operations more difficult. The economic effects, however, are not serious enough to have effect on recycling, but in some cases, e.g., air pollution control (see Table 19, page 51), where industry structure is changed somewhat to achieve economies of scale, processing and smelting costs are increased somewhat by added investment costs. Those problems for copper are:

- Wire insulation removal
- Declining markets
- Air pollution control
- Public prejudices.

Table 19 presents these problems along with a discussion of problem definition, problem magnitude, and problem analysis.

The solid wastes generated by the copper recycling industry and their disposal do not appear to be a problem. Wire and cable insulation, which has been removed during processing activities, appears in a relatively dense form and is simply and inexpensively removed from the processor's yard to the landfill by truck. Smelter slags also appear in a dense form and are easily removed to the disposal site by truck. These are the only important solid wastes generated by the copper recycling industry.

TABLE 19. IDENTIFICATION AND ANALYSIS OF PROBLEMS WHICH DO NOT DIRECTLY REDUCE THE AMOUNT OF COPPER THAT IS RECYCLED (1)

Title	Wire Insulation Removal	Declining Secondary Copper Markets
PROBLEM DEFINITION	1. Most cable and wire has been insulated or covered with either lead, polyethylene, PVC, rubber, asbestos or paper and cloth. 2. To be recyclable, the insulation must be removed. 3. However, due to stringency of air pollution regulations, processors must use either incineration equipment with suitable pollution abatement equipment, or mechanical methods such as cable stripping or fragmentizing. 4. There is a trend toward fragmentizing most ordinary insulated wires and separating copper from insulation with air blowers or other suitable techniques. However, the process is difficult with armored or greased cables.	1. Brass/bronze foundries have lost the new railroad car journal bearing market to roller bearings, and the repair railroad journal segment is expected to decline to zero within 10 to 15 years. Other brass/bronze application markets, e.g., plumbing fittings, are also expected to see reduction in share of market due to competition from plastic materials. 2. Increasing competition from aluminum in such areas as service drop cable, bus bars, and power cable--where less serious design constraints exist is expected. However, in some magnet wire applications, e.g., consumer appliances--where design is more constraining--might become a future problem. 3. Use of some brass mill products, especially those used in construction, e.g., plumbing tube, copper/brass trim, etc., will decline relative to plastics, aluminum, etc.
EFFECT ON RECYCLING RATE	No significant effect on recycling. Some economic effect because of increased investment for equipment.	No significant effect on rate (2) of recycling. Some effect on amount of recycling for particular applications on a long-term basis.
PROBLEM ANALYSIS	1. The stringency of air pollution laws is forcing processors into higher cost equipment. 2. This is creating need for larger processing operations to justify higher cost equipment. 3. Development of cheaper and more versatile equipment methods would be of great help.	1. It is unlikely that continued decline of those markets where some other product has been found superior can be slowed or averted. 2. New products and alloys should be developed to utilize properties possessed by copper as compared with its substitutes.

(1) Problems adversely affect economics or practice of recycling but the effect in terms of amount cannot be measured. This situation is considered an indirect effect.

(2) $\text{Rate of recycling} = \dfrac{\text{Material recycled}}{\text{Total available to be recycled}}$

TABLE 19. IDENTIFICATION AND ANALYSIS OF PROBLEMS WHICH DO NOT DIRECTLY REDUCE THE AMOUNT OF COPPER THAT IS RECYCLED (1) (Continued)

Title	Air Pollution Control	Customer Prejudice
PROBLEM DEFINITION	1. During melting of brass at a foundry, ingot maker, or secondary smelter, small quantities of zinc and other materials are oxidized and expelled from the melt as flue dust. 2. Nothing can be done to solve particulate pollution by melters except by purchasing pollution abatement equipment. 3. Efforts to combat this problem in many cases may entail higher costs.	1. Two charges often made against the recycling industry are: (a) Recycling materials industry is often the most important reason for fluctuations in price of refined copper. (b) Users of refined copper wire bar not made entirely from ore sources sometimes claim that such material is inferior to that made entirely from ore sources.
EFFECT ON RECYCLING RATE	No significant effect on the amount of copper recycled. Some economic effect on smaller foundries because of increased investment cost.	No significant effect on the amount of copper recycled. Little or no economic effect.
PROBLEM ANALYSIS	1. This will probably result in fewer, but larger foundries and ingot makers. 2. Development of cheaper and better pollution control equipment would be of great help.	1. Consumers and large producers of copper find a small secondary copper source a convenient target when copper prices are rising. Swings in refined or other copper prices are not primarily due to the recycling industry, but due to a combination of causes. Some of these are: sharp increases/decreases in demand by copper users, sharp decreases/increases in supply by all copper suppliers including changes in governmental stockpile levels. 2. Consumers find a small secondary copper source a convenient target when they have processing difficulties. Refined copper wire bar made to specification from some scrap sources is equivalent to that made completely from ore in price and maximum impurity levels. Yet, many consumers of copper will purchase refined copper made only from ore sources. 3. Making secondary copper products equivalent to primary copper products in reputation, in addition to specification, would be of great help.

COURSES OF ACTION CONCERNING RECYCLING OF COPPER

In this section, the problems delineated in the above analysis are evaluated to determine priorities, and recommended courses of action are made to help solve or reduce these problems - with the emphasis on increasing recycling of copper in order to reduce solid waste problems.

Selection of Opportunities

In order to identify those problems that have the highest priority for attention, evaluations based on several criteria were made on the problems identified.* See Table 20. The highest total scores, then, indicate the problems of highest importance. As shown, the following problem subjects are the most significant: copper wire and tube, magnet wire, and other brass.

TABLE 20. EVALUATION OF PROBLEMS INVOLVED IN RECYCLING OF COPPER

	Criteria and Scores			
	Solution of Problem Will Improve Environment (10)	Solution of Problem Will Conserve Natural Resources (5)	Ease of Solution (5)	Total Scores
Copper Wire and Tube	10	5	2	17
Magnet Wire	10	5	2	17
Cartridge Brass	2	5	5	12
Other Brass, nec.	10	5	2	17
Legislative Problems	3	4	5	12
Wire Insulation Removal	3	1	5	9
Declining Markets	0	0	5	5
Air Pollution Control	7	0	5	12
Public Prejudices	0	0	5	5

Notes: (1) First criteria is considered most important and is assigned max score of 10.
(2) Other two criteria are considered less important and are assigned max scores of 5 each.
(3) The higher the total score, the more attractive the problem is for further action.

* One problem, copper additives, was not evaluated for the following reason: collection of copper used in small quantities in steel, aluminum, chemicals, and other products for recycling beyond an unforeseen development seems impossible.

Recommended Actions

In the above, all problems were separated into the following categories:

(1) High priority for action

(2) Low priority for action

(3) Not worthy of further consideration.

Highest priority ideas are those which are so important that the public, in addition to the copper/copper recycling industry, would have interest in their solution. Consequently, these problems are important enough to be acted upon by EPA. These problems with their recommended actions are shown in Table 21.

Low priority ideas are those that are important for the recycling industry to solve, but which aren't important enough for full-scale participation by the public. Consequently, these problems aren't felt to be important enough to be acted upon by EPA. These problems with their recommended actions are shown in Table 22.

TABLE 21. RECOMMENDED ACTION, HIGH PRIORITY COPPER PROBLEMS

Title	Copper Wire and Tube*	Copper Magnet Wire	Brass Products**
ACTIONS RECOMMENDED	1. R&D should be undertaken to develop economical techniques and technology for the mechanical separation of copper wire and tube from aluminum, steel, plastics, and insulations of various kinds.	1. R&D should be undertaken to develop an economic process for recovery of copper magnet wire from small motors.	1. An investigation should be undertaken to determine why 496,500 short tons of copper contained in brass products were not recycled in 1969.
BY WHOM (1)(2)(3)	EPA/NASMI	EPA/NASMI	EPA/NASMI
	1. NASMI form a committee of three copper smelters and three major scrap processors. 2. Committee discuss problem with several of each of the following: • electric utilities • cable manufacturers • manufacturers of: consumer durables and durable goods that employ copper wire and tube. 3. Survey the following organizations to find out where copper wire and tube are going when discarded: • scrap processors • building dismantlers • secondary smelters • municipal waste handlers. 4. Analyze the results of 2 and 3 above to determine if recycle rate is indeed low; if so, analyze how to increase it. 5. Take appropriate actions on feasible ideas generated by analysis.	1. NASMI form a committee of three copper smelters and three major scrap processors. 2. Committee discuss problem with several of each of the following companies: • manufacturers of fractional horsepower motors • manufacturers of magnet wire. 3. Survey the following organizations to find out where magnet wire products are going when discarded. • scrap processors • secondary smelters • municipal waste handlers • other. 4. Analyze the results of 2 and 3 above to determine if recycle rate is indeed low; if so, analyze how to increase it. 5. Take appropriate actions on feasible ideas generated by analysis.	1. NASMI form a committee of two copper smelters, two major scrap processors, and two ingot makers. 2. Committee analyze why there is a low recycle rate for brass products. 3. Committee discuss problem with U.S. Bureau of Mines, Department of Commerce, and Copper Development Association to find possible reporting errors. 4. Committee discuss problem with original equipment manufacturers and other final users of brass products to find out where and how much brass goes into various major markets. 5. Survey the following organizations to find out where brass products are going when discarded: • scrap processors • secondary smelters • municipal waste handlers • other. 6. Analyze the results of 3, 4, and 5 above to determine if recycle rate is indeed low, and if it is, how to increase it. 7. Take appropriate actions on feasible ideas generated by analysis.

Notes: * Except copper magnet wire.
** Except the following:
(a) cartridge brass
(b) unalloyed copper wire and tube.
(1) The responsibility for recommended actions shown in this table are based on importance of the action, benefit to the taxpayers, and opportunities for NASMI. They are the best judgments of Battelle.
(2) Recommended actions were distributed between high priority and lower priority based on the evaluation with three criteria.
(3) It is suggested that NASMI continue its leading role in recycling, recognizing that other organizations such as the Bureau of Mines, Department of Commerce, Council of Environmental Quality, HEW Office of Information, and State, Local, and Federal Legislatures must be involved.

TABLE 22. RECOMMENDED ACTIONS, LOWER PRIORITY PROBLEMS

Title	Cartridge Brass	Legislative Problems
ACTIONS RECOMMENDED	An investigation should be made. Find out why 76,000 short tons of copper contained in cartridge brass were not recycled in 1969. A good portion of this may be explainable by errors of reporting or by exports of copper contained in cartridge brass from Southeast Asia to countries other than the United States.	An investigation should be initiated to determine what steps can be taken to amend various legislation practices which aren't in the best interest of the recycling industry and the public. These problems are: • Sale of emergency stockpiles • Restrictions on the exportation of certain types of scrap.
BY WHOM (1)(2)(3)	NASMI	NASMI
RECOMMENDED STEPS	1. Form a committee representing • major scrap processors and • major export/import dealers 2. Committee analyze why there is a low recycle rate for obsolete cartridge brass. 3. Committee discuss this problem with U.S. Bureau of Mines, Department of Commerce, Department of Defense, and Copper Development Association. 4. Committee discuss this problem with several of each of the following: • Brass mills • Cartridge and artillery shell producers	1. Form a committee representing • NASMI, • major scrap processors, • and smelters. 2. Inform pertinent committees in Congress on the effects of various legislation on the recycling of copper materials.

(1) The responsibility for recommended actions shown in this table are based on importance of the action, benefit to the taxpayers, and opportunities for NASMI. They are the best judgments of Battelle.
(2) Recommended actions were distributed between high priority and lower priority based on the evaluation with three criteria.
(3) It is suggested that NASMI continue its leading role in recycling, recognizing that other organizations such as the Bureau of Mines, Department of Commerce, Council of Environmental Quality, HEW Office of Information, and State, Local, and Federal Legislatures must be involved.

TABLE 22. RECOMMENDED ACTIONS, LOWER PRIORITY PROBLEMS (Continued)

Title	Wire Insulation Removal	Declining Markets
ACTIONS RECOMMENDED	An investigation should be undertaken to develop more effective methods of wire insulation removal.	Continue R&D efforts and initiate additional programs to find new uses for copper and brass products.
BY WHOM	NASMI	NASMI/COPPER DEVELOPMENT ASSOCIATION/ BRASS & BRONZE INGOT INSTITUTE, PRIMARY PRODUCERS
RECOMMENDED STEPS	1. Form a committee of major scrap processors. 2. Committee analyze present methods and problems of removing insulation. 3. Committee investigate methods and processes for removing armored steel and grease, etc., from cable. 4. If no acceptable methods are found, determine if it is feasible to carry on R&D to find out economic methods to remove the above.	1. All interested organizations cooperate in R&D programs to promote continued use of copper and develop new applications, supplementing efforts of copper and copper alloy producers.

TABLE 22. RECOMMENDED ACTIONS, LOWER PRIORITY PROBLEMS (Continued)

Title	Air Pollution Control	Customer Prejudices
ACTIONS RECOMMENDED	An investigation should be undertaken to determine the best present pollution abatement methods, and to find improved, cheaper methods.	A campaign should be undertaken to inform copper users of quality of secondary copper.
BY WHOM	NASMI/INGOT MAKERS AND SECONDARY SMELTERS	NASMI
RECOMMENDED STEPS	1. Set up a committee of: • ingot makers and • secondary smelters. 2. Committee analyze present pollution abatement practices of industries with problems similar to it. 3. Committee should obtain advice from prominent pollution control equipment manufacturers concerning suitable equipment and cost.	1. Continue general publicity and educational programs including sponsorship of technical seminars. 2. Start advertising and educational program to publicize recycling of copper.

APPENDIX A

MAJOR PRODUCERS OF COPPER

TABLE A-1. U.S. COPPER REFINERY CAPACITY

(Annual capacity at end of 1969 in tons of 2,000 lb)

Electrolytic	
The Anaconda Company, Great Falls, Montana	190,000
Asarco	
Baltimore, Maryland	318,000
Perth Amboy, New Jersey	168,000
Tacoma, Washington	156,000
Cerro Copper & Brass - Div. of Cerro Corp., St. Louis, Missouri	44,000
Inspiration Consolidated Copper, Inspiration, Arizona	70,000
International Smelting and Refining Co., Raritan, Perth Amboy, New Jersey	150,000
Kennecott Copper Corp., Garfield, Utah	186,000
Kennecott Refining Corp., Anne Arundel County, Maryland	276,000
Phelps Dodge Refining Corp.	
El Paso, Texas	420,000
Laurel Hill, Long Island, New York	155,000
United States Metals Refining Co., Carteret, New Jersey, a subsidiary of American Metal Climax, Inc.	175,000
TOTAL TANK CAPACITY	2,308,000
Lake and Fire Refining	
Calumet & Hecla Corp., Universal Oil Products Company, Hubbell, Michigan	30,000
Kennecott Copper Corp., Hurley, New Mexico	103,000
Phelps Dodge Refining Corp.	
El Paso, Texas	25,000
Laurel Hill, Long Island, New York	20,000
Quincy Mining Co., Hancock, Michigan	15,000
United States Metals Refining Co., Carteret, New Jersey, a subsidiary of American Metal Climax, Inc.	85,000
White Pine Copper Co., White Pine, Michigan	90,000
TOTAL LAKE AND FIRE REFINED	368,000
TOTAL REFINED COPPER CAPACITY	2,676,000
Casting Capacity	
(1) Electrolytic (including scrap)	2,380,000
(2) Lake	135,000
(3) Fire refining (in addition to capacity reported under Item 1)	208,000

TABLE A-2. PRINCIPAL COPPER FABRICATORS

CAPTIVE FABRICATORS

Brass Mills

Chase Brass and Copper	Kennecott Corporation
The Okonite Company	Kennecott Corporation
The Anaconda American Brass Corporation	The Anaconda Company
Phelps Dodge Copper Products Corporation	Phelps Dodge
Calumet & Hecla-Wolverine Tube Division	Calumet & Hecla
C. G. Hussey & Company, Division of Cooper Range Company	Cooper Range
New Haven Copper Company	Tennessee Corporation
Cerro Copper & Brass Company, Division of Cerro Corporation	Cerro Corporation

Wire Mills

Anaconda Wire and Cable	Anaconda Company
Cycle Wire and Cable Corporation	Cerro Corporation
Hatfield Wire and Cable Division	Continental Copper and Steel Industries, Inc.

INTERDEPENDENTS

Brass Mills

Bohn Aluminum & Brass Corporation
Bridgeport Brass Company, Division of National Distillers & Chemical Corporation
Bridgeport Rolling Mills Company
The Bristol Brass Corporation
Chicago Extruded Metals Company
Detroit Gasket & Manufacturing Company
The Electric Materials Company
International Silver Company
Miller Company
Mueller Brass Company
New England Brass Company
Olin Mathieson Chemical Corporation
H. K. Porter Company, Inc., Riverside-Alloy Metal Division
Reading Tube Company, Division Reading Industries
Scovill Manufacturing Company
Triangle Conduit & Cable Company, Inc.
U.S. Mint Service
Volco Brass & Copper Company
Western Electric Company, Inc.

Wire Mills

Rods, Inc.
Rome Cable Corporation
Triangle Conduit & Cable Company, Inc.
Western Electric Company, Inc.

APPENDIX B

END USES FOR COPPER PRODUCTS

Table B-1 shows consumption of brass mill products by type of alloy and product form. Note that copper forms have consistently averaged from 35 to 40 percent of total consumption.

Table B-2 shows the final uses for brass mill shipments irrespective of alloy for 1965 and 1969. Most end uses have retained their market segments. However, building product uses have declined somewhat from 29.7 percent of the total in 1965 to 23.5 percent in 1969.

Table B-3 gives consumption of wire mill products by end-use markets. communications wire and cable, magnet wire, and building/transportation wire and cable represent the largest markets for copper wire mill products. Total copper wire markets have increased from 760 thousand short tons in 1960 to 1,294 thousand short tons in 1969.

Tables B-4 and B-5 give consumption of various types of copper foundry products and powder products by type. Although foundry products are shown to have increased in the past ten years, the markets for foundry products have not grown since a high of approximately 600 thousand short tons, gross metal weight, was achieved in 1951. Consumption of copper powder products increased rapidly from 1960 to 1965 but remained essentially constant thereafter.

TABLE B-1. CONSUMPTION OF BRASS MILL PRODUCTS, BY TYPE OF ALLOY AND FORM
(thousands of short tons)

	1950	1955	1960	1965	1966	1967	1968	1969
Copper								
Sheet	181.0	153.0	88.0	136.0	177.0	120.0	95.0	119.0
Rod & Mechanical Wire	39.5	60.5	50.5	76.5	80.5	65.0	70.0	83.5
Tube	224.5	234.0	236.5	419.0	224.0	320.5	330.5	387.5
Total	445.0	447.5	375.0	631.5	662.5	505.5	495.5	590.0
Copper-base Alloy								
Sheet	355.0	348.5	290.0	374.0	479.5	383.5	421.5	458.5
Rod & Mechanical Wire	389.0	389.0	269.5	404.5	440.5	325.5	380.5	422.5
Tube	88.0	81.0	55.5	77.0	80.5	83.0	80.5	80.0
Total	832.0	818.5	565.0	855.5	1,000.5	792.0	882.5	961.0
Total Supply	1,277.0	1,266.0	940.0	1,487.0	1,663.0	1,297.5	1,378.0	1,551.0
Pure Copper as a Percentage of Brass Mill Products	35	35	40	42	40	40	36	38

Source: Copper Development Association, Annual Data 1970.

TABLE B-2. FINAL USES FOR BRASS MILL PRODUCT SHIPMENTS

Final Uses	1965 Quantity Thousand S.T.	1965 Percent	1969 Quantity Thousand S.T.	1969 Percent
Building products	442.1	29.7	365.4	23.5
Automotive and other transportation	254.5	17.1	228.6	14.7
Consumer's goods (include coinage)	125.0	8.4	116.6	7.5
Fasteners and fastenings	77.4	5.2	57.5	3.7
Air conditioning, refrigeration, and appliances	105.7	7.1	136.8	8.8
Electrical goods	212.9	14.3	208.4	13.4
Machinery and industrial equipment	221.8	14.9	228.6	14.7
Military	43.2	2.9	206.8	13.3
Export	6.0	0.4	6.2	0.4
Total	1,488.6	100.0	1,554.9	100.0

Source: Copper Development Association estimates.
Battelle estimates.
U.S. Department of Commerce, Business and Defense Services, Administration, Copper Report.

TABLE B-3. CONSUMPTION OF WIRE MILL PRODUCTS IN END-USE MARKETS
(thousands of short tons, copper content)

Product/End Use	1960	1965	1966	1967	1968	1969 (1)	Percent of Total, 1969
			QUANTITY				
Bare Wire							
Fasteners	-	-	-	-	-	6.82	0.5
Machinery, Ex. Elect.	-	-	-	-	-	4.84	0.4
Electrical Machinery	-	-	-	-	-	96.92	7.4
Transportation Equipt.	-	-	-	-	-	2.42	0.2
Total Bare Wire	88.0	103.0	134.5	117.5	102.5	110.0	8.5
Insulated Communication	191.0	270.0	282.5	271.5	267.5	357.5	27.6
Other Insulated							
Magnet	-	-	-	-	-	290.93	22.5
Power	-	-	-	-	-	148.77	11.5
Building/Transportation	-	-	-	-	-	311.59	24.1
Appliance	-	-	-	-	-	75.21	5.8
Total Other Insulated	481.0	715.5	830.0	789.0	812.0	826.5	63.9
Grand Total	760.0	1,088.5	1,247.0	1,178.0	1,182.0	1,294.0	100.0

(1) Battelle Memorial Institute.

Source: U.S. Department of Commerce, Bureau of the Census, Business and Defense Service Administration, Copper Report.

TABLE B-4. CONSUMPTION OF COPPER AND COPPER-BASE ALLOY CASTINGS

(thousands of short tons, gross metal weight)

Type	1960	1965	1966	1967	1968	1969
Sand	358.5	396.5	428.0	408.5	413.5	448.0
Permanent Mold	22.5	22.5	23.0	18.5	13.5	21.5
Die	7.5	10.5	15.0	13.0	15.5	14.0
Other	11.5	15.0	37.0	43.0	41.5	33.5
Total	400.0	444.5	503.0	483.0	484	567.0

Source: U.S. Department of Commerce, Business and Defense Services Administration, Copper Report.

TABLE B-5. CONSUMPTION OF POWDER PRODUCTS

(total metal weight, thousand short tons)

Product	1960	1965	1966	1967	1968	1969
Granular	16.5	28.5	30.0	25.0	28.5	29.0
Flake	3.0	2.5	3.5	3.0	3.0	3.0
Total	19.5	31.0	33.5	28.0	31.5	32.0

Source: Copper Development Association, Annual Data 1970.

VOLUME IV

LEAD REPORT

TABLE OF CONTENTS

TABLE OF CONTENTS (Continued)

LIST OF TABLES

TABLE OF CONTENTS (Continued)

LIST OF TABLES (Continued)

TABLE OF CONTENTS (Continued)

LIST OF TABLES (Continued)

LIST OF FIGURES

SUMMARY

Lead, because of its relative inertness in metallic form, is seldom lost, and it is valuable enough so that industry has always sought to recover it. Consequently, its recycling record is rather good with about 49 percent of total U.S. lead production in 1969 being recycled lead. However, according to Battelle-Columbus estimates, 821,000 tons or almost 60 percent of the lead theoretically available for recycling in 1969 is not recycled. It is possible that solution of problems identified during the study could mean that about an additional 250,000 tons of lead could be recycled.

The Lead Recycling Industry[1]

The lead recycling industry takes scrapped lead from the point of scrappage to a point of reuse.[2] The functions include buying and selling, physical movement, and change of form of the lead. The scrap materials are old batteries, other old lead and lead alloys, and lead drosses from melting operations. The recycled lead that is the output of the industry covers a range of types and purities of lead and lead alloys of which some are equivalent in characteristics and uses to primary lead.

The importance of recycled lead in the total lead market is shown by 1969 supply data for lead:

Lead Source	Short Tons of Lead	Percent of Total
Domestic ore	515,000	34
Imported Ore	125,000	8
Imported Metal	285,000	18
Recycled Lead	605,000	39
U.S. Stockpile	15,000	1
TOTAL	1,545,000	100

(1) Home scrap is not included in this report.
(2) For a discussion of the functions of the recycling industry, see Vol. 1, General Report.

Figure I summarizes data concerning the recycling of lead for the year 1969. The quantities of lead that were calculated to be available for recycling in 1969 are shown at the left (light shading). The quantities not recycled are shown next (dark shading). No tetraethyl lead or lead oxides are recycled because the nature of these applications makes recovery nearly impossible. Most solder and ammunition are not recycled for the same reason.

The lead that is recycled is shown in the unshaded portions. It is apparent that large quantities of lead are being recycled from several sources. This recycled lead is then being marketed for several applications as shown on the right of Figure I. Overall, the recycling of lead is highly successful, yet only 42 percent of the amount theoretically available is being recycled.

Problems of Lead Recycling

The problems of lead recycling are of two types: (1) those that directly reduce the recycling of lead, and (2) those that do not directly reduce the recycling of lead. Those in the first category are problems that reduce recycling in measurable quantities. Those in the second are problems that adversely affect economics or practices of recycling but the effect in terms of amounts of lead can not be measured.

Table I describes the problem situation for each of the five major scrap sources and the extent to which lead was not recycled in 1969 in each case. The relative degree of recycling shown is based on a Battelle estimate of the amount of scrap of each type theoretically available for recycling that year.

Table II presents the five problems that do not directly reduce the recycling of lead. The first two are market problems and the other three are operating problems of the recycling industry.

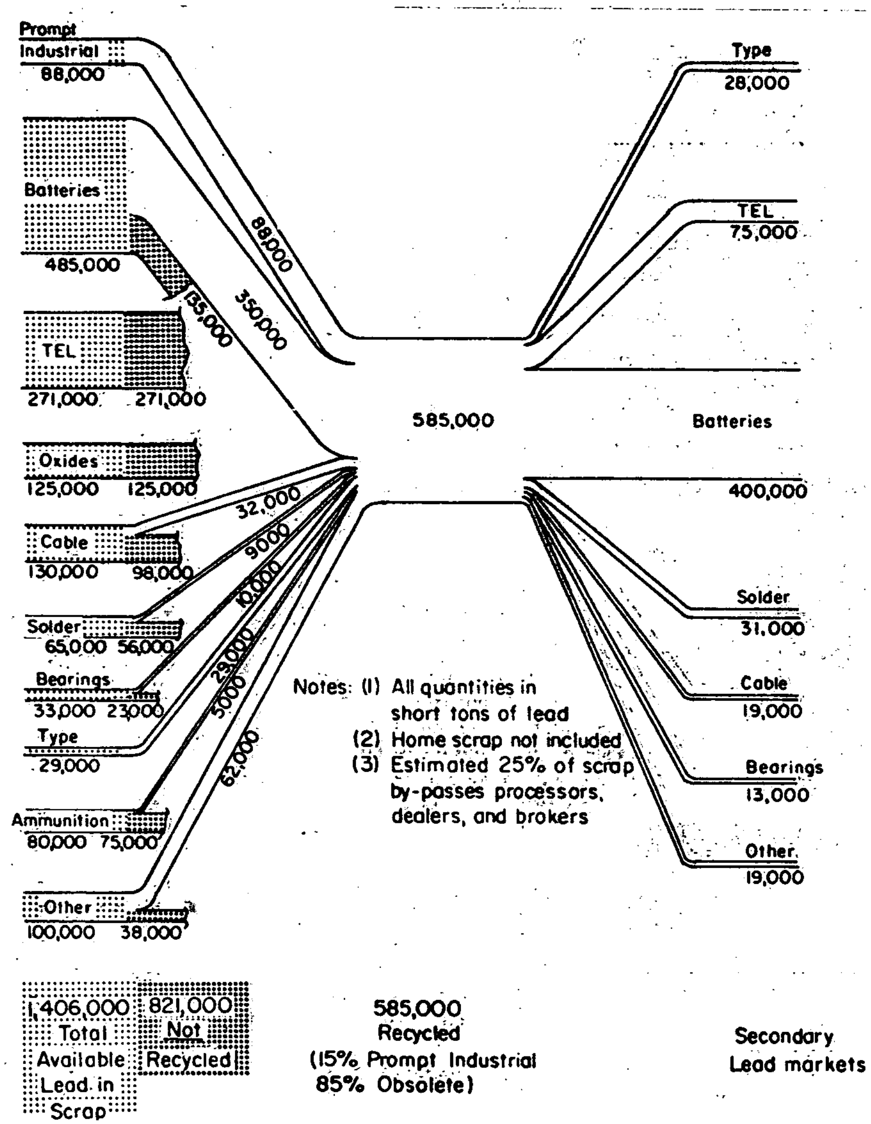


FIGURE I SCRAP/SECONDARY LEAD FLOW, 1969

TABLE I IDENTIFICATION AND ANALYSIS OF PROBLEMS CONCERNING LEAD THAT WAS NOT RECYCLED IN 1969

	Scrap Categories Where Some Lead Was Not Recycled				
	Battery Lead	Lead Cable Sheathing	Solders	Bearing Lead	Other Obsolete Lead Scrap
PROBLEM DEFINITION	1. Antimonial lead is used for structural and electrical parts of lead-acid storage batteries. 2. Lead oxides (usually produced by the battery manufacturers) are used for active materials on battery electrodes. 3. A typical automotive battery contains 10 lbs of antimonial lead and 10 lbs of lead oxides when manufactured. 4. Automotive battery sales are based on a trade-in allowance for the old batteries. 5. Thus, most worn out batteries are collected by sellers of new batteries.	1. Lead, because of its corrosion resistance, is used to sheath underground power and communications cables. 2. Polyethylene and other elastomeric sheathings have been developed that have economic advantages over lead. 3. Consumption of lead for cable sheathing has decreased to about 25% of what it once was. 4. At the end of their service lives, lead-sheathed cables are sold as scrap.	1. Tin-lead mixtures are commonly used as solders. 2. Cost of solders is decreased by increasing the lead content. 3. High-lead solders are commonly used for auto body and radiator use, cans, and other non-critical applications. 4. In most uses, the lead becomes intimately attached in small quantities to much larger quantities of other materials (copper, steel). 5. At the end of the useful lives of soldered products, method of disposal depends on value of materials other than the solder.	1. Lead-base alloys are often used as bearing surfaces for rotating parts. 2. Such bearings are used where the lower friction of rolling type bearing is not needed, or where cost or environmental factors rule against rolling-type bearings. 3. Lead is a small constituent of a much larger system of other materials in bearing uses. 4. Disposal of smaller lead bearings depends generally on the other materials. 5. Disposal of larger lead bearings is sometimes based on the lead value.	1. Considerable lead is used for its corrosion resistance in pipe, fittings, and sheet. 2. Some lead is used in foil and collapsible tubes. 3. Considerable lead is used as caulking material. 4. Some lead is used in weights and ballasts. 5. Some lead is used for several minor uses such as in terne metal, electric plating, annealing, and galvanizing. 6. Disposal methods vary widely depending on use and location at the end of the product's useful life.
TONS OF LEAD NOT RECYCLED	135,000	98,000	56,000	23,000	38,000
% OF AVAILABLE LEAD NOT RECYCLED	28	75	86	70	38
PROBLEM ANALYSIS	1. Most worn-out batteries are collected in economically recyclable quantities as a result of marketing practices for new batteries. 2. The recycling industry is set up to recycle battery lead effectively. 3. Logic and industry opinion would indicate that only a few % of battery lead should not be recycled. 4. Yet 28% is not recycled. 5. This is a promising area in which to increase recycling of lead.	1. After an average service life of 40 years, lead-sheathed cable is nearly 100% sold as scrap according to electric utilities and phone companies that use it. 2. Nearly all this lead is economically recoverable once it enters the recycling industry. 3. Thus only a few % should not be recycled. 4. Yet 75% is not recycled. 5. This is a promising area in which to increase recycling of lead.	1. In most cases, lead in solder ends its service life as minute quantities of lead bonded to other metals. 2. Thus, collection of this lead for recycling usually is incidental to collection of the other metals to which the lead is attached. 3. In most cases, economics dictate that the lead not be separated from these other materials. 4. In some cases it is separated and recovered as lead, especially when the tin content of the solder can be recovered as tin. 5. This is an area that has some promise for increasing the recycling of lead.	1. Much bearing lead is disposed of as part of a system that is primarily made of other metals. (For example, it does not pay to disassemble an auto engine for the small amount of lead in the bearings.) 2. When bearings are large and easily accessible, lead is often separated and recycled. 3. This area is not promising for increased recycling of lead.	1. Some of this lead (for example, foil, collapsible tubes, terne metal) is in forms or locations that make recycling difficult. 2. Some is easily recyclable (such as weights and ballasts, pipe and fittings, sheet). 3. Other (caulking, annealing) is marginal as to the economics of recycling and depends on specific cases. 4. Overall, the recycle rate is relatively high. 5. This area has limited possibilities for increased recycling of lead.

TABLE 11. IDENTIFICATION AND ANALYSIS OF PROBLEMS THAT DO NOT DIRECTLY REDUCE THE AMOUNT OF LEAD THAT IS RECYCLED[1]

	Declining Overall Markets[2]	Customer Prejudices	Battery Case Disposal	Battery Acid Disposal	Battery Breaking
Problem Definition	1. The tetraethyl lead market segment is expected to decline to zero within 10 years. 2. Cable sheathing, type metal, and caulking lead markets are expected to continue to decline slowly in the future. 3. Overall, growth of conventional markets for lead will be very small in the future.	1. Some lead users claim that secondary lead is inferior to primary lead. 2. It is doubtful if they actually believe this generalization. 3. They probably use this as basis for bargaining purposes.	1. For every ton of battery lead that is recycled, one-fourth to one-half ton of byproduct cases are produced. 2. These are worthless and a possible source of lead poisoning. 3. The disposal problem is large in quantity of cases, and requires care in method of disposal.	1. For every ton of battery lead that is recycled, one-fourth to one-half ton of byproduct acid is produced. 2. This is worthless and can pollute surface and ground waters. 3. The disposal problem is large in quantity of acid, and requires care in method of disposal.	1. Scrap batteries must have the case opened to get the lead out. 2. Hand and machine methods are used. 3. Tops are sheared or sawed off. Or cases are broken by sledge hammers or crushing machines. 4. Manual and hand-operated machine breaking are unpleasant jobs, making it difficult to hire and retain workers. 5. There is a trend to more automatic machine breaking. 6. Some industrial batteries are in metal containers requiring cutting torches to get the batteries out.
Effect on Recycle Rate	Some pressure on economics of recycling but no significant effect on quantities of lead that will be recycled.	No significant effect on quantities of lead that are recycled. Little economic effect.	No significant effect on quantities of lead that are recycled. Slight economic effect because of disposal cost.	No significant effect on quantities of lead that are recycled. Slight economic effect because of disposal cost.	No significant effect on the quantities of lead recycled. Some economic effect because of increas[ed] labor cost and investment cost fo[r] equipment.
Problem Analysis	1. It is unlikely that decline of tetraethyl lead market segment can be prevented in face of government pressure, and policies of auto manufacturers & oil companies. 2. It is unlikely that continued decline of some other market segments can be prevented where plastics and other materials have performance and economic advantages over lead. 3. Promotion and development efforts should be concentrated on market segments where lead has advantages. 4. Also, new uses and new alloys or fabrication methods should be developed to create new market segments for lead.	1. Secondary lead is <u>not</u> inferior to primary for the same grades. 2. Promotional efforts informing customers of equal quality of secondary, plus advantages of recycling may be desirable.	1. Battery cases cause an unusually large and unique disposal problem. 2. However, disposal costs are <u>not</u> a large percent of total operating cost. 3. Finding some uses for battery cases would be advantageous. 4. There is a trend to plastic cases in place of rubber. It is possible to charge these to the smelting furnaces.	1. Battery acid causes an unusually large and difficult disposal problem. 2. However, disposal costs are <u>not</u> a large percent of total operating costs. 3. Finding improved disposal methods would be advantageous.	1. Unavailability of labor, plus increasing cost of labor is forcing expansion of machine breaking methods. 2. This is causing larger and few[er] breaking operations. 3. Continued development of bette[r] and safer machine breaking methods is desirable.

(1) Problems adversely affect economics or practices of recycling but the effect in terms of amount can not be measured. This situation is considered an indirect effect.
(2) Includes markets for primary and recycled metals.

Recommendations

The ten problems were assigned priorities based on three factors:

- Potential for improvement of the environment
- Potential for conservation of natural resources
- Possibilities for realistic solutions.

On this basis, three of the problems were classified as high priority, and the other seven as lower priority. Table III gives recommended actions for the high priority problems. Table IV gives recommendations for the lower priority problems.

The question of who takes action is difficult to answer. Battelle suggests that NASMI and EPA continue their leadership in working on solid waste problems, recognizing that many other Federal Government agencies such as the Bureau of Mines, Council of Environmental Quality, and Department of Commerce, as well as state and local agencies will be involved.

TABLE III. RECOMMENDED ACTIONS, HIGH PRIORITY LEAD RECYCLING PROBLEMS

	Battery Lead That is Not Recycled	Lead Cable Sheathing That is Not Recycled	Battery Case Disposal
Actions Recommended	An investigation should be undertaken to determine why 135,000 tons of battery lead were not recycled in 1969. Once this determination has been made, appropriate additional analyses and plans can be made to increase the recycle rate if feasible.	An investigation should be undertaken to determine why 98,000 tons of lead cable sheathing were not recyled in 1969. Part of this may be explainable by errors in reporting by recycle companies or the U.S. Bureau of Mines. However, it is difficult to see how the entire 98,000 tons could be explained this way. Once reasons for the low recycle rate are determined, appropriate additional actions can be planned.	Disposal of battery cases provides an excellent subject for analysis of solid-waste by product problems. Cases are generated in large volume, cannot be burned without air pollution, are hazardous to health, and are dirty and unpleasant to handle. An investigation should be undertaken to find uses for the cases. If major uses can be found, the generation of solid waste will be greatly reduced, and economics of battery lead recycling will be improved.
By Whom (1)(2)(3)	EPA/NASMI	EPA/NASMI	EPA/NASMI
Specific Steps	1. Form a committee of secondary lead smelters and major processors of lead scrap. 2. Committee analyze and discuss the possible and probable reasons for the large quantity of battery lead that is not recycled. 3. Survey organizations involved in battery lead recycling: scrap processors secondary smelters battery retailers to determine what batteries are not being recycled and why. 4. Analyze survey results to determine if it is feasible to increase the recycle rate for battery lead, and if so how. 5. Take necessary actions (based on 4) to increase battery lead recycling.	1. Form a committee of secondary lead smelters and major processors of lead scrap. 2. Committee analyze and discuss the possible reasons for the low recycle rate for lead cable sheathing. 3. Discuss with the U.S. Bureau of Mines possible misunderstandings in reporting of lead cable sheathing. 4. Survey organizations involved in lead cable sheathing recycling: scrap processors secondary smelters electric utilities telephone companies cable manufacturers. 5. Analyze survey results to determine if recycle rate is indeed low, and if it is, how to increase it. 6. Take appropriate actions (based on results of 5).	1. Form a committee of battery breakers, smelters, scrap processors, and specialists in breaking. 2. Committee prepare rather comprehensive write-up on battery cases: sizes materials condition of cases foreign materials (lead, acid, dirt), etc. 3. Retain research organization to seek uses via . idea generation by creative groups . interviews with people and organizations pertinent to the subject . evaluation of idea for new uses . recommendations for additional actions if any 4. Investigate technical feasibility of best ideas for uses 5. Conduct R&D on feasible ide[illegible]

(1) The responsibility for recommended actions shown in this table are based on importance of the action, benefit to the taxpayers, and opportunities for NASMI. They are the best judgments of Battelle.

(2) Recommended actions were distributed between high priority and lower priority based on the evaluation with three criteria.

(3) It is suggested that NASMI continue its leading role in recycling, recognizing that other organizations such as the Bureau of Mines, Department of Commerce, Council of Environmental Quality, HEW Office of Information, and State, Local, and Federal Legislatures must be involved.

TABLE IV RECOMMENDED ACTIONS. LOWER PRIORITY LEAD RECYCLING PROBLEMS

	• Solders • Bearing Lead • Other Obsolete Lead Scrap that are Not Recycled	Declining Market Segments	Customer Prejudices	Battery Acid Disposal	Battery Breaking
Actions Recommended	A brief investigation should be undertaken to determine the feasibility of increasing the recycling of solders, bearing lead, and other obsolete lead scrap. If any feasible possibilities are found, additional actions can then be planned.	R&D should be pursued to develop new markets for lead. This may include new alloys or compounds, new forms, etc.	Publicity should be used to inform lead users of the purity and quality of secondary and primary lead. Additionally, the public service aspects of using secondary lead should be featured--clean up the environment, save natural resources.	An investigation should be undertaken to determine present battery acid disposal methods, and to find improved methods.	An investigation should be undertaken to develop improved methods of battery breaking.
(1)(2)(3) By Whom	NASMI	NASMI/Lead Industries Association/ILZRO	NASMI/NASMI Member Companies	NASMI/Battery Breakers	NASMI/Battery Breakers
Specific Steps	1. Set up a committee of secondary smelters and scrap processors. 2. Committee analyze what is not being recycled and why. 3. Recommend if it is feasible to try to increase recycling rate or not. 4. Survey recycling industry, if justified (based on 3), to more accurately determine what and why of materials not being recycled. 5. Determine what next actions to take.	1. Set up a committee of one NASMI staff member, and 2 secondary smelters to coordinate recycling industry interests with Lead Industries Association/ILZRO activities. 2. Discuss with Lead Industries Association how to work together to develop new lead markets--funding of R&D, selection of projects, etc.	1. Continue general publicity programs that promote recycling. 2. Inaugurate specific program to publicize recycling of lead. 3. Help member companies design publicity and advertising programs.	1. Set up a committee of battery breakers-smelters, scrap processors and specialists in breaking. 2. Prepare a report on present disposal methods and problems. 3. Investigate similar disposal problems of other industries. 4. Discuss improved methods of disposal with equipment and materials suppliers 5. Determine what additional actions should be taken.	1. Set up a committee of battery breakers-smelters, scrap processors, and specialists in breaking. 2. Prepare a report on present breaking methods, equipment, and problems. 3. Investigate improv methods of breakir 4. Determine what additional steps to take.

(1) The responsibility for recommended actions shown in this table are based on importance of the action, benefit to the taxpayers, and opportunities for NASMI. They are the best judgments of Battelle.

(2) Recommended actions were distributed between high priority and lower priority based on the evaluation with three criteria.

(3) It is suggested that NASMI continue its leading role in recycling, recognizing that other organizations such as the Bureau of Mines, Department of Commerce, Council of Environmental Quality, HEW Office of Information, and State, Local, and Federal Legislatures must be involved.

INTRODUCTION

In June, 1970, Battelle-Columbus undertook a research program for the National Association of Secondary Material Industries, Inc. (NASMI). This work was carried out under a subcontract from an Office of Solid Waste Management grant to NASMI. This report on lead is one of a series of eight commodity reports plus a general or summary report.

Background

The Office of Solid Waste Management is responsible for formulating and recommending Federal Government policies in the area of solid waste pollution. This includes pursuing appropriate research to determine the status and problems of solid waste activities, and to develop programs to reduce solid waste pollution.

One approach to the reduction of solid waste pollution is to reclaim waste materials for reuse - the recycling concept. A well established industry--the secondary materials industry--exists to accomplish this recycling. NASMI is the trade association representing the nonferrous metals, paper, and textiles portion of this industry.

The scrap processors, secondary smelters, and other companies that make up the secondary materials industry have developed effective channels and methods for recycling nearly all waste materials of economic value. These companies have performed their difficult and essential functions well in the traditional economic environment.

More recently additional dimensions have been added to this traditional economic environment. These new dimensions are (1) improvement of the environment in which we live, and (2) increased need for conservation of natural resources. These new dimensions provide new challenges and opportunities for the recycling industry. No longer is economic gain the sole driving force for recycling of waste materials. Social gain has been added in the forms of improved living conditions and preservation of resources for future generations. In an economics-based nation this creates problems of interpretation and evaluation of noneconomics-based goals and activities.

The purpose of this series of reports is to identify obstacles to the recycling of solid wastes, and to recommend directions for investigation and research to overcome these obstacles.

Objectives

The objective of the study on which this report is based was to identify opportunities for the increased utilization of solid waste. The major sub-objectives were:

(1) To determine the structure and functions of the secondary materials industry, and its relationships to sources of supply and markets

(2) To identify and evaluate problems of recycling - materials, sources, industry, and markets, and

(3) To determine opportunities for increased recycling.

Scope

The major subjects included in the scope of the study are the secondary materials industry, the materials it recycles, the sources of solid wastes, and the markets for recycled materials. Activities peripheral to these major subjects are considered where pertinent to recycling.

The materials included in the study are:

Aluminum	Nickel and Nickel Alloys
Copper and Copper Alloys	Precious Metals (Silver, Gold, and Platinum)
Lead	Paper
Zinc	Textiles

Research Methods

The methods and procedures used in the study are discussed under four types of activities. They include (A) literature search, (B) extensive survey, (C) in-depth survey, and (D) analysis and synthesis.

Literature Search

The literature search included reviewing and studying books, Government reports, industry reports, and trade journals covering solid waste handling and problems, recovery and market data, and recycling of valuable materials.

The results of this effort included the accumulation of data and descriptive material, and an organized bibliography dealing with each of the commodities covered in the scope of the study.

Extensive Survey

The extensive survey of the secondary materials industry consisted of a mail survey and personal interviews with management personnel of companies involved with the collection, processing, and sale of secondary materials. About 600 responses were received.

The information developed through the extensive survey included dollar sales, tons of major materials handled, types of solid waste processed, sources of materials, investment, equipment and facilities, number of employees, the amount of space used, and the grades and quantities of secondary materials produced.

The data from the extensive survey provided statistical tabulations of the regional distribution of the secondary materials industries by type of commodity in terms of numbers of establishments, volume of business, and numbers of employees.

In-depth Survey

The in-depth survey of selected members of the secondary materials industries, their suppliers, and the users of their products served to identify the major technical and economic problems facing those companies involved with secondary material utilization. About 200 interviews were completed. Battelle and NASMI commodity specialists jointly selected the companies to be interviewed in depth.

Interview guides for each of the commodities were prepared. The problems and potential solutions for greatest recycling and waste utilization that were developed from the literature search and prior Office of Solid Waste

Management work plus the knowledge of the NASMI commodity specialists provided the basis for designing the interview guide. Sample guides are reproduced in the Appendix.

Analysis and Synthesis

The analysis and synthesis step was concerned with the collation and analysis of data and information derived from both the literature, extensive survey, and in-depth survey. The analysis and synthesis activity covered the following tasks:

(1) Economic Data on the Secondary Materials Industries. The economic data developed through the extensive survey of the secondary materials industries were tabulated and analyzed as to the amount and type of solid waste handled and as to operational data such as number of employees, amount of space required, capitalization, and geographic locations.

(2) Flow Diagrams and Life Cycles. Flow diagrams were developed to indicate the flow of materials from primary production and scrap sources through fabrication. Life cycle estimates of various products were used to develop data on quantities available for possible recycling.

(3) Demand-Supply Relationships. Estimates were made of future demand and supply levels for secondary materials. The relationship between these data provide an indication of potential surpluses or shortages of recycled materials through 1980.

(4) Stability of Flow and Consumption. This analysis is closely related to the supply-demand analysis described above and identifies the ability of the various secondary materials to

compete as source materials for manufacturers. A number of factors were examined such as price changes in the secondary materials, the availability of materials, and the effect of sudden changes in the magnitude of demand.

(5) Direct Impacts of Technological Change. Direct technical and technological factors were examined to determine their effect on rates of processing and recycling. Potential changes that could take place in technology that could decrease or increase the rate of solid waste recovery were examined. This includes the identification of potentially recoverable solid wastes, the problems limiting the recovery to current levels, and the possibilities of technical advances through the use of known technology or through added scientific and engineering research.

(6) Constraints on Expansion of the Secondary Materials Industries. This analysis included consideration of elements critical to expansion of recycling - labor and management availability, laws and regulations, equipment availability, nature of solid waste materials, market needs, etc.

(7) Potentials for Expansion of the Secondary Materials Industries. Based on the constraints identified in the above task, plus examination of various methods for overcoming constraints, this task determined the ability of the secondary materials industries to meet new opportunities for recycling.

(8) Indirect Technological Change. The broad overall technological trends indirectly affecting the secondary materials industries were examined, and their probable impacts determined.

THE LEAD INDUSTRY

Primary and recycled lead can be used interchangeably for most applications. Thus, many of the markets for recycled lead are the same as those for primary lead, and there is competition between the two sources to supply lead to its markets.

This first section of the report provides a brief review of the lead industry - including both primary and recycled producers. Included are:

- Characteristics of Lead
- Characteristics of the Lead Industry
- Markets for Lead
- Market Outlook.

Characteristics of Lead

A variety of types and forms of lead are produced. Major among these are:

- Pig lead
- Antimonial lead
- Miscellaneous lead-base alloys
- Lead oxides, pigments, and chemicals.

Pig Lead

Table 1 gives specifications for the four common grades of pig lead (also called soft lead). Of these grades, corroding lead and chemical lead are not normally produced from scrap.

A fifth grade of pig lead is remelt lead produced from scrap. Since this is not reduced or refined, it is not a standard specification product. Its composition will vary depending upon the composition of the scrap that is melted.

Antimonial Lead

Antimonial lead (also called hard lead) includes a range of alloys meeting the specifications of different users. It is produced mainly from battery scrap and used largely in the manufacture of new batteries. Table 2 is a quote from The Association of American Battery Manufacturers, Inc. (AABM) yearbook pertinent to antimonial lead.

TABLE 1
STANDARD SPECIFICATIONS FOR PIG LEAD

(A.S.T.M. Designation B29-55)

	Corroding Lead	Chemical Lead	Acid Copper Lead	Common Desilverized Lead
Silver, maximum, percent	0.0015	0.020	0.002	0.002
Silver, minimum, percent	--	0.002	--	--
Copper, maximum, percent	0.0015	0.080	0.080	0.0025
Copper, minimum, percent	--	0.040	0.040	--
Silver and copper together, maximum, percent	0.0025	--	--	--
Arsenic, antimony, and tin together, maximum, percent	0.002	0.002	0.002	0.005
Zinc, maximum, percent	0.001	0.001	0.001	0.002
Iron, maximum, percent	0.002	0.002	0.002	0.002
Bismuth, maximum, percent	0.050	0.005	0.025	0.150
Lead (by difference), minimum, percent	99.94	99.90	99.90	99.85

TABLE 2

BATTERY MATERIALS SPECIFICATIONS

Unless otherwise detailed in this specification all material used in the construction of batteries shall conform to the best commercial practices. Active material, grid alloy or miscellaneous lead parts smelted from other batteries must be refined prior to subsequent use in new batteries.

Source: American Association of Battery Manufacturers, Yearbook, 1970.

Miscellaneous Lead-Base Alloys

A variety of other lead-base alloys are produced in limited quantities. More important among these are:

- Babbitts - used as bearing materials
- Solders - used for joining and filling metals
- Type metals - used in printing plates.

These alloys are generally produced to customer specifications, standard specifications, and brand names.

Lead Oxides, Pigments, and Chemicals

Nonmetal forms of lead that are produced in significant quantities include:

- Litharge
- Red lead
- White lead
- Black oxide
- Tetraethyl lead.

Specifications for oxides used in batteries (black oxide, litharge) are covered by the quote of Table 2. Other oxides meet public or private specifications depending on the customer.

Characteristics of the Lead Industry

The lead industry includes the institutions and activities necessary to process the lead-containing raw materials into the various usable grades of lead and lead compounds. Included are several types of companies:

Integrated producers	- mining, concentrating, smelting and refining
Miners	- mining, concentrating of ores
Primary smelters	- smelting and refining from ore
Secondary smelters	- smelting and refining from scrap
Scrap processors	- collecting, sorting, melting of scrap.

Materials Sources

The U.S. lead industry depends on the following sources for lead materials:[1]

	1969 Supply (lead content), tons
Domestic ores	515,000
Imported ores	125,000
Imported metal	285,000
Drosses, residues, and scrap	605,000

In recent years, domestic ores have increased substantially as a materials source, while the other three sources have remained constant.

(1) U.S. Bureau of Mines.

Materials Flow

There are four major sources of lead raw materials as shown above. In addition, the U.S. Strategic Stockpile can be a source or a market depending on whether it is a net seller or buyer in a specified year.

Figure 1 provides a materials flow balance for lead for the year 1969. The major importance of recycled lead is apparent, as is the heavy market dependence on batteries and tetraethyl lead. None of the other individual uses exceed 90,000 tons or about 5 percent of total consumption.

Lead Producers

Production of primary lead in the U.S. is dominated by five producers with over 85 percent of the total primary production:[1]

American Smelting & Refining Company	(38%)
St. Joseph Minerals Company	(20%)
American Metal Climax Company	(n.a.)
Bunker Hill Company	(19%)
U.S. Smelting, Refining & Mining Company	(7%)

There are over 200 additional companies that smelt or remelt lead in the United States. Most of these are secondary producers. The largest of these is NL Industries Inc.

Table 3 provides 1967 data (latest available) concerning primary and secondary lead smelters. This table is incomplete because more diversified companies are not included. Even so, it shows 19 primary and 112 secondary companies.

(1) "Economic Analysis of the Lead-Zinc Industry", April 1969, Chas. River Associates, Inc., Cambridge, Mass.

TABLE 3

GENERAL STATISTICS FOR LEAD ESTABLISHMENTS, 1967

Industry of Product Class Code	Industry or Product Class	Establishments (number)	All Employees: Number (1,000)	All Employees: Payroll ($ million)	Value Added by Manufacture ($ million)	Cost of Materials ($ million)	Value of Shipments ($ million)	Capital Expenditures, new ($ million)
3332	Primary Lead							
	Entire industry	19	2.7	18.9	48.3	270.8	304.0	18.5
33413	Secondary Lead (pig, ingot, shot, etc.)							
	(Primary product class of establishment)	62	3.4	23.3	43.0	218.6	263.5	3.4
	Establishments with 75% or more specialization	50	2.4	16.5	26.9	149.0	178.5	3.0

Source: U.S. Department of Commerce, Bureau of the Census, 1967 Census of Manufacturers, "Smelting and Refining of Nonferrous Metals and Alloys", p. 33C-10 and p. 33C-19.

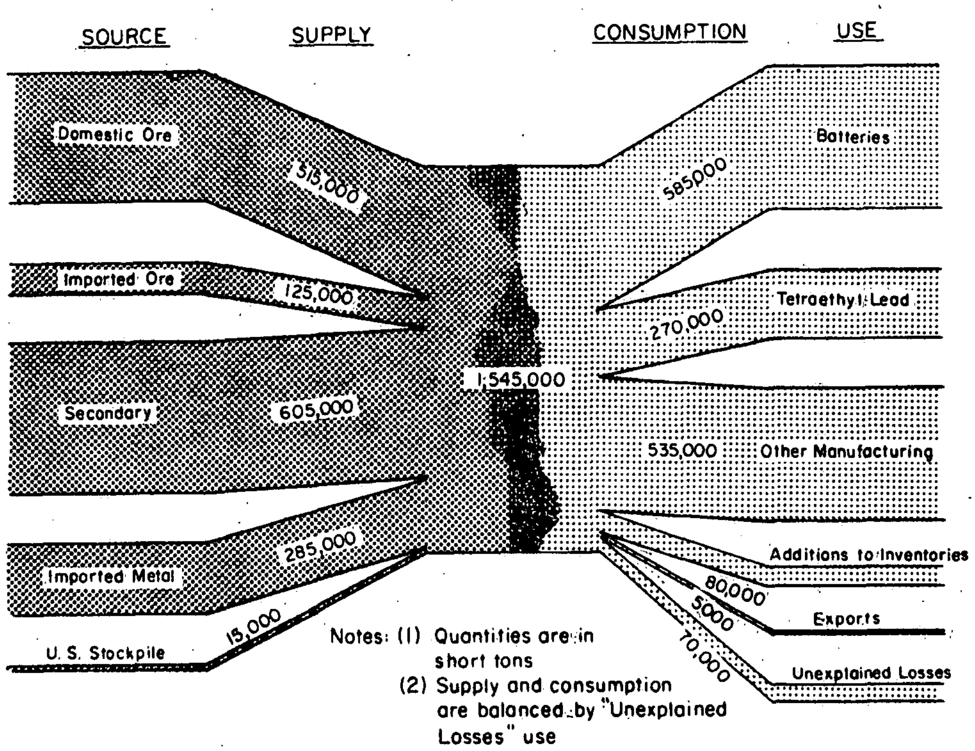


FIGURE 1. MATERIALS FLOW BALANCE, LEAD, 1969
Source: U. S. Bureau of Mines, Minerals Yearbook, 1969, "Lead" chapter

Markets for Lead

Markets for lead have increased slowly over the past 25 years - at an average annual rate of 0.5 percent. Figure 2 gives annual consumption since 1945 as reported by the U.S. Bureau of Mines.

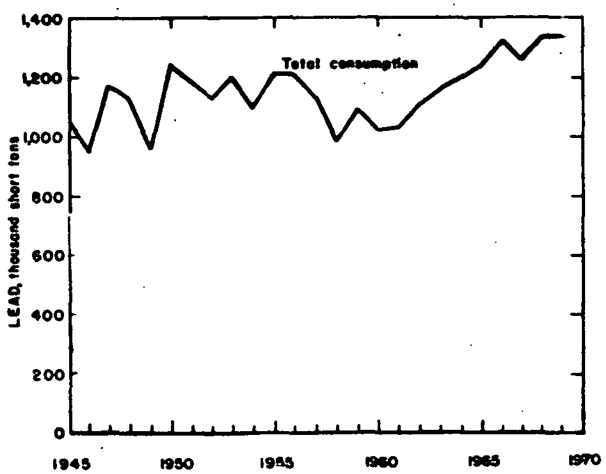


FIGURE 2. LEAD CONSUMTPION, U.S., 1945-1969

Source: U.S. Bureau of Mines, Minerals Yearbook, 1969, p. 625.

Table 4 gives a breakdown of lead consumption for 1969 by type of metal. Much of the soft lead is further processed to make lead oxides and tetraethyl lead. Most of the antimonial lead is used to manufacture storage battery parts.

Figure 2-A provides historical price data monthly for a 10-year period.

FIGURE 2-A. MONTHLY AVERAGE LEAD PRICES AT NEW YORK AND LONDON, 1960-1969

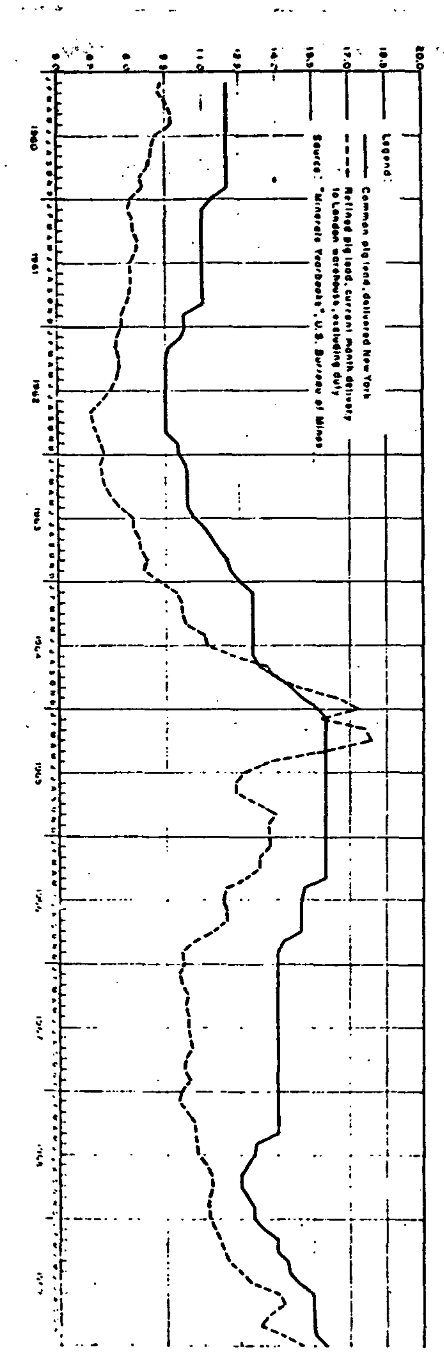


TABLE 4

LEAD CONSUMPTION BY TYPE OF METAL, U.S., 1969

Type of Metal	Short Tons of Lead
Soft Lead	900,858
Antimonial Lead	384,324
Alloys (other than copper-base)	51,426
Copper-Base Alloys	15,367
Other	37,383
TOTAL	1,389,358

Source: U.S. Bureau of Mines, Minerals Yearbook, 1969, "Lead" chapter.

Lead Use Pattern

The market for lead is characterized by one very large use (storage batteries - representing about 40 percent of the lead consumed annually), one large use (tetraethyl lead - representing about 20 percent of the lead consumed), and many small uses. Table 5 provides a use pattern for lead for 1969. Additional information is given in the Appendix concerning uses of lead.

Secondary Lead Markets

Markets for secondary lead accounted for 585,000 tons in 1969. This is included in the previous subsections on markets and use patterns. A more complete consideration of markets for secondary lead is presented in a later section, "The Lead Recycling Industry".

Market Outlook

The market outlook for lead is not favorable. If present trends continue, it is expected that tetraethyl lead (TEL) demand will decrease to nearly zero

TABLE 5

LEAD CONSUMPTION IN THE U.S., BY PRODUCTS (Short tons)

Product	1969
Metal Products:	
Ammunition	79,233
Bearing Metals	17,406
Brass and Bronze	21,512
Cable Covering	54,203
Caulking Lead	44,857
Casting Metals	9,918
Collapsible Tubes	12,484
Foil	5,881
Pipes, Traps, and Bends	19,407
Sheet Lead	25,818
Solder	72,626
Storage Batteries:	
Battery Grids, Posts, etc.	280,386
Battery Oxides	302,160
Terne Metal	1,583
Type Metal	25,660
TOTAL	973,134
Pigments:	
White Lead	6,617
Red Lead and Litharge	79,898
Pigment Colors	14,670
Other (1)	1,201
TOTAL	102,386
Chemicals:	
Gasoline Antiknock Additives	271,128
Miscellaneous Chemicals	602
TOTAL	271,730
Miscellaneous Uses:	
Annealing	4,252
Galvanizing	1,797
Lead Plating	406
Weights and Ballast	17,366
TOTAL	23,821
Other, Unclassified Uses	18,287
GRAND TOTAL (2)	1,389,358

(1) Includes lead content of leaded zinc oxide and other pigments.

(2) Includes lead which went directly from scrap to fabricated products.

Source: U.S. Bureau of Mines, Minerals Yearbook, 1969, "Lead" chapter.

during the next 10 years based on redesign of automotive engines and increased production of higher octane gasoline constituents. The automobile manufacturers and petroleum companies seem to be dedicated to this course.

The U.S. Bureau of Mines estimates annual growth rates during the 1970's as follows:

	Percent
Primary lead	1.6
Secondary lead	2.5

These estimates do not take into account the decreasing demand for lead in TEL. If the TEL market it lost by 1980, this is an annual average loss of 1.7 percent of the total lead market during the 11-year period from 1969-1980. Subtracting this from the 2.1 percent growth rate estimated by the Bureau of Mines gives a growth rate of only 0.4 percent annually. This compares with an average annual growth rate of 0.5 percent during the last 25 years.

The importance of this low future growth rate is that it may depress lead prices. This could then adversely affect the recycling of lead because of depressed scrap prices.

THE LEAD RECYCLING INDUSTRY

The lead recycling industry is organized to collect, process, and refine scrapped lead, and again make it available for use.[1] This industry and the materials it handles are reviewed in this section. The topics included are:

- Characteristics of Lead Materials
- Characteristics of the Lead Recycling Industry
- Recycled Lead Markets
- Materials Flow Pattern for Lead Recycling
- Demand/Supply Analysis.

Characteristics of Recycled Lead

Secondary Lead

All grades of lead can be made from scrap by secondary smelters. However, ASTM corroding lead and ASTM chemical lead are not normally produced by secondary smelters. Antimonial lead to customer specifications is the largest single tonnage of secondary lead. Other alloys such as bearing metals, type metals, and solders are important. Soft lead is also a large output of secondary smelters. Large tonnages of this soft lead are used to make tetraethyl lead and battery oxides.

Scrap and Drosses

The raw materials of the lead recycling industry are a variety of types of scrap and drosses. These materials vary from almost pure soft lead to drosses and alloys with over 25 percent impurities. Also, some lead scrap is mechanically mixed with other materials and must be separated. Notable examples of such products are storage batteries and lead-sheathed electrical cable.

(1) For a discussion of the functions of the recycling industry see Vol. I, General Report.

Table 6 provides NASMI definitions of standard grades of lead scrap.

Characteristics of the Lead Recycling Industry

Scrap metal dealers collect, handle, sort, segregate, and process the various grades of lead scrap for eventual shipment to secondary lead smelters, refiners, and consumers. A majority of these dealers also collect and handle other scrap metals. However, some dealers specialize in lead scrap, particularly those processing scrap batteries.

Dealers utilize modern equipment and materials handling methods in the processing of lead scrap. Lead cable strippers, for example, are used in removing the lead sheathing from cable. The separation of battery lead from batteries now involves saws, choppers, and guillotines.

A large proportion of scrap batteries by-passes the scrap metal dealer who is not a specialist. The processing of scrap batteries requires expensive equipment. Also, disposal of cases and acids is often difficult.

Lead scrap consumers consist of remelters, smelters, refiners, and manufacturers who convert scrap and residues into useful products.

Equipment and facilities in the secondary lead smelting and refining industry range from small remelting pots to complex furnace operations. These operations involve furnaces of various types, such as sweaters, blast and reverberatory furnaces, refining kettles, and special systems to recover lead and alloy metals. All secondary metal plants are equipped with chemical analysis facilities and spectrographic units. These are used to determine the compositions of the purchased scrap, and to adjust composition of the refined lead to desired specifications.

TABLE 6
GRADES OF LEAD SCRAP AND DROSSES

SCRAP LEAD - SOFT

Shall consist of clean soft scrap lead, free of all foreign materials such as drosses, battery lead, lead covered cable, hard lead, collapsible tubes, foil, type metals, zinc, iron, and brass fittings, dirty chemical lead. Free of radioactive materials.

MIXED HARD/SOFT SCRAP LEAD

Shall consist of clean lead solids, free of foreign materials, such as drosses, battery lead, lead covered cable, collapsible tubes, type metals, zinc, iron and brass fittings, dirty chemical lead. Free of radioactive materials.

BATTERY PLATES

If cells (plates, separators, and lugs) or battery plates, must be reasonably free of rubber. May be bought and sold by assay or as agreed between buyer and seller.

DRAINED WHOLE BATTERIES

Batteries to be free of liquid and extraneous material content. Aircraft (aluminum or steel cased) and other special batteries subject to special agreement.

BATTERY LUGS

Shall be free from battery plates, rubber and foreign material. A minimum of 97 percent metallic content is required.

LEAD COVERED COPPER CABLE

Free of armored covered cable, and foreign material.

LEAD DROSS

Should be clean and reasonably free of foreign matter, iron, dirt, harmful chemicals or other metals. Free of radioactive materials. Assay basis, or as agreed between buyer and seller. Other metals present such as antimony, tin, etc., to be accounted for as agreed between buyer and seller.

LEAD WEIGHTS

May consist of lead balances with or without iron, as may be specified. Free of foreign materials.

MIXED COMMON BABBITT

Shall consist of lead base bearing metal containing not less than 8 percent tin, free from Allens Metal, Ornamental, Antimonial and Type Metal. Must be free from all zincy and excessive copper in the alloy.

Source: NASMI.

Materials Sources

Lead for recycling comes from melters of lead (mostly as drosses and residues), from users of lead who generate scrap in making lead products, from users of lead-containing products as obsolete scrap, from demolition of buildings, and from scrappage of obsolete equipment containing lead.

The importance of the various types of lead scrap is shown in Table 7 which gives lead scrap consumption data by type of scrap.

TABLE 7

CONSUMPTION OF LEAD SCRAP BY TYPE, 1969

Type of Scrap	Short Tons of Scrap
Soft lead	57,791
Hard lead	15,553
Cable lead	31,983
Battery-lead plates	520,913
Mixed common babbitt	12,220
Solder and tinny lead	11,853
Type metals	32,462
Drosses and residues	114,988
GRAND TOTAL	797,763

Source: U.S. Bureau of Mines, Minerals Yearbook, 1969, "Lead" chapter.

Lead scrap prices vary greatly depending on prices of new lead, the grade of scrap, geographical location, availability, and other factors. Table 8 provides a rough indication of typical prices in 1969.

TABLE 8

LEAD SCRAP PRICES, 1969

Item	Price, ¢ per lb
Dross	8
Soft lead	12
Battery plates	7
Whole batteries, (drained)	4
Common Babbitt	10

Source: NASMI lead committee.

Recycled Lead Markets

Table 9 gives a 10-year history of recycled lead production (consumption is about the same as production). Also included is secondary production as a percent of total lead consumption. This has remained in the range of 40-46 percent for the 10-year period.

TABLE 9

RECYCLED LEAD PRODUCTION, 1960-1969

Year	Short Tons of Secondary Lead	Percent of Total Lead Consumption
1960	470,000	46
1	453,000	44
2	444,000	40
3	493,000	42
4	542,000	45
5	576,000	46
6	573,000	43
7	554,000	44
8	551,000	42
9	604,000	44

Source: U.S. Bureau of Mines, Minerals Yearbook, 1964 and 1969, "Lead" chapter.

Use Patterns

The use pattern for secondary lead is similar to that for all lead. Secondary and primary lead are more often than not indistinguishable from each other. Table 10 gives 1969 consumption data for secondary lead. The importance of batteries and tetraethyl lead as markets is apparent.

TABLE 10

CONSUMPTION OF SECONDARY LEAD BY USE, 1969

Use	Tons of Lead	Percent of Total
Batteries	400,000[1]	69
Tetraethyl lead	75,000[2]	13
Solder	31,000[3]	5
Type metal	28,000[3]	5
Cable sheathing	19,000[3]	3
Bearing metal	13,000[3]	2
Other uses	19,000[3]	3
TOTAL	585,000[3]	100

Notes: (1) Battelle estimate based on U.S. Bureau of Mines data.
(2) Battelle estimate based on opinions of secondary lead industry.
(3) U.S. Bureau of Mines data.
Source: U.S. Bureau of Mines, Minerals Yearbook, 1969, "Lead" chapter.

Industry Data

A survey of the recycling industry developed data to afford profiles of the industry and the companies making up the industry. Volume I, General Report, in this series gives many of these data. A few data concerning lead are given here and in Appendix B of this report.

The average recycler of lead compares with the average recycler of all commodities as follows:[1]

	Investment in Plant and Equipment	Number of Employees	Investment per Employee
Lead	$1,652,000	95	17,300
All commodities	1,480,000	71	20,800

Figure 3 shows the variation in size by census region of (1) lead scrap processors and (2) lead smelters. There is little correlation of sizes with population density, degree of industrialization, or other common regional indicators.

(1) Data from extensive survey.

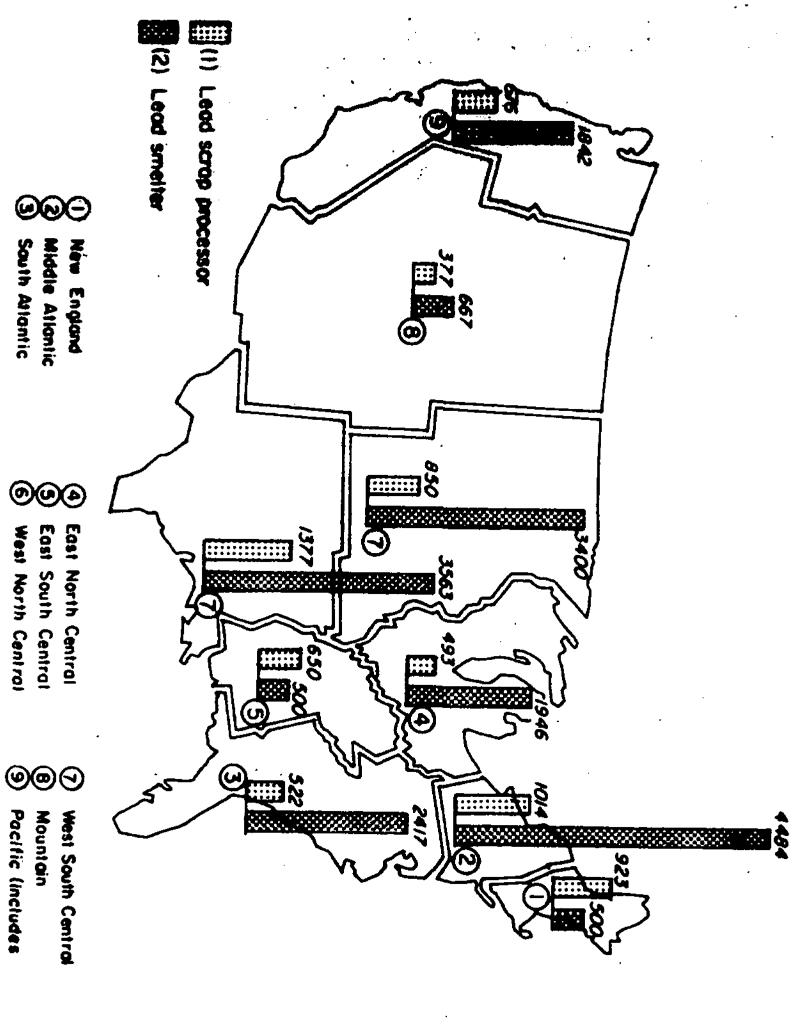


FIGURE 3. AVERAGE SIZE IN TONS PER YEAR OF LEAD OF (1) LEAD SCRAP PROCESSORS, AND (2) LEAD SMELTERS, BY REGION, 1969
Source: Extensive Survey

Materials Flow Pattern for Lead Recycling

Using data on scrap sources and markets for secondary lead in 1969, plus calculations of the quantities of lead scrap that should have been generated in 1969, it is possible to develop a materials flow pattern. Table 11 presents these data. Footnotes show sources and methods of derivation.

The first column of the table gives data concerning the quantities of lead that should have been scrapped in 1969 based on life cycles of the various sources. Thus, drosses are immediately available as a byproduct of lead melting. At the other extreme are lead sheathings for cable which are in use for an average of 40 years before they are scrapped. The quantity of lead used in production of cable sheathing in 1929 (actually the 1923-1935 average was used to smooth year-to-year variations) is the amount that should have been scrapped in 1969, and this is the 130,000 tons shown in Table 11. The other entries in the first column were calculated in a similar manner using the life cycles given in footnote (2).

Figure 4 presents the data of Table 11 in graphic form. The widths of the various channels are proportional to the quantities involved. The total amount of lead calculated to be available for recycling is shown by lightly shaded areas, the recycled lead is shown by the unshaded areas, and the lead that is not recycled is shown by darkly shaded areas. It can be seen that industrial scrap is not a problem - essentially all of it is recycled. But for the large categories of obsolete scrap--batteries, oxides, and cable sheathing--large quantities apparently are not recycled. The major reason for this is that it is not economically feasible. This will be discussed later in a problems section.

LEAD SCRAP RECYCLING, 1969

Scrap Source[1]	Tons of Lead Calculated to be Available for Recycling[2]	Tons of Lead Recycled	Percent Recycled	Tons of Lead Not Recycled
Drosses and residues	88,000	88,000[3]	100	--
Batteries	485,000[4]	350,000[3]	72	135,000
Tetraethyl lead	271,000	--	0	271,000
Oxides and chemicals	125,000	--	0	125,000
Cable sheathing	130,000	32,000[3]	25	98,000
Solder	65,000	9,000[3]	14	56,000
Bearing metal	33,000	10,000[3]	30	23,000
Type metal	29,000	29,000[3]	100	--
Ammunition	80,000	5,000[5]	6	75,000
Other obsolete scrap[6]	100,000	62,000[3]	62	38,000
TOTAL	1,406,000	585,000[3]	42	821,000

Notes: (1) "Drosses and residues" covers prompt industrial scrap. All other headings in column cover obsolete scrap.

(2) Calculated from estimated life cycles and consumption of lead that number of years prior to 1969. The life cycles used, and the years for which consumption data obtained are as follows:

Source	Life Cycle (years)	Years of Lead Consumption Used to Calculate Lead Availability
Drosses and residues	0.1	1969
Batteries	2.3	1966-1967 average
TEL	0.2	1969
Oxides and chemicals	20.0	1949-1950 average
Cable sheathing	40.0	1923-1935 "
Solder	20.0	1949-1950 "
Bearing metal	20.0	1949-1950 "
Type metal	2.0	1966-1968 "
Ammunition	0.5	1968-1969 "
Other obsolete scrap	30.0	1938-1939 "

(3) Based on U.S. Bureau of Mines data.

(4) Includes 40,000 tons/year of lead in litharge (Battelle estimate).

(5) Estimated by Battelle.

(6) Copper-based alloys not included.

Source: U.S. Bureau of Mines, Minerals Yearbooks, 1935 to 1969, "Lead" chapters.

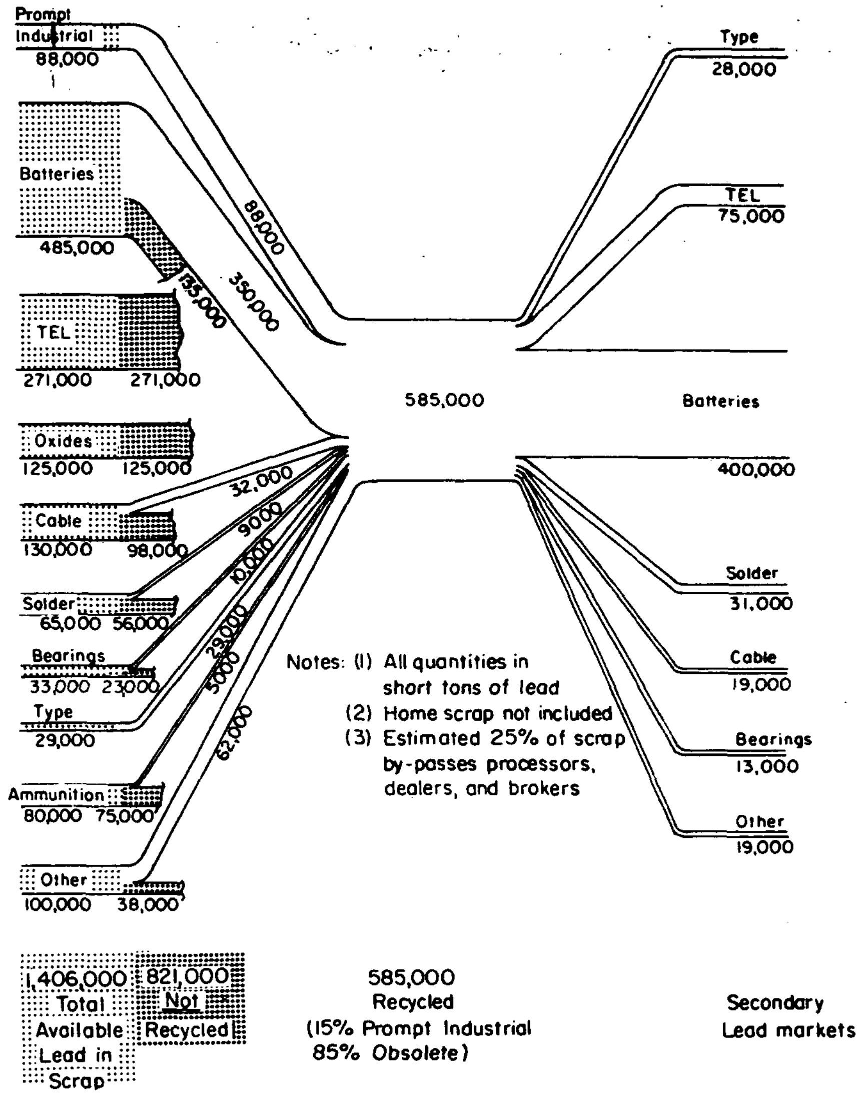


FIGURE 4. SCRAP/SECONDARY LEAD FLOW, 1969

Demand/Supply Analysis

A brief analysis of expected future demand and supply for secondary lead provides one indication of the future environment for lead recycling.

Demand

Demand for secondary lead in 1969 and future years is forecast as follows: (Based on growth rate for secondary lead of 0.4 percent annually [see Market Outlook subsection, p. 15]).

	Short Tons
1969	585,000
1974	595,000
1979	610,000

Supply

Future availability of secondary lead, based on present recovery rates is as follows: (Calculated by same method used to calculate 1969 availability [see Table 11]).

	Secondary Production
1969	585,000
1974	740,000
1979	830,000

Demand/Supply Balance

Surpluses of secondary lead (or lead scrap) are indicated for 1974 and 1979 based on (1) current recovery practices, (2) scrap availability forecasts, and (3) market forecasts:

	Short Tons of Lead 1974	1979
Demand	595,000	610,000
Supply	740,000	830,000
Surplus	145,000	220,000

The major reasons for the apparent future surplus of secondary lead are: (1) loss of TEL market, (2) nongrowth and decline of other markets (cable sheathing, type metal, solder, plumbing products, etc.), (3) rapidly increasing availability of lead scrap as calculated from life cycle data. However, these surpluses do not show what will happen. In reality it is expected that demand will increase to the supply level at the expense of lower demand for primary lead. The price of recycled lead is discounted to encourage its use. Buying prices for scrap are set to follow price reductions. However, if recycling increases more rapidly than expected, markets for secondary lead may become more critical to the recycling process in the future.

Effect on Lead Industry

It is reasonable to expect that an additional 213,000 short tons of lead could be recycled annually under ideal conditions.(1) If this much additional lead can be recycled by 1974, about 25 percent will be added to the predicted recycled lead supply in that year.

This is less than 13 percent of total supplies, or about a 2-1/2 percent increase each year for the 5 years between 1969 and 1974. This should not cause major upheaval in the lead industry. This additional recycled lead will be marketed at the expense of lower sales of domestic and imported primary lead because of the lower price for recycled. Since, there are large year-to-year variations in primary lead supplies (in the 1965-1969 period imported metal varied by 175,000 tons from lowest to highest year, production from domestic ores varied by 250,000 tons), growth of recycled lead supplies over a 5-year period should not cause unusual problems for the primary suppliers.

(1) The 213,000 tons was calculated based on the following changes in percent recycled:

	1969, percent	Goal, percent	Additional Recycled, tons
Batteries	72	90	86,500
Cable	25	90	85,000
Solders	14	50	23,500
Other Obsolete	62	80	18,000
		TOTAL	213,000

LEAD SCRAP RECYCLING PROBLEMS

There are several problems that directly reduce the amount of lead that is recycled.(1) In order to provide as quantitative a base as possible for analyzing the effects of the problems on recycling, the organization of this section follows the types of scrap.

Industrial Scrap

There are no types of prompt industrial lead scrap that are not close to 100 percent recycled. This is also true of drosses, flue dusts, and other materials generated during smelting of secondary lead. Some lead is lost in slags during secondary smelting, but these losses are very small. Thus, there are no problems concerning industrial lead scrap that directly reduce the amount of lead that is recycled.

Obsolete Scrap

Recycling of lead according to class of use varies from 0 percent (tetraethyl lead) to nearly 100 percent (type metal). The problem areas involve the following classes of uses:(2)

(1) Tetraethyl lead

(2) Oxides

(3) Cable sheathing

(4) Bearing lead

(5) Battery lead

(6) Solder

(7) Ammunition lead

(8) Other obsolete lead scrap.

(1) Problems that do not directly reduce the amount of lead that is recycled are discussed in the next major section of the report.
(2) Type metal scrap is not included because it is about 100 percent recycled.

Table 12 presents these problems in eight columns based on 1969 data. Included are: (1) definitions of the problems (2) tons of lead not recycled, (3) percent of lead calculated to be available but that was not recycled, and (4) analyses of the problems.

Four of the problems hold little or not promise for increased recycling of lead under present econimic conditions. These involve the following categories of lead that is not recycled:

- Tetraethyl lead
- Lead oxides and chemicals
- Ammunition lead
- Bearing lead.

In all four of these cases the lead is so widely dispersed, or so contaminated with other materials as to be virtually unrecoverable. Only for tetraethyl lead is this condition likely to change in the future. If catalytic air pollution control systems are installed on motor vehicles, the lead may be recoverable by the service stations that service the catalytic systems. Or if the systems do not require servicing, the lead might be recoverable when the auto is scrapped.

Two of the problems hold considerable promise for increased recovery and recycling of lead. These are the following categories where not all lead is now recycled:

- Battery lead
- Lead cable sheathing.

In both of these areas it is difficult to explain the high losses since recycling is economically attractive. It is believed that errors in reporting may account for some of the apparent losses. Some lead cable sheathing is probably reported in the "other" category. Perhaps even some of the battery lead is

TABLE 12 IDENTIFICATION AND ANALYSIS OF PROBLEMS CONCERNING LEAD THAT WAS NOT RECYCLED IN 1969

	Tetraethyl Lead	Lead Oxides and Chemicals (Excluding Battery Oxides and Tetraethyl Lead)
PROBLEM DEFINITION	1. Tetraethyl lead is added to gasoline in minute quantities. 2. The lead is converted to lead oxides and other compounds in the engine cylinder. 3. This lead is then deposited on engine parts, in the exhaust system, and exhausted to the atmosphere.	1. Included in this category are white lead, red lead, litharge (except for batteries), leaded zinc oxide, and miscellaneous chemicals. 2. These oxides and chemicals are used primarily in paints, ceramic glazes, rubber, insecticides, and several minor uses. 3. In nearly all uses, the lead compound becomes a minor constituent of a larger system.
TONS OF LEAD NOT RECYCLED	271,000	125,000
% OF AVAILABLE LEAD NOT RECYCLED	100	100
PROBLEM ANALYSIS	1. Annual discharge of lead for an average auto is 5 lb. 2. Recovery of this lead has insignificant economic value to the auto owner. 3. In the future, pollution-control devices may collect the lead. 4. These devices will probably require regular servicing. 5. The lead may be economically recoverable by the service station, and could then be recycled. 6. But lead in gasoline will decrease in future to reach near zero in 10 years. 7. Therefore, this is not a promising area in which to increase recycling of lead.	1. Lead is usually under 1% of a system with other materials. 2. The other materials are usually low-value materials such as wood, rubber, ceramics, or steel. 3. Little of these other materials are recycled. 4. It is nearly impossible technically and economically to separate the lead from the other materials for recycling the lead only. 5. This is not a promising area in which to increase recycling of lead.

TABLE 12 IDENTIFICATION AND ANALYSIS OF PROBLEMS CONCERNING LEAD THAT WAS NOT RECYCLED IN 1969 (Continued)

	Scrap Categories Where Some Lead Was Not Recycled		
	Battery Lead	Lead Cable Sheathing	Ammunition Lead
PROBLEM DEFINITION	1. Antimonial lead is used for structural and electrical parts of lead-acid storage batteries. 2. Lead oxides (usually produced by the battery manufacturers) are used for active materials on battery electrodes. 3. A typical automotive battery contains 10 lbs of antimonial lead and 10 lbs of lead oxides when manufactured. 4. Automotive battery sales are based on a trade-in allowance for the old batteries. 5. Thus, most worn out batteries are collected by sellers of new batteries.	1. Lead is used to sheath underground power and communications cables because of its corrosion resistance. 2. Polyethylene and other elastomeric sheathings have been developed that have economic advantages over lead. 3. Consumption of lead for cable sheathing has decreased to about 25% of what it once was. 4. At the end of their service lives, lead-sheathed cables are sold as scrap.	1. Lead is used for most small arms slugs and shot. 2. This lead is fired from guns at targets. 3. Most targets are outdoors (hunting areas, battlefields, trap-shooting ranges). 4. Thus, small bits of lead are scattered over thousands of square miles of land and water. 5. Some lead is fired into backstopped targets at shooting ranges.
TONS OF LEAD NOT RECYCLED	135,000	98,000	75,000
% OF AVAILABLE LEAD NOT RECYCLED	28	75	94
PROBLEM ANALYSIS	1. Most worn-out batteries are collected in economically recyclable quantities as a result of marketing practices for new batteries. 2. The recycling industry is set up to recycle battery lead effectively. 3. Logic and industry opinion would indicate that only a few % of battery lead should not be recycled. 4. Yet 28 percent is not recycled. 5. This is a promising area in which to increase recycling of lead.	1. After an average service life of 40 years, lead-sheathed cable is nearly 100% sold as scrap according to electric utilities and phone companies that use it. 2. Nearly all this lead is economically recoverable once it enters the recycling industry. 3. Thus only a few % should not be recycled. 4. Yet 75% is not recycled. 5. This is a promising area in which to increase recycling of lead.	1. Except for some shooting range ammunition, the lead is scattered in tiny bits over large land and water areas of the earth. 2. Each bit is worth only a fraction of a cent. 3. Thus, collection of this lead (except from shooting ranges) is completely uneconomic. 4. This area has no promise for increased recycling of lead.

TABLE 12 IDENTIFICATION AND ANALYSIS OF PROBLEMS CONCERNING LEAD THAT WAS NOT RECYCLED IN 1969 (Continued)

	Solders	Bearing Lead	Other Obsolete Lead Scrap
PROBLEM DEFINITION	1. Tin-lead mixtures are commonly used as solders. 2. Cost of solders is decreased by increasing the lead content. 3. High-lead solders are commonly used for auto body and radiator use, cams, and other non-critical applications. 4. In most uses, the lead becomes intimately attached in small quantities to much larger quantities of other materials (copper, steel). 5. At the end of the useful lives of soldered products, method of disposal depends on value of materials other than the solder.	1. Lead-base alloys are often used as bearing surfaces for rotating parts. 2. Such bearings are used where the lower friction of rolling type bearing is not needed, or where cost or environmental factors rule against rolling-type bearings. 3. Lead is a small constituent of a much larger system of other materials in bearing uses. 4. Disposal of smaller lead bearings depends generally on the other materials. 5. Disposal of larger lead bearings is sometimes based on the lead value.	1. Considerable lead is used for its corrosion resistance in pipe, fittings, and sheet. 2. Some lead is used in foil and collapsible tubes. 3. Considerable lead is used as caulking. 4. Some lead is used in weights and ballasts. 5. Some lead is used for several minor uses such as terne metal, lead plating, annealing, and galvanizing. 6. Disposal methods vary widely depending on use and location at the end of useful lives of products.
TONS OF LEAD NOT RECYCLED	56,000	23,000	38,000
% OF AVAILABLE LEAD NOT RECYCLED	86	70	38
PROBLEM ANALYSIS	1. In most cases, lead in solder ends its service life as minute quantities of lead bonded to other metals. 2. Thus, collection of this lead for recycling usually is a side light to collection of the other metals to which the lead is attached. 3. In most cases, economics dictate that the lead not be separated from these other materials. 4. In some cases it is separated and recovered as lead, often when the tin content of the solder is recovered as tin. 5. This is an area that has some promise for increasing the recycling of lead.	1. Much bearing lead is disposed of as part of a system that is primarily made of other metals. (For example, it does not pay to disassemble an auto engine for the small amount of lead in the bearings.) 2. When bearings are large and easily accessible, lead is often separated and recycled. 3. This area is not promising for increased recycling of lead.	1. Some of this lead (for example, foil, collapsible tubes, terne metal) is in forms or locations that make recycling difficult. 2. Some is easily recyclable (such as weights and ballasts, pipe and fittings, sheet). 3. Other (caulking, annealing) is marginal as to the economics of recycling and depends on specific cases. 4. Overall, the recycle rate is relatively high. 5. This area has limited possibilities for increased recycling of lead.

reported in the "other" category. Incomplete reporting by scrap processors and smelters may account for additional errors. However, it is unlikely that such errors can account for more than one-fourth of the apparent loss of the battery lead or more than one-half of the apparent loss of cable sheathing.

Discounting possible reporting errors, the actual loss of battery lead would still exceed 100,000 tons in 1969. This can be explained by such possible loss categories as military batteries, discards into trash collection channels, "permanent storage" losses in homes and garages, and similar factors.

The other two problem areas offer limited possibilities for increased recycling of lead:

- Solders
- Other obsolete lead scrap.

In both of these categories there are wide variations in the types of applications so that some lead is economically recoverable while other lead is not. It is doubtful that more than a minor amount of additional lead could be realistically recycled in these categories.

Other Problems

Depletion Allowances

One other important problem that directly reduces the recycling of lead but for which it is impossible to measure the magnitude of the reduction, is the subsidy allowed the primary industry in the form of ore depletion allowances. A similar subsidy for the secondary lead industry would allow higher scrap purchase prices and processing costs at fixed profit levels and sales prices. An unknown additional quantity of lead would be recycled as a result.[1]

(1) See Volume I, General Report, for additional discussion of depletion allowances.

Calcium Lead

Another problem may arise in the future that could seriously affect the recycling of battery lead. This is a change from antimonial lead to calcium lead alloys for storage battery parts. There is activity in the area of such a change, but it is impossible to predict if and when such a change will occur for the bulk of automotive batteries.

If this change does take place rapidly it could seriously interfere with recycling. Antimonial lead would be pouring into the smelter as scrap, but antimony would have to be removed and calcium added to provide the new alloys required by the battery manufacturers. This could slow the flow of metal through the smelters as they adjust to new operating procedures. It could also cause a buyers' market in antimony that would make it difficult to sell the antimony.

If this problem does arise, it would be temporary in nature. Within a few years the calcium batteries would be coming back as scrap. The smelters would settle down to the new routine of smelting calcium lead instead of antimonial lead.

LEAD RECYCLING INDUSTRY PROBLEMS

There are several problems faced by the lead recycling industry that have no direct measurable effect on the rate of recycling. Rather, they have economic effects on the industry, or make operations more difficult. These may indirectly affect the recycling rate. These problems are:

(1) Declining markets for lead

(2) Customer prejudices against secondary lead

(3) Battery case disposal

(4) Battery acid disposal

(5) Slag disposal

(6) Battery breaking.

Table 13 discusses each of these problems. Included are (1) titles of problems, (2) definitions of problems, (3) effect on recycling, and (4) analyses of problems.

Two of the problems in Table 13 concern the markets for lead:

- Declining markets
- Customer prejudices.

Customer prejudices against secondary lead are relatively minor and do not cause a serious problem. It is deserving of little or no attention other than to say promotional efforts could help erase any irrational user preference for primary over secondary.

Declining market segments for lead could have significant affects on the economics of lead recycling. The secondary smelters will have to find new markets as tetraethyl lead demand falls off. Equally important, prices for lead may decline because of this loss of an important market.

TABLE 13 IDENTIFICATION AND ANALYSIS OF PROBLEMS THAT DO NOT DIRECTLY[(1)] REDUCE THE AMOUNT OF LEAD THAT IS RECYCLED

	Declining Overall Markets[(2)]	Customer Prejudices	Battery Case Disposal
Problem Definition	1. The tetraethyl lead market segment is expected to decline to zero within 10 years. 2. Cable sheathing, type metal, and calking lead markets are expected to continue to decline slowly in the future. 3. Overall, market growth for lead will be very small in the future	1. Some lead users claim that secondary lead is inferior to primary lead. 2. It is doubtful if they actually believe this generalization. 3. They probably use this as basis for bargaining purposes.	1. For every ton of battery lead that is recycled, one-fourth to one-half ton of byproduct cases are produced. 2. These are worthless and a possible source of lead poisoning. 3. The disposal problem is large in quantity of cases, and requires care in method of disposal.
Effect on Recycle Rate	Some pressure on economics of recycling but no significant effect on quantities of lead that will be recycled.	No significant effect on quantities of lead that are recycled. Little or no economic effect.	No significant effect on quantities of lead that are recycled. Slight economic effect because of disposal cost.
Problem Analysis	1. It is unlikely that decline of the tetraethyl lead market segment can be prevented in face of government pressure, and policies of auto manufacturers & oil companies. 2. It is unlikely that continued decline of some other market segments can be prevented where plastics and other materials have performance and economic advantages over lead. 3. Promotion and development efforts should be concentrated on market segments where lead has advantages. 4. Also, new uses and new alloys or fabrication methods should be developed to create new market segments for lead.	1. Secondary lead is not inferior to primary for the same grades. 2. Promotional efforts informing customers of equal quality of secondary, plus advantages of recycling may be desirable.	1. Battery cases cause an unusually large and unique disposal problem. 2. However, disposal costs are not a large percent of total operating cost. 3. Finding some uses for battery cases would be advantageous. 4. There is a trend to plastic cases in place of rubber. It is possible to charge these to the smelting furnaces.

(1) Problems adversely affect economics or practices of recycling but the effect in terms of amount can not be measured. This situation is considered an indirect effect.

(2) Includes markets for primary and recycled metals.

TABLE 13 IDENTIFICATION AND ANALYSIS OF PROBLEMS THAT DO NOT DIRECTLY REDUCE THE AMOUNT OF LEAD THAT IS RECYCLED (Continued)

	Battery Acid Disposal	Slag Disposal	Battery Breaking
Problem Definition	1. For every ton of battery lead that is recycled, one-fourth to one-half ton of byproduct acid is produced. 2. This is worthless and can pollute surface and ground waters. 3. The disposal problem is large in quantity of acid, and requires care in method of disposal.	1. Significant quantities of lead-containing slags are produced as a byproduct of secondary smelting of lead. 2. These have no economic value. 3. They are commonly disposed of by dumping on company premises. 4. Alternative disposal methods may be required at some future date.	1. Scrap batteries must have the case opened to get the lead out. 2. Hand and machine methods are used. 3. Tops are sheared or sawed off. Or cases are broken by sledge hammers or crushing machines. 4. Manual and hand-operated machine breaking are unpleasant jobs, making it difficult to hire and retain workers. 5. There is a trend to more automatic machine breaking. 6. Some industrial batteries are in metal containers requiring cutting torches to get the batteries out.
Effect on Recycle Rate	No significant effect on quantities of lead that are recycled. Slight economic effect because of disposal cost.	No effect on recycling. Little or no economic effect now.	No significant effect on the quantities of lead recycled. Some economic effect because of increasi[ng] labor cost and investment cost for equipment.
Problem Analysis	1. Battery acid causes an unusually large and difficult disposal problem. 2. However, disposal costs are <u>not</u> a large percent of total operating costs. 3. Finding improved disposal methods would be advantageous.	1. Slag disposal is a normal type of business activity. 2. No attention need be given to this problem.	1. Unavailability of labor, plus increasing cost of labor is forcing expansion of machine breaking methods. 2. This is causing larger and fewe[r] breaking operations. 3. Continued development of better and safer machine breaking methods is desirable.

The other four problems of Table 13 involve operations of the lead recycling industry:

- Battery case disposal
- Battery acid disposal
- Slag disposal
- Battery breaking.

The first three of these problems involve waste disposal. Of these, slag disposal is relatively minor. It could become more important in the future, but has little or no effect on recycling at present.

Disposal of battery cases and battery acid are much more serious problems than slag disposal. Both wastes can be classed as hazardous because of lead content (as sludge). Both are generated in relatively large quantities. Both warrant attention so as to prevent pollution and health hazards.

Battery breaking is the last problem. It is an unpleasant operation if mechanized breaking equipment is not used. Thus, labor is hard to find to fill breaking jobs. Fortunately, the recycling industry is making good progress in the mechanization of the breaking operation, and the problem is being solved.

COURSES OF ACTION CONCERNING THE RECYCLING OF LEAD

Having identified the major problems concerning the recycling of lead, it is necessary to evaluate them and select those that are amenable to solutions. Then, courses of action can be developed to lead to solutions for the problems.

Evaluation of Problems

The fourteen problems that have been identified cover a wide range of importance and possibilities for solutions. It is necessary to evaluate the differences in order to assign priorities for actions.

Four of the problems can be assigned low priorities readily. These, with the reasons they are low priority, are as follows:

Problem	Reason for Low Priority
Tetraethyl lead that is not recycled	The actions leading to the solution of the problem are already underway: (1) Lead is being removed from gasoline. (2) Automotive pollution control devices are under development that could make the lead recyclable.
Lead oxides that are not recycled	Collection and separation of the lead is beyond any foreseeable technical or economic development that would make it feasible.
Ammunition lead that is not recycled	No feasible collection method seems possible.
Slag disposal	This is no more than a minor operating problem of the secondary smelters.

It is recommended that no further attention be given to these four problems.

The other ten problems are all of some importance and a method was needed for determining which ones are more important.

The method used is based on how the ten compare with each other when scored with three criteria:

- Solution of the problem will improve the environment
- Solution of the problem will conserve natural resources
- Realistic solutions can be found

In the context of this report, the first of these criteria is believed to be more important than the other two. It is weighted to allow a high score equal to the total of the other two.

Table 14 presents the results of the evaluation of the ten problems using the three criteria. In this evaluation three of the problems have total scores substantially higher than the other seven. They are those involving battery lead, lead cable sheathing, and battery case disposal.

These three problems are rated as high priority, and actions to solve them should be fully investigated before considering the seven lower priority problems.

Recommended Actions

The recommendations of what to do about the ten major problems of the lead recycling industry are covered in two parts:

(1) High priority actions

(2) Lower priority actions

The high priority actions should be dealt with before attention is given to the lower priority actions.

TABLE 14 EVALUATION OF TEN PROBLEMS RELATED TO RECYCLING OF LEAD

Problems	Criteria and Scores: Solution of Problem Will Improve Environment (10)	Solution of Problem Will Conserve Natural Resources (5)	Realistic Solutions Can be Found (5)	Total Scores
Battery lead	10	5	5	20
Lead cable sheathing	8	4	5	17
Solders	4	2	1	7
Bearing lead	2	1	1	4
Other obsolete lead scrap	3	2	3	8
Declining markets	0	0	5	5
Customer prejudices	0	0	5	5
Battery case disposal	10	0	5	15
Acid disposal	5	0	5	10
Battery breaking	1	0	5	6

Notes: (1) First criteria is considered most important and is assigned maximum score of 10.
(2) Other two criteria are considered less important and are assigned maximum scores of 5 each.
(3) The higher the total score, the more attractive the problem is for further action.

High Priority Actions

The high priority actions recommended here are important and far-reaching enough to be in the public interest. Thus, participation by EPA is desirable. Participation by NASMI and its members is also desirable since the problems and actions are predominately within the boundaries of the lead recycling industry.

Table 15 presents the recommended action programs for the high priority lead recycling problems.

The solutions to the first two problems-- battery lead and lead cable sheathing--involve learning the details as to why large quantities of lead are shown as not being recycled. The members of the recycling industry interviewed suggest that these are statistical errors based on incomplete or inaccurate reporting. The U.S. Bureau of Mines does not think such large quantities can be accounted for in this way. The Battelle-Columbus method of calculating quantities (based on life cycles) available for recycling probably introduces some error. These possible statistical errors may mean that the 135,000 tons of battery lead shown as not being recycled is as much as 25 percent too high. If so, about 100,000 tons were not recycled - still a large amount. Table 15 recommends that NASMI survey members discover why this lead is not being recycled, and based on this determine what actions to take. A similar recommendation is made concerning lead cable sheathing.

The solution recommended for the third high priority problem--battery case disposal--is to seek economic uses for battery cases.

TABLE 15 RECOMMENDED ACTIONS. HIGH PRIORITY LEAD RECYCLING PROBLEMS

	Battery Lead That is Not Recycled	Lead Cable Sheathing That is Not Recycled	Battery Case Disposal
Actions Recommended	An investigation should be undertaken to determine why 135,000 tons of battery lead were not recycled in 1969. Once this determination has been made, appropriate additional analyses and plans can be made to increase the recycle rate if feasible.	An investigation should be undertaken to determine why 98,000 tons of lead cable sheathing were not recycled in 1969. Part of this may be explainable by errors in reporting by recycle companies or the U.S. Bureau of Mines. However, it is difficult to see how the entire 98,000 tons could be explained this way. Once reasons for the low recycle rate are determined, appropriate additional actions can be planned.	Disposal of battery cases provides an excellent subject for analysis of solid-waste by product problems. Cases are generated in large volume, cannot be burned without air pollution, are hazardous to health, and are dirty and unpleasant to handle. An investigation should be undertaken to find uses for the cases. If major uses can be found, the generation of solid waste will be greatly reduced, and economics of battery lead recycling will be improved.
By Whom(1)(2)(3)	EPA/NASMI	EPA/NASMI	EPA/NASMI
Specific Steps	1. Form a committee of secondary lead smelters and major processors of lead scrap. 2. Committee analyze and discuss the possible and probable reasons for the large quantity of battery lead that is not recycled. 3. Survey organizations involved in battery lead recycling: scrap processors secondary smelters battery retailers to determine what batteries are not being recycled and why. 4. Analyze survey results to determine if it is feasible to increase the recycle rate for battery lead, and if so how. 5. Take necessary actions (based on 4) to increase battery lead recycling.	1. Form a committee of secondary lead smelters and major processors of lead scrap. 2. Committee analyze and discuss the possible reasons for the low recycle rate for lead cable sheathing. 3. Discuss with the U.S. Bureau of Mines possible misunderstandings in reporting of lead cable sheathing. 4. Survey organizations involved in lead cable sheathing recycling: scrap processors secondary smelters electric utilities telephone companies cable manufacturers. 5. Analyze survey results to determine if recycle rate is indeed low, and if it is, how to increase it. 6. Take appropriate actions (based on results of 5).	1. Form a committee of battery breakers, smelters, scrap processors, and specialists in breaking. 2. Committee prepare rather comprehensive write-up on battery cases: sizes materials condition of cases foreign materials (lead, acid, dirt), etc. 3. Retain research organization to seek uses via . idea generation by creative groups . interviews with people and organizations pertinent to the subject . evaluation of idea for new uses . recommendations for additional actions if any 4. . Investigate technical feasibility of best ideas for uses 5. . Conduct R&D on feasible ide.

(1) The responsibility for recommended actions shown in this table are based on importance of the action, benefit to the taxpayers, and opportunities for NASMI. They are the best judgments of Battelle.

(2) Recommended actions were distributed between high priority and lower priority based on the evaluation with three criteria.

(3) It is suggested that NASMI continue its leading role in recycling, recognizing that other organizations such as the Bureau of Mines, Department of Commerce, Council of Environmental Quality, HEW Office of Information, and State, Local, and Federal Legislatures must be involved.

Lower Priority Actions

The lower priority actions that are recommended are neither important enough, nor far-reaching enough to be of much interest to the public. Thus, participation by EPA is not recommended. The problems involve primarily NASMI, its members, other companies involved in the lead recycling industry, and other organizations concerned with lead.

Table 16 presents the recommended action programs for the lower priority problems of lead recycling.

Programs are already underway concerning two of these problems. The Lead Industries Association has an R&D program to develop new markets for lead to replace declining market segments. NASMI has a program to promote recycled materials, including lead, as a means of overcoming customer prejudices.

Other Actions

Additional actions involving markets, scrap sources, recycling industry operations, equipment, and legal requirements are recommended in Volume I, the General Report of this series. Some of these relate to the recycling of lead. Refer to the General Report for additional information.

TABLE 16 RECOMMENDED ACTIONS, LOWER PRIORITY LEAD RECYCLING PROBLEMS

	• Solders • Bearing Lead • Other Obsolete Lead Scrap that are Not Recycled	Declining Market Segments	Customer Prejudices	Battery Acid Disposal	Battery Breaking
Actions Recommended	A brief investigation should be undertaken to determine the feasibility of increasing the recycling of solders, bearing lead, and other obsolete lead scrap. If any feasible possibilities are found, additional actions can then be planned.	R&D should be pursued to develop new markets for lead. This may include new alloys or compounds, new forms, etc.	Publicity should be used to inform lead users of the purity and quality of secondary and primary lead. Additionally, the public service aspects of using secondary lead should be featured--clean up the environment, save natural resources.	An investigation should be undertaken to determine present battery acid disposal methods, and to find improved methods.	An investigation should be undertaken to develop improved methods of battery breaking.
(1)(2)(3) By Whom	NASMI	NASMI/Lead Industries Association/ILZRO	NASMI/NASMI Member Companies	NASMI/Battery Breakers	NASMI/Battery Breakers
Specific Steps	1. Set up a committee of secondary smelters and scrap processors. 2. Committee analyze what is not being recycled and why. 3. Recommend if it is feasible to try to increase recycling rate or not. 4. Survey recycling industry, if justified (based on 3), to more accurately determine what and why of materials not being recycled. 5. Determine what next actions to take.	1. Set up a committee of one NASMI staff member, and 2 secondary smelters to co-ordinate recycling industry interests with Lead Industries Association/ILZRO activities. 2. Discuss with Lead Industries Association how to work together to develop new lead markets--funding of R&D, selection of projects, etc.	1. Continue general publicity programs that promote recycling. 2. Inaugurate specific program to publicize recycling of lead. 3. Help member companies design publicity and advertising programs.	1. Set up a committee of battery breakers-smelters, scrap processors and specialists in breaking. 2. Prepare a report on present disposal methods and problems. 3. Investigate similar disposal problems of other industries. 4. Discuss improved methods of disposal with equipment and materials suppliers 5. Determine what additional actions should be taken.	1. Set up a committee of battery breakers-smelters, scrap processors, and specialists in breaking. 2. Prepare a report on present breaking methods, equipment, and problems. 3. Investigate improved methods of breaking 4. Determine what additional steps to take.

(1) The responsibility for recommended actions shown in this table are based on importance of the action, benefit to the taxpayers, and opportunities for NASMI. They are the best judgments of Battelle.

(2) Recommended actions were distributed between high priority and lower priority based on the evaluation with three criteria.

(3) It is suggested that NASMI continue its leading role in recycling, recognizing that other organizations such as the Bureau of Mines, Department of Commerce, Council of Environmental Quality, HEW Office of Information, and State, Local, and Federal Legislatures must be involved.

APPENDIX A

LEAD MARKETS

Uses of Lead

Table A-1 provides a detailed breakdown of lead consumption by use since 1965.

TABLE A-1. **United States Consumption of Lead** *
(In short tons)

	1965	1966	1967	1968	1969[a]
Ammunition	57,322	78,435	78,766	82,193	79,233
Bearing metals	21,600	21,588	19,561	18,441	17,406
Brass and bronze	23,699	25,447	20,467	21,021	21,512
Cable covering	59,645	66,491	63,037	53,456	54,203
Calking lead	66,584	63,250	48,789	49,718	44,857
Casting metals	5,046	6,671	10,083	8,693	9,918
Collapsible tubes	10,893	11,987	11,299	9,310	12,484
Foil	4,805	6,041	6,148	6,114	5,881
Pipe, traps and bends	19,837	19,984	20,184	21,098	19,407
Sheet lead	27,569	28,938	26,763	28,271	25,818
Solder	77,819	78,898	68,833	74,074	72,626
Storage batteries	455,347	472,492	466,665	513,703	582,546
Terne metal	2,109	1,966	1,620	1,427	1,583
Type metal	33,416	30,421	28,554	27,981	25,660
White lead	8,414	8,131	8,087	5,857	6,617
Red lead and litharge	79,853	89,500	76,589	86,480	79,898
Pigment colors	12,553	13,695	13,041	14,163	14,670
Other pigments	8,063	8,562	5,473	3,234	1,201
Gasoline antiknock additives	225,203	246,879	247,170	261,897	271,128
Misc. chemicals	346	614	609	629	602
Annealing	5,719	5,441	4,202	4,194	4,252
Galvanizing	1,775	1,639	1,854	1,755	1,797
Lead plating	240	428	532	389	406
Weights and ballast	14,135	18,090	15,794	16,768	17,366
Other uses unclassified	19,490	18,289	16,396	17,924	18,289
TOTAL	1,241,482	1,323,877	1,260,516	1,328,790	1,389,358

* U.S. Bureau of Mines, Minerals Yearbooks, 1965, 1967, and 1969, "Lead" chapters.

Storage Batteries. Table A-2 gives the percent distribution of numbers of motor vehicle batteries shipped by category of usage for the 3-year period 1966-1968.

TABLE A-2. SHIPMENTS OF BATTERIES, U.S. MANUFACTURERS, BY USE CATEGORY, PERCENT, 1966-1968 AVERAGE

Use Category	Percent of Total Units
Replacement	76
Original Equipment	23
Export	1
TOTAL	100

Source: American Association of Battery Manufacturers, Yearbook, 1970.

Figure A-1 shows lead consumption by battery manufacturers annually since 1946.

Year	Tons
1946	260,000
1947	380,000
1948	373,300
1949	280,600
1950	406,800
1951	353,800
1952	330,000
1953	356,500
1954	337,300
1955	380,000
1956	370,771
1957	361,015
1958	312,725
1959	380,732
1960	353,196
1961	367,998
1962	419,906
1963	439,100
1964	429,348
1965	455,347
1966	472,492
1967	466,665
1968	513,703
1969	582,546

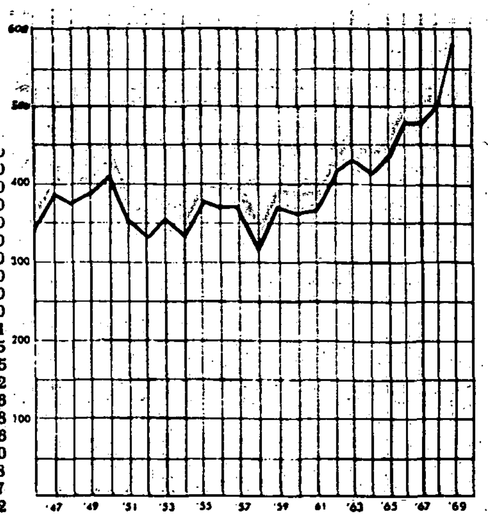


FIGURE A-1. TOTAL LEAD USED BY BATTERY MANUFACTURERS Includes primary, secondary, and antimonial lead in tons of 2000 lbs.

Source: U.S. Bureau of Mines, Minerals Yearbooks, 1946 to 1969, "Lead" chapters.

Figure A-2 shows the annual production of lead oxide by battery manufacturers since 1946.

Year	Tons
1947	69,000
1948	69,000
1949	55,000
1950	80,000
1951	77,000
1952	76,000
1953	82,000
1954	79,233
1955	113,800
1956	106,956
1957	127,583
1958	120,324
1959	152,341
1960	139,847
1961	147,130
1962	161,023
1963	182,934
1964	178,038
1965	192,655
1966	198,941
1967	203,571
1968	214,346

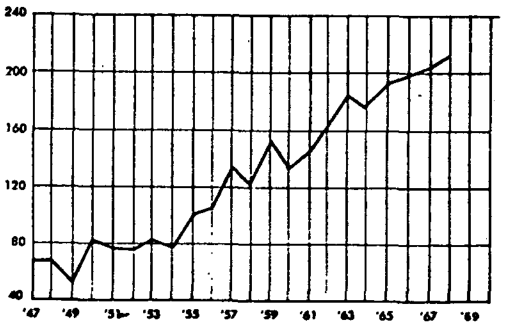


FIGURE A-2. LEAD OXIDE MADE BY BATTERY MANUFACTURERS (lead content)
Source: U.S. Bureau of Mines, Minerals Yearbooks, 1947 to 1969, "Lead" chapters.

The average lives of batteries have been increasing during the last 20 years. Table A-3 shows the average lives for four 5-year periods. This extension of service life reduces the number of batteries purchased and thus the amount of lead that might be used if battery life was not increasing.

TABLE A-3. AVERAGE BATTERY LIFE, 1949-1968

5-Year Period	Average Life, Months
1949-1953	21
1954-1958	24
1959-1963	25
1964-1968	27

Source: American Association of Battery Manufacturers, Yearbook, 1970.

The yield of batteries per ton of total lead consumed increased until the mid-1950's. Since then it has remained about constant. Table A-4 shows the number of batteries manufactured per ton of lead consumed for three 3-year periods.

TABLE A-4. BATTERIES PRODUCED PER TON OF LEAD CONSUMED, 1946-1968

3-Year Period	Number of Batteries Per Ton of Lead
1946-1948	82
1956-1958	92
1966-1968	90

Source: American Association of Battery Manufacturers, Yearbook, 1970.

The yield of batteries per ton of lead is expected to remain about constant in the future. However, battery life will probably continue to increase. Thus, annual lead consumption for batteries will increase somewhat slower than the increase for motor vehicles in use.

Tetraethyl Lead. Table A-5 provides historical data on consumption of lead for the production of tetraethyl lead. This material is used as a constituent of antiknock additives for gasoline.

TABLE A-5. CONSUMPTION OF LEAD IN THE PRODUCTION OF TETRAETHYL LEAD, 1964-1969

Year	Tons of Lead
1964	223,466
1965	225,203
1966	246,879
1967	247,170
1968	261,897
1969	271,128

Source: U.S. Bureau of Mines, Minerals Yearbooks, 1964 to 1969, "Lead" chapters.

It is expected that tetraethyl lead will be phased out of motor vehicle fuels within the next ten years for the following reasons:

(1) The U.S. Government is currently considering taxing lead content of motor fuels to reduce air pollution. This method or some other action is expected to discourage lead use.

(2) The auto manufacturers have taken a stand favoring removal of lead from gasolines.

(3) The petroleum companies have recently introduced lead-free fuels, and are planning new refinery facilities to upgrade octane values of blending stocks.

Other Oxides, Pigments, and Chemicals. Table A-6 gives consumption data for lead in nonmetallic applications (except battery oxide and tetraethyl lead).

TABLE A-6. U.S. CONSUMPTION OF LEAD AS OXIDES, PIGMENTS, AND CHEMICALS, EXCEPT BATTERIES AND TETRAETHYL LEAD (tons)

	1965	1966	1967	1968	1969
White lead	8,414	8,131	8,087	5,857	6,617
Red lead and litharge	79,853	89,500	76,589	86,480	79,898
Pigment colors	12,553	13,695	13,041	14,163	14,670
Other pigments	8,063	8,562	5,473	3,234	1,201
Lead plating	240	428	532	389	406
Misc. chemicals	346	614	609	629	602

Source: U.S. Bureau of Mines, Minerals Yearbooks, 1965 to 1969, "Lead" chapters.

Consumption of the major lead oxides by use is given in Table A-7.

TABLE A-7. DISTRIBUTION OF WHITE LEAD (DRY AND IN OIL), LITHARGE, AND RED LEAD SHIPMENTS,(1) BY INDUSTRIES, 1969 (short tons)

Industry			
White Lead	- Paints		5,969
	Ceramics		67
	Other		4,323
		TOTAL	10,359
Red Lead	- Paints		9,191
	Other		12,986
		TOTAL	22,177
Litharge	- Ceramics		21,570
	Oil refining		1,603
	Rubber		1,794
	Other		110,752
		TOTAL	135,719

(1) Excludes basic lead sulfate, figures withheld to avoid disclosing individual company confidential data.

Source: U.S. Bureau of Mines, Minerals Yearbook, 1969, "Lead" chapter.

APPENDIX B

LEAD RECYCLING INDUSTRY DATA FROM EXTENSIVE SURVEY

TABLE B-1. SECONDARY MATERIALS INDUSTRY--AVERAGE BUSINESS STATISTICS FOR LEAD

Average Investment in Plant and Equipment	Average Number of Employees	Average Investment per Employee
1,652,000	95	17,300

TABLE B-2. AVERAGE SIZE OF LEAD SCRAP PROCESSORS, ANNUAL TONS, BY REGION

Region	Tons per Year of Lead
Total United States	731.1
New England	922.7
Middle Atlantic	1,014.3
South Atlantic	522.2
East North Central	493.4
East South Central	650.0
West North Central	850.0
West South Central	1,376.9
Mountain	377.3
Pacific	676.2

TABLE B-3. AVERAGE SIZE OF SECONDARY LEAD SMELTERS, ANNUAL TONS, BY REGION

Region	Tons per Year
Total United States	2,532.8
New England	500.0
Middle Atlantic	4,483.9
South Atlantic	2,416.7
East North Central	1,945.7
East South Central	500.0
West North Central	3,400.0
West South Central	3,562.5
Mountain	666.7
Pacific	1,842.1

VOLUME V

ZINC REPORT

TABLE OF CONTENTS

Page

TABLE OF CONTENTS (Continued)

LIST OF APPENDIXES

LIST OF TABLES

TABLE OF CONTENTS (Continued)

LIST OF TABLES (Continued)

TABLE OF CONTENTS (Continued)

LIST OF FIGURES

SUMMARY

The economic recycling of waste materials is a desirable approach to the disposal of solid wastes. Recycling therefore is of interest to the Office of Solid Waste Management whose responsibility it is to formulate and recommend solid waste programs for the United States. This report on the recycling of zinc provides information and analyses to be used as a basis for program planning. The report was prepared by Battelle-Columbus with the guidance and help of the National Association of Secondary Material Industries (NASMI). It is based on a 12-month study of zinc recycling.

The report reviews briefly the demand and supply for zinc in the United States - both primary and secondary. It analyzes the recycling of zinc - the operations of scrap processors and smelters, sources of zinc scrap, markets for recycled zinc, and recycling rates by types of scrap. Based on this analysis the report presents the problems faced by the zinc recycling industry. Finally, it evaluates these problems to determine priorities, and recommends courses of actions to solve or reduce these problems - with the emphasis on increasing recycling of zinc in order to reduce solid waste disposal problems.

Zinc Consumption and Production

Although zinc is used in hundreds of consumer products, four basic markets account for 85 percent of the total consumption of zinc:

	Percent
Die casting	35
Galvanizing	28
Oxides and chemicals	12
New brassmaking	10

Recycled zinc, however, comprises only a small percentage of total U.S. zinc production:[1]

	Percent
Primary zinc production	90
Recycled zinc production	10

The Zinc Recycling Industry[2]

The zinc recycling inudstry takes scrapped zinc from the point of scrappage to a point of reuse.[3] The functions include buying and selling, physical movement, and change of form of the zinc. The scrap materials are mostly drosses and residues from zinc melting operations. The recycled zinc that is the output of the industry covers a range of types and purities of zinc and zinc alloys of which some are equivalent in characteristics and uses to primary zinc.

The importance of recycled zinc in the total zinc market is shown by 1969 supply data for zinc:

Zinc Source	Short Tons of Zinc	Percent of Total
Domestic ores	459,000	26
Imported ores	582,000	33
Imported metal	329,000	19
Recycled zinc	378,000[4]	22
TOTAL	1,748,000	100

Figure I summarizes data concerning the recycling of zinc for the year 1969. The quantities of zinc that were calculated to be available for recycling in 1969 are shown at the left (light shading). The quantities not recycled are shown next (dark shading). No galvanized steel or zinc oxides and chemicals are recycled because the nature of the applications for these materials makes recovery nearly impossible.

(1) Zinc recycled as a constituent of brass is not included.
(2) Home scrap is not included in this report.
(3) For a discussion of the functions of the recycling industry, see Vol. I, General Report.
(4) Includes 194,000 tons of zinc recycled as brass.

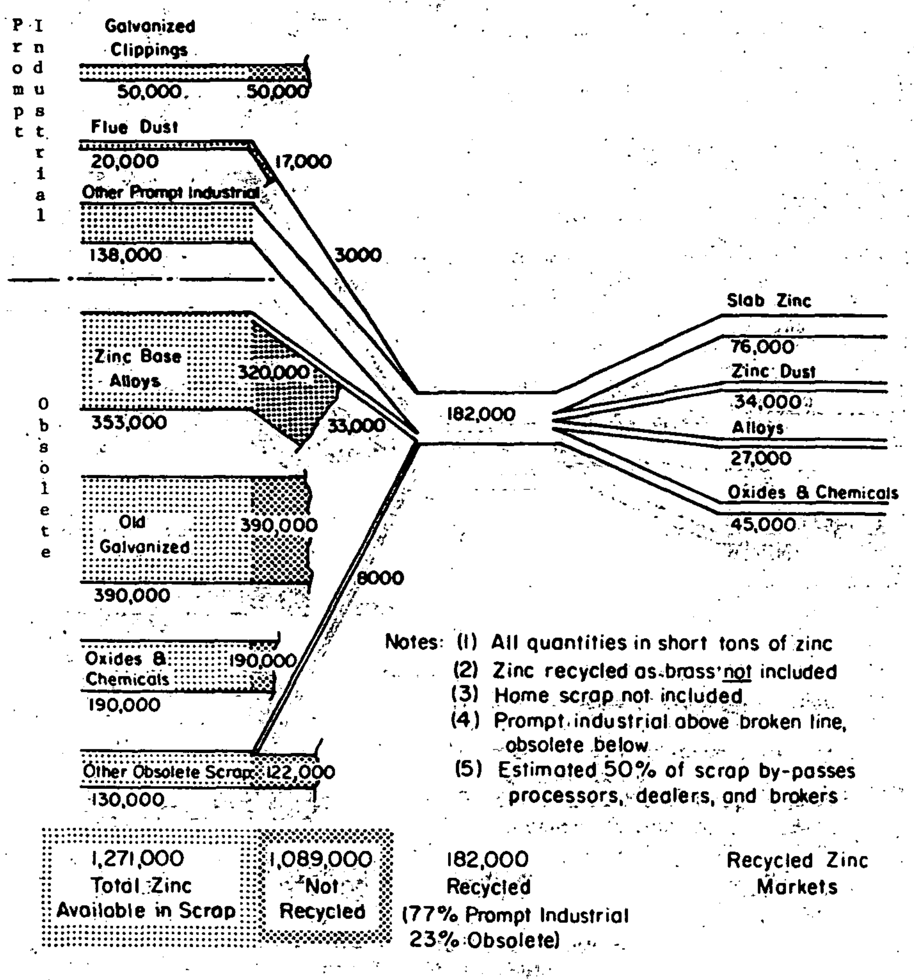


FIGURE I. SCRAP/RECYCLED ZINC FLOW, 1969

The zinc that is recycled is shown in the unshaded portion. It is apparent that large quantities of zinc are being recycled from industrial sources, but not from other sources. The recycled zinc is then marketed for several applications as shown on the right of Figure 1, namely, slab zinc, zinc dust, alloys, and oxides and chemicals. Overall, the recycling of zinc is at a very low rate with less than 15 percent of the amount theoretically available being recycled.

Problems of Zinc Recycling

The problems of zinc recycling are of two types: (1) those that directly reduce the recycling of zinc, and (2) those that do not directly reduce the recycling of zinc. Those in the first category are problems because they reduce recycling in measurable quantities. Those in the second because they adversely affect economics or practices of recycling but the affect in terms of amounts of zinc can not be measured.

Table I presents the 6 problems that directly reduce recycling. They are classified by the type of zinc scrap to be recycled. The problems in each category is the very sizeable amounts of zinc that are not recycled. In some instances there are real reasons why the zinc cannot be recycled.

Table II presents the three problems that do not directly reduce the recycling of zinc. The first two are market problems and the other one is an operating problem of the recycling industry.

TABLE I. IDENTIFICATION AND ANALYSIS OF PROBLEMS CONCERNING ZINC THAT WAS NOT RECYCLED IN 1969

	Scrap Categories Where Some Zinc Was Not Recycled		
	Galvanized Clippings	Flue Dust	Zinc Base Alloys
Problem Definition	1. Fabrication of galvanized sheet and strip gives trimmings that are scrapped. 2. This is recycled as steel scrap with the zinc still on it. 3. This zinc is lost out the stack of the steel furnace or is collected by air pollution control equipment and dumped. 4. The zinc often corrodes furnace refractories during steel melting. 5. Thus, none of the clippings are recycled for zinc content.	1. In smelting of zinc and brass, some zinc is evaporated. 2. Much of this zinc is now recovered by air pollution control equipment. 3. In most cases, the material is high in chlorine content, and is quite fluffy. 4. Because of the chlorine and low density, it is difficult and costly to recycle. 5. Thus, only 15 percent is recycled.	1. Nearly all zinc base alloy scrap is in the form of die castings. 2. The die castings vary in size from fractional ounce to a few pounds. 3. The die castings often contain inserts of steel, brass, or other materials. 4. Over half of the die castings are in autos. 5. Most of the remainder are also attached to large amounts of other materials in home appliances, machinery, farm equipment, etc. 6. There has been no economical method for separating most of the die castings from the other materials. 7. Thus, less than 10 percent of the zinc base alloys are recycled.
Tons of Zinc <u>Not</u> Recycled	50,000	17,000(1)	320,000
Percent of Available Zinc <u>Not</u> Recycled	100	85	91
Problem Analysis	1. Galvanized clippings contain 4 or 5 percent zinc and 95 or 96 percent steel. 2. The materials values per ton are about: Steel - $30 Zinc - <u>$12</u> Total $42 3. Only about $30 per ton of clipping is now being paid. 4. An economic method for separating the zinc from the steel would increase the value by $12 per ton--a 40 percent increase. 5. In addition, it would reduce corrosion of steel furnace refractories and make air pollution control easier.	1. Flue dusts from zinc and brass smelting usually contain 40 to 50 percent zinc. 2. Each pound of dust contains 5 to 7¢ worth of zinc. 3. An economic method of recovering the zinc would increase the recycling of zinc. 4. Also, it would provide additional incentive for strict air pollution control measures.	1. Zinc in die castings has low impurity levels. 2. Inserts of other metals can be easily removed. 3. The difficulties involve economical separation of the die castings from the larger products (autos, appliances, etc.) of which the die castings are a part. 4. Larger, easily-accessible die castings can be removed by hand. 5. Smaller, nonaccessible die castings can be removed by disintegration and separation equipment such as auto hulk shredders. 6. Separation from ferrous metals is easily accomplished magnetically. 7. Separation from nonferrous metals is much more difficult. 8. More economic methods of separation of zinc from nonferrous scrap would increase recycling substantially.

(1) Does not include steel furnaces.

(2) This is total quantity of zinc that were originally used. By the time of scrappage much of the zinc has been washed away (maybe 50 percent) and would be virtually impossible to recover.

TABLE I. IDENTIFICATION AND ANALYSIS OF PROBLEMS CONCERNING ZINC THAT WAS NOT RECYCLED IN 1969 (Continued)

	Scrap Categories Where Some Zinc Was Not Recycled		
	Old Galvanized	Oxides and Chemicals	Other Obsolete Scrap
Problem Definition	1. Old galvanized metal is scrapped in a great variety of forms--buckets, tanks, bridges, fencing, autos, farm silos, etc. 2. Much of the zinc has been corroded away while protecting the base metal during the useful lives of the products. The zinc has been washed off into the ground or into sewers and streams. 3. If the products are recycled, it is as the base metal, not as zinc. 4. Thus, no old galvanized zinc is recycled. It is wasted in the flue gases of iron and steel furnaces if not washed away in use.	1. Close to half of the zinc oxides and chemicals are scrapped as constituents of rubber products. 2. Most of the remainder are scrapped as constituents of paints, papers, textiles, and chemicals. 3. Zinc oxides and chemicals are nearly always a minor percentage of these products. 4. These products are generally not recycled. 5. It is not economic to recycle the zinc in these products. 6. Thus, no zinc oxides or chemicals are recycled.	1. Other obsolete zinc scrap includes rolled zinc (used in dry cells), zinc dust (used in paints), and a variety of minor uses. 2. Recycling of this zinc is generally not economic because it is in very small and contaminated pieces (such as dry cells), or is intimately mixed with and attached to other materials (such as in paint). 3. Thus, only a small percentage of this zinc scrap is recycled.
Tons of Zinc Not Recycled	390,000[(2)]	190,000 [(2)]	122,000
Percent of Available Zinc Not Recycled	100	100	94
Problem Analysis	1. In most cases, the percentage of zinc in old galvanized products is too small to be economically separated. 2. Thus, it is more practical to recycle the zinc with the steel scrap. 3. In the iron or steel furnace, the zinc evaporates and can be collected from the flue gases by air pollution control equipment. 4. In the flue dust, the zinc is mixed with iron oxide and other materials. 5. Zinc content can range from under 5 percent to over 25 percent. 6. Economic recovery methods for this zinc could substantially increase the recycling of zinc. 7. In addition, the incentive would be increased to install good air pollution control equipment.	1. Economic recovery of zinc oxides and chemicals from scrapped rubber products might be possible if economic recycling of rubber is accomplished. 2. Another possibility is recovery of zinc as flue dust if scrapped rubber can be burned as fuel. 3. Recovery of zinc oxides and chemicals from most other products will remain uneconomic because of dilution and dispersion in use. 4. Economic rubber recycling methods could allow zinc recovery, and substantially increase the recycling of zinc.	1. Dispersion and dilution of most forms of other obsolete scrap prevent economic recovery. 2. Opportunities for increased recycling are strictly limited.

TABLE II. IDENTIFICATION AND ANALYSIS OF PROBLEMS THAT DO NOT DIRECTLY[(1)] REDUCE THE AMOUNT OF ZINC THAT IS RECYCLED

	Declining Overall Markets[(2)]	Customer Prejudices	Air Pollution Control
Problem Definition	1. Zinc's largest market segment--die casting --has not grown since 1965. 2. The consensus of industry spokesmen is that little or no growth will occur in the future--perhaps there will be a decline. 3. Other market segments are expected to continue present growth rates in the future.	1. Some zinc users claim that recycled zinc is inferior to primary. 2. This is seldom true. 3. Some users will be using recycled zinc without knowing it because they buy from a primary producer and think this means they get primary zinc.	1. Most zinc smelters use chloride fluxes that make flue gases extremely corrosive. 2. Collection of solid pollutants from flue gases is difficult with bag houses because the chlorides attack the fabrics. 3. The collected dust is high in zinc (40 - 50 percent), but of low value because of high chloride and because very fluffy and hard to handle. 4. Investment cost for equipment is relatively high for small smelters.
Effect on Recycle Rate	Perhaps slight pressure on economics, but not important. No significant effect on quantities recycled.	This has some effect on economics of zinc recycling--causing price discounting. No significant effect on recycle rate.	Pollution control measures effect economics of recycling moderately by adding to investment and operating costs of a smelter. No measurable effect on quantities that are recycled.
Problem Analysis	1. Competitive materials (such as plastic moldings, aluminum die castings), and redesign of products to reduce need for decorative die castings are reducing the demand for zinc die castings. 2. Development of improved designs and fabrication methods to reduce costs of zinc die castings could prevent loss of markets. 3. Also, development of alloys with greatly improved properties could gain new markets in new applications (such as replacement of brass in valves and other plumbing products).	1. Recycled zinc is <u>not</u> inferior to primary zinc for the same grades. 2. Promotion of equal quality and desirability of recycling could help overcome prejudices.	1. Air pollution control problems of zinc smelting are rather severe and require costly equipment. 2. Some smelters may have problems providing investment capital for air pollution control equipment. 3. Aid in borrowing money may be needed.

(1) Problems adversely affect economics or practices of recycling but the effect in terms of amount cannot be measured. This situation is considered an indirect effect.
(2) Includes markets for primary and recycled metals.

Recommendations

The nine problems were assigned priorities based on three factors:

- Potential for improvement of the environment
- Potential for conservation of natural resources
- Possibilities for realistic solutions.

On this basis, three of the problems were classified as high priority, and the other six as lower priority. Table III gives recommended actions for the high priority problems. Table IV gives recommendations for the lower priority problems.

The question of who takes action is difficult to answer at this time. Battelle suggests that NASMI and EPA continue their leadership in working on solid waste programs, recognizing that many other Federal Government agencies such as the Bureau of Mines, Council of Environmental Quality, and Department of Commerce, as well as state and local agencies, will be involved.

TABLE III. RECOMMENDED ACTIONS, HIGH PRIORITY ZINC RECYCLING PROBLEMS

	Zinc Base Alloys	Old Galvanized	Air Pollution Control
Actions Recommended	R&D should be undertaken to develop economical methods and equipment for the mechanized separation of zinc, aluminum, copper, and nonmagnetic stainless steels.	R&D should be undertaken to develop an economical process for recovery of zinc from flue dusts. (In addition to steel and iron furnaces, this should include zinc and brass furnaces.)	An investigation should be made of the need for financial help by smelters in meeting, air pollution standards. Also, methods for providing help if needed.
By Whom (1)(2)(3)	EPA/NASMI	EPA/NASMI	EPA/NASMI
Specific Steps	1. Form a committee of scrap processors. 2. Committee analyze the major sorting problems for nonferrous metals • types of metals • forms of metals • quantities, etc. • etc. 3. Committee analyze the major sorting methods now in use: • hand picking • heavy media • sweating • etc. 4. Committee review problems and methods with major equipment manufacturers to determine if economic sorting methods can be installed with present equipment. 5. If so, prepare guidebook of practical installations. 6. If not, undertake R&D to develop methods and equipment needed.	1. Form a flue dust committee representing zinc smelters, brass smelters, steel mills (using high-zinc scrap charge), iron foundries (using high-zinc scrap charge). 2. Committee survey other smelters and mills to determine present flue dust: • recovery methods • composition of dust • disposal of dust • etc. 3. Committee analyze present recycle methods and economics for zinc flue dusts. 4. Initiate R&D on promising approaches with goal of developing economic processes for recycling most dusts.	1. Establish a committee to conduct the investigation. 2. Committee survey the zinc smelters to collect data concerning status, methods, and problems of air pollution control. Emphasis on economic impact on smelters. 3. Committee to develop financing plans to meet investment needs of smelter for air pollution control systems where hardships occur. 4. Committee present data and recommendations to EPA and legislative bodies concerning needs--fast tax writeoffs, guaranteed loans, etc.

(1) The responsibility for recommended actions shown in this table are based on importance of the action, benefit to the taxpayers, and opportunities for NASMI. They are the best judgments of Battelle.

(2) Recommended actions were distributed between high priority and lower priority based on the evaluation with three criteria.

(3) It is suggested that NASMI continue its leading role in recycling, recognizing that other organizations such as the Bureau of Mines, Department of Commerce, Council of Environmental Quality, HEW Office of Information, and State, Local, and Federal Legislatures must be involved.

TABLE IV. RECOMMENDED ACTIONS, LOWER PRIORITY ZINC RECYCLING PROBLEMS

	Galvanized Clippings	Oxide and Chemicals	Other Obsolete Scrap	Declining Markets	Customer Prejudices
Actions Recommended	R&D should be undertaken to develop an economical process for the recovery of zinc from galvanized clippings.	R&D should be undertaken to develop processes for the recovery of materials from tires and other rubber products. Included are the rubber, zinc oxide, sulfur compounds, carbon black, fibers, and steel wire. Or, develop methods for using old rubber as fuel and recovering by-products of combustion.	An investigation should be made of the feasibility of recycling additional quantities of other obsolete zinc scrap--dry cells, zinc dust, etc.	R&D should be continued to develop higher-performance zinc alloys that can gain new markets for zinc die castings.	Publicity should be used to inform users of recycled zinc that it is equal in quality to primary zinc. Tie publicity to saving the environment and saving natural resources.
By Whom (1) (2) (3)	NASMI	NASMI	NASMI	NASMI/Zinc Institute	NASMI/KASMI Member Companies
Specific Steps	1. Query M&T Chemicals Company concerning its degalvanizing process. 2. If it looks good and is soon to be commercialized, NASMI stop actions. 3. If not to be soon commercialized, determine why and what additional work needed. 4. If promising, encourage further development and commercialization of the M&T process. 5. If not promising, initiate an R&D program to develop a sound and economic degalvanizing process.	1. Investigate present status of old rubber recycling: • quantities available • present recycling activities • R&D underway • etc. 2. Undertake R&D to develop economic methods for recycling old rubber.	1. NASMI set up committee of scrap processors. 2. Committee analyze what zinc scrap is not now recycled and why. 3. Committee decide whether or not it would be feasible to try to increase recycle rate for some of this scrap. 4. If feasible (3 above), investigate more closely what needs to be done to increase recycling. 5. Recommend actions required to increase recycling.	1. NASMI set up committee of one NASMI staff member and two die-casting alloy producers to coordinate recycling industry interests with Zinc Institute R&D activities. 2. Committee discuss with Zinc Institute how to work together to develop new zinc die-casting alloys, manufacturing methods, and markets--projects, funding, etc.	1. NASMI continue general promotion of recycling concept. 2. KASMI and appropriate member companies start specific program to promote recycled zinc.

(1) The responsibility for recommended actions shown in this table are based on importance of the action, benefit to the taxpayers, and opportunities for NASMI. They are the best judgments of Battelle.

(2) Recommended actions were distributed between high priority and lower priority based on the evaluation with three criteria.

(3) It is suggested that NASMI continue its leading role in recycling, recognizing that other organizations such as the Bureau of Mines, Department of Commerce, Council of Environmental Quality, HEW Office of Information, and State, Local, and Federal Legislatures must be involved.

INTRODUCTION

In June, 1970, Battelle-Columbus undertook a research program for the National Association of Secondary Material Industries, Inc. (NASMI). This work was carried out under a subcontract from the Office of Solid Waste Management grant to NASMI. This report on zinc is one of a series of eight commodity reports plus a general or summary report.

Background

The Office of Solid Waste Management is responsible for formulating and recommending Federal Government policies in the area of solid waste pollution. This includes pursuing appropriate research to determine the status and problems of solid waste activities, and to develop programs to reduce solid waste pollution.

One approach to the reduction of solid waste pollution is to reclaim waste materials for reuse - the recycling concept. A well established industry--the secondary materials industry--exists to accomplish this recycling. NASMI is the trade association representing the nonferrous metals, paper, and textiles portion of this industry.

The scrap processors, secondary smelters, and other companies that make up the secondary materials industry have developed effective channels and methods for recycling nearly all waste materials of economic value. These companies have performed their difficult and essential functions well in the traditional economic environment.

More recently additional dimensions have been added to this traditional economic environment. These new dimensions are (1) improvement of the environment in which we live, and (2) increased need for conservation of natural resources. These new dimensions provide new challenges and opportunities for the recycling industry. No longer is economic gain the sole driving force for recycling of waste materials. Social gain has been added in the forms of improved living conditions and preservation of resources for future generations. In an economics-based nation this creates problems of interpretation and evaluation of noneconomics-based goals and activities.

The purpose of this series of reports is to identify obstacles to the recycling of solid wastes, and to recommend directions for investigation and research to overcome these obstacles.

Objectives

The objective of the study on which this report is based was to identify opportunities for the increased utilization of solid waste. The major sub-objectives were:

(1) To determine the structure and functions of the secondary materials industry, and its relationships to sources of supply and markets

(2) To identify and evaluate problems of recycling - materials, sources, industry, and markets, and

(3) To determine opportunities for increased recycling.

Scope

The major subjects included in the scope of the study are the secondary materials industry, the materials it recycles, the sources of solid wastes, and the markets for recycled materials. Activities peripheral to these major subjects are considered where pertinent to recycling.

The materials included in the study are:

Aluminum	Nickel and Nickel Alloys
Copper and Copper Alloys	Precious Metals (Silver and Gold)
Lead	Paper
Zinc	Textiles

Research Methods

The methods and procedures used in the study are discussed under four types of activities. They include (A) literature search, (B) extensive survey, (C) in-depth survey, and (D) analysis and synthesis.

Literature Search

The literature search included reviewing and studying books, Government reports, industry reports, and trade journals covering solid waste handling and problems, recovery and market data, and recycling of valuable materials.

The results of this effort included the accumulation of data and descriptive material, and an organized bibliography dealing with each of the commodities covered in the scope of the study.

Extensive Survey

The extensive survey of the secondary materials industry consisted of a mail survey and personal interviews with management personnel of companies involved with the collection, processing, and sale of secondary materials. About 600 responses were received.

The information developed through the extensive survey included dollar sales, tons of major materials handled, types of solid waste processed, sources of materials, investment, equipment and facilities, number of employees, the amount of space used, and the grades and quantities of secondary materials produced.

The data from the extensive survey provided statistical tabulations of the regional distribution of the secondary materials industries by type of commodity in terms of numbers of establishments, volume of business, and numbers of employees.

In-depth Survey

The in-depth survey of selected members of the secondary materials industries, their suppliers, and the users of their products served to identify the major technical and economic problems facing those companies involved with secondary material utilization. About 200 interviews were completed. Battelle and NASMI commodity specialists jointly selected the companies to be interviewed in depth.

Interview guides for each of the commodities were prepared. The problems and potential solutions for greatest recycling and waste utilization that were developed from the literature search and prior Office of Solid Waste

Management work plus the knowledge of the NASMI commodity specialists provided the basis for designing the interview guide. Sample guides are reproduced in the Appendix.

Analysis and Synthesis

The analysis and synthesis step was concerned with the collation and analysis of data and information derived from both the literature, extensive survey, and in-depth survey. The analysis and synthesis activity covered the following tasks:

(1) Economic Data on the Secondary Materials Industries. The economic data developed through the extensive survey of the secondary materials industries were tabulated and analyzed as to the amount and type of solid waste handled and as to operational data such as number of employees, amount of space required, capitalization, and geographic locations.

(2) Flow Diagrams and Life Cycles. Flow diagrams were developed to indicate the flow of materials from primary production and scrap sources through fabrication. Life cycle estimates of various products were used to develop data on quantities available for possible recycling.

(3) Demand-Supply Relationships. Estimates were made of future demand and supply levels for secondary materials. The relationship between these data provide an indication of potential surpluses or shortages of recycled materials through 1980.

(4) Stability of Flow and Consumption. This analysis is closely related to the supply-demand analysis described above and identifies the ability of the various secondary materials to

compete as source materials for manufacturers. A number of factors were examined such as price changes in the secondary materials, the availability of materials, and the effect of sudden changes in the magnitude of demand.

(5) Direct Impacts of Technological Change. Direct technical and technological factors were examined to determine their effect on rates of processing and recycling. Potential changes that could take place in technology that could decrease or increase the rate of solid waste recovery were examined. This includes the identification of potentially recoverable solid wastes, the problems limiting the recovery to current levels, and the possibilities of technical advances through the use of known technology or through added scientific and engineering research.

(6) Constraints on Expansion of the Secondary Materials Industries. This analysis included consideration of elements critical to expansion of recycling - labor and management availability, laws and regulations, equipment availability, nature of solid waste materials, market needs, etc.

(7) Potentials for Expansion of the Secondary Materials Industries. Based on the constraints identified in the above task, plus examination of various methods for overcoming constraints, this task determined the ability of the secondary materials industries to meet new opportunities for recycling.

(8) Indirect Technological Change. The broad overall technological trends indirectly affecting the secondary materials industries were examined, and their probable impacts determined.

THE ZINC INDUSTRY

This first section of the report provides a brief description of the zinc industry--the overall framework of which zinc recycling is a part. Included are the characteristics of zinc--primary and recycled, and the characteristics of the zinc industry--primary and recycled.

Characteristics of Zinc

The major forms of primary and recycled zinc that are produced are:

Slab zinc

Zinc dust

Zinc die casting alloys

Zinc oxide.

Grades of Slab Zinc and Zinc Dust

Slab zinc is produced in six standard grades which range from about 98.3 to more than 99.99 percent zinc.

The specifications (ASTM designation: Revision: B6-62T) for primary slab zinc provide that the zinc be made from ore or other material by distillation or electrolysis, and not by "sweating" or remelting of scrap. The grades and maximum impurities are shown in Table 1.

Zinc produced from newly mined ores is termed primary or virgin zinc. When zinc is produced from scrap or residues, it is termed secondary redistilled or remelt zinc dependent upon the process utilized for recovery. Primary zinc is referred to as electrolytic or distilled zinc according to the reduction process used.

TABLE 1

GRADES OF SLAB ZINC

Name	Maximum, percent[(1)] Lead	Iron	Cadmium	Total	Minimum Percent Zinc[(2)]
Special high grade	0.003	0.003	0.003	0.010	99.99
High grade	0.07	0.02	0.03	0.10	99.90
Intermediate	0.20	0.03	0.40	0.50	99.50
Brass special	0.60	0.03	0.50	1.0	99.00
Prime Western	1.60	0.05	0.05	--	98.0

(1) ASTM Standards, B6-62T.
(2) Difference, by deduction of listed allowable impurities.

NOTE: Analysis shall not regularly be made for tin but when used for die castings, if found, by the purchaser, tin shall not exceed 0.001 percent. Greater amounts may constitute cause for rejection.

Where it is specified by the purchaser at the time of purchase that the special high-grade zinc is to be used for the manufacture of zinc-base, die-casting alloy ingot, the maximum permissible tin content shall be 0.002 percent and the maximum permissible lead content shall be 0.005 percent.

Analysis shall not regularly be made for aluminum. When used for the manufacture of rolled zinc or brass, aluminum, if found by the purchaser, shall not exceed 0.005 percent. Greater amounts may constitute cause for rejection.

Specifications for zinc dust have not been adopted by the industry, but chemical purity and particle sizes are closely controlled to particular customer requirements. Commercial zinc dust ranges from 95 to 99.8 percent zinc with the balance being principally oxidized zinc plus impurities of lead and iron. A representative particle size gradation would be 100 percent minus 100-mesh and 25 percent minus 325-mesh although some specifications call for more than 97 percent passing a 325-mesh screen.

Zinc Die Casting Alloys

Zinc die casting alloys are any of several zinc-base alloys in which aluminum and copper are the principal alloying elements. The most widely used of these alloys have compositions described by ASTM Specification B 86, -63 alloys AG40A and AC41A (die castings) and ASTM Specification B 240, alloys AG40A and AC41A (ingots). These specifications are shown in Table 2.

TABLE 2

ASTM B 240--63-STANDARD SPECIFICATION FOR ZINC-BASE ALLOYS IN INGOT FORM FOR DIE CASTING

	AG40A	AC41A
Composition	Alloy	Alloy
Percent	XXIII	XXV
Aluminum	3.9 - 4.3	3.9 - 4.3
Copper	.10 Max.	.75 - 1.25
Magnesium	.025 - .05	.03 - .06
Nickel	--	--
Iron	.075 Max.	.075 Max.
Lead	.004 "	.004 "
Cadmium	.003 "	.003 "
Tin	.002 "	.002 "
Zinc	*	*

* Remainder.

Zinc Oxide

Zinc burns in air to form the white powdery zinc oxide used widely in pigments and rubber. Table 3 presents ASTM Specifications (D-79-44) for American and French process zinc oxide.

TABLE 3

ASTM SPECIFICATIONS FOR AMERICAN AND FRENCH PROCESS ZINC OXIDE

	Percent	American Process(1)	French Process(2)
Zinc oxide	Minimum	98.0	99.0
Sulfur	Maximum	0.2	0.1
Moisture and other volatiles	"	0.5	0.5
Total impurities	"	2.0	1.0
Retained on 325-mesh (44-micron) sieve	"	1.0	1.0

(1) Produced directly from ores.
(2) Produced from slab zinc or zinc scrap.

Characteristics of the Zinc Industry

The zinc industry includes the institutions and activities required to process zinc-containing raw materials to produce zinc metal, oxides, and chemicals. Included are several types of companies:

Type of Company	Activities
Integrated producers	- mining, concentrating, smelting and refining
Miners	- mining, concentrating of ores
Smelters	- smelting and refining from ore
Secondary smelters	- distillation, smelting, and refining from scrap, and production of die casting alloys
Scrap processors	- collecting, sorting, etc., of scrap

Materials Sources

The U.S. zinc industry depends on the following sources for zinc materials:(1)

	1969 Consumption (zinc content, tons)
Domestic ores	459,000
Imported ores	582,000
Imported metal	329,000
Recycled zinc	378,000(2)

Materials Flow

The 4 sources of zinc raw materials shown above, plus the U.S. strategic stockpile supplied the U.S. zinc market in 1969. Figure 1 provides a materials flow balance based on these 5 sources of zinc. Although scrap is a major source of zinc, over half is alloyed with copper and is recycled as brass. Thus, it is not zinc scrap, but only a constituent of copper-base alloys scrap.

The use pattern of Figure 1 shows the heavy dependence of zinc on die casting (zinc base alloys) and galvanizing for its markets. Oxides are also large because zinc oxide is used in rubber tires.

Zinc Producers

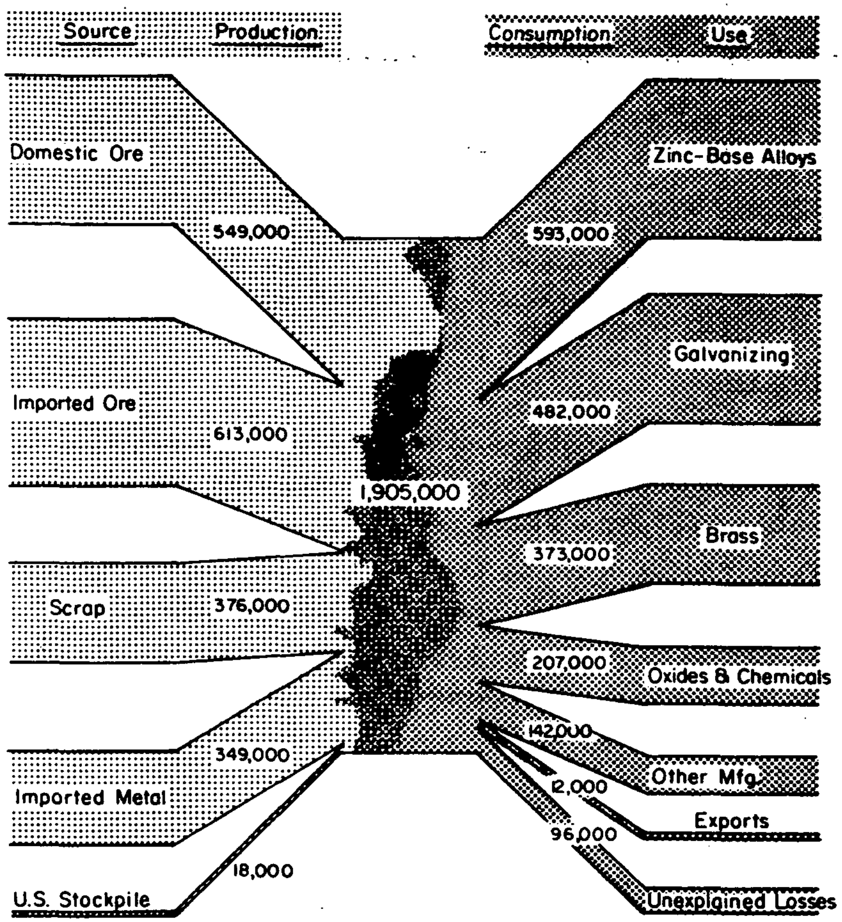
Production of slab zinc in the United States has been dominated by seven producers with over 85 percent of the total (includes primary and recycled).(3)

	Percent		Percent
St. Joseph Lead Co.	17	New Jersey Zinc Co.	12
The Anaconda Co.	16	American Zinc. Co.	11
American Smelting & Refining Co.	14	Bunker Hill Co.	8
		American Metal Climax	8

(1) U.S. Bureau of Mines, Minerals Yearbook, 1969, "Zinc" chapter.

(2) Includes 194,000 tons of zinc in copper-base alloys. This is nearly all recycled as brass and bronze rather than being recovered as zinc.

(3) Based on 1966 production, from "Economic Analysis of the Lead-Zinc Industry", April 1969. Chas. River Associates Inc., Cambridge, Mass.



Notes: 1. Quantities in short tons
2. Includes brass scrap that is recycled as brass scrap without extraction of zinc. This accounts for 194,000 tons of zinc. Thus, only 179,000 tons of zinc were used to make new brass

FIGURE 1. MATERIALS FLOW BALANCE, ZINC, 1969
Source: U.S. Bureau of Mines, Minerals Yearbook, 1969, "Zinc" chapter

Table 4 gives 1967 data (latest available) concerning primary and secondary zinc smelters. These data are misleading in the case of secondary zinc. There are many more than 14 establishments involved in recycling of zinc. The remelters, smelters, oxide producers, etc., are not included in the table.

Markets for Zinc

The markets for zinc have increased at an average annual rate of about 1.8 percent since 1945. Figure 2 gives annual consumption data for this period.

Table 5 provides a breakdown of zinc consumption for 1969 by type of material. Most of the slab zinc is used for galvanizing, die casting alloys, and brassmaking. Much of the "other and unspecified" category is zinc oxide made from ore and scrap.

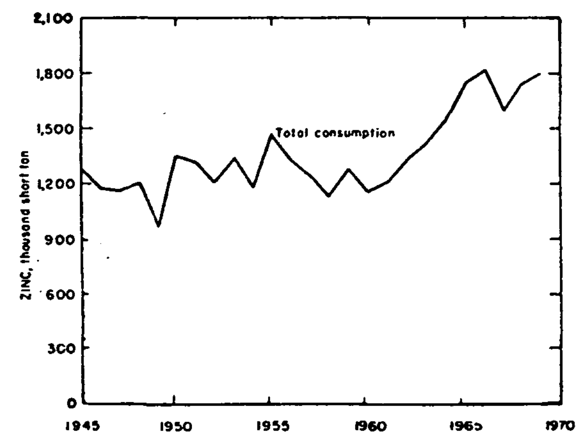


FIGURE 2. TRENDS IN THE ZINC INDUSTRY IN THE UNITED STATES, 1945-1969

Source: U.S. Bureau of Mines, Minerals Yearbook, 1969, "Zinc" chapter, p. 1144.

TABLE 4

GENERAL STATISTICS FOR ZINC ESTABLISHMENTS, 1967

Industry of Product Class Code	Industry or Product Class	Establishments (number)	All Employees: Number (1,000)	All Employees: Payroll ($ million)	Value Added by Manufacture ($ million)	Cost of Materials ($ million)	Value of Shipments ($ million)	Capital Expenditures, new ($ million)
3333	Primary Zinc							
	Entire industry	18	8.1	57.8	119.5	220.8	332.8	25.8
33414	Secondary Zinc (pig, ingot, shot, etc.)							
	(Primary product class of establishment)	14	0.6	4.2	7.9	30.3	39.1	0.5

Source: U.S. Department of Commerce, Bureau of the Census, 1967 Census of Manufacturers, "Smelting and Refining of Nonferrous Metals and Alloys", pp 33C-10 and 33C-20.

TABLE 5

ZINC CONSUMPTION BY TYPE OF MATERIAL, U.S., 1969

Type of Material	Short Tons of Zinc
Slab zinc	1,368,000
Recycled copper-base alloys	194,000
Zinc dust	55,000
Other and unspecified	288,000
TOTAL	1,905,000

Source: U.S. Bureau of Mines, Minerals Yearbook, 1969, "Zinc" chapter.

Figure 2-A shows monthly average zinc prices at East St. Louis and Londo 1960-1969. It is interesting to note that domestic zinc prices were steady at 13 cents per pound during 1960, dropped to 11.5 cents in 1961 and 1962, then rose, stepwise, to 14.5 cents in later 1964 and stayed at this level until early in 1967 when prices dropped to 13.5 cents. Prices eventually rose to 15.5 cents during th last half of 1969. London prices have been below domestic price levels except during 1964 and early 1965.

Zinc Use Patterns

The market for slab zinc is dominated by two large uses - die casting and galvanizing. Table 6 gives a percent distribution by major uses of slab zinc sales in 1969. Additional information is given in the appendix concerning the various uses of zinc.

TABLE 6

ZINC USE PATTERN, 1969

Use	Tons of Zinc	Percent of Total
Die casting	585,000	42
Galvanizing	482,000	34
Brassmaking	184,000	13
Rolled zinc	49,000	4
Other uses	100,000	7
TOTAL	1,400,000	100

Source: U.S. Bureau of Mines, Minerals Yearbook, 1969, "Zinc" chapter.

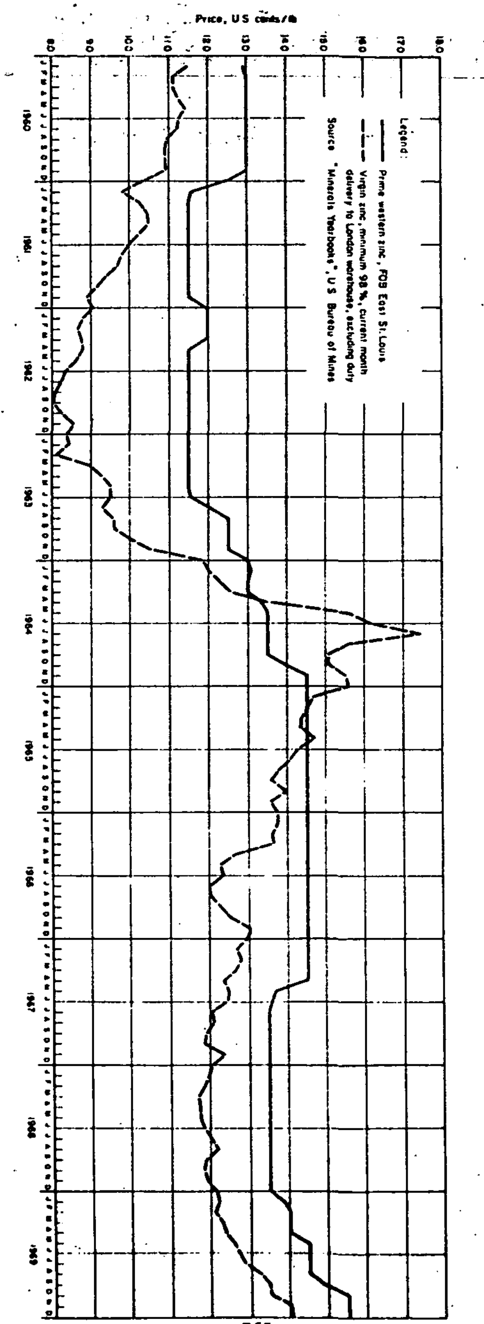


FIGURE 2-A. MONTHLY AVERAGE ZINC PRICES AT EAST ST. LOUIS AND LONDON, 1960-1969

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272

Markets for Recycled Zinc

Markets for recycled zinc totaled 376,000 tons in 1969. This zinc is included in the foregoing data on zinc markets and use patterns. A more complete consideration of markets for recycled zinc is presented in the next major section, "The Zinc Recycling Industry".

Market Outlook

The market outlook for zinc is not good. The U.S. Bureau of Mines forecasts the following annual growth rates in the 1970's:

	Percent
Primary zinc	1.1
Recycled zinc	1.2

Applying the Bureau of Mines growth factors to zinc gives future markets as follows:(1)

	Short Tons of Zinc		
	Total	Primary	Recycled
1969	1,532,000	1,350,000	182,000
1974	1,623,000	1,430,000	193,000
1979	1,715,000	1,510,000	205,000

Increased availability of old zinc die casting scrap could boost recycled zinc markets substantially - probably at the expense of primary zinc. It is expected that the supply of old die casting scrap will increase greatly as more shredders of steel scrap are put in operation, and improved methods are developed for separation of the nonferrous metals fraction. Based on this, one can speculate that recycled zinc markets may be 250,000 tons by 1974 and 300,000 tons by 1979 - or perhaps much higher than these figures.

(1) Zinc content of old and new brass **not** included.

THE ZINC RECYCYING INDUSTRY

The zinc recycling industry is organized to collect, process, and refine scrapped zinc, and make it available for reuse.(1) This industry and the materials it handles are reviewed in this section. The topics covered are:

Characteristics of Zinc Materials

Characteristics of the Zinc Recycling Industry

Recycled Zinc Markets

Materials Flow Pattern for Zinc Recycling

Demand/Supply Analysis.

Characteristics of Zinc Materials

Secondary Zinc

Not all grades of slab zinc can be produced by a secondary smelter. As an example, Special High Grade is 99.99 percent zinc and the secondary smelter cannot achieve this purity. In practice, the only grade of recycled slab that is produced in substantial quantities is Prime Western. The other important types of recycled zinc are dust, oxide, die casting alloys, and brass. Of these, over half the recycled zinc is contained in recycled brass.

Scrap and Drosses

A variety of zinc scrap and drosses provide the raw materials for zinc recycling. In composition, these materials vary from almost 100 percent zinc content to about 60 percent zinc.

Standard grades of zinc scrap and drosses have been defined by NASMI. These are shown in Table 7.

(1) For a discussion of the functions of the recycling industry see Vol I, General Report.

TABLE 7

GRADES OF ZINC SCRAP AND DROSSES

OLD ZINC DIE CAST SCRAP

Shall consist of miscellaneous old zinc base die castings, with or without iron and other foreign attachments. Must be free of borings, turnings, dross pieces, chunks, melted pieces and skimmings. All unmeltables, dirt, foreign attachments, and volatile substances (such as rubber, cork, plastic, grease, etc.) are deductible. Material containing in excess of 30 percent iron will not constitute good delivery.

NEW ZINC DIE CAST SCRAP

Shall consist of new or unused, clean, zinc base die castings. Castings to be unplated, unpainted, and free from corrosion.

NEW PLATED ZINC DIE CAST SCRAP

Shall consist of new or unused clean, plated zinc base die castings, free from corrosion.

ZINC DIE-CAST AUTOMOTIVE GRILLES

Shall consist of clean, old or used zinc base die cast automotive grilles, free from soldered material. All foreign attachments and extraneous material are deductible.

OLD SCRAP ZINC

Shall consist of clean dry scrap zinc, such as sheets, jar lids, clean unalloyed castings and anticorrosion plates. Borings and turnings are not acceptable. Material must not be excessively corroded or oxidized. All foreign attachments and extraneous materials are deductible.

NEW ZINC CLIPPINGS

Shall consist of any new pure zinc sheets or stampings free from corrosion. To contain no foreign material or attachments. Printers zinc, such as engravers zinc, lithograph sheets and addressograph plates subject to special arrangements. Printers zinc to be free of routings.

ZINC DIE CAST SLABS OR PIGS

Shall consist of melted zinc base die cast materials, in smooth clean solid slabs or pigs. Material to be free from drosses and to contain a minimum zinc content of 90 percent.

GALVANIZERS SLAB ZINC DROSS

Shall consist of galvanizers unsweated zinc dross in slabs with a minimum zinc content of 92 percent and shall be free of skimmings. Broken metallic pieces under 2 inches in diameter shall not exceed 10 percent of the weight of each shipment. Slabs shall not weigh over 100 pounds each.

PRIME ZINC DIE CAST DROSS

Shall consist of metal skimmed from the top of pot of molten zinc die cast metal. Must be unsweated, unfluxed, shiny, smooth, metallic and free from corrosion or oxidation. Should be poured in molds or in small mounds weighing not over 75 pounds each. Zinc shall be a minimum of 85 percent.

ANY OTHER GRADES OF ZINC-BEARING MATERIALS NOT MENTIONED ARE SUBJECT TO SPECIAL ARRANGEMEN

Source: NASMI.

Characteristics of the Zinc Recycling Industry

Scrap metal processors collect, handle, sort, segregate, and otherwise process the various grades of zinc scrap for shipment to secondary smelters. Most of these processors also handle other scrap metals. A small amount of zinc scrap was generated as a by-product of steel shredders in 1969. This quantity is increasing so more old die casting scrap is recycled each year.

Old zinc scrap is often contaminated with dirt, plating, inserts, or other items. Because of the contaminants, and the low melting and boiling points of zinc, sweating the zinc off the contaminants is a common practice. This operation is done by both processors and smelters. The secondary smelters, in addition to sweating, distill, refine, and alloy zinc to produce slab, alloys, dust, or oxide.

Materials Sources

Zinc for recycling comes as prompt industrial scrap (mostly drosses, skimmings, and residues), and as obsolete scrap (mostly old die castings and rolled zinc). Table 8 gives zinc scrap consumption data.

TABLE 8

CONSUMPTION OF NEW AND OLD ZINC SCRAP IN THE UNITED STATES IN 1969

(short tons)

Class of Consumer and Type of Scrap	Consumption: New Scrap	Consumption: Old Scrap	Consumption: Total
New clippings	670	--	670
Old zinc	--	6,463	6,463
Engravers' plates	--	3,392	3,392
Skimmings and ashes	74,269	--	74,269
Sal skimmings	8,397	--	8,397
Die-cast skimmings	4,890	--	4,890
Galvanizers' dross	66,496	--	66,496
Diecastings	--	38,312	38,312
Rod and die scrap	--	1,590	1,590
Flue dust	8,603	--	8,603
Chemical residues	36,797	--	36,797
TOTAL	200,122	49,757	249,879

Source: U.S. Bureau of Mines, Minerals Yearbook, 1969, "Zinc" chapter.

Zinc scrap prices fluctuate depending on slab zinc prices, type, and quality of scrap, location of scrap, availability of scrap, and other factors. Table 9 provides a rough indication of 1969 prices for zinc scrap. When scrap prices are at a low level, zinc dusts and low grade scraps are not recycled. This means that more solid waste is generated and disposed of and our natural resources depleted.

TABLE 9

ZINC SCRAP PRICES, 1969

Item	Price, cents per lb
New die cast scrap	10
New clippings	9
Old zinc scrap	7
Old irony die cast scrap	6
Galvanizers' drosses	9
Die casters' drosses	7

Source: Zinc recycling companies.

Recycled Zinc Markets

Table 10 gives a 10-year history of recycled zinc production (consumption is about the same). This table shows total zinc recycling and zinc recycling excluding copper-base alloys. The amount of noncopper-base zinc recycled has maintained a relatively constant ratio with total consumption at around 10 percent over the period.

TABLE 10

RECYCLED ZINC PRODUCTION(1), 1960-1969

Year	Total	Excluding Copper-Base
	(Short tons of Zinc)	
1960	266,000	158,000
1961	238,000	139,000
1962	262,000	148,000
1963	268,000	149,000
1964	298,000	164,000
1965	353,000	191,000
1966	360,000	193,000
1967	320,000	177,000
1968	355,000	192,000
1969	376,000	182,000

(1) Includes production of alloys.

Source: U.S. Bureau of Mines, Minerals Yearbooks, 1961, 1963, 1965, 1967, 1969, "Zinc" chapters.

Use Patterns

Table 11 gives consumption data for recycled zinc by form of recovery. Copper base alloys are over half the total. This zinc remains in the alloy - it is not separated as zinc. Other forms of recovery are small compared with copper base alloys.

TABLE 11

CONSUMPTION OF SECONDARY ZINC BY USE, 1969

Form of Recovery	1969
As metal:	
By distillation:	
Slab zinc(1)	68,677
Zinc dust	33,241
By remelting	5,639
TOTAL	107,557
In zinc-base alloys	19,980
In brass and bronze	196,244
In aluminum-base alloys	6,853
In magnesium-base alloys	459
In chemical products:	
Zinc oxide (lead-free)	21,049
Zinc sulfate	11,986
Zinc chloride	10,917
Miscellaneous	1,346
TOTAL	268,834
GRAND TOTAL	376,391

(1) Includes zinc content of redistilled slab made from remelt die-cast slab.

Source: U.S. Bureau of Mines, Minerals Yearbook, 1969, "Zinc" chapter.

Industry Data

A survey of the recycling industry developed data to afford profiles of the industry and the companies making up the industry. Volume I, General Report in this series, gives many of these data. A few data concerning zinc are given here and in Appendix B of this report.

The average recycler of zinc compares with the average recycler for all commodities as follows:(1)

	Investment in Plant and Equipment	Number of Employees	Investment per Employee
Zinc	$1,103,000	43	$25,500
All commodities	1,480,000	71	20,800

Figure 3 shows the variation in size by census region of (1) zinc scrap processors and (2) zinc smelters. There is some correlation of sizes of smelters with degree of industrialization - the heavily industrialized Middle Atlantic and East North Central regions support much larger smelters than the other regions.

(1) Data from extensive survey.

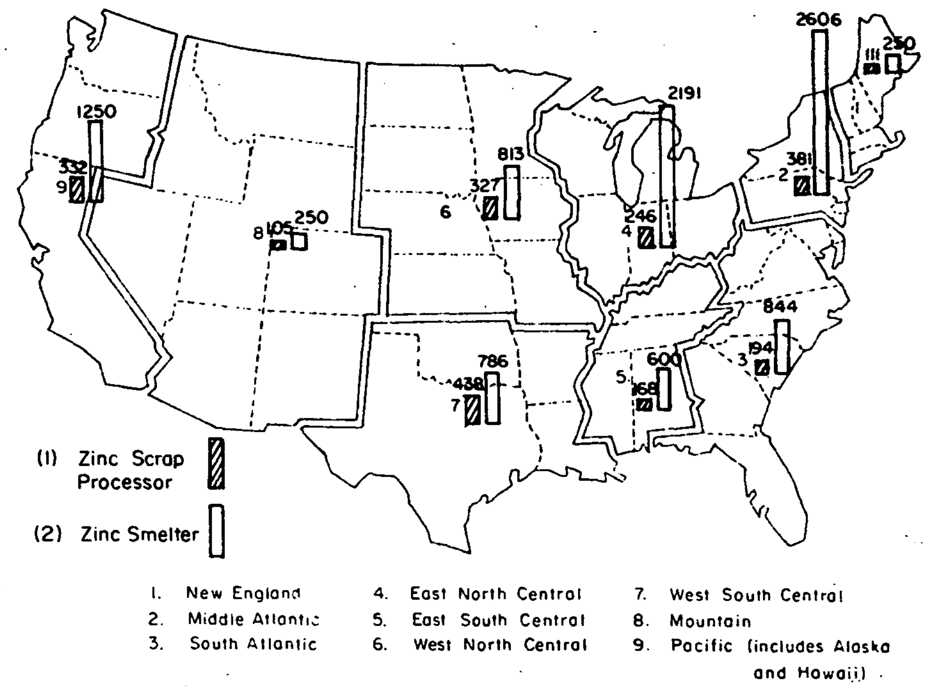


FIGURE 3. AVERAGE SIZE IN TONS PER YEAR OF ZINC OF (1) ZINC SCRAP PROCESSORS AND (2) ZINC SMELTERS, BY REGION, 1969
Source: Extensive Survey

Materials Flow Pattern for Zinc Recycling

With data on scrap sources and markets for secondary zinc in 1969, plus calculations of the quantities of zinc scrap that should have been generated in 1969, it is possible to develop a materials flow pattern. Table 12 presents these data. Footnotes show sources and methods of derivation.

The first column of the table gives data concerning quantities of zinc that should have been scrapped in 1969 based on life cycles of the various sources. Thus, drosses are immediately available as a by-product of galvanizing and die casting operations. At the other extreme is old galvanized which is in use for an average of 20 years before being scrapped. The quantity of zinc used in galvanizing in 1949 (actually the 1948-1950 average was used to smooth year-to-year variations) is the amount that should have been scrapped in 1969, and this is the 390,000 tons shown in Table 12. The other entries in the first column were calculated in a similar manner using the life cycles given in footnote (2).

Figure 4 presents the data of Table 12 in graphic form. The widths of the various channels are proportional to the quantities involved. The total amount of zinc calculated to be available for recycling is shown by lightly shaded areas, the recycled zinc is shown by unshaded areas, and the zinc that is not recycled is shown by darkly shaded areas. It can be seen that industrial scrap is not a problem except for galvanized clippings and flue dust.

All categories of obsolete scrap zinc show very low recycle rates--large quantities apparently are not recycled. The major reason for this is that it has not been economically feasible--except for zinc base alloy scrap. This is not recycled because of a combination of technical and economic reasons based on difficulty of separation of the die castings from junked autos, appliances, and other products. This will be discussed later in a problems section.

TABLE 12

ZINC SCRAP RECYCLING, 1969

Scrap Sources(1)	Tons of Zinc Available for Recycling(2)	Tons of Zinc Recycled	Percent Recycled	Tons of Zinc Not Recycled
Galvanized clippings	50,000(3)	-	0	50,000
Flue dust	20,000(4)	3,000(5)	15	17,000
Other prompt industrial(6)	138,000	138,000(5)	100	-
Zinc base alloys	353,000	33,000(5)	9	320,000
Old galvanized	390,000	-	0	390,000
Oxides and chemicals	190,000	-	0	190,000
Other obsolete scrap(6)	130,000	8,000(5)	6	122,000
Total(6)	1,271,000	182,000	14	1,089,000

Notes: (1) "Galvanized Clippings", "Flue Dust" and "Other Prompt Industrial" cover all the prompt industrial scrap. All other sources in this column cover obsolete scrap.

(2) Calculated from estimated life cycles, and consumption of zinc that number of years prior to 1969. The life cycles used, and the years for which consumption data were used are as follows:

Source	Life Cycle (Years)	Years of Zinc Consumption Used to Caluclate Zinc Availability
Galvanized clippings	0.2	1969
Flue dusts	0.1	1969
Other prompt industrial	0.2	1969
Zinc base alloys	12	1956 - 1958 ave.
Old galvanized	20	1948 - 1950 ave.
Oxides and chemicals	3	1966
Other obsolete scrap	2	1967

(3) Calculated at 20 percent of galvanized sheet and strip zinc consumption.

(4) Calculated at 1/2 percent of recycled zinc.

(5) Based on U. S. Bureau of Mines data.

(6) Copper-base alloys not included.

Source: U.S. Bureau of Mines, Minerals Yearbook, 1948 to 1969, "Zinc" chapter.

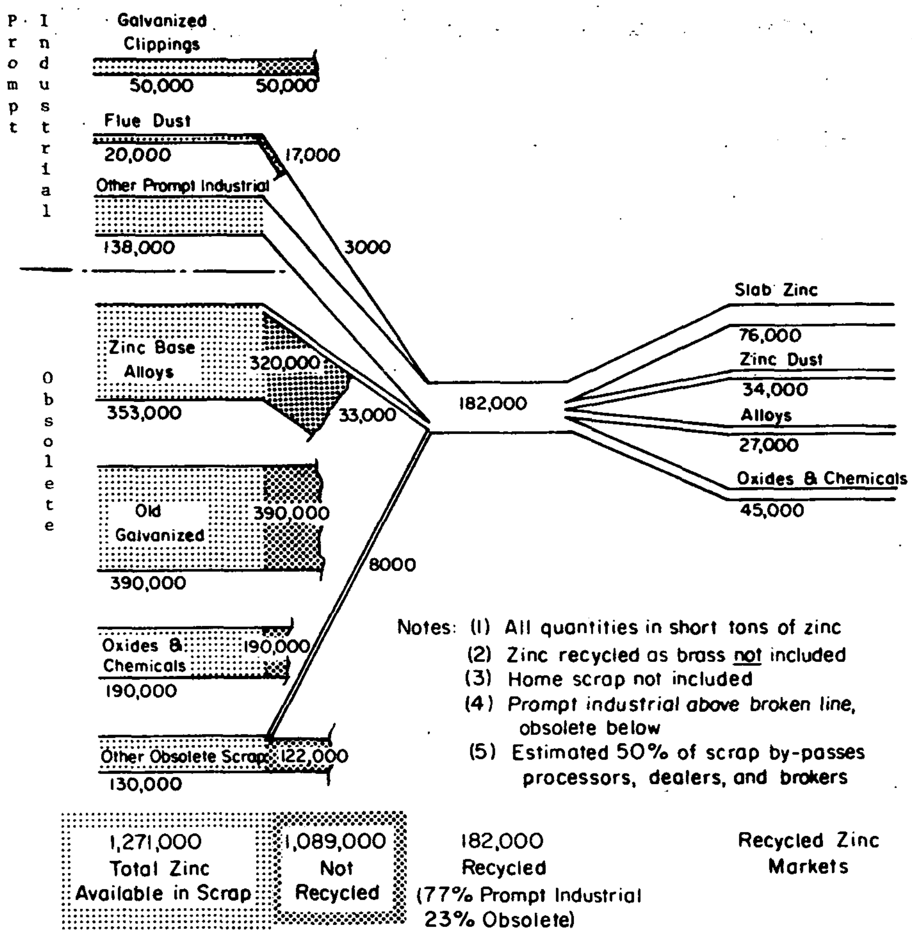


FIGURE 4. SCRAP/RECYCLED ZINC FLOW, 1969

Demand/Supply Analysis

A brief analysis of expected future demand and supply for recycled zinc provides an indication of the future recycling environment.

Demand

The demand for secondary zinc in 1969 and two future years, 1974 and 1979, is forecast as follows (see p. 16):

Year	Short Tons
1969	182,000
1974	193,000
1979	205,000

Supply

Future availability of recycled zinc, based on present rates of recovery is as follows:

Year	Production of Recycled Zinc
1969	182,000
1974	196,000
1979	212,000

Demand/Supply Balance

An insignificant surplus of recycled zinc is indicated for the future based on present recovery practices:

	Short tons 1974	1979
Demand	193,000	205,000
Supply	196,000	212,000
Surplus	3,000	7,000

It is expected that production of recycled zinc will be higher than indicated for 1974 and 1979, based on better recovery of old die castings. Thus, the indicated surpluses may be much larger than shown, resulting in possible downward price pressures, and requiring more aggressive marketing.

Effect on Zinc Industry

It is reasonable to expect that an additional 274,000 short tons of zinc could be recycled annually under ideal conditions.[1] If this much additional zinc can be recycled by 1974, about 140 percent will be added to the predicted recycled zinc supply in that year. However, this is only about 20 percent of total supply. This is less than a 4 percent increase each year for the 5 years between 1969 and 1974. This should not cause major upheaval in the zinc industry. This additional recycled zinc will be marketed at the expense of lower sales of domestic and imported primary zinc because of the lower price for recycled. Since, there are large year-to-year variations in primary zinc supplies (in the 1965-1969 period imported metal varied by 175,000 tons from lowest to highest year, production from domestic ores varied by 115,000 tons), and because imported metal supplies are increasing rapidly, growth of recycled zinc supplies over a 5-year period should not cause unusual problems for the primary suppliers.

(1) The 274,000 tons was calculated based on the following changes in percent recycled:

	1969, percent	Goal, percent	Additional Recycled, tons
Galvanized Clippings	0	80	40,000
Flue Dust	15	80	13,000
Zinc Base Alloys	9	50	143,000
Old Galvanized	0	20	78,000
TOTAL			274,000

ZINC SCRAP RECYCLING PROBLEMS

There are several problems that directly reduce the amount of zinc that is recycled.[1] In order to provide as quantitative a base as possible for analyzing the effects of the problems on recycling, the organization of this section follows the types of scrap.

Industrial Scrap

There are two types of prompt industrial zinc scrap that have a low recycle rate: (1) galvanized clippings and (2) flue dusts. Table 13 presents these problems along with those concerning obsolete scrap.

Obsolete Scrap

Recycling of obsolete zinc scrap is generally under 10 percent of scrap calculated to be available for recycling. The problem areas of obsolete scrap involve the following classes of uses:

(1) Zinc base alloys (die castings)

(2) Old galvanized

(3) Oxides and chemicals

(4) Other obsolete zinc scrap.

Table 13 presents these problems based on 1969 data. Included are: (1) definitions of the problems, (2) tons of zinc not recycled, (3) percent of available zinc not recycled, and (4) analyses of the problems.

(1) Problems that do not directly reduce the amount of zinc that is recycled are discussed in the next major section of the report.

TABLE 13. IDENTIFICATION AND ANALYSIS OF PROBLEMS CONCERNING ZINC THAT WAS NOT RECYCLED IN 1969

	Scrap Categories Where Some Zinc Was Not Recycled		
	Galvanized Clippings	Flue Dust	Zinc Base Alloys
Problem Definition	1. Fabrication of galvanized sheet and strip gives trimmings that are scrapped. 2. This is recycled as steel scrap with the zinc still on it. 3. This zinc is lost out the stack of the steel furnace or is collected by air pollution control equipment and dumped. 4. The zinc often corrodes furnace refractories during steel melting. 5. Thus, none of the clipings are recycled for zinc content.	1. In smelting of zinc and brass, some zinc is evaporated. 2. Much of this zinc is now recovered by air pollution control equipment. 3. In most cases, the material is high in chlorine content, and is quite fluffy. 4. Because of the chlorine and low density, it is difficult and costly to recycle. 5. Thus, only 15 percent is recycled.	1. Nearly all zinc base alloy scrap is in the form of die castings. 2. The die castings vary in size from fractional ounce to a few pounds. 3. The die castings often contain inserts of steel, brass, or other materials. 4. Over half of the die castings are in autos. 5. Most of the remainder are also attached to large amounts of other materials in home appliances, machinery, farm equipment, etc. 6. There has been no economical method for separating most of the die castings from the other materials. 7. Thus, less than 10 percent of the zinc base alloys are recycled.
Tons of Zinc Not Recycled	50,000	17,000[(1)]	320,000
Percent of Available Zinc Not Recycled	100	85	91
Problem Analysis	1. Galvanized clippings contain 4 or 5 percent zinc and 95 or 96 percent steel. 2. The materials values per ton are about: Steel - $30 Zinc - $12 Total $42 3. Only about $30 per ton of clipping is now being paid. 4. An economic method for separating the zinc from the steel would increase the value by $12 per ton--a 40 percent increase. 5. In addition, it would reduce corrosion of steel furnace refractories and make air pollution control easier.	1. Flue dusts from zinc and brass smelting usually contain 40 to 50 percent zinc. 2. Each pound of dust contains 5 to 7¢ worth of zinc. 3. An economic method of recovering the zinc would increase the recycling of zinc. 4. Also, it would provide additional incentive for strict air pollution control measures.	1. Zinc in die castings has low impurity levels. 2. Inserts of other metals can be easily removed. 3. The difficulties involve economical separation of the die castings from the larger products (autos, appliances, etc.) of which the die castings are a part. 4. Larger, easily-accessible die castings can be removed by hand. 5. Smaller, nonaccessible die castings can be removed by disintegration and separation equipment such as auto hulk shredders. 6. Separation from ferrous metals is easily accomplished magnetically. 7. Separation from nonferrous metals is much more difficult. 8. More economic methods of separation of zinc from nonferrous scrap would increase recycling substantially.

(1) Does not include steel furnaces.

(2) This is total quantity of zinc that were originally used. By the time of scrappage much of the zinc has been washed away (maybe 50 percent) and would be virtually impossible to recover.

(Continued)

	Scrap Categories Where Some Zinc Was Not Recycled		
	Old Galvanized	Oxides and Chemicals	Other Obsolete Scrap
Problem Definition	1. Old galvanized metal is scrapped in a great variety of forms--buckets, tanks, bridges, fencing, autos, farm silos, etc. 2. Much of the zinc has been corroded away while protecting the base metal during the useful lives of the products. The zinc has been washed off into the ground or into sewers and streams. 3. If the products are recycled, it is as the base metal, not as zinc. 4. Thus, no old galvanized zinc is recycled. It is wasted in the flue gases of iron and steel furnaces if not washed away in use.	1. Close to half of the zinc oxides and chemicals are scrapped as constituents of rubber products. 2. Most of the remainder are scrapped as constituents of paints, papers, textiles, and chemicals. 3. Zinc oxides and chemicals are nearly always a minor percentage of these products. 4. These products are generally not recycled. 5. It is not economic to recycle the zinc in these products. 6. Thus, no zinc oxides or chemicals are recycled.	1. Other obsolete zinc scrap includes rolled zinc (used in dry cells), zinc dust (used in paints), and a variety of minor uses. 2. Recycling of this zinc is generally not economic because it is in very small and contaminated pieces (such as dry cells), or is intimately mixed with and attached to other materials (such as in paint). 3. Thus, only a small percentage of this zinc scrap is recycled.
Tons of Zinc <u>Not</u> Recycled	390,000[2]	190,000 [2]	122,000
Percent of Available Zinc <u>Not</u> Recycled	100	100	94
Problem Analysis	1. In most cases, the percentage of zinc in old galvanized products is too small to be economically separated. 2. Thus, it is more practical to recycle the zinc with the steel scrap. 3. In the iron or steel furnace, the zinc evaporates and can be collected from the flue gases by air pollution control equipment. 4. In the flue dust, the zinc is mixed with iron oxide and other materials. 5. Zinc content can range from under 5 percent to over 25 percent. 6. Economic recovery methods for this zinc could substantially increase the recycling of zinc. 7. In addition, the incentive would be increased to install good air pollution control equipment.	1. Economic recovery of zinc oxides and chemicals from scrapped rubber products might be possible if economic recycling of rubber is accomplished. 2. Another possibility is recovery of zinc as flue dust if scrapped rubber can be burned as fuel. 3. Recovery of zinc oxides and chemicals from most other products will remain uneconomic because of dilution and dispersion in use. 4. Economic rubber recycling methods could allow zinc recovery, and substantially increase the recycling of zinc.	1. Dispersion and dilution of most forms of other obsolete scrap prevent economic recovery. 2. Opportunities for increased recycling are strictly limited.

Increased recovery and recycling in most of these categories will be quite difficult and complex. Only the "Galvanized Clippings" and "Zinc Base Alloys" categories are amenable to straightforward solutions. The "Flue Dust", "Old Galvanized", and "Oxides and Chemicals" categories require more involved consideration and approaches. The zinc from old galvanized is difficult if not impossible to remove. Thus, it is more promising to charge the old galvanized to steel furnaces as steel scrap, collect the zinc in flue dusts, and attempt to develop economic methods for recovering the zinc from the flue dusts. The flue dust problem is complicated by the wide variation of compositions depending on types of furnaces (zinc, brass, steel) and operating practices.

Solution of a large part of the zinc oxides and chemicals problem depends on developing methods of recovering other values from old rubber products.

As explained in the previous section of the report, all recycling data are based on U.S. Bureau of Mines data. Some members of the recycling industry take exception to these data. This applies primarily to the zinc base alloys category. The industry spokesmen state that the recycle rate in the zinc base alloy category is more like 75 percent than the 9 percent shown in Table 13. Thus, the quantity not recycled in 1969 would be only 90,000 tons instead of the 320,000 tons shown. The U.S. Bureau of Mines does not believe its data can be understated by more than 100 percent.

The situation then is this:

	Tons of Zinc in Zinc Base Alloys That Was Not Recycled in 1969
Table 13 data	320,000
Data within U.S. Bureau of Mines limits of error	290,000-320,000
Zinc recycling industry estimate	90,000

Other Problems

One important other problem directly reduces the recycling of zinc, but it is impossible to measure the magnitude of the reduction. This is the subsidy allowed the primary industry in the form of ore depletion allowances. A similar subsidy for the secondary zinc industry would allow higher scrap purchase prices and processing costs at fixed profit levels and sales prices. An unknown additional quantity of zinc would be recycled as a result.[1]

ZINC RECYCLING INDUSTRY PROBLEMS

There are several problems faced by the zinc recycling industry that have no direct quantitative effect on the rate of recycling. Rather, they have economic effects on the industry, or make operations more difficult. These problems are:

(1) Declining markets for zinc

(2) Customer prejudices against secondary zinc

(3) Air pollution control.

Table 14 discusses each of these problems. Included are (1) titles of problems, (2) definitions of problems, (3) effects on recycling, and (4) analyses of problems.

Two of the problems in Table 14 concern the markets for zinc:

- Declining markets.
- Customer prejudices.

Both problems are relatively minor and deserving of little or no attention.

The third problem--air pollution control--presents a serious economic problem for some secondary zinc smelters. The investment cost for equipment can be high - perhaps beyond the capability of some smelters to raise the money.

(1) See "Report No. 1, Summary" for additional discussion of depletion allowances.

TABLE 14. IDENTIFICATION AND ANALYSIS OF PROBLEMS THAT DO NOT DIRECTLY[1] REDUCE THE AMOUNT OF ZINC THAT IS RECYCLED

	Declining Overall Markets[2]	Customer Prejudices	Air Pollution Control
Problem Definition	1. Zinc's largest market segment--die casting --has not grown since 1965. 2. The consensus of industry spokesmen is that little or no growth will occur in the future--perhaps there will be a decline. 3. Other market segments are expected to continue present growth rates in the future.	1. Some zinc users claim that recycled zinc is inferior to primary. 2. This is seldom true. 3. Some users will be using recycled zinc without knowing it because they buy from a primary producer and think this means they get primary zinc.	1. Most zinc smelters use chloride fluxes that make flue gases extremely corrosive. 2. Collection of solid pollutants from flue gases is difficult with bag houses because the chlorides attack the fabrics. 3. The collected dust is high in zinc (40 - 50 percent), but of low value because of high chloride and because very fluffy and hard to handle. 4. Investment cost for equipment is relatively high for small smelters.
Effect on Recycle Rate	Perhaps slight pressure on economics, but not important. No significant effect on quantities recycled.	This has some effect on economics of zinc recycling--causing price discounting. No significant effect on recycle rate.	Pollution control measures effect economics of recycling moderately by adding to investment and operating costs of a smelter. No measurable effect on quantities that are recycled.
Problem Analysis	1. Competitive materials (such as plastic moldings, aluminum die castings), and redesign of products to reduce need for decorative die castings are reducing the demand for zinc die castings. 2. Development of improved designs and fabrication methods to reduce costs of zinc die castings could prevent loss of markets. 3. Also, development of alloys with greatly improved properties could gain new markets in new applications (such as replacement of brass in valves and other plumbing products).	1. Recycled zinc is <u>not</u> inferior to primary zinc for the same grades. 2. Promotion of equal quality and desirability of recycling could help overcome prejudices.	1. Air pollution control problems of zinc smelting are rather severe and require costly equipment. 2. Some smelters may have problems providing investment capital for air pollution control equipment. 3. Aid in borrowing money may be needed.

(1) Problems adversely affect economics or practices of recycling but the effect in terms of amount cannot be measured. This situation is considered an indirect effect.
(2) Includes markets for primary and recycled metals.

COURSES OF ACTION CONCERNING THE RECYCLING OF ZINC

Having identified the major problems concerning the recycling of zinc it is necessary to evaluate them and select those that are amenable to solutions. Then, courses of action can be developed to lead to solutions for the problems.

Evaluation of Problems

The nine problems concerning the recycling of zinc are not all of equal importance or priority. A method is needed for determining which ones are more important.

The method used is based on how the nine compare with each other when scored with three criteria:

- Solution of the problem will improve the environment
- Solution of the problem will conserve natural resources
- Realistic solutions can be found.

In the context of this report, the first of these criteria is believed to be more important than the other two. It is weighted to allow a high score equal to the total of the other two.

Table 15 presents the results of the evaluation of the nine problems using the three criteria. In this evaluation, three problems have total scores substantially higher than the other six:

Low Recycling Rate of Zinc Base Alloys

Low Recycling Rate of Old Galvanized

Air Pollution Control.

Assignment of Priorities

The three problems listed above are rated as high priority, and actions to solve these should be fully investigated before considering the five lower priority problems (reduced from six because flue dust problem has been transferred to old galvanized problem).

TABLE 15. EVALUATION OF NINE PROBLEMS RELATED TO RECYCLING OF ZINC

Problems	Criteria and Scores: Solution of Problem Will Improve Environment	Solution of Problem Will Conserve Natural Resources	Realistic Solution Can Be Found	Total Score
Galvanized clippings	3	1	5	9
Flue dust	2	1	3	6
Zinc base alloys	10	5	5	20
Old galvanized	10	5	2	17
Oxides and chemicals	6	3	1	10
Other obsolete scrap	5	2	0	7
Declining markets	0	0	5	5
Customer prejudices	0	0	5	5
Air pollution control	10	0	5	15

Notes: (1) First criteria is considered most important and is assigned maximum score of 10.

(2) Other two criteria are considered less important and are assigned maximum scores of 5 each.

(3) The higher the total score, the more attractive the problem is for further action.

Recommended Actions

The recommendations of what to do about the eight major problems of the zinc recycling industry are covered in two parts:

(1) High priority actions

(2) Lower priority actions

The high priority actions should be dealt with before attention is given to the lower priority actions.

High Priority Actions

The high priority actions recommended here are important and far-reaching enough to be in the public interest. Thus, participation by EPA is desirable. Participation by NASMI and its members is also desirable since the problems and actions are predominately within the boundaries of the zinc recycling industry.

Table 16 presents the recommended action programs for the high priority zinc recycling problems.

The solution for the first high priority problem--zinc base alloys--involves improved methods for the separation of old die castings from other materials - primarily from junked autos. The major potential for increased recovery of zinc is from scrap steel shredders. The output of shredders is increasing each year to make more mixed nonferrous scrap available. Zinc is the major constituent of this scrap. The first activity toward a solution of this problem should be a review by a NASMI committee of present separation practices and development efforts. Based on this, further R&D can be undertaken if needed.

TABLE 16. RECOMMENDED ACTIONS, HIGH PRIORITY ZINC RECYCLING PROBLEMS

	Zinc Base Alloys	Old Galvanized	Air Pollution Control
Actions Recommended	R&D should be undertaken to develop economical methods and equipment for the mechanized separation of zinc, aluminum, copper, and nonmagnetic stainless steels.	R&D should be undertaken to develop an economical process for recovery of zinc from flue dusts. (In addition to steel and iron furnaces, this should include zinc and brass furnaces.)	An investigation should be made of the need for financial help by smelters in meeting, air pollution standards. Also, methods for providing help if needed.
By Whom (1)(2)(3)	EPA/NASMI	EPA/NASMI	EPA/NASMI
Specific Steps	1. Form a committee of scrap processors. 2. Committee analyze the major sorting problems for nonferrous metals • types of metals • forms of metals • quantities, etc. • etc. 3. Committee analyze the major sorting methods now in use: • hand picking • heavy media • sweating • etc. 4. Committee review problems and methods with major equipment manufacturers to determine if economic sorting methods can be installed with present equipment. 5. If so, prepare guidebook of practical installations. 6. If not, undertake R&D to develop methods and equipment needed.	1. Form a flue dust committee representing zinc smelters, brass smelters, steel mills (using high-zinc scrap charge), iron foundries (using high-zinc scrap charge). 2. Committee survey other smelters and mills to determine present flue dust: • recovery methods • composition of dust • disposal of dust • etc. 3. Committee analyze present recycle methods and economics for zinc flue dusts. 4. Initiate R&D on promising approaches with goal of developing economic processes for recycling most dusts.	1. Establish a committee to conduct the investigation. 2. Committee survey the zinc smelters to collect data concerning status, methods, and problems of air pollution control. Emphasis on economic impact on smelters. 3. Committee to develop financing plans to meet investment needs of smelter for air pollution control systems where hardships occur. 4. Committee present data and recommendations to EPA and legislative bodies concerning needs--fast tax writeoffs, guaranteed loans, etc.

(1) The responsibility for recommended actions shown in this table are based on importance of the action, benefit to the taxpayers, and opportunities for NASMI. They are the best judgments of Battelle.
(2) Recommended actions were distributed between high priority and lower priority based on the evaluation with three criteria.
(3) It is suggested that NASMI continue its leading role in recycling, recognizing that other organizations such as the Bureau of Mines, Department of Commerce, Council of Environmental Quality, HEW Office of Information, and State, Local, and Federal Legislatures must be involved.

The solution to the second high priority problem of zinc--old galvanized--depends on recovery of the zinc from flue dusts of iron and steel furnaces that use old galvanized scrap charges. It is believed not to be economic to remove the zinc directly from the galvanized scrap. Recovery of zinc from the flue dusts of zinc and brass furnaces should also be included. The first activity toward a solution should be an investigation by a NASMI committee of present flue dust compositions and recovery practices. Based on the results of this, R&D programs can be designed.

The solution to the last high priority zinc problem--air pollution control--involves helping zinc smelters meet air pollution control regulations. The cost of control systems for zinc smelters can be high - as much as one-third of the total cost of new smelting capacity. This can put a severe financial burden on some smelters. They may be unable to borrow sufficient money to install control equipment. The solution proposed is based on an investigation by a NASMI committee to determine possible relief that is needed - fast tax writeoffs, loan guarantees, or other actions.

Lower Priority Actions

The lower priority actions that are recommended are neither important enough, nor far-reaching enough to be of much interest to the public. Thus, participation by EPA is not recommended. The problems involve primarily NASMI, its members, other companies involved in the zinc recycling industry, and other organizations concerned with zinc.

Table 17 presents the recommended action programs for the lower priority problems of zinc recycling. Two of these problems--declining markets and customer prejudices--are relatively minor. Continuation of existing NASMI programs should pretty well solve the customer prejudice problem. Perhaps expanded attention is

TABLE 17. RECOMMENDED ACTIONS, LOWER PRIORITY ZINC RECYCLING PROBLEMS

	Galvanized Clippings	Oxide and Chemicals	Other Obsolete Scrap	Declining Markets	Customer Prejudices
Actions Recommended	R&D should be undertaken to develop an economical process for the recovery of zinc from galvanized clippings.	R&D should be undertaken to develop processes for the recovery of materials from tires and other rubber products. Included are the rubber, zinc oxide, sulfur compounds, carbon black, fibers, and steel wire. Or, develop methods for using old rubber as fuel and recovering by-products of combustion.	An investigation should be made of the feasibility of recycling additional quantities of other obsolete zinc scrap--dry cells, zinc dust, etc.	R&D should be continued to develop higher-performance zinc alloys that can gain new markets for zinc die castings.	Publicity should be used to inform users of recycled zinc that it is equal in quality to primary zinc. Tie publicity to saving the environment and saving natural resources.
By Whom (1)(2)(3)	NASMI	NASMI	NASMI	NASMI/Zinc Institute	NASMI/KASMI Member Companies
Specific Steps	1. Query M&T Chemicals Company concerning its degalvanizing process. 2. If it looks good and is soon to be commercialized, NASMI stop actions. 3. If not to be soon commercialized, determine why and what additional work needed. 4. If promising, encourage further development and commercialization of the M&T process. 5. If not promising, initiate an R&D program to develop a sound and economic degalvanizing process.	1. Investizate present status of old rubber recycling: • quantities available • present recycling activities • R&D underway • etc. 2. Undertake R&D to develop economic methods for recycling old rubber.	1. NASMI set up committee of scrap processors. 2. Committee analyze what zinc scrap is not now recycled and why. 3. Committee decide whether or not it would be feasible to try to increase recycle rate for some of this scrap. 4. If feasible (3 above), investigate more closely what needs to be done to increase recycling. 5. Recommend actions required to increase recycling.	1. NASMI set up committee of one NASMI staff member and two die-casting alloy producers to coordinate recycling industry interests with Zinc Institute R&D activities. 2. Committee discuss with Zinc Institute how to work together to develop new zinc die-casting alloys, manufacturing methods, and markets--projects, funding, etc.	1. NASMI continue general promotion of recycling concept. 2. NASMI and appropriate member companies start specific program to promote recycled zinc.

(1) The responsibility for recommended actions shown in this table are based on importance of the action, benefit to the taxpayers, and opportunities for NASMI. They are the best judgments of Battelle.

(2) Recommended actions were distributed between high priority and lower priority based on the evaluation with three criteria.

(3) It is suggested that NASMI continue its leading role in recycling, recognizing that other organizations such as the Bureau of Mines, Department of Commerce, Council of Environmental Quality, HEW Office of Information, and State, Local, and Federal Legislatures must be involved.

needed for declining markets since additional quantities of recycled zinc are expected to become available in the future.

The oxides and chemicals problem warrants investigation by NASMI to determine the Association's position relative to scrap rubber. A successful solution may require utilization of zinc, sulfur, and other values in addition to the rubber.

The other two lower priority problems--galvanized clippings and other obsolete scrap--involve solutions that require more knowledge concerning present practices and potential opportunities. In the case of other obsolete scrap the need is a close look at what scrap processors are handling to determine what is and what is not being handled. It is a matter of looking closely for additional opportunities for recycling.

The solution suggested for galvanized clippings is to check with M&T Chemicals Co. concerning its dezincing process. Based on the results, decisions can be made concerning the practicability of dezincing and how to fit it into the recycling industry.

Other Actions

The reader is referred to Volume I of this series - General Report. It presents problems and recommended actions that apply to the entire recycling industry. Problem categories include markets, scrap sources, recycling industry operations, equipment, and legal requirements.

APPENDIX A

ZINC MARKETS

APPENDIX A

ZINC MARKETS

Die Casting

Table A-1 gives use pattern for zinc die castings.

TABLE A-1

ZINC DIE CASTINGS USE PATTERN, 1969

Using Industry	Tons of Zinc	Percent of Total
Auto	315,000	54
Home appliances	95,000	16
Machinery and tools	80,000	14
Other	95,000	16
TOTAL	585,000	100

Source: Discussion with Die Casting Institute.

Galvanizing

Table A-2 gives the use pattern for zinc in galvanizing.

TABLE A-2

GALVANIZING ZINC USE PATTERN

Use	Tons of Zinc	Percent of Total
Sheet and strip	252,000	53
Tube and pipe	66,000	14
Wire	32,000	7
Structural shapes	19,000	4
Fencing and other mesh	18,000	4
Tube and pipe fittings	11,000	2
Other uses	78,000	16
TOTAL	476,000	100

Source: Discussion with Hot Dip Galvanizers Association.

Brass Products

In 1969, 179,000 tons of slab zinc were used to produce brass and other copper-base alloys, and an additional 194,000 tons of zinc were contained in recycled brass and other copper-base alloys.(1)

Oxides and Chemicals

Table A-3 shows the 1969 content of zinc in oxides and chemicals - total and by zinc source.

TABLE A-3

ZINC CONTENT OF ZINC PIGMENTS(1) AND COMPOUNDS PRODUCED BY DOMESTIC MANUFACTURES, BY SOURCES, 1969

(short tons)

	Zinc in Pigments and Compounds Produced From:				Total Zinc in pigments and Compounds
	Ore				
Pigment or Compound	Domestic	Foreign	Slab Zinc	Secondary Material	
Zinc oxide	82,643	23,949	41,362	28,115	176,069
Leaded zinc oxide	1,705	1,539	--	--	3,244
TOTAL	84,348	25,488	41,362	28,115	179,313
Zinc chloride(2)	--	--	W	W	11,632
Zinc sulfate	5,503	5,342	--	10,897	21,742

W - Withheld to avoid disclosing individual company confidential data.
(1) Excludes zinc sulfide and lithopone; figures withheld to avoid disclosing individual company confidential data.
(2) Includes zinc content of zinc ammonium chloride and chromated zinc chloride.
Source: U.S. Bureau of Mines, Minerals Yearbook, 1969, "Zinc" chapter.

Other Uses

Other uses for zinc in the U.S. in 1969 were as follows (zinc content in short tons)(2):

Rolled zinc	49,000
Zinc dust	55,000
Other Uses	38,000

(1) For an analysis of brass, see the report in this series on copper and copper-base alloys.
(2) U.S. Bureau of Mines, Minerals Yearbook, 1969, "Zinc" chapter.

APPENDIX B

ZINC RECYCLING INDUSTRY DATA FROM EXTENSIVE SURVEY

APPENDIX B

ZINC RECYCLING INDUSTRY DATA FROM EXTENSIVE SURVEY

TABLE B-1

AVERAGE SIZE OF ZINC SCRAP PROCESSORS, ANNUAL TONS, BY REGION

Region	Tons Per Year
Total U.S.	273.7
New England	110.9
Middle Atlantic	380.9
South Atlantic	193.5
East North Central	245.8
East South Central	167.5
West North Central	327.3
West South Central	437.5
Mountain	104.5
Pacific	332.1

TABLE B-2

AVERAGE SIZE OF ZINC SMELTERS, ANNUAL TONS, BY REGION

Region	Tons Per Year
Total U.S.	1654.3
New England	250.0
Middle Atlantic	2605.8
South Atlantic	843.8
East North Central	2190.8
East South Central	600.0
West North Central	812.5
West South Central	785.7
Mountain	250.0
Pacific	1250.0

TABLE B-3

SECONDARY MATERIALS INDUSTRY - AVERAGE BUSINESS STATISTICS FOR ZINC

Average Investment in Plant and and Equipment	Average Number of Employees	Average Investment Per Employee
403,000	43	25,500

VOLUME VI

NICKEL AND STAINLESS STEEL REPORT

TABLE OF CONTENTS

Page

TABLE OF CONTENTS
(Continued)

TABLE OF CONTENTS
(Continued)

LIST OF TABLES

LIST OF TABLES
(Continued)

LIST OF FIGURES

SUMMARY

The economic recycling of waste materials is a desirable approach to the disposal of solid wastes. Recycling, therefore, is of interest to the Office of Solid Waste Management Problems, whose responsibility it is to formulate and recommend solid waste programs for the United States. This report on recycling of nickel and nickel stainless steel provides information and analyses to be used as a basis for program planning. The report was prepared by Battelle-Columbus with the guidance and help of the National Association of Secondary Material Industries (NASMI). It is based on a twelve-month study of nickel recycling.

The report is divided into two sections, nickel and nickel stainless steel. Each section reviews briefly the demand and supply for nickel or nickel stainless steel in the United States. Each analyzes the recycling of nickel - the operations of scrap processors and smelters, sources of nickel or stainless steel scrap, markets for recycled nickel or stainless steel, and recycling rates by types of scrap. Based on this analysis, the report presents the problems faced by the nickel and stainless steel recycling industry. Finally, it evaluates these problems to determine priorities, and recommends courses of actions to solve or reduce these problems - with the emphasis on increasing recycling of nickel and stainless steel in order to reduce solid waste disposal problems.

The Recycling Industry

The task of the procurement, identification and sorting, refining, and sale of nickel alloy or stainless scrap for use by nickel or stainless steel users is the function of the nickel recycling industry. Scrap processors, brokers, and secondary smelters have developed efficient means of recycling the many different types and forms of nickel alloy or stainless steel scrap.

Recycled nickel contents of nickel alloys and stainless steels make up a significant proportion of total nickel consumption as seen below:

Source	Percent of Total Nickel Consumption
Recycled Nickel	35
Primary Nickel	65
Total	100

Nickel Alloy Problems

Estimates of percentage recycling for the major identifiable markets were made to outline those channels for which there was some obstacle to recycling. Figure I is a schematic diagram for the recycling of nickel in nickel alloys. It shows estimates of total amounts available for recycling, total amounts recycled, and total amounts not recycled for the major nickel alloys except stainless steel. About 40 percent of the total nickel available for recycling is returned to some nickel use.

Table I shows identification and analysis of the problems concerning nickel alloys that were not recycled in 1969.

Table II shows identification and analysis of those problems which do not directly reduce the amount of nickel alloys recycled. These are problems that might have economic effects on an individual company or on the industry, or make operations more difficult.

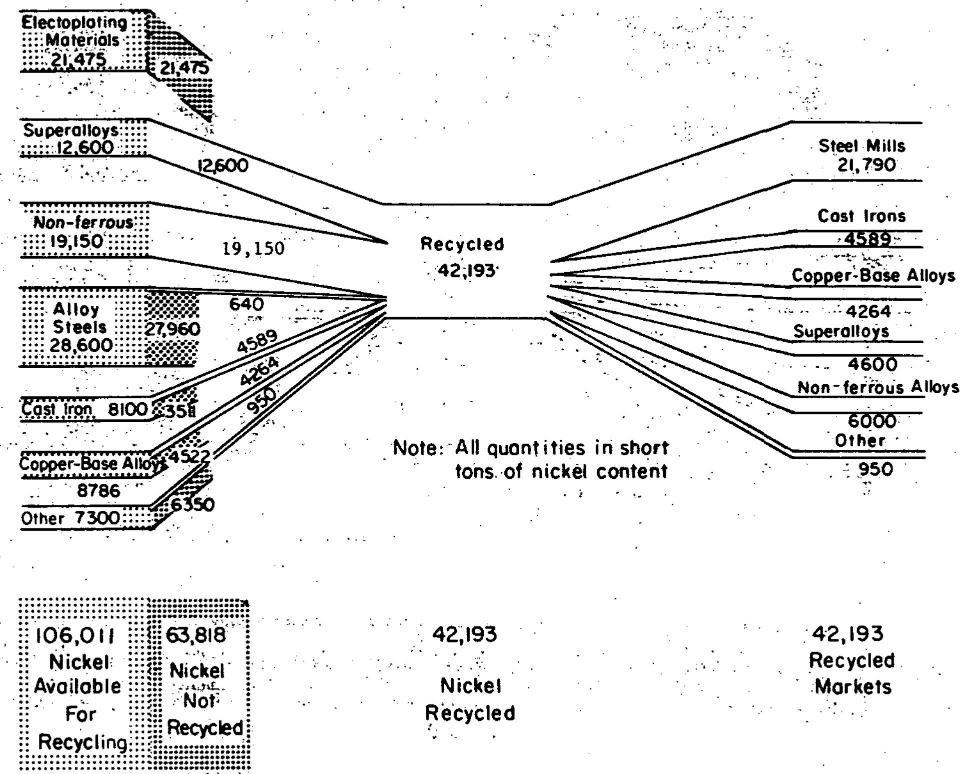


FIGURE I. NICKEL RECYCLING FLOW DIAGRAM, 1969

Note: See Table 12, page 30, for breakdown between prompt industrial and obsolete.

Source: U.S. Department of Interior, Bureau of Mines, Minerals Yearbooks, "Nickel" and "Iron and Steel Scrap" chapters; Battelle-Columbus estimates.

TABLE I. IDENTIFICATION AND ANALYSIS OF PROBLEMS CONCERNING NICKEL AND NICKEL ALLOYS THAT WERE NOT RECYCLED IN 1969.

Title	Scrap Categories Where Some Nickel Was Not Recycled: Industrial Low Alloy Steel	Electroplating Materials	Obsolete Low Alloy Steel
Problem Definition	1. Nickel contents in low alloy steel average about 0.80 percent. 2. Low alloy steel is shipped to various original equipment manufacturers (OEM) who machine and otherwise fabricate it. 3. After fabrication, scrap is usually returned back to steel mills.	1. Nickel is used in thicknesses of 1.2 to 1.6 mils as an underplate for automobile bumper, grills, and other trim. About 1 pound of nickel is used for each bumper. Automotive applications represent about 50 percent of total nickel plating market. 2. Nickel is used in thicknesses of 0.4 to 1.2 mils for consumer appliances, furniture, and sports equipment. These applications represent the bulk of the remaining portion of the nickel plating market. 3. In all uses, nickel becomes a minor constituent of a larger system.	1. Nickel contents in low alloy steel run from about 0.40 to 3.75 percent with an average around 0.80 percent. Generally, other elements are present, too. 2. Nickel containing low alloy steels represent about 16 percent of total low alloy steel production. 3. Low alloy steels are used in many diverse applications as a standard constructional material. When a low alloy steel part is scrapped, the low alloy steel is generally <u>not</u> recycled as a nickel alloy steel but as a low alloy steel. Consequently, the nickel is diluted enough to be considered lost.
Tons of Nickel <u>Not</u> Recyled	3,100	21,475	25,500
Percent of Available Nickel <u>Not</u> Recycled	81	100	100
Problem Analysis	1. Nickel is just one of several different constituents of low alloy steel. 2. It is fairly easy to determine (unlike obsolete low alloy scrap) what type of low alloy steel is being recycled without testing. Knowledge of OEM's processing provides needed information. 3. Yet <u>only</u> 19 percent of the available nickel is recycled. 4. This seems a promising area to increase the recycling.	1. Nickel is small part of larger system and is covered on two sides by metal. 2. For automobiles, other system components are steel, copper, chromium, zinc and zinc-alloys 3. Steel-chromium items are generally recycled back to the steel industry--<u>but</u> the nickel is diluted so much as to be called lost. Zinc items, in many instances, aren't being recycled. 4. For consumer goods, other systems components are plastic, copper, steel, wood, and glass. In addition, these items are small and generally are discarded to municipal waste after termination of useful life. 5. This is not a promising area to increase recycling.	1. Nickel is only one of several different constituents of low alloy steel. In most common low alloy steels, <u>total</u> alloy content is generally less than 3 percent. 2. It is difficult to distinguish one alloy steel grade from another (for nickel content) or from mild steel. 3. Since scrap prices for nickel containing types of low alloy steel are roughly equal to those of nonnickel containing grades, there is little incentive to segregate small quantities of steel. 4. This is not a promising area to increase the recycling of nickel.

TABLE I. IDENTIFICATION AND ANALYSIS OF PROBLEMS CONCERNING NICKEL AND NICKEL ALLOYS THAT WERE NOT RECYCLED IN 1969 (Continued)

Title	Scrap Categories Where Some Nickel Was Not Recycled: Cast Iron	Copper-Base Alloys
Problem Definition	1. Nickel is used in residual amounts of about 0.10 percent in gray iron. 2. Nickel is used as a carrier for magnesium in ductile iron in amounts up to 0.65 percent. 3. Almost all cast iron production is gray iron with some malleable and some ductile. 4. Gray iron is used for a number of different applications; such as motor vehicles and miscellaneous industrial equipment. Ductile iron is used for automotive applications and in miscellaneous types of industrial equipment.	1. Nickel is used in copper-base alloys for coinage, condenser tubing, nickel silver products, and nickel brasses/bronzes. 2. Coinage and condenser tube are generally recycled. 3. Nickel silver, however, is used for a wide variety of consumer applications: springs, tableware; fishing reels; and other similar uses. 4. Disposal of these alloys depends partly on the value of other materials and partly on the shape and size of nickel silver part.
Tons of Nickel <u>Not</u> Recyled	3,511	4,522
Percent of Available Nickel <u>Not</u> Recycled	43	53
Problem Analysis	1. After an average life cycle of 16 years, cast iron is sold as scrap. 2. As most of the nickel contained in obsolete scrap is in gray iron, and most materials recycled are gray iron going into gray iron production, it would follow that most of the nickel should be recycled. 3. Yet only 57 percent is being recycled. This is a promising area in which to increase recycling of nickel.	1. In 1969, 17,267 s.t. of nickel silver (containing about 15 percent nickel) were recycled. About 4,666 s.t. of cupronickel was recycled. 2. Nickel and copper are valuable commodities, selling for \$1.33/lb and \$0.50/lb respectively in primary form. 3. Cupronickel is generally used in heat exchangers and is easily recovered. Coinage is generally recovered by the mint but some is lost to hoarding. Nickel silver is often plated with silver; this is generally recycled. 4. Yet <u>only</u> 47 percent is being recycled. This is a promising area in which to increase recycling of nickel.

TABLE II. IDENTIFICATION AND ANALYSIS OF PROBLEMS THAT DO NOT DIRECTLY REDUCE THE AMOUNT OF NICKEL AND NICKEL ALLOYS THAT ARE RECYCLED (1)

Problem	Customer Prejudices	Alloy Separation	Conservation of Elements Other Than Nickel
PROBLEM DEFINITION	1. There have been periodic shortages of primary nickel in the past 20 years. There was a very serious shortage existent from 1967 to 1970. 2. This has forced some users of nickel to favor primary over recycled in times of nickel overcapacity so that allocations will be made to them in "tight" times. 3. In addition, despite good economics of using scrap, it is "easier" to use primary.	1. Superalloys and some nonferrous alloys are of very similar composition. All are nonmagnetic and are difficult to identify by other usual methods, e.g., color, spark, acid testing. 2. However, small differences in chemistry cause large differences in physical properties of superalloys. 3. Consequently, much effort is expended in separation of these alloys.	1. All superalloys contain significant amounts of other elements beside nickel, e.g., molybdenum, cobalt, columbium, titanium, tungsten. 2. In recent years, most superalloys have been recycled into stainless steel melting; this recovers the nickel and chromium contents of scrap but dilutes to a minimum most other elements.
EFFECT ON RECYCLE RATE	No significant effect on the amount of nickel recycled.	No significant effect on the amount of nickel recycled.	No significant effect on the amount of nickel recycled; great effects on other materials.
PROBLEM ANALYSIS	1. Recycled nickel scrap is <u>not</u> inferior to primary materials in most steel melts. 2. There is a need for promotional efforts that will inform buyers and actual users (many times different persons in steel mills, for instance) of advantages of using recycled materials. 3. New methods should be developed to aid buyers and users of scrap to make scrap easier to use.	1. This is a normal business activity in the recycling industry, but a more difficult one. 2. As all material is being recycled, no grave problems exist. 3. Continued development by superalloy melters and recycling industry on new recycling methods to recycle scrap back to superalloy melters, instead of stainless melters, is desirable from a conservation standpoint (for this problem, see next column).	1. All superalloys, by definition are melted in vacuum induction equipment. Little, if any, refining can be done in these furnaces. 2. Any heat with off-specification chemistry must be scrapped if dilution of impurities is not possible. All superalloys are produced to Aerospace Material Specifications, military specifications with strict chemistry and physical property requirements. 3. Superalloy melters consider the risk of using scrap to be great. However, a few of the leading melters are using some scrap in their melt charges. However, of the total amount of scrap generated, only a small fraction is returned to superalloy melting. 4. In the late 1960's, there was a great shortage of primary nickel. Stainless steel melters, desperate for nickel supplies, learned how to use superalloy scrap as nickel and chromium inputs in stainless steel melting. 5. Continued development by superalloy melters and recycling industry on methods to increase recycling of superalloy scrap is desirable.

(1) Problems adversely affect economics or practices of recycling but the effect in terms of amount cannot be measured. This situation is considered an indirect effect.

Nickel Alloy Recommendations

In order to identify those problems that have the highest priority for attention, evaluations based on several criteria were made on each problem. Highest priority ideas are those that are so important that the public, besides the nickel alloys recycling industry, would have interest in their solution. Consequently, these problems are important enough to be acted upon by EPA. These problems with their recommended actions are shown in Table III for nickel alloys. Lower priority ideas are those which are sufficiently important for the recycling industry to solve, but which aren't important enough for full-scale participation by the public. Consequently, these problems aren't important enough to be acted upon by EPA. These problems with their recommended actions are shown in Table IV for nickel alloys.

TABLE III. RECOMMENDED ACTIONS, HIGH PRIORITY NICKEL AND NICKEL ALLOY PROBLEMS

Title	Conservation of Resources Other Than Nickel
RECOMMENDED ACTIONS	An investigation should be undertaken to determine what elements and how much of other elements are being lost during the recycling of superalloy.
BY WHOM(1)(2)(3)	EPA/NASMI
SPECIFIC STEPS	1. Form a committee representing the following: • Nickel processors • Secondary nickel smelters • Vacuum melter of superalloys 2. The committee should discuss and analyze why superalloy scrap is being recycled into less exotic materials such as stainless steels. 3. The committee should study the basic problems of scrap reuse in superalloys, if any. 4. The committee should discuss the costs and benefits of problem solution. 5. The committee should determine what additional actions should be taken.

(1) The responsibility for recommended actions shown in this table are based on importance of the action, benefit to the taxpayers, and opportunities for NASMI. They are the best judgments of Battelle.
(2) Recommended actions were distributed between high priority and lower priority based on the evaluation with three criteria.
(3) It is suggested that NASMI continue its leading role in recycling, recognizing that other organizations such as the Bureau of Mines, Department of Commerce, Council of Environmental Quality, HEW Office of Information, and State, Local, and Federal Legislatures must be involved.

TABLE IV. RECOMMENDED ACTIONS, LOWER PRIORITY NICKEL ALLOY PROBLEMS

Title	Electroplating Products	Low Alloy Steel (Obsolete)	Low Alloy Steel (Industrial)
RECOMMENDED ACTIONS	A brief investigation should be made to determine whether any recycling of nickel in electroplated nickel products is economically feasible. If any potential solutions are found, action can be planned at that point.	An investigation should be made to determine why an estimated 100 percent of the nickel in available nickel alloy steel is not being recycled. Part or all of this may be explained by reporting errors by the recycling companies, or by lack of statistics reported by the U.S. Bureau of Mines.	An investigation should be made to determine why an estimated 80 percent of the nickel in available industrial nickel alloy steel is not being recycled. Part or all of this may be explained by various reporting errors or incomplete reporting.
BY WHOM(1)(2)(3)	NASMI/NASMI MEMBERS	ISIS(4)/ISIS MEMBERS	ISIS/ISIS MEMBERS
SPECIFIC STEPS	1. Set up a committee composed of nickel processors and nickel smelters. 2. The committee should analyze the recycling problems pertinent to electroplated nickel. 3. The committee should determine whether there is any way to increase recycling that is attractive. 4. If anything appears to be attractive, the committee should recommend specific steps to take in order to make recycling feasible.	1. Form a committee composed of processors. 2. The committee should analyze and discuss the possible reasons for the relatively low recycle rate. 3. The committee should discuss with the Bureau of Mines why there are possible reporting errors. 4. The committee should analyze all of the data to select the next action.	1. Form a committee composed of processors. 2. The committee should analyze and discuss the possible reasons for the relatively low recycle rate. 3. The committee should discuss with the Bureau of Mines why there are possible reporting errors. 4. The committee should analyze all of the data to select the next action.

(1) The responsibility for recommended actions shown in this table are based on importance of the action, benefit to the taxpayers, and opportunities for NASMI. They are the best judgments of Battelle.

(2) Recommended actions were distributed between high priority and lower priority based on the evaluation with three criteria.

(3) It is suggested that NASMI continue its leading role in recycling, recognizing that other organizations such as the Bureau of Mines, Department of Commerce, Council of Environmental Quality, HEW Office of Information, and State, Local, and Federal Legislatures must be involved.

(4) Institute of Scrap Iron and Steel (ISIS).

TABLE IV. RECOMMENDED ACTIONS, LOWER PRIORITY NICKEL ALLOY PROBLEMS (Continued)

Title	Cast Iron	Copper-Base Alloys
RECOMMENDED ACTIONS	An investigation should be made to determine why about 43 percent of the nickel in available cast iron is not recycled.	An investigation should be made to determine why an estimated 53 percent of the nickel in copper-base alloys is not recycled. Part of this error may be explained by reporting errors or incomplete reporting.
BY WHOM	ISIS/ISIS MEMBERS	NASMI/NASMI MEMBERS
SPECIFIC STEPS	1. Form a committee composed of proccessors. 2. The committee should analyze and discuss the possible reasons for the relatively low recycle rate. 3. The committee should discuss with the Bureau of Mines why there are possible reporting errors. 4. The committee should analyze all of the data to select the next action.	1. Form a committee composed of nickel processors. 2. The committee should analyze and discuss the possible reasons for the relatively low recycle rate of nickel-containing copper-base alloys. 3. The committee should discuss with the Bureau of Mines possible misunderstandings in the reporting of nickel-containing copper-base. 4. A survey of the recycling and user industries to determine where these alloys are used and where they might be lost should be initiated. 5. The committee should analyze all data to select the next actions.

TABLE IV. RECOMMENDED ACTIONS, LOWER PRIORITY NICKEL ALLOY PROBLEMS (Continued)

Title	Alloy Separation	Customer Prejudices
RECOMMENDED ACTIONS	An investigation should be made to look for improved methods of nickel alloy segregation.	Publicity programs should be undertaken to point out the advantages of using recycled materials over competitive materials
BY WHOM	NASMI/NASMI MEMBERS	NASMI/NASMI MEMBERS
SPECIFIC STEPS	1. Form a committee composed of nickel processors. 2. The committee should analyze the present attempts to expedite, and to make more accurate, the analysis of various nickel-base scraps. 3. The committee should investigate new techniques in alloy separation. 4. The committee should determine what future steps are necessary to solve the problem.	1. NASMI should continue its present publicity programs and seminars. 2. NASMI should develop specific programs toward nickel recycling in areas where it would be most advantageous. 3. NASMI should retain a metallurgical or other consultant to assist NASMI in finding ways to use scrap and to instruct potential scrap users in these methods.

Nickel Stainless Steel Problems

Figure II is a schematic diagram for the recycling of stainless steels. It shows estimates of total amounts available for recycling, total amounts recycled, and total amounts not recycled for stainless steel. An estimated 88 percent of the total stainless steel available for recycling is reused in one way or another.

Table V shows identification and analysis of the problems concerning nickel stainless steel that was not recycled in 1969.

Table VI shows identification and analysis of those problems which do not directly reduce the amount of stainless steel recycled. These are problems that might have economic effects on an individual company or on the industry, or make operations more difficult.

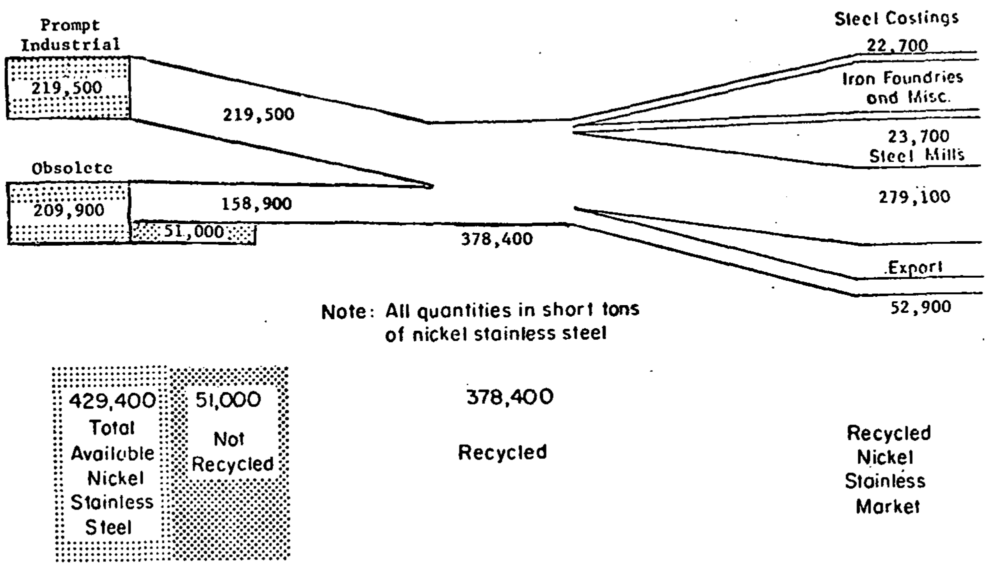


FIGURE II. RECYCLED NICKEL STAINLESS STEEL FLOW, 1969

Source: U.S. Department of the Interior, Bureau of Mines, Minerals Yearbooks, "Nickel" and "Iron and Steel Scrap" chapters.

TABLE V. IDENTIFICATION AND ANALYSIS OF PROBLEMS CONCERNING STAINLESS STEEL THAT WAS NOT RECYCLED IN 1969

Title	Obsolete Stainless Steel
PROBLEM DEFINITION	1. Prompt stainless steel scrap is estimated to be about 100 percent recycled. Obsolete stainless steel scrap is only 76 percent recycled. 2. This problem cannot be broken down further due to the lack of adequate statistical information. 3. Stainless steel is used in a myriad of different applications, e.g., automobile parts and trim, aircraft engine components, and appliances and cutlery. 4. Applications where stainless steel is a large part of a system are generally recycled, but those applications, e.g., cutlery and small appliances, where stainless steel is a small part of a system are probably not completely recycled.
TONS OF STAINLESS NOT RECYCLED	51,000
PERCENT OF AVAILABLE STAINLESS NOT RECYCLED	24
PROBLEM ANALYSIS	1. Stainless steel is often a small part of a larger system in consumer appliances and other stainless uses. 2. These items are small and generally are discarded to municipal waste after termination of useful life. 3. This seems a promising area to increase recycling.

TABLE VI. IDENTIFICATION AND ANALYSIS OF PROBLEMS THAT DO NOT DIRECTLY REDUCE THE AMOUNT OF NICKEL STAINLESS STEEL THAT IS RECYCLED, 1969(1)

Title	Customer Prejudices Against Scrap
PROBLEM DEFINITION	1. Some scrap types, e.g., stainless steel turnings, aren't being purchased by some scrap users and are being exported overseas to foreign steel producers. 2. Despite good economics of using scrap, stainless steel mills sometimes prefer primary over scrap because (a) it is easier to use primary and (b) they prefer to use more expensive primary so that they are assured adequate nickel supplies during shortages.
EFFECT ON RECYCLE RATE	None. Most of this scrap is recycled by exporting it overseas.
PROBLEM ANALYSIS	1. For most applications, stainless steel made from recycled scrap is not inferior to that made only from primary materials. 2. There is a need for promotional and educational efforts that will inform buyers and actual users of advantages of using recycled materials.

(1) Problems adversely affect economics or practices of recycling but the effect in terms of amount cannot be measured. This situation is considered an indirect effect.

Nickel Stainless Steel Recommendations

In order to identify those problems that have the highest priority for attention, evaluations based on several criteria were made on each problem. Highest priority ideas are those that are so important that the public, besides the stainless steel recycling industry, would have interest in their solution. Consequently, these problems are important enough to be acted upon by EPA. These problems with their recommended actions are shown in Table VII for nickel stainless steel. Lower priority ideas are those which are sufficiently important for the recycling industry to solve, but which aren't important enough for full-scale participation by the public. Consequently, these problems aren't important enough to be acted upon by EPA. These problems with their recommended actions are shown in Table VIII for nickel stainless steel.

TABLE VII. RECOMMENDED ACTIONS, HIGH PRIORITY STAINLESS STEEL PROBLEMS

Title	Obsolete Stainless Steel
RECOMMENDED ACTIONS	An investigation should be undertaken to determine why approximately 51,000 tons of nickel stainless steel were not recycled in 1969.
BY WHOM(1)(2)(3)	EPA/NASMI
SPECIFIC STEPS	1. Form a committee representing the following: • Stainless steel processors • Stainless steel fabricators • Stainless steel mills 2. The committee should discuss the problem with other people knowledgeable in the area of obsolete stainless steel scrap including: • Municipal land fill operators • Small scrap collectors 3. The committee should discuss and analyze why obsolete stainless steel scrap is not being recycled. 4. The committee should determine what additional actions should be taken.

(1) The responsibility for recommended actions shown in this table are based on importance of the action, benefit to the taxpayers, and opportunities for NASMI. They are the best judgments of Battelle.
(2) Recommended actions were distributed between high priority and lower priority based on the evaluation with three criteria.
(3) It is suggested that NASMI continue its leading role in recycling, recognizing that other organizations such as the Bureau of Mines, Department of Commerce, Council of Environmental Quality, HEW Office of Information, and State, Local, and Federal Legislatures must be involved.

TABLE VIII. RECOMMENDED ACTIONS, LOWER STAINLESS STEEL PRIORITY PROBLEMS

Title	Customer Prejudice Against Recycled Material
RECOMMENDED ACTIONS	NASMI should undertake a broad publicity program to: (1) Outline to the public the conservation features of using scrap. (2) Help large users of scrap to publicize their conservational actions. (3) Help small users of scrap with their problems so they will be less reticent to use scrap.
BY WHOM(1)(2)(3)	NASMI/NASMI MEMBERS
SPECIFIC STEPS	(1) NASMI should continue its recycle programs, conferences, etc., to inform the public and promote conservation aspects of recycling. (2) Furthermore, NASMI should promote seminars to discuss new and useful techniques of using additional stainless scrap inputs in steelmaking. (3) NASMI should promote research in methods of utilizing higher amounts of scrap.

(1) The responsibility for recommended actions shown in this table are based on importance of the action, benefit to the taxpayers, and opportunities for NASMI. They are the best judgments of Battelle.
Recommended actions were distributed between high priority and lower priority based on the evaluation with three criteria.
It is suggested that NASMI continue its leading role in recycling, recognizing that other organizations such as the Bureau of Mines, Department of Commerce, Council of Environmental Quality, HEW Office of Information, and State, Local, and Federal Legislatures must be involved.

INTRODUCTION

In June, 1970, Battelle-Columbus undertook a research program for the National Association of Secondary Material Industries, Inc. (NASMI). This work was carried out under a subcontract from the Office of Solid Waste Management grant to NASMI. This report on nickel and stainless steel is one of a series of eight commodity reports plus a general or summary report.

Background

The Office of Solid Waste Management is responsible for formulating and recommending Federal Government policies in the area of solid waste pollution. This includes pursuing appropriate research to determine the status and problems of solid waste activities, and to develop programs to reduce solid waste pollution.

One approach to the reduction of solid waste pollution is to reclaim waste materials for reuse - the recycling concept. A well established industry--

the secondary materials industry--exists to accomplish this recycling. NASMI is the trade association representing the nonferrous metals, paper, and textiles portion of this industry.

The scrap processors, secondary smelters, and other companies that make up the secondary materials industry have developed effective channels and methods for recycling nearly all waste materials of economic value. These companies have performed their difficult and essential functions well in the traditional economic environment.

More recently, additional dimensions have been added to this traditional economic environment. These new dimensions are (1) improvement of the environment in which we live, and (2) increased need for conservation of natural resources. These new dimensions provide new challenges and opportunities for the recycling industry. No longer is economic gain the sole driving force for recycling of waste materials. Social gain has been added in the forms of improved living conditions and preservation of resources for future generations. In an economics-based nation this creates problems of interpretation and evaluation of noneconomics-based goals and activities.

The purpose of this series of reports is to identify obstacles to the recycling of nonferrous solid wastes, and to recommend directions for investigation and research to overcome these obstacles.

Objectives

The objective of the study on which this report is based was to identify opportunities for the increased utilization of solid waste. The major subobjectives were:

(1) To determine the structure and functions of the secondary materials industry, and its relationships to sources of supply and markets

(2) To identify and evaluate problems of recycling - materials, sources, industry, and markets

(3) To determine opportunities for increased recycling.

Scope

The major subjects included in the scope of the study are the secondary materials industry, the materials it recycles, the sources of solid wastes, and the markets for recycled materials. Activities peripheral to these major subjects are considered where pertinent to recycling.

The materials included in the study are:

Aluminum	Nickel and Nickel Alloys
Copper and Copper Alloys	Precious Metals (Silver, Gold, and Platinum)
Lead	Paper
Zinc	Textiles.

Research Methods

The methods and procedures used in the study are discussed under four types of activities. They include (A) literature search, (B) extensive survey, (C) in-depth survey, and (D) analysis and synthesis.

Literature Search

The literature search included reviewing and studying books, Government reports, industry reports, and trade journals covering solid waste handling and problems, recovery and market data, and recycling of valuable materials.

The results of this effort included the accumulation of data and descriptive material, and an organized bibliography dealing with each of the commodities covered in the scope of the study.

Extensive Survey

The extensive survey of the secondary materials industry consisted of a mail survey and personal interviews with management personnel of companies involved with the collection, processing, and sale of secondary materials. About 600 responses were received.

The information developed through the extensive survey included dollar sales, tons of major materials handled, types of solid waste processed, sources of materials, investment, equipment and facilities, number of employees, the amount of space used, and the grades and quantities of secondary materials produced.

The data from the extensive survey provided statistical tabulations of the regional distribution of the secondary materials industries by type of commodity in terms of numbers of establishments, volume of business, and numbers of employees.

In-Depth Survey

The in-depth survey of selected members of the secondary materials industries, their suppliers, and the users of their products served to identify the major technical and economic problems facing those companies involved with the secondary material utilization. About 200 interviews were completed. Battelle and NASMI commodity specialists jointly selected the companies to be interviewed in depth.

Interview guides for each of the commodities were prepared. The problems and potential solutions for greatest recycling and waste utilization that were developed from the literature search and prior Office of Solid Waste Management

work plus the knowledge of the NASMI commodity specialists provided the basis for designing the interview guide.

Analysis and Synthesis

The analysis and synthesis step was concerned with the collation and analysis of data and information derived from the literature, extensive survey, and in-depth survey. The analysis and synthesis activity covered the following tasks:

(1) Economic Data on the Secondary Materials Industries. The economic data developed through the extensive survey of the secondary materials industries were tabulated and analyzed as to the amount and type of solid waste handled and as to operational data such as number of employees, amount of space required, capitalization, and geographic locations.

(2) Flow Diagrams and Life Cycles. Flow diagrams were developed to indicate the flow of materials from primary production and scrap sources through fabrication. Life cycle estimates of various products were used to develop data on quantities available for possible recycling.

(3) Demand-Supply Relationships. Estimates were made of future demand and supply levels for secondary materials. The relationship between these data provide an indication of potential surpluses or shortages of recycled materials through 1980.

(4) Stability of Flow and Consumption. This analysis is closely related to the supply-demand analysis described above and identifies the ability of the various secondary materials to

compete as source materials for manufacturers. A number of factors were examined such as price changes in the secondary materials, the availability of materials, and the effect of sudden changes in the magnitude of demand.

(5) Direct Impacts of Technological Change. Direct technical and technological factors were examined to determine their effect on rates of processing and recycling. Potential changes that could take place in technology that could decrease or increase the rate of solid waste recovery were examined. This includes the identification of potentially recoverable solid wastes, the problems limiting the recovery to current levels, and the possibilities of technical advances through the use of known technology or through added scientific and engineering research.

(6) Constraints on Expansion of the Secondary Materials Industries. This analysis included consideration of elements critical to expansion of recycling - labor and management availability, laws and regulations, equipment availability, nature of solid waste materials, market needs, etc.

(7) Potentials for Expansion of the Secondary Materials Industries. Based on the constraints identified in the above task, plus examination of various methods for overcoming constraints, this task determined the ability of the secondary materials industries to meet new opportunities for recycling.

(8) Indirect Technological Change. The broad overall technological trends indirectly affecting the secondary materials industries were examined, and their probable impacts determined.

THE NICKEL INDUSTRY

Although nickel is used in unalloyed forms, such as on electroplated surfaces and in chemical process equipment, most nickel is used in alloy form. Nickel is used in varying amounts in stainless steel, low alloy steel, cast iron, cupronickels, permanent magnet materials, and many other different applications. The nickel used in stainless steels, however, is the subject of the second section of this report; except for clarification in statistical form, the subject of stainless steels will not be mentioned further in this discussion of nickel.

Characteristics of Nickel

Nickel is used in a number of different forms. The most popular of which are:

Electrolytic cathode
Nickel oxide sinter
Ferronickel
Pellets and powder
Recycled nickel.

Electrolytic Cathode

Electrolytic cathode accounts for over 60 percent of the total U. S. consumption of primary nickel. Electrolytic cathode, one of the purest forms of primary nickel, can be used in virtually any application that requires nickel. Table 1 gives the American Society for Testing and Materials (ASTM) Specification for electrolytic cathode. Appendix A describes other grades of primary nickel.

TABLE 1. REFINED ELECTROLYTIC NICKEL SPECIFICATIONS

Ni	99.80 min	P, Mn, Si, As, Pb, Sb, Bi, Sn, Zn, less than 0.005 each
Co	0.15 max	
Cu	0.02 max	
C	0.03 max	
Fe	0.02 max	
S	0.01 max	

Source: American Society for Testing and Materials

Characteristics of the Nickel Industry

Unlike the copper industry, producers of nickel do not process their nickel and make finished goods. Most nickel is sold in the primary form. International Nickel does, however, produce semifinished nickel alloy forms.

Materials Sources

U. S. nickel consumers depended on the following sources for their nickel in 1969:

Source	1969 Consumption* (Short Tons, Nickel Content)
Domestic Refined Metal	8,119
Foreign Refined Metal	94,160
Recycled Metal	42,193
Total	144,472

* Excludes primary nickel and stainless steel scrap going into stainless steel melting. The second section of this report will discuss this further.

Materials Flow

A diagram outlining the materials flow from source of nickel to fabricated product is shown in Figure 1. As shown, the major sources of nickel for U. S. consumers are foreign refined and domestic recycled materials.

Markets for Nickel

Historically, the main markets for nickel have been as alloying additions to steel and nonferrous alloys, as electroplating products, and as additions in other miscellaneous applications.

Prices

Historical prices for primary nickel are shown in Table 2. Note the rapid rate of increase in prices from $0.78 per pound in 1965 to $1.33 per pound at present. Reasons for the recent increases in the price are twofold: (1) the demand/supply imbalance for nickel, and (2) the rapid increase in cost of extracting nickel from ore. From 1967 to 1969, a severe shortage of nickel resulted due to a long miners' strike and unanticipated nickel demand increases. Also during this period, inflationary trends forced operating costs up.

Use Patterns

The major uses for nickel are for alloying additions to stainless steel, low alloy constructional steels, cast irons, and copper-base alloys; for electroplating products; for superalloys and other nickel-base alloys; for uses in other applications such as batteries, chemicals, catalysts, and electronic alloys. Table 3 gives consumption of primary nickel for the above uses. Note the importance of the steel industry to primary nickel consumption.

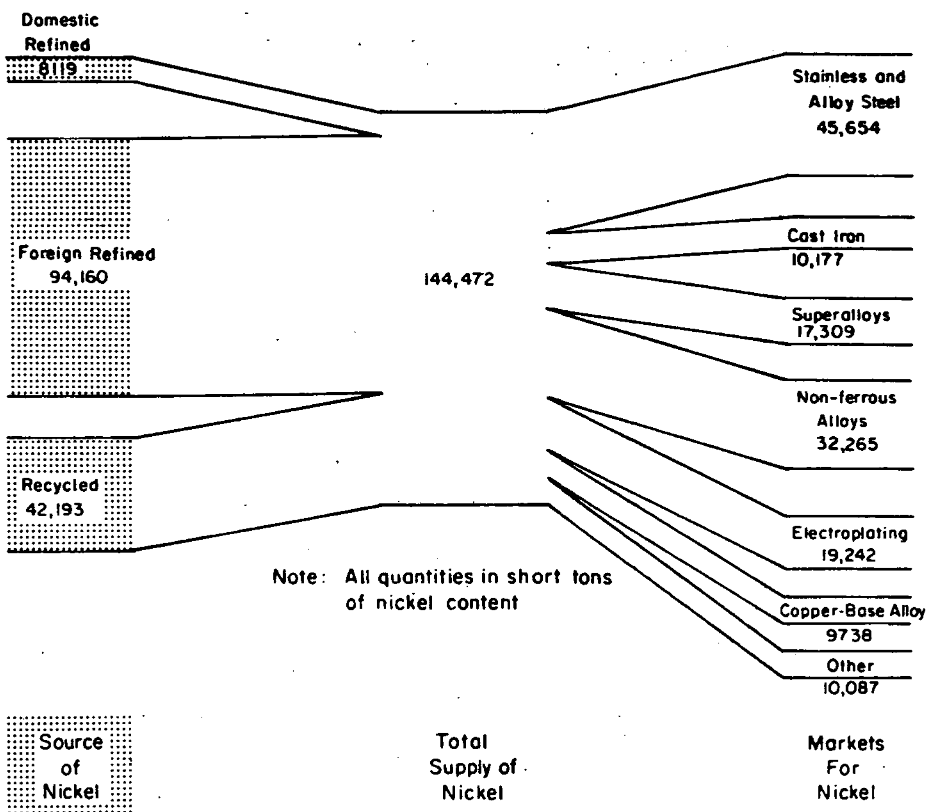


FIGURE 1. MATERIALS FLOW BALANCE* FOR NICKEL, 1969
(*EXCLUDES PRIMARY NICKEL AND RECYCLE STAINLESS STEEL SCRAP GOING INTO STAINLESS MELTING)

Source: Battelle estimates; U.S. Department of Interior, Bureau of Mines; Minerals Yearbook, "Nickel" and "Iron and Steel Scrap" chapters.

TABLE 2. HISTORICAL PRICES FOR NICKEL, SELECTED YEARS 1940-1971

Basis: Electrolytic cathode, dollars (U.S.) per pound, fob Port Colborn.

Year	Price Dollars Per Pound
1940	0.35
1945	0.35
1950	0.44792
1955	0.645
1960	0.74
1961	0.77653
1962	0.79895
1963	0.79
1964	0.79
1965	0.7775
1966	0.8525
1967	0.94
1968	1.03
1969	1.28
Present	1.33

TABLE 3. CONSUMPTION OF PRIMARY NICKEL IN THE UNITED STATES

Consumption in the United States (exclusive of scrap) by uses as reported by the U. S. Bureau of Mines, in short tons of nickel.

	1960	1961	1962	1963	1964	1965	1966	1967	1968	1969
Ferrous:										
Stainless Steel	30,086	34,213	29,711	34,140	48,301	51,700	65,910	53,936	44,858	39,458
Other Steels	15,331	18,238	18,608	19,727	24,679	27,009	27,807	23,661	29,014	23,864
Cast Iron	4,605	4,649	5,503	5,509	6,605	6,937	7,286	6,596	6,322	5,588
Nonferrous[a]	26,567	28,789	28,215	24,794	23,639	37,082	57,303	47,400	47,048	{ 12,709[b] 26,265[c] 5,474[d]
High temperature[e] and electrical-resistance alloys	10,095	11,294	12,862	13,505	15,291	18,464	5,423[e]	4,311	3,886	--
Electroplating:										
Anodes[f]	15,847	15,737	16,953	18,621	19,446	19,450	13,828	23,721	24,919	{ 19,242
Solutions[g]	970	770	904	1,050	1,645	2,037	1,925	4,041	3,522	
Catalysts	1,515	1,519	1,566	1,613	2,167	2,241	(h)	(h)	(h)	(h)
Ceramics	365	366	439	554	529	501	(h)	(h)	(h)	(h)
Magnets	778	773	910	777	664	828	807	806	748	--
Other	1,970	2,167	3,006	3,796	3,954	5,835	7,544	6,019	8,349	9,137
Total, partly estimated	108,159	118,515	118,677	124,478	146,920	172,084	187,833	173,798	159,306	141,737

(a) Comprises copper-nickel alloys, nickel-silver, brass, bronze, beryllium alloys, magnesium and aluminum alloys, Monel, Inconel, and malleable nickel.
(b) Superalloys.
(c) Other nickel and nickel alloys.
(d) Nickel-copper and copper-nickel alloys.
(e) High temperature alloys now under nonferrous alloys or with heat-resisting under stainless.
(f) Figures represent quantity of nickel used for production of anodes, plus cathodes used as anodes in plating operations.
(g) Figures do not cover all consumers.
(h) Now included in "other" group.

Source: U.S. Department of Interior, Bureau of Mines, Minerals Yearbook, "Nickel" chapter.

Table 4 gives consumption of nickel, primary and recycled, in its principal uses for 1969. Recycled nickel containing products are used extensively by the steel industry. It accounted for consumption of 117,662 short tons of nickel content in 1969. Other industries, e.g., cast iron and copper-base alloys producers, also relied on recycled nickel for a large fraction of their nickel inputs. Among all nickel users, only the electroplating industry relied little on recycled nickel materials.

TABLE 4. U. S. CONSUMPTION OF PRIMARY AND RECYCLED NICKEL BY USE, 1969

	Short Tons of Nickel Content		
	Primary	Recycled	Total
Stainless/Alloy Steel	63,322	54,340	117,662
Cast Iron	5,588	4,589	10,177
Superalloys	12,709	4,600	17,309
Electroplating	19,242	0	19,242
Nonferrous Alloys	26,265	6,000	32,265
Copper-Base Alloys	5,474	4,264	9,738
Other	9,137	950	10,087
Total	141,737	74,743	216,480

Source: U.S. Department of Interior, Bureau of Mines, Minerals Yearbook, "Nickel" chapter, and Battelle-Columbus estimates.

Stainless Steel. Since stainless steel consumes from 30 to 35 percent of the primary nickel each year and almost an equal amount of nickel in mill revert and recycled scrap, nickel stainless steels are important enough to be considered as a separate topic and are discussed separately in the second section of this report. See the next section for stainless steel recycling information, problems, and recommendations for action.

Low Alloy Steels. Nickel is used in amounts of 0.50 to 3.50 percent to strengthen and otherwise modify steels of low alloy content. There are five types of nickel-containing low alloy steel: nickel, nickel-chromium, nickel-molybdenum, nickel-chromium-molybdenum, and nickel-chromium-molybdenum-vanadium. At present, the largest markets for nickel-containing low alloy steels are the automotive, farm implement, electrical equipment, aerospaces, mining, and metal-working industries. These steels are used in making many kinds of machinery parts, such as gears, axles, drill bits, and turbine/generator rotors. Although nickel containing low alloy steels continue to be used in quantity, the rate of growth has slowed in the last five years. See Appendix B for further detailed consumption of alloy steel.

Electroplating Materials. Nickel is consumed in several different forms in electroplating baths. A rolled anode, containing 99 percent nickel and small amounts of nickel oxide to depolarize it has been the leading product for electroplating. It is still being used by platers in some quantity. Another popular product for use in plating baths is sheared electrolytic nickel cathodes which are contained in titanium baskets as anode material. There has been a very significant trend in the increased usage of electrolytic nickel (called SD nickel), with small additions of sulfur (about 0.02 percent) so that rapid dissolution of the anode material will occur, and in nickel plating salts that are introduced as additions directly to the plating baths.

For years, electroplating has been a large and growing consumer of nickel. In 1969, electroplating accounted for roughly 14 percent of total nickel consumption. Electroplaters, in general among nickel consumers, have been the most affected by the recent nickel shortage. Small platers had extreme problems in obtaining enough nickel even at greatly increased prices.

About 50 percent of the nickel consumed for electroplating applications is for automotive use. About 1 pound of electroplated nickel is used on each car bumper; other applications include grills, door handles, lower body trim, and windshield wiper parts. For car applications that must endure corrosion and denting, e.g., bumpers, plated nickel thicknesses must be 1.5 mils.

The bulk of the remaining nickel is used in home appliances, utensils, furniture, and sports equipment. These applications consume about 30 to 35 percent of the nickel consumed for electroplating. Most of these applications require only 25 to 50 percent of the plating thicknesses of automotive applications. There are other small industrial plating applications for nickel, and nickel is also electroformed.

Superalloys.* These alloys are generally used in elevated temperature portions of aircraft jet engines, industrial gas turbines, rockets, and similar uses. Many of the alloys are nickel-base with small additions of various elements to achieve specific property characteristics in strength, fatigue resistance, and oxidation resistance. Some of the most common superalloy compositions are shown in Table 5. Many of these compositions are casting alloys for making blades and vanes, while others are forging alloys for discs, shafts, rings, and casings.

* These alloys have been developed to achieve high values of structural integrity and low cycle fatigue resistance at elevated temperatures. Consequently, these alloys are to be differentiated from other nickel-base alloys.

TABLE 5. COMPOSITIONS AND COMMON FORMS OF SUPERALLOYS

Alloy Designation	Nominal chemical composition, percent															Form		
	C	Mn	Si	Cr	Ni	Co	Mo	W	Cb	Fe	Ti	Al	B	Zr	Other	Cast	Bar	Sheet
Alloy 713C	0.12			12.5	Bal		4.2		2.0		0.8	6.1	0.012	0.10		x		
Alloy 713LC	.05			12.0	Bal		4.5		2.0		.6	5.9	.010	.10		x		
Alloy 901	.05	0.10	0.10	12.5	42.5		5.7			Bal	2.8	.2	.015				x	
Alloy 901																		x
A-286	.05	1.35	.50	15.0	26.0		1.3			Bal	2.0	.2	.015				x	
B-1900	.10			8.0	Bal	10.0	6.0				1.0	6.0	.015	.10	4.0 Ta	x		
D-979	.05	.25	.20	15.0	Bal		4.0	4.0		27.0	3.0	1.0	.010				x	
Discaloy	.04	.90	.80	13.5	26.0		2.7			Bal	1.7	0.1	.005				x	
GMR 235-D	.15			15.5	Bal		5.0			4.5	2.5	3.5	.050			x		
Hastelloy alloy R-235	.15			15.5	Bal		5.5			10.0	2.5	2.0						x
Hastelloy alloy X	.10	.50	.50	22.0	Bal	1.5	9.0	.6		18.5								x
Inconel alloy 625	.05	.15	.30	22.0	Bal		9.0		4.0	3.0	.2	.2					x	
Inconel alloy 700	.12	.10	.30	15.0	Bal	28.5	3.7			.7	2.2	3.0					x	
Inconel alloy 702	.04	.05	.20	15.6	Bal					.4	.7	3.4						x
Inconel alloy 718	.04	.20	.30	18.6	Bal		3.1		5.0	18.5	.9	.4					x	
Inconel alloy 718																		x
Inconel alloy 722	.04	.55	.20	15.0	Bal					6.5	2.4	.6						x
Inconel alloy 750	.04	.70	.30	15.0	Bal				.9	6.8	2.5	.8					x	
Inconel alloy 750																		x
IN 100	.18			10.0	Bal	15.0	3.0				4.7	5.5	.014	.06	1.0 V	x		
IN 102	.06			15.0	Bal		3.0	3.0	3.0	7.0	.6	.4	.005	.03	.02 Mg		x	
L-605	.10	1.50	.50	20.0	10.0	Bal		15.0										x
M-22	.13			5.7	Bal		2.0	11.0				6.3		.60	3.0 Ta	x		
MAR-M 200	.15			9.0	Bal	10.0		12.5	1.0		2.0	5.0	.015	.05		x		
MAR-M 246	.15			9.0	Bal	10.0	2.5	10.0			1.5	5.5	.015	.05	1.5 Ta	x		
M-252	.15	.50	.50	20.0	Bal	10.0	10.0				2.6	1.0	.005				x	
Nicrotung	.10			12.0	Bal	10.0		8.0			4.0	4.0	.050	.05		x		
Nimonic alloy 80A	.06	.10	.70	19.5	Bal	1.1					2.5	1.3					x	
Nimonic alloy 90	.07	.50	.70	19.5	Bal	18.0					2.4	1.4					x	
Nimonic alloy 115	.15			15.0	Bal	15.0	3.5				4.0	5.0					x	
N-155	.15	1.50	.50	21.0	20.0	20.0	3.0	2.5	1.0	Bal					.15 N		x	
PDRL 162	.12			10.0	Bal		4.0	2.0	1.0	Bal	1.0	6.5	.020	.10	2.0 Ta	x		
Refractaloy 26	.03	.80	1.00	18.0	Bal	20.0	3.2			16.0	2.6	.2					x	
Rene 41	.09			19.0	Bal	11.0	10.0				3.1	1.5	.005				x	
Rene 41																		x
S-816	.38	1.20	.40	20.0	20.0	Bal	4.0	4.0	4.0	4.0							x	
TD-Nickel	.01	<.01	<.01	<.01	Bal	.03	<.01			<.01		<0.1			2.2 ThO₂		x	
TD-Nickel																		x
TRW 1900	.11			10.3	Bal	10.0		9.0	1.5		1.0	6.3	.030	.10		x		
Udimet 500	.08			18.0	Bal	18.5	4.0				2.9	2.9	.006	.05			x	
Udimet 500	.07			19.0	Bal	19.0	4.2				3.0	3.0	.007	.05		x		
Udimet 520	.05			19.0	Bal	12.0	6.0	1.0			3.0	2.0	.005				x	
Udimet 630	.03			18.0	Bal		3.0	3.0	6.5	18.0	1.0	.5					x	
Udimet 700	.08			15.0	Bal	18.5	5.2				3.5	4.3	.030				x	
Unitemp AF 1753	.24			16.3	Bal	7.2	1.6	8.4		9.5	3.2	1.9	.008	.06			x	
Waspaloy	.08			19.5	Bal	13.5	4.3				3.0	1.3	.006	.06			x	
X-40	.50	.75	.75	25.5	10.5	Bal		7.5								x		
16-25-6	.06	1.35	.70	16.0	25.0		6.0			Bal					.15 N	x		

Source: U.S. Bureau of Standards, Nickel and Its Alloys, Samuel J. Rosenburg, Washington, GPO, 1968.

One trend in the materials used for aerospace applications is the replacement of iron-based superalloys with nickel-and-cobalt-based superalloys as higher, more efficient temperatures are sought in advanced engines. The trend can be illustrated from the materials trends in GE engines as follows:

ALLOY BASE, PERCENT

Speed	Engine	Time Period	Al, Mg	Ti	Fe	Ni, Co	Engine Dry Weight, Pound
Subsonic	J47	1950	22	0	70	8	2,554
Supersonic	J79	1955	3	2	85	10	3,620
Mach 3	C93	1960	1	7	24	68	n.a.
Subsonic	TF39	1969	2	33	18	47	7,026
Fan	CF 6	1969	2	33	18	47	7,026
Supersonic	GE 4	1974	1	12	15	72	11,303

Appendix B gives estimates of the markets for vacuum melted wrought and cast superalloys in 1969.

Cast Iron. There are four basic types of nickel-containing cast iron: (1) nickel-containing gray iron, (2) ductile iron, (3) Ni-resist iron, and (4) Ni-hard iron. Of these, nickel-containing gray irons and ductile irons are by far the largest and most important.

The production of gray iron was about 16 million short tons in 1969. Its nickel composition is about 0.10 percent. Not much nickel is deliberately added to gray iron production, but since large quantities of iron and steel scrap are used by this industry, a residual of 0.10 to 0.15 percent nickel will be present. Gray iron is used in a myriad of different applications; motor vehicles, agricultural equipment, mining and construction equipment, machine-tool frames, and foundry metal working equipment are a few typical applications for gray iron.

The annual production of ductile iron has increased from about 190 thousand short tons in 1960 to about 1.6 million short tons in 1969. Nickel is used in ductile iron to carry magnesium, a necessary nodulizing agent. Ductile iron is used for the following automotive applications: steering knuckles for passenger cars and trucks, crankshaft gears, disc brake components, and flywheels. Ductile iron is also used in farm, industrial, and construction machinery and tractors.

Ni-resist and Ni-hard cast irons contain higher amounts of nickel than do other cast irons to develop unique combinations of properties. Ni-resist, generally containing 18 to 22 percent nickel, is used for valve and pump parts in the marine and petrochemical fields, and for piston and piston ring inserts for automotive applications. Ni-hard is used for grinding balls and liners for ball mills, rolls for steel mills, and in various types of crushing equipment.

Nonferrous Alloys. These alloys, like most of the superalloys, are nickel-base, but are used primarily for their corrosion and oxidation resistance at ambient or moderately elevated temperatures. These materials are used as industrial heat treating racks, trays, and furnace parts and as pyrolysis furnace parts in the petrochemical industry. However, they can also be used in lower temperature applications in chemical, marine, and consumer product applications. A few of the principal materials included are: nickel, Inconel 600, Monel 400, Hastelloy B, Hastelloy C, Incoloy 800, and Carpenter 20CB-3. Estimated consumption of these alloys is shown in Appendix B.

Copper-Base Alloys. The principal copper-base alloys containing nickel are: (1) cupronickel and cupronickel-copper composite for coinage, (2) cupronickel condenser tubing, (3) nickel-silver, and (4) cast bronzes and brasses. It is expected that growth of nickel consumption in these materials will not be above 2 or 3 percent per year unless desalination programs, presently hampered by political and technical problems, show a resurgence. Appendix B gives nickel consumption estimates for copper-base alloys.

Market Outlook

Battelle-Columbus estimates that the annual growth rates for nickel will continue at a moderate rate of increase. Battelle-Columbus estimates that growth of total nickel consumption in nickel alloys will average about 6 percent per year through 1979.

THE NICKEL RECYCLING INDUSTRY

Characteristics of Nickel Materials

The main products of the nickel recycling industry are: (1) master alloys used as additions in foundry and steel mill melting, (2) segregated scrap, and (3) refined recycled nickel.

Master Alloys

These alloys are used by foundries, steel mills, and other users as alloying additions to heats. Table 6 shows typical master alloys available in pig, bar, and shot from most nickel alloy recyclers. Ferronickel, Monel, and nickel-magnesium are also available. In addition to the above, master alloys containing known, but usable, residual contents are promoted by recyclers--usually at a price below that of the major master alloys.

Scrap

Segregated scrap is the most widely used form of recycled nickel material. A very active national and international market exists for stainless steel and high nickel alloy scrap. Typical specifications for nickel-containing scraps are listed in Table 7.

Secondary Nickel

One producer has taken complex alloy mixtures, those difficult to upgrade by conventional techniques, e.g., a nickel-cobalt-copper-molybdenum-other alloy, and blended these into sulfide mattes with controlled sulfur contents to

TABLE 6. TYPICAL NICKEL BEARING MASTER ALLOYS AVAILABLE TO USERS OF RECYCLED MATERIALS

STAINLESS STEELS	C max.	Mn max.	Si max.	Cr	Ni	OTHER P .04, S .03 unless otherwise noted
201: AISI 201	.15	5.5 - 7.5	1.0	16.0 - 18.0	3.5 - 5.0	P .06 max.; N .25 max.
202: AISI 202	.15	7.5 - 10.0	1.0	17.0 - 19.0	4.0 - 6.0	P .06 max.; N .25 max.
302: AISI 302	.08 - .20	2.0	1.0	17.0 - 19.0	8.0 - 10.0	
ACI-CF-20	.20	1.5	2.0	18.0 - 21.0	8.0 - 11.0	S .04 max.
AMS-5358	.25	2.0	1.0	17.0 - 19.0	8.0 - 10.0	Mo .5 max.; Cu .5 max.
303: AISI 303, SAE 30303F	.15	2.0	1.0	17.0 - 19.0	8.0 - 10.0	P, S, Se .07 min.; Zr + Mo .6 max.
SAE 60303A, ACI-CF-16Fe	.16	1.5	2.0	18.0 - 21.0	9.0 - 12.0	S .20 - .40; Mo .40 - .80
AMS 5640E	.15	2.0	1.0	17.0 - 19.0	8.0 - 10.0	S .18 - .35; Mo .75 max.; Cu .50 max.
304: AISI 304, SAE 30304	.08	2.0	1.0	18.0 - 20.0	8.0 - 11.0	
SAE 60304, ACI-CF-8	.08	1.5	2.0	18.0 - 21.0	8.0 - 11.0	S .04 max.
304LC: WAD 8370	.04	1.0 - 2.0	1.0	18.0 - 21.0	8.0 - 11.0	Mo, Cu .50 max.
304ELC:	.03	1.0 - 2.0	1.0	18.0 - 20.0	9.0 - 11.0	Mo, Cu .40 max.
308: AISI 308	.08	2.0	1.0	19.0 - 21.0	10.0 - 12.0	
SAE 70308, ACI-HF	.20 - .40	2.0	2.0	18.0 - 23.0	9.0 - 12.0	Mo .50 max.; S .04 max.
309: AISI 309, SAE 30309	.20	2.0	1.0	22.0 - 24.0	12.0 - 15.0	
SAE 60309, ACI-CH-20	.20	1.5	2.0	22.0 - 26.0	12.0 - 15.0	S .04 max.
SAE 70309, ACI-HH	.20 - .50	2.0	2.0	24.0 - 28.0	11.0 - 14.0	Mo .50 max.; N .20 max.; S .04 max.
310: AISI 310, SAE 30310	.25	2.0	1.5	24.0 - 26.0	19.0 - 22.0	
SAE 60310, ACI-CK-20	.20	1.5	2.0	23.0 - 27.0	19.0 - 22.0	S .04 max.
AMS 5365A	.10 - .18	2.0	.5 - 1.5	23.0 - 26.0	19.0 - 22.0	S .04 max.; Mo, Cu .50 max.
AMS 5366A	.18	2.0	.5 - 1.5	23.0 - 26.0	19.0 - 22.0	Mo, Cu .50 max.
SAE 70310, ACI-HK	.20 - .60	2.0	3.0	24.0 - 28.0	18.0 - 22.0	S .04 max.; Mo .50 max.
SAE 70310A, ACI-HL	.20 - .60	2.0	3.0	28.0 - 32.0	18.0 - 22.0	S .04 max.; Mo .50 max.
312: SAE 60312, ACI-CE-30	.30	1.5	2.0	26.0 - 30.0	8.0 - 11.0	S .04 max.
SAE 70312, ACI-HE	.20 - .50	2.0	2.0	26.0 - 30.0	8.0 - 11.0	Mo .50 max.; S .04 max.
316: AISI-316	.10	2.0	1.0	16.0 - 18.0	10.0 - 14.0	Mo 2.0 - 3.0
AISI-316L	.03	2.0	1.0	16.0 - 18.0	10.0 - 14.0	Mo 1.75 - 2.5
SAE 60316, ACI-CF-8M	.08	1.5	1.5	18.0 - 21.0	9.0 - 12.0	Mo 2.0 - 3.0; S .04 max.
AMS 5360A	.15	2.0	.75	16.0 - 18.0	12.0 - 14.0	Mo 1.5 - 2.25; Cu .50 max.
AMS 5361B	.15 - .25	2.0	1.0	17.0 - 20.0	12.0 - 15.0	S .04 max.; Mo 1.75 - 2.5
321: AISI 321	.08	2.0	1.0	17.0 - 19.0	8.0 - 11.0	Ti 5.0 x C min.
327: SAE 70327, ACI-HD	.50	1.5	2.0	26.0 - 30.0	4.0 - 7.0	Mo .50 max.; S .04 max.
330: SAE 70330, ACI-HT	.35 - .75	2.0	2.5	13.0 - 17.0	33.0 - 37.0	Mo .50 max.; S .04 max.
331: SAE 70331, ACI-HU	.35 - .75	2.0	2.5	17.0 - 21.0	37.0 - 41.0	Mo .50 max.; S .04 max.
334: SAE 70334, ACI-HW	.35 - .75	2.0	2.5	10.0 - 14.0	58.0 - 62.0	Mo .50 max.; S .04 max.
347: AISI 347	.08	2.0	1.0	17.0 - 19.0	9.0 - 12.0	Cb 10.0 x C min.
SAE 60347, ACI-CF-8C	.08	1.5	2.0	18.0 - 21.0	9.0 - 12.0	Cb 8.0 x C - 1.0; S .04 max.
AMS 5363A	.10	2.0	1.5	17.0 - 20.0	9.0 - 12.0	Cb + Ta 10.0 x C - 1.35; Mo, Cu .50 max.; S .04 max.
AMS 5362C	.12	2.0	1.0	18.0 - 19.5	10.0 - 14.0	Cb + Ta 10.0 x C - 1.5; Mo, Cu .50 max.

HIGH TEMPERATURE ALLOYS	C max.	Mn max.	Si max.	P/S max.	Cr	Ni	Mo	Co	OTHER
AMS 5355 (17 - 4PH*)	.08	1.0	1.0	.04/.04	15.5 - 17.5	3.0 - 5.0	—	—	Cu 3.0 - 5.0; Cb+Ta .45 max.; N .04
AMS 5398 (17 - 4PH*)	.08	1.0	1.0	.04/ 04	15.5 - 17.5	3.0 - 5.0	—	—	Cu 3.0 - 5.0; Cb+Ta .45 max.; N .04
AMS 5373A (Stellite 6**)	.90 - 1.4	1.0	1.5	—	27.0 - 31.0	3.0 max.	1.5 max.	Rem.	W 3.5 - 5.5; Fe 3.0 max.
AMS 5387 (Stellite 6**)	.90 - 1.4	1.0	1.5	—	27.0 - 31.0	3.0 max.	1.5 max.	Rem.	W 3.5 - 5.5; Fe 3.0 max.
AMS 5375B (Stellite 23**)	.35 - .45	1.0	1.0	—	23.0 - 27.0	.50 - 3.0	1.0 max.	Rem.	W 4.0 - 6.0; Fe 2.0 max.
AMS 5378B (Stellite 27**)	.35 - .45	1.0	1.0	—	23.0 - 26 0	30.0 - 35.0	4.5 - 6.5	Rem.	Fe 2.0 max.
AMS 5380C (Stellite 30**)	.40 - .50	1.0	1.0	—	24.0 - 28.0	14.0 - 16.0	5.5 - 6.5	Rem.	Fe 2.0 max.
AMS 5382B (Stellite 31**)	.45 - .55	1.0	1.0	.04/.04	24.5 - 26.5	9.5 - 11.5	—	Rem.	W 7.0 - 8.0; Fe 2.0 max.
AMS 5385C (Stellite 21**)	.20 - .30	1.0	1.0	—	25.0 - 29.0	1.75 - 3.75	5.0 - 6.0	Rem.	Fe 3.0 max.; B .007 max.
AMS 5388B (Hastelloy C**)	.15	1.0	1.0	—	15.0 - 17.5	Rem.	16.0 - 18.0	2.5 max.	W 3.75 - 5.25; Fe 4.5 - 7.0; V .20 - .60
AMS 5389A (Hastelloy C**)	.15	1.0	1.0	—	15.0 - 17.5	Rem.	16.0 - 18.0	2.5 max.	W 3.75 - 5.25; Fe 4.5 - 7.0; V .20 - .60
AMS 5390 (Hastelloy X**)	.20	1.0	1.0	.04/.03	20.5 - 23.0	Rem.	8.0 - 10.0	.50 - 2.5	W .20 - 1.0; Fe 17.0 - 20.0
AMS 5392D (Ni-Resist 1A***)	2.4 - 2.8	1.0 - 1.5	1.5 - 2.5	.30/.12	1.8 - 2.4	14.0 - 16.0	—	—	Cu 6.0 - 7.0; Pb .003 max.

Source: Alloy Metal Products, Inc.

TABLE 7. TYPICAL SPECIFICATIONS FOR NICKEL CONTAINING SCRAP

NEW NICKEL SCRAP

Shall consist of new clippings, plate, skeleton, and all other rolled shapes. Nickel plus Cobalt, minimum - 99%; Cobalt, maximum - 0.25%; Copper, maximum - 0.50%. This grade shall be free of all castings.

OLD NICKEL SCRAP

All rolled nickel scrap shall come under this classification. Shall consist of clean scrap and shall be free of soldered, brazed, sweated, welded, or painted material. Nickel, minimum - 98%; Copper, maximum - 0.50%.

MISCELLANEOUS NICKEL SCRAP

Shall consist of miscellaneous Nickel Scrap such as Carbonized Scrap, Castings, Strippings, Peelings, Baskets and/or Turnings, and shall be packed and sold separately on basis of analysis.

S-816 ETC.

Shall consist of alloys in which the principal constituents are nickel, cobalt, chromium, and other alloying elements. It shall be sold on the basis of description and analysis. (This category refers to such alloys as Hastelloys, Stellites, S-816, etc.)

NI-RESIST SOLIDS

Shall consist of clean Ni-Resist Solids and shall be sold according to type or analysis (Type 1 - approximately 6% Copper, all others, such as Types II, III, IV, and V - free of Copper); shipment shall be of uniform grade unless otherwise agreed on by buyer and seller and must be free of foreign attachments and all other contamination.

NI-RESIST BORINGS

Shall consist of clean and dry Ni-Resist Borings and shall be sold according to type or analysis (Type I - approximately 6% copper, all others, such as Types II, III, IV, and V - free of copper); shipment shall be of uniform grade unless otherwise agreed on by buyer and seller. Must be free of all contamination.

NEW CUPRO-NICKEL CLIPPINGS AND SOLIDS

Shall consist of new, clean Cupro-Nickel clippings, plate, pipe, and other rolled forms. The shipment must be of a uniform grade and form agreed on by buyer and seller, whether it be 70 Copper 30 Nickel, 80 Copper 20 Nickel, 90 Copper 10 Nickel, or any other standard Copper Nickel Alloy. Must be free of foreign attachments and all other contamination.

OLD CUPRO-NICKEL SOLIDS

Shall consist of old, clean Cupro-Nickel Solids. The shipment must be of a uniform grade agreed on by buyer and seller, whether it be 70 Copper 30 Nickel, 80 Copper 20 Nickel, 90 Copper 10 Nickel, or any other standard Copper Nickel Alloy. It must be free of soldered, brazed, or sweated material, as well as foreign attachments and all other contamination. Mixed solids should be packed and sold separately.

SOLDERED CUPRO-NICKEL SOLIDS

Shall consist of soldered, brazed, or sweated Cupro-Nickel Solids. The shipment must be of a uniform grade agreed on by buyer and seller, whether it be 70 Copper 30 Nickel, 80 Copper 20 Nickel, 90 Copper 10 Nickel, or any other standard Copper Nickel Alloy. Must be free of trimmed seams and edges, and all other contamination. Mixed solids should be packed and sold separately.

CUPRO-NICKEL TURNINGS AND BORINGS

Shall consist of clean and dry Cupro-Nickel Turnings and Borings. The shipment must be of a uniform grade agreed on by buyer and seller, whether it be 70 Copper 30 Nickel, 80 Copper 20 Nickel, 90 Copper 10 Nickel, or any other standard Copper Nickel Alloy. Mixed Turnings should be packed and sold separately. Must be free of all contamination.

TABLE 7. TYPICAL SPECIFICATIONS FOR NICKEL CONTAINING SCRAP (Continued)

MISCELLANEOUS NICKEL COPPER AND NICKEL-COPPER-IRON SCRAP
Shall consist of miscellaneous scrap in which the basic elements, by weight, are Nickel and Copper, such as Copper Nickel Peelings, Plating Racks and Hangers and all Nickel and Copper in attached or combined form. In all cases, miscellaneous Nickel Copper Scrap should be sold by description and analysis.
NEW MONEL CLIPPINGS AND SOLIDS
Shall consist of new, clean, regular and/or R-Monel Clippings, plate, and other rolled shapes. Must be free of foreign attachments and all other contamination.
MONEL RODS AND FORGINGS
Shall consist of regular and/or R-Monel Rods and Forgings. K and KR Monel Rods and Forgings must be packed and sold separately. Must be free of foreign attachments and all other contamination.
OLD MONEL SHEET AND SOLIDS
Shall consist of clean, regular and/or R-Monel Solids, such as sheet, Plate, Pipe, Rods, and Forgings, and Screen or Wire Cloth. Must be free of foreign attachments and all other contamination, soldered, brazed, welded, or sweated material.
SOLDERED MONEL SHEET AND SOLIDS
Shall consist of soldered and/or brazed regular and/or R-Monel Sheet and Solids. Must be free of trimmed seams and edges and all other contamination.
SOLDERED MONEL WIRE, SCREEN, AND CLOTH
Shall consist of soldered and/or brazed Regular Monel Wire, Screen, and Cloth. Must be free of trimmed seams and edges, nonmetallic filling, and all other contamination.
NEW MONEL WIRE, SCREEN, AND CLOTH
Shall consist of new, clean Regular Monel Wire, Screen and Cloth, free of soldered material, as well as all other contamination.
MONEL CASTINGS
Must contain a minimum of 60% Nickel and shall consist of clean, Regular, S or H Monel Castings. Must be free of foreign attachments and all other contamination.
MONEL TURNINGS AND BORINGS
Must contain a minimum of 60% Nickel and shall consist of clean and dry Regular and R-Monel Turnings and Borings. K, KR, S, H or mixed Monel Turnings and Borings must be packed and sold separately. Must be free of all contamination.

Source: NASMI, Circular NF-66.

be toll refined into pure nickel by the Sherritt-Gordon ammonia leach process. Other researchers have described other techniques for separating nickel from scrap.*

Characteristics of the Nickel Recycling Industry(1)

Secondary nickel processors collect, sort, and otherwise process various grades of nickel and nickel-containing scrap for potential use by foundries, steel mills, and other users. Most major superalloy producers specialize only in this material or one other material, such as cobalt alloys or titanium alloys. Other nickel alloys generally are handled by secondary stainless steel processors.

When processing superalloy scrap, such as obsolete jet engine turbine components or new machine turnings, dealers use a variety of different methods to segregate scrap. To identify and separate various grades of obsolete scrap, spark testing followed by more accurate chemical and spectrum analysis is employed. For machine turnings, processing steps include crushing, degreasing, analysis, and packaging.

The consumers of nickel and nickel alloy scrap are generally steel mills, foundries, and melters of superalloys.

Materials Sources

Available data on the consumption of new and old nickel scrap are incomplete. Table 8 gives nickel and nickel alloy scrap consumption in 1969 by type of scrap and source.

* See Powell, H. E., Smith, L. L., and Cochran, A. A., "Solvent Extraction of Nickel and Zinc from a Waste Phosphate Solution", Bureau of Mines Report of Inv. 7336, 1970, 14 pp.

(1) For a discussion of the functions of the recycling industry see Volume I, General Report.

TABLE 8. CONSUMPTION OF NICKEL AND NICKEL ALLOY, INCLUDING STAINLESS, SCRAP IN 1969

Type	Short Tons of Scrap
Unalloyed nickel	8,538
Monel metal	3,887
Nickel silver	17,267
Cupronickel	4,666
Miscellaneous nickel alloys	4,951
Nickel residues	6,255
Stainless	326,000
Alloy steel	83,500
Cast iron	4,589,000
Total	5,044,064

Source: U.S. Bureau of Mines, Minerals Yearbook, "Nickel" and "Iron and Steel Scrap" chapters, and Battelle-Columbus estimates.

Markets for Recycled Nickel and Nickel Alloys

The markets for recycled nickel and nickel alloy scrap are generally much the same as those for primary nickel. Steel mills, foundries, and other metal melters have traditionally been the largest users of recycled nickel materials.

Use Patterns

Recycled nickel materials come in two basic forms: those containing relatively low amounts of nickel, e.g., stainless steels, cast irons, and low alloy steels, and those containing higher amounts, e.g., superalloys, nonferrous alloys, and copper-base alloys. Table 9 shows the consumption of low-nickel bearing materials by type of customer and type of scrap. Table 10 shows the same for high-nickel alloys.

TABLE 9. CONSUMPTION OF NICKEL BEARING FERROUS SCRAP, BY TYPE OF MANUFACTURE, IN 1968(1)

	Consumption of Scrap (Thousand Short Tons)		
	Stainless	Alloy	Cast Iron
Steel mills	815	2,685	5,737
Manufacturers of steel castings	29	131	323
Iron foundries and miscellaneous users	34	133	8,063
Total	878	2,949	14,123

(1) No statistics reported for 1969.

Source: U. S. Department of Interior, Bureau of Mines, Minerals Yearbook, "Iron and Steel Scrap" chapter, Battelle-Columbus estimates.

TABLE 10. STOCKS AND CONSUMPTION OF NEW AND OLD NICKEL SCRAP IN THE UNITED STATES IN 1969

(Gross Weight, Short Tons)

Class of consumer and type of scrap	Stocks beginning of year	Receipts	Consumption			Stocks, end of year
			New	Old	Total	
Smelters and refiners:						
Unalloyed nickel	108	1,560	1,108	470	1,578	90
Monel metal	507	3,892	582	3,061	3,643	756
Nickel silver [1]	564	5,643	738	4,954	5,692	515
Cupronickel [1]	98	381	------	428	428	51
Miscellaneous nickel alloys	------	4,961	51	4,900	4,951	10
Nickel residues	21	6,974	2,453	2,799	5,252	1,743
Total	636	17,387	4,194	11,230	15,424	2,599
Foundries and plants of other manufacturers:						
Unalloyed nickel	394	13,637	72	6,888	6,960	7,071
Monel metal	10	268	92	152	244	34
Nickel silver [1]	1,999	11,656	11,475	100	11,575	2,080
Cupronickel [1]	5,060	320	4,088	150	4,238	1,142
Nickel residues	335	858	297	706	1,003	190
Total	739	14,763	461	7,746	8,207	7,295
Grand total:						
Unalloyed nickel	502	15,197	1,180	7,358	8,538	7,161
Monel metal	517	4,160	674	3,213	3,887	790
Nickel silver [1]	2,563	17,299	12,213	5,054	17,267	2,595
Cupronickel [1]	5,158	701	4,088	578	4,666	1,193
Miscellaneous nickel alloys	------	4,961	51	4,900	4,951	10
Nickel residues	356	7,532	2,750	3,505	6,255	1,933
Total	1,375	32,150	4,655	18,976	23,631	9,894

[1] Excluded from totals because it is copper-base scrap, although containing considerable nickel.

Source: U. S. Department of Interior, Bureau of Mines, Minerals Yearbook, "Nickel" chapter.

Prices

Table 11 shows prices for selected nickel scraps in 1970. These scrap prices reflected the tight supply of primary nickel in early 1970 by being slightly above the producer's price for cathode nickel during the first quarter of 1970. However, as the supply imbalance eased in the latter half of 1970, scrap nickel prices dropped to about 60 percent of the first quarter 1970 prices by early 1971.

TABLE 11. DEALER'S BUYING PRICES FOR NICKEL SCRAP

Basis: FOB New York, Dollars Per Pound

	Date			
	March 5, 1970	June 4, 1970	September 3, 1970	January 7, 1971
Nickel anodes rolled	1.25-1.50	1.00-1.10	1.00-1.10	0.80-0.90
Nickel rod ends	1.25-1.50	1.00-1.10	1.00-1.10	0.80-0.90
Nickel sheet, clips	1.25-1.50	1.00-1.10	1.00-1.10	0.75-0.80
Nickel turnings	0.75-1.00	0.70-0.80	0.70-0.80	0.60-0.65

Source: Iron Age, for dates specified in Table.

Recycling Industry Data

A survey of the recycling industry developed data to provide a profile of the industry and the companies comprising the industry. The General Report, Volume I, gives many of these data. Information concerning the nickel and nickel alloys portion of the industry are given below.

The average recycler of nickel and nickel alloys compares with the average recycler of all commodities as follows: *

	Average Investment in Plant and Equipment	Average Number of Employees	Average Investment Per Employee
Nickel and Nickel Alloy	$1,348,000	59	$22,700
All Commodities	1,480,000	71	20,800

Figure 2 shows the variation in size by census region of nickel and nickel alloy processors. There appears to be some correlation with population density, degree of industrialization, and other common regional indicators.

Materials Flow Pattern for Nickel Alloys Recycling

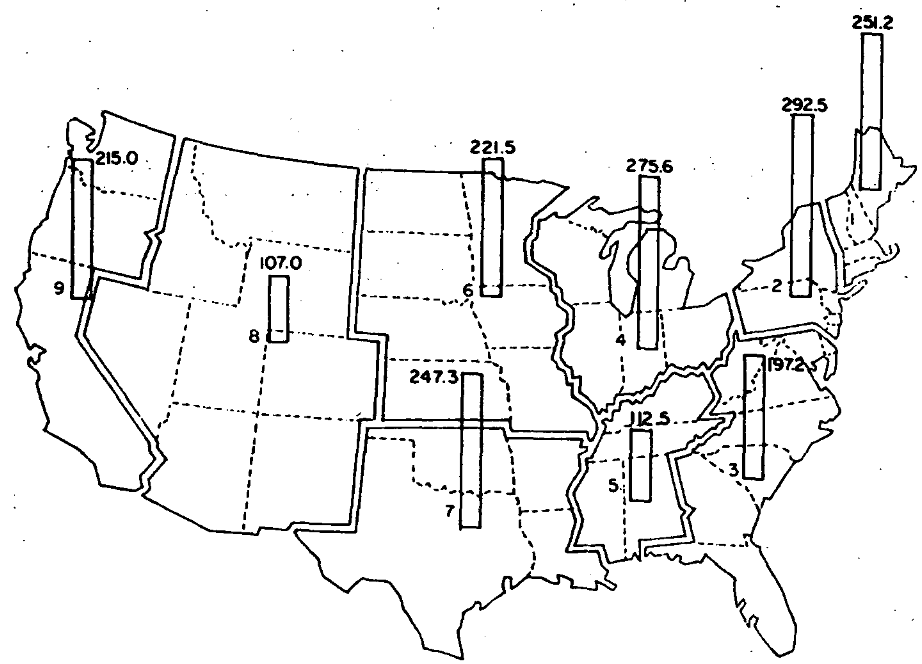
Table 12 gives Battelle-Columbus estimates concerning nickel alloy recycling in 1969. Many simplifying assumptions were made so that construction of this table could be possible. The assumptions, sources, and methodology used are included as footnotes to the table. Figure 3 shows these estimates in a flow diagram.

As shown, about 40 percent of the available nickel in nickel alloy scrap is being recycled.

Demand/Supply Analysis

To show what can be expected of nickel alloy recycling, an analysis of expected future demand and supply is made in this section.

* Data from extensive survey.



1. New England
2. Middle Atlantic
3. South Atlantic
4. East North Central
5. East South Central
6. West North Central
7. West South Central
8. Mountain
9. Pacific (includes Alaska and Hawaii)

FIGURE 2. AVERAGE AMOUNTS OF NICKEL AND NICKEL ALLOY, EXCLUDING STAINLESS STEEL, PROCESSED BY EACH DEALER IN EACH CENSUS REGION. ALL FIGURES IN NET TONS PER YEAR

TABLE 12. NICKEL ALLOY SCRAP RECYCLING, 1969

Kind and Type of Scrap	Nickel Available for Recycling(15) (Short Tons)	Nickel Recycled (Short Tons)	Percent Recycled	Nickel Not Recycled (Short Tons)
Electroplating Materials				
Prompt Industrial	350(4)	0	0	350
Obsolete	21,125(1)	0	0	21,125
TOTAL	21,475	0	0	21,475
Superalloys(2)				
Prompt Industrial	7,350(3)	n.a.	--	--
Obsolete	5,250(3)	n.a.	--	--
TOTAL	12,600	12,600(13)	100	0
Nonferrous Alloys(2)				
Prompt Industrial	6,250(10)	2,170	--	--
Obsolete	12,900	11,331	--	--
TOTAL	19,150	13,501(14)	100	0
		5,649 New +		
		19,150 Old		
Alloy Steel				
Prompt Industrial	3,100(5)	n.a.	--	--
Obsolete	25,500(5)	n.a.	--	--
TOTAL	28,600	640(9)	2	27,960
Cast Iron				
Prompt Industrial	--(8)	--(8)	--	--
Obsolete	8,100(6)	4,589(12)	57	3,511
TOTAL	8,100	4,589	57	3,511
Copper-Base Alloys				
Prompt Industrial	3,486	3,486	100	0
Obsolete	5,300	778	15	4,522
TOTAL	8,786	4,264	47	4,522
Permanent Magnet Alloys				
Prompt Industrial	100(7)	n.a.	--	100
Obsolete	800	n.a.	--	800
TOTAL	900	n.a.	--	900
Chemicals and Chemical Uses				
Prompt Industrial	100(7)	n.a.	--	100
Obsolete	800	n.a.	--	800
TOTAL	900	n.a.	--	900
Other Uses				
Prompt Industrial	800(7)	600(11)	75	200
Obsolete	4,700	350(11)	7	4,350
TOTAL	5,500	950	17	4,550
TOTAL INDUSTRIAL	21,536	--	--	--
TOTAL OBSOLETE	84,475	--	--	--
GRAND TOTAL	106,011	42,193	40	63,818

Note: Footnotes are listed on the following page.

FOOTNOTES TO TABLE 12

(1) Source: International Nickel Company

(2) Superalloys and other nickel-base alloys differentiated in the following way:

(a) Superalloys - those nickel-base alloys used for their structural integrity and low cycle fatigue resistance at elevated temperatures.

(b) Nonferrous alloys - those alloys which are used either at high or low temperatures for their oxidation or corrosion resistance to various media. Includes Inconel (ordinary types), Incoloy, nickel, etc.

(3) Source: Battelle-Columbus estimates -

1964 estimated superalloy mill product shipments	(A)	= 42,000,000 lbs
Percentage scrap rate	(B)	= 50 percent
Average nickel content	(C)	= 50 percent

(A) x (B) x (C) = TOTAL NICKEL USED IN PARTS = 10,500,000 lbs.

(4) Any bar anode scrap is consumed by electroplater as scrap held in titanium baskets. Material lost is material lost in filtration, etc., during bath purification.

(5) ASSUMED: (a) 40 percent of each heat contained nickel alloy scrap
(b) 50 percent yield of each ingot to mill product
(c) 15 percent scrappage of industrial uses of alloy products.

(6) ASSUMED: (a) Primary nickel additions average about 60 percent of total nickel content although total scrap usage is relatively high
(b) Foundry yield from melt to shipped casting averages about 63 percent.

(7) Source: Battelle-Columbus estimates.

(8) Recycled mostly at foundry.

(9) Estimated nickel content of nickel alloy steel recycled.

(10) Estimated 20 percent industrial scrap generation.

(11) Reported by U. S. Bureau of Mines as aluminum-base.

(12) Estimated nickel content of nickel contained in cast iron recycled.

(13) All superalloy scrap recycled in either of two places: stainless steel melting or superalloy melting.

(14) Some nonferrous scrap going into stainless melting. Battelle-Columbus estimates about 5,700 short tons, or the remaining amount available, has been consumed by stainless steel melters.

(15) Calculated from estimated life cycles of various end-use products. Consumption for each end-use item was estimated using the following life cycles and consumption patterns:

Source	Life Cycle (Years)	Years of Nickel Consumption Used to Calculate Nickel Availability
Electroplating		
Automobiles } Consumer Products }	12	1957
Superalloys		
Jet Engine	4 } 3	1966
Other Aerospace	0.5 }	
Nonferrous Alloys		
Chemical	10 } 7	1962
Heat Treating	5 }	
Alloy Steel	16	1953
Cast Irons	16	1953
Copper-Base Alloys	18	1951-1952 Average
Permanent Magnets	10	1959-1960 Average
Chemicals and Chemical Uses	2	1967-1968 Average
Other Uses	10	1959-1960 Average

Source: Battelle-Columbus Estimates, and U.S. Department of Interior, Bureau of Mines, "Nickel" and "Iron and Steel Scrap" chapters.

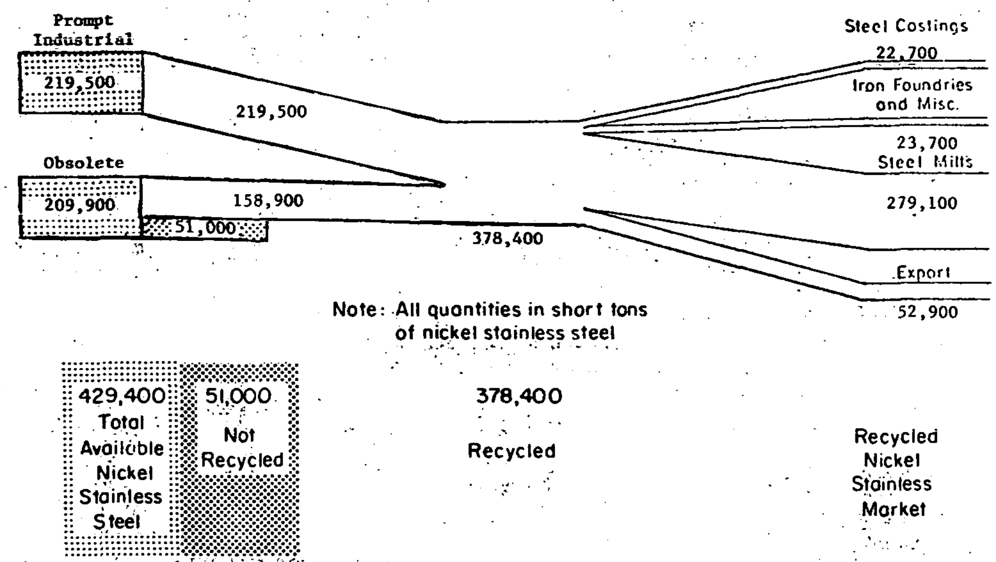


FIGURE 3. RECYCLED NICKEL STAINLESS STEEL FLOW, 1969

Source: U.S. Department of the Interior, Bureau of Mines, Minerals Yearbooks, "Nickel" and "Iron and Steel Scrap" chapters.

Demand for Recycled Nickel and Nickel Alloys

The demand for nickel inputs in 1969 and the estimates for future years, 1974 and 1979, are shown in Table 13. As shown, the demand for nickel contained in recycled alloys is expected to increase at about 6 percent per year in the 1969-1979 period. During this period, demand for recycled nickel content will increase from 42,193 short tons in 1969 to 75,400 short tons in 1979.

TABLE 13. ESTIMATED DEMAND FOR NICKEL CONTAINED IN NICKEL ALLOY SCRAP

Year	Short Tons of Nickel Content
1969	42,193
1974	56,300
1979	75,400

Source: Battelle-Columbus Estimates.

Supply of Recycled Nickel and Nickel Alloys

Using the same technique that was employed to develop the total availability of nickel as shown in Table 14, the supply of recycled nickel was calculated for 1974 and 1979 assuming similar recycling rates as in 1969.

Demand/Supply Balance in Future

In order to provide a view of what the future will be for the nickel alloy recycling industry, a demand/supply balance has been constructed using data from Tables 13 and 14, and is shown in Table 15.

TABLE 14. SUPPLY OF NICKEL AVAILABLE FOR RECYCLING

Year	Recycled Nickel Content (Short Tons)
1969	42,193
1974	49,300
1979	59,700

Source: Battelle-Columbus Estimates.

TABLE 15. DEMAND/SUPPLY BALANCE FOR RECYCLED NICKEL FOR 1974 AND 1979

(Short Tons, Nickel Content)

Year	Demand	Supply	Apparent Deficit
1974	56,300	49,300	7,000
1979	75,400	59,700	15,700

Source: Battelle-Columbus Estimates.

Since Table 15 assumes that the same incentives, i.e., price, cost, etc., are the same in 1974 and 1979 as exist today, an apparent balance can be calculated. Recycled nickel shortages (apparent) of 7,000 short tons and 15,700 short tons are expected in 1974 and 1979. It is expected that these apparent shortages will force nickel prices upward with the following effects on the nickel industry with everything else being held equal:

Industry	Effect
(1) Recycling industry	Will encourage increased recycling
(2) Nickel users	Will discourage increased usage of nickel.

If incentives are different in 1974 and 1979 than as exist today, e.g., if recycling is encouraged by new legislation, new technology, etc., Battelle estimates that only small increases in nickel alloy recycling (or about a 5 percent increase in the recycled nickel supply) will result. Main reasons are:

- High nickel containing superalloys and nonferrous alloys, currently representing about 30 percent of nickel available for recycling (not including nickel in stainless steels), are presently 100 percent recycled.
- Nickel contained in electroplating materials and alloy steels, currently representing about 50 percent of nickel available for recycling (not including nickel in stainless steels), occur as such small percentages in a larger system (see Table 16, page 38) that only massive, and presently unforeseen, incentives will cause nickel recycling in these materials to increase.

PROBLEMS THAT DIRECTLY REDUCE THE RECYCLING OF NICKEL SCRAP

There are several problems that directly reduce the rate of recycling of nickel scrap. These are discussed in detail in the following.

Industrial Scrap

As shown in Table 12, all industrial nickel bearing scrap generated, including grindings, turnings, and other materials, is about 100 percent recycled. There are known to be small amounts lost in electroplating solution effluents, or about 350 short tons in 1969, and there are lesser amounts lost in electrolytic machining of superalloys; these amounts aren't considered great enough to be classified as a problem. Although adequate statistical data are not available, it is known that greater amounts of nickel are lost through dilution of nickel containing low alloy steel. About 81 percent, or about 2,500 short tons of nickel contained in industrial alloy steel scrap are not being recycled.

Obsolete Scrap

As shown in Table 12, the recycling of nickel obsolete scrap varies from nearly 100 percent for superalloys and nonferrous alloys, to 57 and 47 percent for cast iron and copper-base alloys, respectively; to 0 percent each for low alloy steel and electroplating. The main problems that directly reduce the rate of nickel recycling are related to the following obsolete scrap meterials:

Electroplating materials
Low alloy steel
Cast iron
Copper-base alloys
Other uses for nickel.

Table 16 presents these problems, along with the prompt low alloy steel scrap problem, with a discussion of problem definition, problem magnitude, and problem analysis.

Other Direct Recycling Problems

Other problems that directly reduce the amount of recycling, but which cannot be measured quantitatively, are those problems caused by legislative action. They are as follows:

(1) Sale of emergency nickel stockpile

(2) Restrictions on the exportation of certain types of nickel bearing scraps

(3) Subsidies allowed to primary industries, but not to recycling industries, in the form of ore depletion allowances.

All of the above problems will decrease the price for nickel scrap, everything else being equal. Since lowered prices might decrease collection and segregation of nickel scraps in those areas where it had been economic to do so, a lowered recovery rate might result. The General Report, Volume I, gives a discussion of these problems that are common to entire secondary industry.

TABLE 16. IDENTIFICATION AND ANALYSIS OF PROBLEMS CONCERNING NICKEL AND NICKEL ALLOY THAT WAS NOT RECYCLED IN 1969

Title	Scrap Categories Where Some Nickel Was Not Recycled		
	Industrial Low Alloy Steel	Electroplating Materials	Obsolete Low Alloy Steel
Problem Definition	1. Nickel contents in low alloy steel average about 0.80 percent. 2. Low alloy steel is shipped to various original equipment manufacturers (OEM) who machine and otherwise fabricate it. 3. After fabrication, scrap is usually returned back to steel mills.	1. Nickel is used in thicknesses of 1.2 to 1.6 mils as an underplate for automobile bumper, grills, and other trim. About 1 pound of nickel is used for each bumper. Automotive applications represent about 50 percent of total nickel plating market. 2. Nickel is used in thicknesses of 0.4 to 1.2 mils for consumer appliances, furniture, and sports equipment. These applications represent the bulk of the remaining portion of the nickel plating market. 3. In all uses, nickel becomes a minor constituent of a larger system.	1. Nickel contents in low alloy steel run from about 0.40 to 3.75 percent with an average around 0.80 percent. Generally, other elements are present, too. 2. Nickel containing low alloy steels represent about 16 percent of total low alloy steel production. 3. Low alloy steels are used in many diverse applications as a standard constructional material. When a low alloy steel part is scrapped, the low alloy steel is generally <u>not</u> recycled as a nickel alloy steel but as a low alloy steel. Consequently, the nickel is diluted enough to be considered lost.
Tons of Nickel <u>Not</u> Recyled	3,100	21,475	25,500
Percent of Available Nickel <u>Not</u> Recycled	81	100	100
Problem Analysis	1. Nickel is just one of several different constituents of low alloy steel. 2. It is fairly easy to determine (unlike obsolete low alloy scrap) what type of low alloy steel is being recycled without testing. Knowledge of OEM's processing provides needed information. 3. Yet <u>only</u> 19 percent of the available nickel is recycled. 4. This seems a promising area to increase the recycling.	1. Nickel is small part of larger system and is covered on two sides by metal. 2. For automobiles, other system components are steel, copper, chromium, zinc and zinc-alloys 3. Steel-chromium items are generally recycled back to the steel industry--<u>but</u> the nickel is diluted so much as to be called lost. Zinc items, in many instances, aren't being recycled. 4. For consumer goods, other systems components are plastic, copper, steel, wood, and glass. In addition, these items are small and generally are discarded to municipal waste after termination of useful life. 5. This is not a promising area to increase recycling.	1. Nickel is only one of several different constituents of low alloy steel. In most common low alloy steels, <u>total</u> alloy content is generally less than 3 percent. 2. It is difficult to distinguish one alloy steel grade from another (for nickel content) or from mild steel. 3. Since scrap prices for nickel containing types of low alloy steel are roughly equal to those of nonnickel containing grades, there is little incentive to segregate small quantities of steel. 4. This is not a promising area to increase the recycling of nickel.

TABLE 16. IDENTIFICATION AND ANALYSIS OF PROBLEMS CONCERNING NICKEL AND NICKEL ALLOY THAT WAS NOT RECYCLED IN 1969 (Continued)

Title	Scrap Categories Where Some Nickel Was Not Recycled: Cast Iron	Copper-Base Alloys
Problem Definition	1. Nickel is used in residual amounts of about 0.10 percent in gray iron. 2. Nickel is used as a carrier for magnesium in ductile iron in amounts up to 0.65 percent. 3. Almost all cast iron production is gray iron with some malleable and some ductile. 4. Gray iron is used for a number of different applications; such as motor vehicles and miscellaneous industrial equipment. Ductile iron is used for automotive applications and in miscellaneous types of industrial equipment.	1. Nickel is used in copper-base alloys for coinage, condenser tubing, nickel silver products, and nickel brasses/bronzes. 2. Coinage and condenser tube are generally recycled. 3. Nickel silver, however, is used for a wide variety of consumer applications: springs, tableware, fishing reels, and other similar uses. 4. Disposal of these alloys depends partly on the value of other materials and partly on the shape and size of nickel silver part.
Tons of Nickel Not Recyled	3,511	4,522
Percent of Available Nickel Not Recycled	43	53
Problem Analysis	1. After an average life cycle of 16 years, cast iron is sold as scrap. 2. As most of the nickel contained in obsolete scrap is in gray iron, and most materials recycled are gray iron going into gray iron production, it would follow that most of the nickel should be recycled. 3. Yet only 57 percent is being recycled. This is a promising area in which to increase recycling of nickel.	1. In 1969, 17,267 s.t. of nickel silver (containing about 15 percent nickel) were recycled. About 4,666 s.t. of cupronickel was recycled. 2. Nickel and copper are valuable commodities, selling for \$1.33/lb and \$0.50/lb respectively in primary form. 3. Cupronickel is generally used in heat exchangers and is easily recovered. Coinage is generally recovered by the mint but some is lost to hoarding. Nickel silver is often plated with silver; this is generally recycled. 4. Yet only 47 percent is being recycled. This is a promising area in which to increase recycling of nickel.

PROBLEMS THAT DO NOT DIRECTLY REDUCE THE RECYCLING OF NICKEL

These are problems that might have economic effects on an individual company or on the secondary industry, or make operations more difficult. Those for nickel are:

- Customer Prejudices
- Alloy Separation
- Conservation of Resources, other than nickel.

Table 17 presents these problems along with a discussion of the following: problem definition, problem magnitude, and problem analysis.

COURSES OF ACTION CONCERNING RECYCLING OF NICKEL

To determine those problems that are important enough to be of interest to the public, and therefore EPA, a screening of the problems was made to separate out those problems that are important - but not far reaching enough to interest the public.

Selection of Opportunities

In order to identify those problems that have the highest priority for action, evaluations based on several criteria were made on each problem in Table 18. The highest scores, then, indicate the problems of highest importance.

TABLE 17. IDENTIFICATION AND ANALYSIS OF PROBLEMS THAT DO NOT DIRECTLY REDUCE THE AMOUNT OF NICKEL AND NICKEL ALLOYS THAT ARE RECYCLED (1)

Problem	Customer Prejudices	Alloy Separation	Conservation of Elements Other Than Nickel
PROBLEM DEFINITION	1. There have been periodic shortages of primary nickel in the past 20 years. There was a very serious shortage existent from 1967 to 1970. 2. This has forced some users of nickel to favor primary over recycled in times of nickel overcapacity so that allocations will be made to them in "tight" times. 3. In addition, despite good economics of using scrap, it is "easier" to use primary.	1. Superalloys and some nonferrous alloys are of very similar composition. All are nonmagnetic and are difficult to identify by other usual methods, e.g., color, spark, acid testing. 2. However, small differences in chemistry cause large differences in physical properties of superalloys. 3. Consequently, much effort is expended in separation of these alloys.	1. All superalloys contain significant amounts of other elements beside nickel, e.g., molybdenum, cobalt, columbium, titanium, tungsten. 2. In recent years, most superalloys have been recycled into stainless steel melting; this recovers the nickel and chromium contents of scrap but dilutes to a minimum most other elements.
EFFECT ON RECYCLE RATE	No significant effect on the amount of nickel recycled.	No significant effect on the amount of nickel recycled.	No significant effect on the amount of nickel recycled; great effects on other materials.
PROBLEM ANALYSIS	1. Recycled nickel scrap is <u>not</u> inferior to primary materials in most steel melts. 2. There is a need for promotional efforts that will inform buyers and actual users (many times different persons in steel mills, for instance) of advantages of using recycled materials. 3. New methods should be developed to aid buyers and users of scrap to make scrap easier to use.	1. This is a normal business activity in the recycling industry, but a more difficult one. 2. As all material is being recycled, no grave problems exist. 3. Continued development by superalloy melters and recycling industry on new recycling methods to recycle scrap back to superalloy melters, instead of stainless melters, is desirable from a conservation standpoint (for this problem, see next column).	1. All superalloys, by definition are melted in vacuum induction equipment. Little, if any, refining can be done in these furnaces. 2. Any heat with off-specification chemistry must be scrapped if dilution of impurities is not possible. All superalloys are produced to Aerospace Material Specifications, military specifications with strict chemistry and physical property requirements. 3. Superalloy melters consider the risk of using scrap to be great. However, a few of the leading melters are using some scrap in their melt charges. However, of the total amount of scrap generated, only a small fraction is returned to superalloy melting. 4. In the late 1960's, there was a great shortage of primary nickel. Stainless steel melters, desperate for nickel supplies, learned how to use superalloy scrap as nickel and chromium inputs in stainless steel melting. 5. Continued development by superalloy melters and recycling industry on methods to increase recycling of superalloy scrap is desirable.

(1) Problems adversely affect economics or practices of recycling but the effect in terms of amount cannot be measured. This situation is considered an indirect effect.

TABLE 18. EVALUATION OF PROBLEMS INVOLVED IN RECYCLING OF NICKEL

	Criteria and Scores			
	Solution of Problem Will Improve Environment (1) (10)	Solution of Problem Will Conserve Natural Resources (2) (5)	Ease of Solution (2) (5)	Total Scores (3)
Electroplating Products	4	5	0	9
Low Alloy Steel	4	5	0	9
Cast Iron	4	4	3	11
Copper-base Alloys	4	4	3	11
Customer Prejudices	0	3	5	8
Alloy Separation	5	4	2	11
Conservation of Resources Other Than Nickel	10	5	2	17

(1) First criterion is considered most important and is assigned maximum score of 10.
(2) Other two criteria are considered less important and are assigned maximum scores of 5 each.
(3) The higher the total score, the more attractive the problem is for further action.

Recommended Actions

In the above, all problems were separated into the following categories:

(1) Highest priority for action

(2) Low priority for action

(3) Worthy of immediate high priority consideration without screening.

Highest priority ideas are those which are so important that the public, besides the nickel recycling industry, would have interest in their solution. Consequently, these problems are important enough to be acted upon by EPA. These problems with their recommended actions for solution are shown in Table 19.

TABLE 19. RECOMMENDED ACTIONS, HIGH PRIORITY NICKEL AND NICKEL ALLOY PROBLEMS

Title	Conservation of Resources Other Than Nickel
RECOMMENDED ACTIONS	An investigation should be undertaken to determine what elements and how much of other elements are being lost during the recycling of superalloy.
BY WHOM(1)(2)(3)	EPA/NASMI
SPECIFIC STEPS	1. Form a committee representing the following: • Nickel processors • Secondary nickel smelters • Vacuum melter of superalloys 2. The committee should discuss and analyze why superalloy scrap is being recycled into less exotic materials such as stainless steels. 3. The committee should study the basic problems of scrap reuse in superalloys, if any. 4. The committee should discuss the costs and benefits of problem solution. 5. The committee should determine what additional actions should be taken.

(1) The responsibility for recommended actions shown in this table are based on importance of the action, benefit to the taxpayers, and opportunities for NASMI. They are the best judgments of Battelle.
(2) Recommended actions were distributed between high priority and lower priority based on the evaluation with three criteria.
(3) It is suggested that NASMI continue its leading role in recycling, recognizing that other organizations such as the Bureau of Mines, Department of Commerce, Council of Environmental Quality, HEW Office of Information, and State, Local, and Federal Legislatures must be involved.

Lower priority ideas are those which are important for the recycling industry to solve, but which aren't important enough for full-scale participation by the public. Consequently, these problems aren't important enough to be acted upon by EPA. These problems with their recommended actions are shown in Table 20.

One problem, that of the lack of adequate statistical information, is worthy of immediate further consideration. The lack of statistics on the consumption and recycling of some types of nickel containing products makes accurate analysis difficult.

TABLE 20. RECOMMENDED ACTIONS, LOWER PRIORITY NICKEL ALLOY PROBLEMS

Title	Electroplating Products	Low Alloy Steel (Obsolete)	Low Alloy Steel (Industrial)
RECOMMENDED ACTIONS	A brief investigation should be made to determine whether any recycling of nickel in electroplated nickel products is economically feasible. If any potential solutions are found, action can be planned at that point.	An investigation should be made to determine why an estimated 100 percent of the nickel in available nickel alloy steel is not being recycled. Part or all of this may be explained by reporting errors by the recycling companies, or by lack of statistics reported by the U.S. Bureau of Mines.	An investigation should be made to determine why an estimated 80 percent of the nickel in available industrial nickel alloy steel is not being recycled. Part or all of this may be explained by various reporting errors or incomplete reporting.
BY WHOM(1)(2)(3)	NASMI/NASMI MEMBERS	ISIS(4)/ISIS MEMBERS	ISIS/ISIS MEMBERS
SPECIFIC STEPS	1. Set up a committee composed of nickel processors and nickel smelters. 2. The committee should analyze the recycling problems pertinent to electroplated nickel. 3. The committee should determine whether there is any way to increase recycling that is attractive. 4. If anything appears to be attractive, the committee should recommend specific steps to take in order to make recycling feasible.	1. Form a committee composed of processors. 2. The committee should analyze and discuss the possible reasons for the relatively low recycle rate. 3. The committee should discuss with the Bureau of Mines why there are possible reporting errors. 4. The committee should analyze all of the data to select the next action.	1. Form a committee composed of processors. 2. The committee should analyze and discuss the possible reasons for the relatively low recycle rate. 3. The committee should discuss with the Bureau of Mines why there are possible reporting errors 4. The committee should analyze all of the data to select the next action.

(1) The responsibility for recommended actions shown in this table are based on importance of the action, benefit to the taxpayers, and opportunities for NASMI. They are the best judgments of Battelle.
(2, Recommended actions were distributed between high priority and lower priority based on the evaluation with three criteria.
(3) It is suggested that NASMI continue its leading role in recycling, recognizing that other organizations such as the Bureau of Mines, Department of Commerce, Council of Environmental Quality, HEW Office of Information, and State, Local, and Federal Legislatures must be involved.
(4) Institute of Scrap Iron and Steel (ISIS).

TABLE 20. RECOMMENDED ACTIONS, LOWER PRIORITY NICKEL-ALLOY PROBLEMS (Continued)

Title	Cast Iron	Copper-Base Alloys
RECOMMENDED ACTIONS	An investigation should be made to determine why about 43 percent of the nickel in available cast iron is not recycled.	An investigation should be made to determine why an estimated 53 percent of the nickel in copper-base alloys is not recycled. Part of this error may be explained by reporting errors or incomplete reporting.
BY WHOM	ISIS/ISIS MEMBERS	NASMI/NASMI MEMBERS
SPECIFIC STEPS	1. Form a committee composed of proccessors. 2. The committee should analyze and discuss the possible reasons for the relatively low recycle rate. 3. The committee should discuss with the Bureau of Mines why there are possible reporting errors. 4. The committee should analyze all of the data to select the next action.	1. Form a committee composed of nickel processors. 2. The committee should analyze and discuss the possible reasons for the relatively low recycle rate of nickel-containing copper-base alloys. 3. The committee should discuss with the Bureau of Mines possible misunderstandings in the reporting of nickel-containing copper-base. 4. A survey of the recycling and user industries to determine where these alloys are used and where they might be lost should be initiated. 5. The committee should analyze all data to select the next actions.

TABLE 20. RECOMMENDED ACTIONS, LOWER PRIORITY NICKEL ALLOY PROBLEMS (Continued)

Title	Alloy Separation	Customer Prejudices
RECOMMENDED ACTIONS	An investigation should be made to look for improved methods of nickel alloy segregation.	Publicity programs should be undertaken to point out the advantages of using recycled materials over competitive materials
BY WHOM	NASMI/NASMI MEMBERS	NASMI/NASMI MEMBERS
SPECIFIC STEPS	1. Form a committee composed of nickel processors. 2. The committee should analyze the present attempts to expedite, and to make more accurate, the analysis of various nickel-base scraps. 3. The committee should investigate new techniques in alloy separation. 4. The committee should determine what future steps are necessary to solve the problem.	1. NASMI should continue its present publicity programs and seminars. 2. NASMI should develop specific programs toward nickel recycling in areas where it would be most advantageous. 3. NASMI should retain a metallurgical or other consultant to assist NASMI in finding ways to use scrap and to instruct potential scrap users in these methods.

THE STAINLESS STEEL INDUSTRY

Stainless steel, an alloy usually containing chromium, nickel, and iron, is used in a number of different end-use markets. It is generally produced by most of the large steel mills that also manufacture carbon, tool, and other steels and is provided in any shape and in different chemical compositions. The U. S. stainless steel industry is large and currently is producing at a rate of about 1 million ingot tons per year.

Characteristics of Nickel Stainless Steels

The major types of nickel stainless steels are:

American Iron and Steel Institute (AISI) 300 series or chrome-nickel-iron alloys

AISI 200 series or chrome-nickel-manganese-iron alloys.

Nickel-Bearing Stainless Steels

The AISI 300 series stainless steels are the most popular grades of all stainless steel products. There are a number of different grades; some of the most popular are shown with their compositions in Table 21. Compositions of the most popular grades in the 300 series steels are about 18 percent chromium, 8 percent nickel, and the balance iron. However, a few grades of stainless steel, e.g., 316, 310, 309, contain more than 10 percent nickel. Also shown are two grades of the AISI 200 series steels that also contain some nickel. In these grades manganese has replaced a portion of the nickel content. For example, the composition of these grades is about 18 percent chromium, 4.5 percent nickel, 6.5 percent manganese, and the balance iron.

The AISI 400 series stainless steels contain little, if any, nickel. Consequently, nickel contained in these steels represents a negligible fraction of the total amount of nickel being recycled.

TABLE 21. MOST COMMON NICKEL BEARING STAINLESS STEELS

AISI Type No.	Chromium	Nickel	Carbon	Manganese	Silicon	Sulphur	Phosphorous	Other Elements
201	16.00-18.00	3.50- 5.50	0.15 max.	5.50- 7.50	1.00 max	0.030 max.	0.060 max.	N 0.25 max.
202	7.00-19.00	4.00- 6.00	0.15 max.	7.50-10.00	1.00 max	0.030 max.	0.060 max.	0.75 max.
301	16.00-18.00	6.00- 8.00	Over 0.08-0.20	2.00 max.	1.00 max.	0.030 max.	0.045 max.	
302	17.00-19.00	8.00-10.00	Over 0.06-0.20	2.00 max.	1.00 max.	0.030 max.	0.045 max.	
303	17.00-19.00	8.00-10.00	0.15 max.	2.00 max.	1.00 max.	0.07 min.		S 0.07 min. Zr or Mo 0.060 max
304	18.00-20.00	8.00-11.00	0.08 max.	2.00 max.	1.00 max.	0.030 max.	0.045 max.	
304L	18.00-20.00	8.00-11.00	0.03 max.	2.00 max.	1.00 max.	0.030 max.	0.045 max.	
308L	19.00-21.00	10.00-12.00	0.03 max.	2.00 max.	1.00 max.	0.030 max.	0.045 max.	
309	22.00-24.00	12.00-15.00	0.20 max.	2.00 max.	1.00 max.	0.030 max.	0.045 max.	
310	24.00-26.00	19.00-22.00	0.25 max.	2.00 max.	1.50 max.	0.030 max.	0.045 max.	
316	16.00-18.00	10.00-14.00	0.10 max.	2.00 max.	1.00 max.	0.030 max.	0.045 max.	Mo 2.00-3.00
316L	16.00-18.00	10.00-14.00	0.03 max.	2.00 max.	1.00 max.	0.030 max.	0.045 max.	
321	17.00-19.00	8.00-11.00	0.08 max.	2.00 max.	1.00 max.	0.030 max.	0.045 max.	Ti 6 x C min.
347	17.00-19.00	10.00-12.00	0.08 max.	2.00 max.	1.00 max.	0.030 max.	0.045 max.	Cb + Ta 8 x C min.-1.25 max.

Source: U.S. Bureau of Standards, Nickel and Its Alloys, Samuel J. Rosenburg, Washington, GPO, 1968.

Characteristics of the Stainless Steel Industry

The nickel stainless steel industry is composed of several different types of companies: producers of stainless steels, fabricators of stainless steels, and the stainless steel recycling industry. The stainless steel recycling industry is discussed in detail in a subsequent section.

Material Sources

The United States stainless steel industry relied on the following sources for its nickel inputs in 1969:

	Nickel Content (thousands of short tons)
Domestic ores	7,500
Imported metal (largely from Canada)	31,958
Recycled Materials	
Stainless steel scrap	32,600
Superalloy and nickel-base scrap	17,742
TOTAL NICKEL CONTAINED IN DOMESTIC PRODUCTION OF STEEL	89,800

Source: Battelle-Columbus estimates, U.S. Bureau of Mines, Minerals Yearbooks, "Nickel" and "Iron and Steel Scrap" chapters.

Materials Flow

Figure 4 shows the amounts of refined nickel metal from foreign and domestic producers and of recycled nickel contained in stainless steel and in superalloy and other nickel-base scrap.

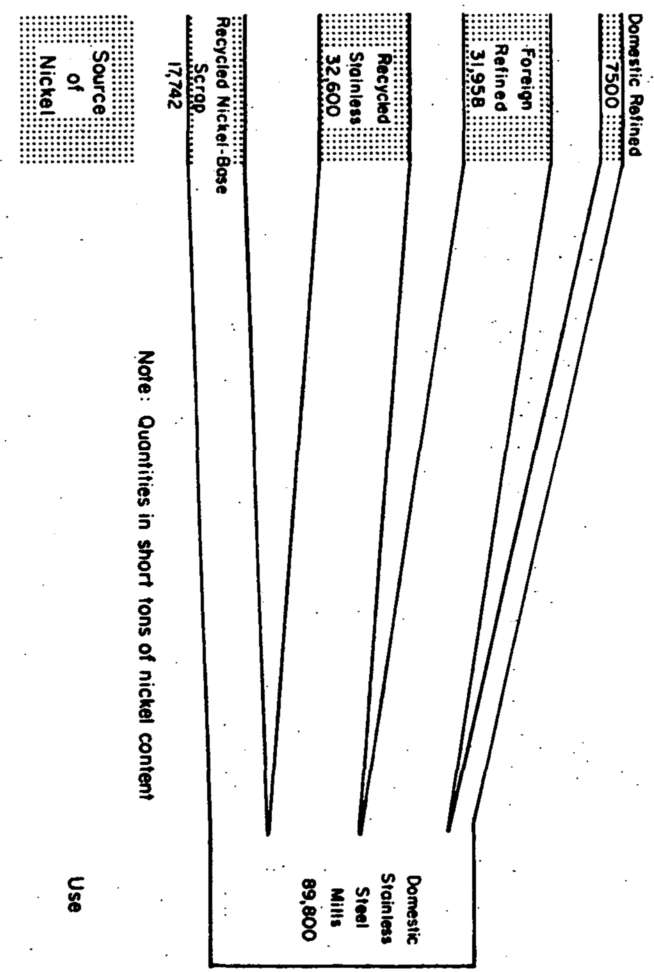


FIGURE 4. MATERIALS FLOW BALANCE, NICKEL STAINLESS STEELS, 1969

Source: Battelle-Columbus estimates, U.S. Department of Interior, Bureau of Mines, Minerals Yearbook, "Nickel" and "Iron and Steel Scrap" chapters.

Stainless Steel Producers

The largest stainless steel producers are the following:

Allegheny-Ludlum Steel Corporation
U. S. Steel Corporation
Republic Steel Corporation
Armco Steel Corporation
Easco Corporation
Crucible Steel Corporation
Jones and Laughlin Steel Corporation

Smaller, but important producers of stainless steel are the following:

Carpenter Technology Corporation
Washington Steel Corporation
Jessop Steel Company
Joslyn Manufacturing and Supply Company

Production

The production of nickel stainless steels has grown about 7 percent per year since their introduction in the 1920's. Table 22 shows the ingot production of the more popular grades of nickel containing stainless steels in recent years. Note that production of nickel stainless steels has remained relatively constant in the last six years.

Markets for Stainless Steels

Stainless steels are used in virtually every industrial, public, or private sector of the economy. Due to its low cost relative to its advantages, e.g., corrosion resistance, appearance, and strength, as compared to other standard materials of construction, the growth in stainless steel usage has been steady and rapid.

Historical Markets

In 1934, the principal applications for nickel containing stainless

TABLE 22. U. S. PRODUCTION OF NICKEL STAINLESS STEEL INGOTS, SHORT TONS

AISI Number	1961	1962	1963	1964	1965	1966	1967	1968	1969
201	21,873	30,648	41,830	44,895	23,818	23,955	29,295	35,836	43,017
202	10,008	8,421	8,119	1,631	1,772	942	474	3,354	408
301	69,015	75,641	105,178	116,620	105,135	107,805	107,919	120,882	117,008
302 }	34,160	25,225	30,814	38,295	35,744	36,178	29,333	30,478	32,343
302B }		435	666	623	118				
303	34,180	40,562	33,224	35,636	42,109	51,947	41,064	39,261	40,508
303C	1,335	2,180	1,589	1,791	2,390	3,070	3,813	1,953	1,949
304	339,813	303,604	340,931	473,615	466,373	577,076	484,586	463,862	517,754
304L	34,747	27,056	40,938	50,270	52,890	56,194	38,545	38,722	36,073
305	6,265	8,386	9,727	11,327	13,629	21,601	15,466	14,633	12,481
308	4,472	3,581	3,606	3,478	4,970	4,688	4,731	2,042	2,973
309	4,614	5,414	5,759	6,818	6,836	7,888	8,548	8,308	7,733
309S	1,981	1,455	3,181	2,154	3,914	3,951	2,211	1,976	2,609
310	6,289	5,869	7,189	7,069	6,513	7,207	5,745	5,292	5,048
310S	966	917	1,184	1,218	983	572	273	209	778
314	247	290	175	309	220	218	46	132	
316	51,104	47,185	52,558	69,776	84,810	93,854	76,169	66,103	74,666
316L	20,112	16,519	19,317	31,160	36,683	39,214	27,913	26,470	27,065
317	746	714	769	1,812	1,330	3,036	883	1,886	1,877
321	27,071	23,734	24,116	30,925	33,214	37,486	24,258	24,105	18,749
347	9,702	9,764	9,877	12,186	11,512	13,553	9,333	8,843	5,955
348	2,401	1,271	1,146	1,026	2,880	2,523	1,507	2,299	1,084
All Other	62,622	61,595	71,625	68,700	70,188	101,047	84,733	72,802	73,297
TOTAL	743,726	700,466	813,518	1,011,034	1,008,031	1,194,005	996,825	970,428	1,023,374

Source: American Iron and Steel Institute, Annual Statistical Reports.

steels were for building trim, household cooking utensils, marine fittings, automobile hardware and fittings, power equipment, military equipment, turbine blading, chemical apparatus, and miscellaneous parts and trim in outdoor equipment. Today, many of the applications have remained the same and have grown in size with their respective industries. However, new applications have been found either by replacing another material, e.g., stainless steel replacing chrome-nickel plated steel consumer products, or by developing totally new applications in new fields, e.g., nuclear, petrochemical, and aerospace.

<u>Prices for Stainless Steel</u>

Base prices for various stainless steel alloys and stainless steel shapes are shown in Table 23. Cold rolled sheet and strip, which accounts for over 50 percent of sales, costs \$0.54 to \$0.5825 per pound for ordinary 18 percent chrome-8 percent nickel varieties, and \$0.78 to \$0.935 per pound for more highly alloyed forms of stainless. The AISI 200 series, often a competitor to the 300 series, are about \$0.125 to \$0.1325 per pound cheaper than their 300 series counterpart.

Table 24 gives a historical picture of prices for AISI 304 stainless steel sheet. As shown, prices of stainless have fluctuated to a small degree over the last six years, but remained essentially constant to October, 1969. At that point, base prices rose considerably from \$0.48 to \$0.5825 per pound by January, 1970. However, it might be added that discounts have been common for the past several years.

<u>Use Patterns</u>

The domestic shipments of stainless steel by major market classification are given in Table 25. Steel service centers and warehouses take the largest amounts of stainless steel. These companies purchase relatively large quantities from steel producers and process it to fill small orders by cutting, coating, polishing, etc. Other large markets for stainless steel are with original equipment manufacturers, e.g., automotive, aircraft, and consumer durables. Other markets include export, construction, transportation, and steel for conversion.

TABLE 23. PRICE FOR TYPICAL ALLOYS AND SHAPES OF STAINLESS STEEL AS OF DECEMBER 24, 1970

Base price, cents per pound, f.o.b. mill.

Produce	201	202	301	302	303	304	316	321	347
Billets, forging	38.00	41.50	43.25	46.25	48.50	46.25	63.25	56.50	61.50
Bars, structures	52.25	56.75	66.50	71.00	74.50	71.00	97.25	86.75	94.25
Plates	41.75	39.50	51.75	55.50	69.75	55.50	84.75	75.75	86.75
Sheets	48.75	53.75	54.00	58.25	56.75	58.25	89.50	78.00	93.50
Strip, hot-rolled	36.00	39.00	37.25	40.50	---	40.50	62.50	53.50	63.50
Strip, cold-rolled	48.75	53.75	54.00	58.25	56.75	58.25	89.50	78.00	93.50
Wire, cold-finished	49.75	54.00	63.75	68.00	71.50	68.00	93.25	83.00	90.25
Rod, hot-rolled	---	46.25	60.50	65.00	68.25	65.00	93.00	79.00	85.25

Source: Iron Age, for date specified in Table.

TABLE 24. HISTORICAL PRICE BEHAVIOR OF STAINLESS STEEL BASE PRICE, 304 STAINLESS STEEL SHEET

(Cents per pound, f.o.b. mill)

Month	1963	1964	1965	1966	1967	1968	1969
January	48.00	41.75	42.50	39.00	41.75	44.00	45.50
February	48.00	41.75	42.50	39.00	41.75	44.00	45.75
March	48.00	41.75	42.50	39.00	41.75	44.00	45.75
April	48.00	42.50	42.50	39.00	41.75	44.00	45.75
May	48.00	42.50	42.50	39.00	41.75	44.00	45.75
June	48.00	42.50	42.50	39.00	41.75	44.00	48.00
July	48.00	42.50	42.50	39.00	41.75	44.00	48.00
August	45.25	42.50	39.00	39.00	41.75	45.50	48.00
September	45.25	42.50	39.00	39.00	41.75	45.50	48.00
October	41.75	42.50	39.00	39.00	44.00	45.50	55.50
November	41.75	42.50	39.00	41.75	44.00	45.50	55.50
December	41.75	42.50	39.00	41.75	44.00	45.50	58.25
Average	45.97	42.31	41.04	39.45	42.31	44.625	49.15

Source: Iron Age, for date specified in Table.

TABLE 25. DOMESTIC SHIPMENTS OF STAINLESS STEELS BY AISI MARKET CLASSIFICATION, 1969

	Market Classification	Net Short Tons
(1)	Steel for conversion	81,133
(2)	Forging	20,659
(3)	Fasteners	18,964
(4)	Service centers	373,701
(5)	Construction	5,236
(6)	Contractors' products	26,138
(7)	Automotive	123,277
(8)	Railroad	3,852
(9)	Shipbuilding	2,226
(10)	Aircraft	11,163
(11)	Oil and gas drilling	558
(12)	Mining, quarrying, and lumbering	420
(13)	Agricultural	1,473
(14)	Machinery, industrial, equipment, and tools	61,331
(15)	Electrical machinery and equipment	20,703
(16)	Appliances, utensils, and cutlery	54,448
(17)	Other domestic and commercial equipment	21,194
(18)	Container packaging and shipping materials	5,295
(19)	Ordnance and other military	2,589
(20)	Export	41,182
(21)	Nonclassified	22,603
	TOTAL	898,145

Source: American Iron and Steel Institute, Annual Statistical Reports.

Within single end-user markets, the major markets for stainless steel in 1969 were as follows:

SIC Number	Major Markets	Approximate Stainless Steel Consumption (Short Tons)
346131	Automotive hubcaps	40,000
3722	Aircraft engines	25,000
3300	On-site construction	25,000
3452	Fasteners, e.g., bolts, rivets, screws	25,000
3461	Home and hospital utensils	20,000
342915	Automotive hardware	20,000
3623	Welding, electrodes	15,000
34294	Builder's hardware	15,000
3431	Metal plumbing fixtures	10,000
14644	Chemical process equipment	10,000

Source: Battelle-Columbus Estimates.

Although the domestic stainless steel industry has remained relatively stagnant in recent years (see Table 22), imported stainless steel products have grown rapidly to supply the growing domestic demand for these steels. For example, imported stainless steels have grown from 79,762 short tons in 1964 to about 175,000 short tons in 1969 (see Table 26). Domestic exports of stainless steel have declined in the same time period. At present, imports represent about 20 per cent of all stainless steel sold in the United States.

TABLE 26. DOMESTIC TRADE BALANCE IN STAINLESS STEEL MILL PRODUCTS

Year	Foreign Steel Imports (Short Tons)	Domestic Steel Exports (Short Tons)	Net Imports (Short Tons)
1964	79,762	74,456	5,306
1965	113,480	54,252	59,228
1966	137,394	55,519	81,875
1967	149,354	65,625	83,729
1968	174,062	52,668	121,394
1969	175,000	41,182	134,000

Source: American Iron and Steel Institute, Annual Statistical Reports.

In addition to the above, an immeasurable amount of stainless steel is being imported as a part in a final product. Japanese cutlery, for example, is currently imported in large quantities and is estimated to have more than 33 percent of the total domestic market.

Consequently, due to the rising amounts of imports, there should be ample amounts of scrap available for recycling in the future. However, since the domestic stainless steel industry isn't growing with domestic stainless steel demand, a surplus of stainless steel scrap may be forthcoming.

Market Outlook

Battelle-Columbus estimates that the annual growth rate for stainless steel will be about 4.5 percent per year in the foreseeable future.

THE STAINLESS STEEL RECYCLING INDUSTRY

The stainless steel recycling industry consists of brokers, dealer/processors, and ingot makers. Generally, in the processing of stainless scrap, many of the above functions are carried out by the same company. The industry purchases new scrap from industrial fabricators and obsolete scrap from dismantlers of old machines, plants, etc.; segregates and otherwise processes it into a product suitable for steel melts. In some cases, scrap is melted down and sold with a guaranteed analysis.

Characteristics of Stainless Steel Scrap Materials

Major types of stainless steel scrap are given in Table 27. Although stainless scrap material is sold by specification only, dealer/processors give

TABLE 27. NASMI SPECIFICATIONS FOR STAINLESS STEEL SCRAP

STAINLESS STEEL SCRAP

18-8 stainless steel scrap shall consist of clean scrap containing a minimum of 7% nickel, 16% chromium and have a maximum of 0.50% molybdenum, 0.50% copper, 0.045% phosphorous, and 0.03% sulphur and otherwise free of harmful contaminants. Material to be prepared to individual consumer's specifications.

STAINLESS STEEL CASTINGS

Stainless steel castings submit analysis, size of pieces, and physical description.

STAINLESS STEEL TURNINGS

18-8 turnings, machine shop grade for direct mill delivery shall contain a minimum of 7% nickel and 16% chromium and be free of all nonferrous metals, nonmetallics, excessive iron, oil, and harmful contaminants.

SHORT OR CRUSHED STAINLESS STEEL TURNINGS

Crushed or short turnings to conform chemically to the machine shop grade specifications.

11-14% CHROME STAINLESS SCRAP

Straight chrome stainless scrap shall contain 11-14% chrome, phosphorous and sulphur 0.03% maximum, and shall not contain over 0.50% nickel and otherwise be free from harmful contaminants. Material to be prepared to individual consumer's specifications.

14-18% CHROME STAINLESS SCRAP

Straight chrome stainless scrap shall contain 14-18% chrome, phosporous and sulphur 0.03% maximum, and shall not contain over 0.50% nickel and otherwise be free from harmful contaminants. Material to be prepared to individual consumer's specifications.

EDISON BATTERIES

To be sold by type and to be free of crates and liquid.

HIGH-NICKEL SCRAP

Shall consist of nickel-steel billet, bloom, bar crops, or other shapes of similar section and equal grade, not over 0.04 percent of phosphorous or sulphur, between 3 percent and 3.5 percent of nickel (lower or higher in nickel content to be duly considered), free from other alloys. Must be clean material. Size of material to be agreed upon between buyer and seller.

NO. 1 CHROMIUM-NICKEL

Shall consist of chromium-nickel steel billet, bloom, bar crop, or other shapes of similar section and equal grade, not over 0.04 percent of phosphorous or sulphur, between 3 and 3.5 percent of nickel (lower or higher nickel content to be duly considered), not over 0.5 percent of chromium, free from other alloys. Must be clean material. Size of material to be agreed upon between buyer and seller.

NO. 2 CHROMIUM-NICKEL

Shall consist of chromium-nickel steel billet, bloom, bar crops, or other shapes of similar section and equal grade, not over 0.04 percent of phosphorous or sulphur, between 1.5 and 2.5 percent of nickel (lower or higher nickel content to be duly considered), between 0.5 and 1 percent of chromium, free from other alloys. Must be clean material. Size of material to be agreed upon between buyer and seller.

NICKEL-STEEL TURNINGS

Shall consist of heavy short first-cut turnings from nickel-steel forgings. Nickel and chromium content to be specified on each individual sale. To weigh not less than 75 pounds per cubic foot. To be free from dirt and other foreign materials.

Source: NASMI, Circular NF-66.

particular attention to the separation of molybdenum-containing grades, e.g., AISI 316, from nonmolybdenum-containing grades, e.g., AISI 304 and 301.

Characteristics of the Stainless Steel Scrap Recycling Industry

Stainless steel scrap is purchased from scrap generators, processed and segregated, and sold to a user of stainless steel scrap--usually a stainless steel mill. Unlike many materials which can be easily identified, e.g., brass by color tests, carbon steel by magnetic means, a stainless steel processor generally is forced to use more costly processing. A stainless steel processor generally uses more costly testing techniques, including spark and acid testing, to properly identify and segregate various grades of stainless steel from similar materials.

Stainless steel scrap is often generated in the form of machine chips and turnings. Processors have procured relatively expensive forms of equipment to crush, degrease, and otherwise process machine turnings. Since ordinary or nonmolybdenum stainless steel machine turnings can be "contaminated" with molybdenum containing stainless steels, processors generally melt down a representative sample of a lot of machine turnings and determine its chemical composition by spectroscopic and x-ray methods. The chips and turnings can be sold "as is" or melted down in electric furnaces to an ingot form with a known composition.

Stainless steel scrap consumers are generally stainless steel mills and steel foundries. These mills, which can use up to 100 percent of total heat weight in scrap, charge stainless scrap along with primary nickel, carbon steel scrap, and ferrochromium. The economics of using stainless steel scrap is closely linked to the price and analysis of scrap versus that of primary materials.

Materials Sources

Sources of nickel inputs come from primary nickel received from domestic and foreign sources and from recycled sources, in the form of both prompt industrial and obsolete scrap. The amount of nickel inputs coming from various sources is shown in Table 28.

TABLE 28. SOURCES OF RECYCLED NICKEL CONTAINING MATERIALS, 1969

Material	Average Nickel Content, Percent	Short Tons of Scrap
Stainless scrap	10	326,000
Other scrap (including superalloy, ferroalloys, and other high nickel containing materials)	50	35,484
TOTAL		361,484

Battelle-Columbus estimates.

Markets for Recycled Nickel Stainless Steel Scrap

The historical markets for recycled stainless steel scrap are: (1) stainless steel mills, (2) stainless steel foundries, and (3) cast iron and other miscellaneous uses. Stainless steel mills are by far the most important consumers of stainless steel scrap and other nickel-containing materials. Stainless steel foundries, other than those captively owned by stainless steel mills, are relatively minor consumers of stainless steel scrap materials.

Historical Markets

Table 29 gives the recent history of the role of recycled nickel stainless steel scrap in stainless steel ingot production. As shown, purchased or recycled scrap represented from 19 to 23 percent of total nickel inputs used in stainless steel production from 1960 to 1968. However, in 1969, recycled scrap represented about 33 percent of the total nickel inputs used in stainless steel production.

TABLE 29. RECYCLED NICKEL STAINLESS SCRAP CONSUMPTION IN THE UNITED STATES, 1961-1969

Year	Estimated Purchased Nickel Stainless Scrap Consumed (Thousands of Short Tons): Total Weight(1)	Estimated Purchased Nickel Stainless Scrap Consumed (Thousands of Short Tons): Nickel Content	Estimated Total Nickel Consumption for Stainless Steels(2) (Thousands of Short Tons)	Nickel Content in Purchased Stainless Scrap as Percent of Total Nickel Consumption in Stainless Steel
1961	143	14	74	19
1962	142	14	70	20
1963	174	17	81	21
1964	209	21	101	21
1965	204	20	101	20
1966	267	27	119	23
1967	232	23	100	23
1968	224	22	97	23
1969	326	33	102	33

(1) Equal to 0.7 times (total scrap consumption - receipts, as reported by U. S. Bureau of Mines).
(2) Equal to 0.10 times (total ingot production of AISI 200 and 300 series stainless steels.)

Source: U.S. Bureau of Mines, Minerals Yearbook, "Nickel" and "Iron and Steel Scrap" chapters, and Battelle-Columbus estimates.

TABLE 31. PRICE RANGES FOR SELECTED NICKEL STAINLESS SCRAP PRODUCTS IN PITTSBURGH, PENNSYLVANIA, 1970-1971

(Dollars Per Gross Ton)

Scrap Type	March 1, 1970	June 1, 1970	August 31, 1970	January 4, 1971
18 Chrome-8 nickel bundles/solids	385-395	385-400	330-340	270-280
18 Chrome-8 nickel turnings	300-310	285-300	230-240	160-170

Source: Iron Age, for dates specified in Table.

Recycling Industry Data

A survey of the recycling industry developed data to provide a profile of the industry and the companies comprising the industry. The General Report, Volume I, gives many of these data. Information concerning the stainless steels portion of the industry are given below.

The average recycler of stainless steels compares with the average recycler of all commodities as follows:*

	Average Investment in Plant and Equipment	Average Number of Employees	Average Investment Per Employee
Stainless Steels	$1,419,000	43	33,400
All Commodities	1,480,000	71	20,800

Figure 5 shows the variation in size by census region of stainless steel processors. There is apparently no correlation with population density, degree of industrialization, and other common regional indicators.

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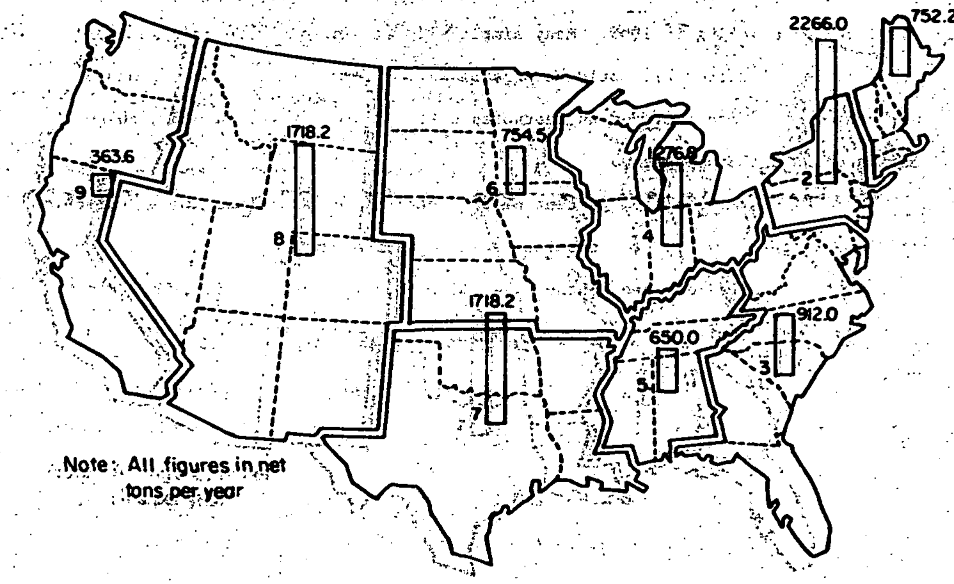
* Extensive survey data.



1. New England
2. Middle Atlantic
3. South Atlantic
4. East North Central
5. East South Central
6. West North Central
7. West South Central
8. Mountain
9. Pacific (includes Alaska and Hawaii)

FIGURE 5. STAINLESS STEEL SCRAP PROCESSED IN EACH CENSUS REGION, PER DEALER

Materials Flow Pattern for Nickel Stainless Steel Recycling

Table 32 gives Battelle-Columbus estimates concerning nickel stainless steel scrap recycling in 1969. Many simplifying assumptions were made so that construction of this table could be possible. The assumptions, sources, and methodology used are included as footnotes of the table. Figure 6 shows these estimates in a flow diagram.

As shown, about 88 percent of the total nickel stainless steel available for recycling (industrial and obsolete scrap) is apparently being recycled. Most of the stainless is returned to the steel mill; however, some of it is sent to iron and steel foundries, and some of it is exported overseas, largely to Japan, Sweden, and Italy.

Demand/Supply Analysis

To show what can be expected in the future for nickel stainless steel recycling, an analysis of expected future demand and supply is made in this section.

Demand

U. S. demand for recycled nickel stainless steel in 1969, 1974, and 1979 is forecast as follows:

	Demand for Recycled Nickel Stainless Steel (Short Tons)
1969	326,000
1974	357,000
1979	445,000

TABLE 32. STAINLESS SCRAP RECYCLING, 1969

Source and Type of Scrap	Stainless Steel Available for Recycling(1) (Thousands of Short Tons)	Stainless Steel Recycled(2)	Percent Recycled
Aerospace and Power			
Industrial	20.6	20.6	~100
Obsolete	36.8	n.a.	--
Construction and Machinery			
Industrial	39.5	39.5	~100
Obsolete	5.8	n.a.	--
Consumer Products			
Industrial	45.9	45.9	~100
Obsolete	58.4	n.a.	--
Automotive			
Industrial	31.2	31.2	~100
Obsolete	58.2	n.a.	--
Chemical, Petrochemical, and Marine			
Industrial	29.9	29.9	~100
Obsolete	20.3	n.a.	--
All Other Stainless Products			
Industrial	52.4	52.4	~100
Obsolete	30.4	n.a.	--
TOTAL INDUSTRIAL	219.5	219.5	~100
TOTAL OBSOLETE AND/OR EXPORTED	209.9	158.9	76
GRAND TOTAL	429.4	378.4	88
TOTAL NOT RECYCLED	Not Applicable	51.0	

Note: Footnotes are listed on the following page.

FOOTNOTES TO TABLE 32

(1) The sources for scraps were calculated in the following way:

Industrial scrap for Industry A = 0.25 x estimated mill shipments to Industry A

Obsolete scrap was calculated from estimated life cycles and the consumption of nickel stainless steel that number of years prior to 1969. The life cycles used, and the years for which consumption data were obtained are as follows:

	Life Cycle	Years of Nickel Stainless Steel Consumption Used to Calculate Nickel Stainless Availability
Aerospace and power	11	1958
Construction and machinery	22	1947
Consumer products	12	1957
Automotive	12	1957
Chemical, petroleum, and marines	12	1957
All other stainless products	20	1949

(2) (a) Industrial scrap is essentially 100 percent recycled. That which is not is estimated at a fraction of 1 percent.

(b) Sources for recycled obsolete scrap could not be determined with any degree of accuracy due to complete lack of statistics in this area. Total amount of obsolete scrap was calculated by the following equation:

Obsolete scrap recycled = Grand total scrap purchased less estimated industrial scrap generated less scrap exports.

(3) All exports assumed to be either industrial or obsolete scrap.

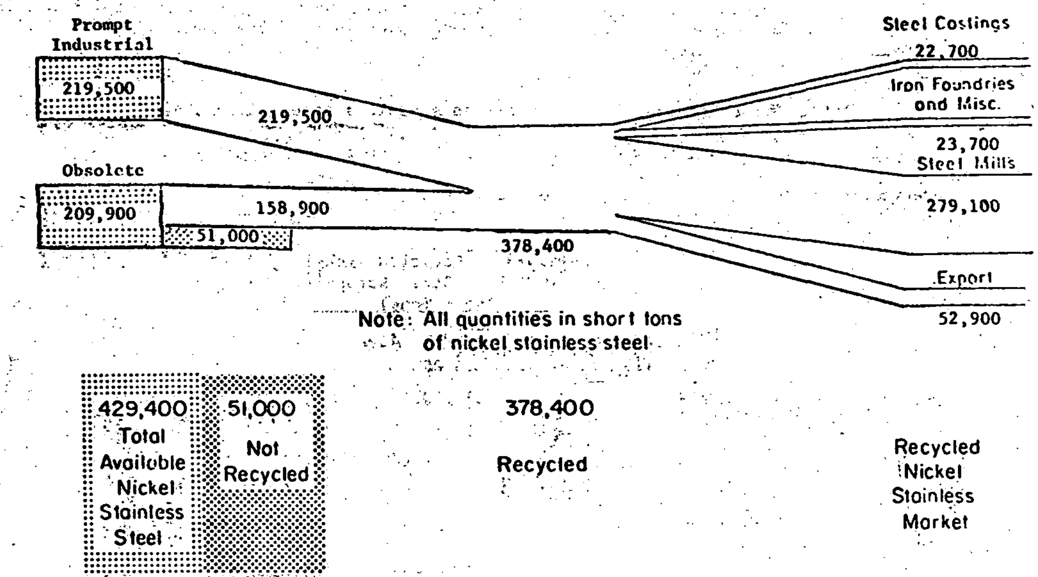


FIGURE 6. RECYCLED NICKEL STAINLESS STEEL FLOW, 1969

Source: U.S. Department of the Interior, Bureau of Mines, Minerals Yearbooks, "Nickel" and "Iron and Steel Scrap" chapters.

By 1974, the industry should have experienced the full effect of the increase in scrap usage per heat due to greater flexibilities of the new argon-oxygen melting technology. Recycled nickel stainless steel demand should increase from 326 thousand short tons in 1969 to 357 thousand short tons in 1974, and to 445 thousand short tons in 1979.

Supply

The future availability of recycled stainless steel scrap, based on the calculations and methodology presented in calculating total scrap available for recycling in Table 32, is given as follows:

	Supply of Recycled Nickel Stainless Steel Scrap(1) (Short Tons)
1969	326,000
1974	366,000
1979	434,000

(1) Total nickel stainless steel scrap recycled less that exported.

The above calculations assume that stainless steel imports and scrap exports will remain about the same in the future as in 1969.

Demand/Supply Balance

Unlike other metals, e.g., copper and lead, the demand/supply picture for stainless steel appears to be essentially in balance based on present recovery estimates, product life cycles, and market forecasts. The future demand/supply picture is expected to be as follows:

	Nickel Stainless Steel (Short Tons)	
	1974	1979
Demand	357,000	445,000
Supply(1)	366,000	434,000
Surplus(+)	9,000	-11,000

(1) Assume about 50,000 tons of nickel stainless steel scrap exported in 1974 and 1979. This was deducted from total domestic generation of scrap to derive total domestic supply.

The surplus and deficit shown are only approximate. It is assumed that domestic prices, domestic scrap supplies, or scrap exports will rise or fall so that a demand/supply balance will be achieved.

If foreign demands for scrap are larger than in the past, a small deficit for 1979 will be turned into a much larger one. This will increase domestic prices.

If incentives are different in 1974 and 1979 than as exist today, e.g., if recycling is encouraged by new legislation, new technology, etc., Battelle estimates that only small increases in stainless, or about a 4 to 5 percent maximum increase in the recycled nickel supply, steel recycling will result. Main reasons are:

- All prompt industrial scrap, or about 220,000 short tons, is presently being recycled.
- Most obsolete scrap (about 75 percent), or about 160,000 short tons, is presently being recycled.

PROBLEMS THAT DIRECTLY REDUCE THE RECYCLING OF NICKEL STAINLESS STEEL SCRAP

Unlike the situation with most other commodities, there are only a few identifiable problems that directly reduce the amount of nickel stainless steel that is recycled.*

Industrial Scrap

Prompt industrial nickel stainless steel scrap is about 100 percent recycled. Those small amounts that are not represent only a very small fraction of one percent. These are usually flue dusts and slags associated with the melting of stainless steel charges.

Obsolete Scrap

Due to the lack of statistics, only an aggregate figure for obsolete scrap recycling can be determined with any degree of accuracy. In this case, recycling of nickel stainless steel scrap is about 76 percent of the total amount available.

Table 33 presents the problems associated with obsolete scrap based on 1969 estimates. Included are: (1) problem definition, (2) tons of nickel stainless steel scrap not recycled, (3) percent of available nickel stainless steel scrap not recycled, and (4) problem analyses.

Other

Other problems that directly effect the recycling of nickel stainless steel--but which are impossible to measure quantitatively--are legislative problems.

* Problems that do not directly reduce the amount of recycling but which are important due to other reasons are discussed in the next major section of the report.

Some of the most important are: (1) discriminatory subsidies allowed nickel producers in the form of ore depletion allowances, (2) purchase and sale of emergency stockpiles primarily include primary nickel producers, (3) export restrictions on movement of stainless scrap. All of the above tend to favor use of primary over recycled, other things remaining equal. If the above problems were resolved, additional amounts of stainless recycling would result.*

* See "Report No. 1, Summary" for additional information of depletion allowances.

TABLE 33. IDENTIFICATION AND ANALYSIS OF PROBLEMS CONCERNING STAINLESS STEEL THAT WAS NOT RECYCLED IN 1969

Title	Obsolete Stainless Steel
PROBLEM DEFINITION	1. Prompt stainless steel scrap is estimated to be about 100 percent recycled. Obsolete stainless steel scrap is only 76 percent recycled. 2. This problem cannot be broken down further due to the lack of adequate statistical information. 3. Stainless steel is used in a myriad of different applications, e.g., automobile parts and trim, aircraft engine components, and appliances and cutlery. 4. Applications where stainless steel is a large part of a system are generally recycled, but those applications, e.g., cutlery and small appliances, where stainless steel is a small part of a system are probably not completely recycled.
TONS OF STAINLESS NOT RECYCLED	51,000
PERCENT OF AVAILABLE STAINLESS NOT RECYCLED	24
PROBLEM ANALYSIS	1. Stainless steel is often a small part of a larger system in consumer appliances and other stainless uses. 2. These items are small and generally are discarded to municipal waste after termination of useful life. 3. This seems a promising area to increase recycling.

PROBLEMS THAT DO NOT DIRECTLY REDUCE RECYCLING OF NICKEL STAINLESS STEEL SCRAP

There is only one problem faced by the stainless steel recycling industry that has no direct quantitative effects on recycling. However, it generally has an economic effect on the industry or industry members, or it has a nuisance effect on the industry.

(1) Customer prejudices against recycled materials.

Table 34 discusses this problem. Included are (1) titles and definitions of problems (2) effects on recycling, and (3) analyses of problems.

TABLE 34. IDENTIFICATION AND ANALYSIS OF PROBLEMS THAT DO NOT DIRECTLY REDUCE THE AMOUNT OF NICKEL STAINLESS STEEL THAT IS RECYCLED, 1969

Title		Customer Prejudices Against Scrap
PROBLEM DEFINITION	1.	Some scrap types, e.g., stainless steel turnings, aren't being purchased by some scrap users and are being exported overseas to foreign steel producers.
	2.	Despite good economics of using scrap, stainless steel mills sometimes prefer primary over scrap because (a) it is easier to use primary and (b) they prefer to use more expensive primary so that they are assured adequate nickel supplies during shortages.
EFFECT ON RECYCLE RATE		None. Most of this scrap is recycled by exporting it overseas.
PROBLEM ANALYSIS	1.	For most applications, stainless steel made from recycled scrap is not inferior to that made only from primary materials.
	2.	There is a need for promotional and educational efforts that will inform buyers and actual users of advantages of using recycled materials.

(1) Problems adversely affect economics or practices of recycling but the effect in terms of amount cannot be measured. This situation is considered an indirect effect.

COURSES OF ACTION CONCERNING RECYCLING OF NICKEL STAINLESS STEEL SCRAP

This section analyzes what actions EPA, the recycling industry, and others should take in resolving problems outlined in the last two sections.

Selection of Opportunities

In the above analysis, two problems were delineated: obsolete nickel stainless steel scrap not recycled and customer prejudices against recycled materials. From an environmental and conservational point of view, the first problem is of much higher priority than the second.

Recommended Actions

High priority ideas are those which are so important that the public, in addition to the stainless steel recycling industry, would have interest in their solution. Consequently, these problems are important enough to be acted upon by EPA. These problems and their recommended actions are shown in Table 35.

Lower priority ideas are those that are important for the recycling industry to solve, but which are not important enough for full participation by the public. Consequently, these problems are not important enough to be acted upon by EPA. These problems with their recommended solutions are shown in Table 36.

One problem, that of the lack of adequate statistical information, is worthy of immediate consideration. The lack of statistics on the consumption and recycling of some types of nickel stainless steel makes accurate analysis difficult.

TABLE 35. RECOMMENDED ACTIONS, HIGH PRIORITY STAINLESS STEEL PROBLEMS

Title	Obsolete Stainless Steel
RECOMMENDED ACTIONS	An investigation should be undertaken to determine why approximately 51,000 tons of nickel stainless steel were not recycled in 1969.
BY WHOM(1)(2)(3)	EPA/NASMI
SPECIFIC STEPS	1. Form a committee representing the following: • Stainless steel processors • Stainless steel fabricators • Stainless steel mills 2. The committee should discuss the problem with other people knowledgeable in the area of obsolete stainless steel scrap including: • Municipal land fill operators • Small scrap collectors 3. The committee should discuss and analyze why obsolete stainless steel scrap is not being recycled. 4. The committee should determine what additional actions should be taken.

(1) The responsibility for recommended actions shown in this table are based on importance of the action, benefit to the taxpayers, and opportunities for NASMI. They are the best judgments of Battelle.
(2) Recommended actions were distributed between high priority and lower priority based on the evaluation with three criteria.
(3) It is suggested that NASMI continue its leading role in recycling, recognizing that other organizations such as the Bureau of Mines, Department of Commerce, Council of Environmental Quality, HEW Office of Information, and State, Local, and Federal Legislatures must be involved.

TABLE 36. RECOMMENDED ACTIONS, LOWER STAINLESS STEEL PRIORITY PROBLEMS

Title	Customer Prejudice Against Recycled Material
RECOMMENDED ACTIONS	NASMI should undertake a broad publicity program to: (1) Outline the conservation features of using scrap to the public. (2) Help large users of scrap to publicize their conservational actions. (3) Help small users of scrap with their problems so they will be less reticent to use scrap.
BY WHOM (1)(2)(3)	NASMI/NASMI MEMBERS
SPECIFIC STEPS	(1) NASMI should continue its recycle programs, conferences, etc., to inform the public and promote conservation aspects of recycling. (2) Furthermore, NASMI should promote seminars to discuss new and useful techniques of using additional stainless scrap inputs in steelmaking. (3) NASMI should promote research in methods of utilizing higher amounts of scrap.

(1) The responsibility for recommended actions shown in this table are based on importance of the action, benefit to the taxpayers, and opportunities for NASMI. They are the best judgments of Battelle.
(2) Recommended actions were distributed between high priority and lower priority based on the evaluation with three criteria.
(3) It is suggested that NASMI continue its leading role in recycling, recognizing that other organizations such as the Bureau of Mines, Department of Commerce, Council of Environmental Quality, HEW Office of Information, and State, Local, and Federal Legislatures must be involved.

APPENDIX A

PRINCIPAL PRIMARY NICKEL GRADES

APPENDIX A

PRINCIPAL PRIMARY NICKEL GRADES

Table A-1 gives the types, producers, approximate nickel content, main uses, and descriptions of the principal grades of primary nickel.

TABLE A-1. PRINCIPAL PRIMARY NICKEL GRADES

Type	Producer*	Approximate Ni Content, percent	Main Uses	Description
Electrolytic (cathode)	(1,3)	99.9	Alloy production, electroplating	Sheared cathodes
Pellets	(2)	99.9	Alloy production	Carbonyl nickel
Briquettes	(5)	99.9	Alloy production	Compacted hydrogen-reduced powder
Rondelles	(4)	99.3	Alloy production	Carbon-reduced molded nickel oxide
Nickel-iron pellets	(3)	1.5	Alloy production	Reduced iron ore pellets
Ferronickel	(6,4)	20 min	Ferrous alloy production	Pyrorefined ingots
Nickel oxide sinter 75	(1)	75	Ferrous alloy production	Product from roasting of refined nickel sulfides
Nickel oxide sinter 90	(1)	90	Ferrous alloy production	Product from roasting of refined nickel sulfides
Powder, carbonyl	(2)	99.9	Nickel and nickel-containing alloys, via powder metallurgy	Powder from decomposition of nickel carbonyl
Powder (CP)	(5)	99.9	Nickel and nickel-containing alloys, via powder metallurgy	Powder obtained by chemical precipitation methods

* (1) The International Nickel Company of Canada, Ltd., Toronto, Ontario.
(2) The International Nickel Company, Ltd., Clydach, England.
(3) Falconbridge Nickel Mines Ltd., Toronto, Ontario.
(4) La Societe "Le Nickel", Le Havre, France.
(5) Sherritt-Gordon Mines Ltd., Toronto, Ontario.
(6) Hanna Mining Company, Cleveland, Ohio.

APPENDIX B

CONSUMPTION OF NICKEL CONTAINING PRODUCTS

APPENDIX B

CONSUMPTION OF NICKEL CONTAINING PRODUCTS

Table B-1 gives the consumption pattern for the principal nickel-containing low alloy steels.

TABLE B-1. MARKETS FOR NICKEL-CONTAINING LOW ALLOY STEEL

Type and Grade	Average Nickel Content, percent	Total Production, short tons 1965	1966	1967	1968	1969
Nickel		50,314	76,727	35,430	38,948	53,649
2515	3.50					
Nickel-Chromium		113,915	102,926	80,055	69,808	78,950
3312	3.50					
Nickel-Molybdenum		493,096	484,126	386,252	370,709	296,845
4620	0.85					
4621	0.85					
4626	0.85					
4815	3.50					
4817	3.50					
4820	3.50					
Nickel-Chromium-Molybdenum-Vanadium		130,878	130,239	182,624	157,452	142,855
4335V	1.82					
Nickel-Chromium-Molybdenum		1,656,269	1,718,158	1,434,339	1,553,654	1,905,279
4317	1.82					
4320	1.82					
4340	1.82					
8620	0.55					
8622	0.55					
8640	0.55					
8645	0.55					
8660	0.55					
8720	0.55					
9310	3.25					
94317	0.45					
GROUP TOTAL	0.77	2,444,472	2,512,176	2,118,700	2,190,571	2,477,578

Source: American Iron and Steel Institute, Annual Statistical Reports.

Table B-2 gives consumption of principal superalloys in 1969.

TABLE B-2. ESTIMATED MARKETS FOR VACUUM-MELTED SUPERALLOYS, BY ALLOY TYPE, 1969

Alloy and Type	Metal Content, short tons	Nickel Content, short tons
Wrought Products		
A-286	5,500	1,375
Incoloy 901	5,000	2,130
Inconel 718	5,000	2,750
X-750	2,750	2,040
Waspaloy	2,000	1,160
V-57	1,000	250
Rene 41	500	280
Inconels 700/702/722	300	160
U-700/Astroloy	300	160
D-979	300	135
Inconel 625	750	450
IN-102/U-520/Inc. 801	150	100
U-500	125	69
All other	3,250	2,130
Total Wrought	26,425	13,189
Cast Products	7,000	5,500
Total Weight	33,425	18,689

Source: Battelle-Columbus estimates.

Table B-3 gives estimated consumption of nickel in principal nickel-base nonferrous alloys in 1969.

TABLE B-3. ESTIMATED PRESENT U.S. CONSUMPTION OF NICKEL-BASE NONFERROUS ALLOYS

Type	Nickel Content, percent	Estimated Nickel Consumption (short tons)
Nickel	100	4,000
Inconel 600	76	6,100
Monel 400	67	10,000
Hastelloy B	64	1,900
Hastelloy C	56	1,700
Incoloy 800	32	4,865
Incoloy 825/Carpenter 20CB-3	42	1,700
Other	50	2,000
TOTAL		32,265

Source: Battelle-Columbus estimates.

Table B-4 gives estimated nickel consumption in principal copper base alloys in 1969.

TABLE B-4. CONSUMPTION OF NICKEL USED IN COPPER-BASE ALLOYS

Type of Product	Nickel Content (thousand short tons) Scrap	Primary	Total
Cupronickel condenser tube, nickel silver, and other wrought products	3.3[1]	5.9[1]	9.2
Cast brasses and bronzes	0.9[1]	--	0.9
TOTAL	4.2	5.9[2]	10.1

Sources: (1) Copper Development Association, Annual Data 1970.
(2) This total slightly higher than that given by U.S. Bureau of Mines.

Table B-5 gives estimated consumption of nickel in various cast irons in 1969.

TABLE B-5. NICKEL USED IN PRODUCTION OF CAST IRON, 1969

Type	Short Tons of Nickel Consumed Scrap[1]	Primary	Total
Gray iron	12,700	3,300	16,000
Ductile iron	6,000	2,000	8,000
Ni-Resist/Ni-Hard	600	300	900
TOTAL	19,300	5,600	24,900

(1) Includes revert and recycled scrap. Recycled scrap accounts for about 4,589 s.t. of nickel consumption in cast iron.

Source: Battelle estimates.

VOLUME VII

PRECIOUS METALS REPORT

TABLE OF CONTENTS

TABLE OF CONTENTS (Continued)

TABLE OF CONTENTS (Continued)

LIST OF APPENDIXES

LIST OF TABLES

LIST OF TABLES (Continued)

LIST OF TABLES (Continued)

LIST OF FIGURES

PRECIOUS METALS RECYCLING

Summary

This report deals with problems and opportunities in the recycling of gold, silver, and the platinum group metals, collectively known as precious metals. To place recycling in its proper perspective, each segment of the precious metals industry is analyzed briefly as to materials sources, materials flow, markets for the metals, and demand-supply relationships.

In general, recycling of the precious metals has been well advanced for a number of years. The metals are relatively high priced and domestic mine sources in the United States have been unable to satisfy the demand for them. Both factors have helped to stimulate recycling when the metal value was readily recognized and economical to recover.

In broad perspective, the recycling of precious metals appears to be related to the usages made of them. Traditionally, they have been prized for their beauty and permanence for personal adornment, art, and household decoration. Such products tend to have extensive useful life cycles, frequently spanning generations, and their return to the recycle system is problematical. Since World War II, increasing recognition has been made of the physical properties of the precious metals that fit them to functional uses in industrial applications. Here, the resulting products have finite life cycles measured in years and the discarded products frequently can be salvaged for recycling of the precious metal content. In all instances, though, the manufacture of products containing precious metals results in unavoidable scrap and waste that is recycled promptly at relatively high levels of recovery, averaging nearly 90 percent of that generated.

Problems associated with recycling of the precious metals are difficult to rate in terms of priorities, but the principal opportunity appears to lie in the salvage of discarded consumer goods and industrial equipment containing the metals.

Gold

Between 1965 and 1969, consumption of gold in nonmonetary uses in the United States rose from about 5.25 million troy ounces to 7.10 million ounces, averaging about 6.25 million ounces annually. Of this average annual consumption, 60 percent was used in the production of jewelry, art and decorative ware, 9 percent in dental applications, and 31 percent in industrial equipment and devices. This contrasts with the traditional pattern of 75 percent for jewelry and the arts, 10 percent for dental, and 15 percent for industrial that pertained prior to 1958. Since then the reliability of performance provided by gold in electronic equipment and components and in space exploration hardware--as electrical connectors, heat shields, and brazing alloys--has rapidly increased its usage in the industrial sector. Concurrently, usage in jewelry in particular has outpaced the rise in personal disposable income (the usual indicator), reflecting an extended period of economic prosperity as well as a shift in consumer preference toward the richer gold alloys.

Between 1958 and 1969, consumption of gold increased at an average annual rate of 13.1 percent. The recessionary economy in 1970 arrested this spectacular growth and indications are that growth in the first half of the 1970 decade may average no more than about 5 percent annually.

The present level of recycling of gold scrap and waste, both the prompt industrial return and salvaged consumer and industrial products, supplies about 29 percent of net nonmonetary consumption. An additional 25 percent is provided by domestic mine production of new gold and the balance comes from imports. There is little prospect that domestic mining can furnish more than incremental additions to supply at present price levels for gold and increases in the amount of recycled gold will be difficult to achieve. Thus, the United States will continue to be dependent on imports of gold to satisfy future demand levels.

Table I summarizes the problems and analyses of gold recycling. The primary obstacle to better recycling of gold is the economic infeasibility of collecting small quantities of gold-containing scrap from individuals or from lean industrial sources. Consumer-oriented products usually have a significant gold content (40 percent or more) but the recycling value to the consumer is only a fraction of the value ascribed to the article and insufficient to motivate him to seek a market outlet except in special circumstances. Accordingly, individual jewelry and art articles, if discarded, are more likely to be consigned to trash dumps than to be returned to the recycle system. Industrially-oriented products normally contain minor quantities of gold (less than 1 percent), complicating identification of gold values and necessitating joint recovery of several salvageable values to be economically feasible. Collection of electronic and industrial equipment scrap containing gold and segregation techniques for ferrous, nonferrous, and precious metal scraps has been feasible only in selected instances of geographic concentration of salvage centers, for example, military salvage depots. Modest increases in the recycling of old industrial gold scrap are possible but will depend on the identification of geographic areas having high levels of equipment discard and the development of efficient disassembly methods to permit segregation of components having gold contents of 2 percent or more.

Because the present level of recycling appears to be approaching the limit of economic feasibility, actions recommended to improve it tend to fall in the category of general promotion of the recycling concept. The principal specific recommendation involves a continuation of training programs instituted

TABLE I. IDENTIFICATION AND ANALYSIS OF PROBLEMS CONCERNING GOLD THAT WAS NOT RECYCLED IN 1969.

Title	Scrap Categories Where Some Gold Was Not Recycled: Prompt Industrial Scrap	Industrial Wastes and Sweepings	Old Industrial Scrap	Old Consumer Scrap
Problem Definition	Manufacturing processes often generate unusable materials in small volume in a number of installations, often these are contaminated and are not recycled.	Polishing, buffing, plating operations and metal melting generate wastes with a small gold content The gold values are not economic to recover. Thus, scrap gold is not recycled.	Gold content of discarded articles is low, frequently less than 1 percent Nongold content is variable, usually other metals and frequently plastics, paper, and cloth This is a major area of gold not being recycled.	Service life of consumer goods dependent on factors other than economics Consumer's idea of article value to be scrapped is much higher than the materials cost Individual article has small amount of gold and variable gold content
GOLD NOT Recycled	100-150,000 ounces annually	20-30,000 ounces annually	400,000 ounces annually	Unknown
Percent of Available GOLD NOT Recycled	10	20	80	Unknown
Problem Analysis	1. Rate of recycling is high when scrap can be segregated by alloy and color 2. Segregation becomes difficult when same worker has to handle several alloys and different product forms in same day 3. Jewelry, arts, and dental industries have many small shops with one or two production workers. 4. In small shops, production of saleable goods represents more economic use of labor than collecting scrap 5. This is not a promising area because the economically recoverable scrap is being recovered 6. Institutional promotion by the refining industry is desirable to maintain level of recovery now achieved	1. Gold content of wastes and sweepings is variable, from 0.1 percent to 5.0 percent 2. Balance of material has no significant recovery value 3. Efficient collection is difficult because of dilution 4. This is not a promising area because the economically recoverable waste is being recycled 5. Institutional promotion by the refining industry is desirable to maintain level of recovery now achieved	1. Aside from military salvage depots no effective mechanism exists for economic collection of discarded equipment 2. Discarded equipment has variable gold content--some none, others up to 1 percent gross weight 3. Identification of gold-bearing scrap is difficult at times 4. No effective processes exist to treat bulk scrap for gold recovery. 5. Upgrading to recoverable gold level is uneconomic unless large volumes of scrap are collected 6. About two-thirds of economically recoverable gold is being recovered 7. Some improvement is possible via joint USBM-DOD programs now underway	1. Consumer has little economic incentive to recycle gold unless a direct replacement of an article is being made 2. Unreported recovery believed to be substantial via small manufacturing jeweler 3. No effective mechanism exists to collect discarded articles from individual consumers 4. Improvement in recycling definitely possible but not necessarily economic for consumer

by the U.S. Department of Defense and the U.S. Bureau of Mines for better identification of gold-containing components of military scrap. Table II summarizes the actions recommended.

Silver

Between 1966 and 1969, consumption of silver in nonmonetary uses in the United States declined from about 184 million troy ounces to a level near 140 million ounces. Primarily, the decrease is attributable to erosion of markets for silver in selected consumer-oriented products and photographic uses accompanied by a lack of growth in industrial applications. Historically, photographic uses for silver have accounted for nearly one-third of annual consumption, consumer-oriented products for about one-fourth, and industrial applications for the balance of a little over 40 percent. In contrast to the situation in gold, industrial applications for silver developed shortly after World War II and appear to have matured technologically. Consumer-oriented applications, especially silver-plated tableware and household furnishings including mirrors, have suffered from substitution of alternative materials--stainless steel and chrome plating in particular--and changes in life style with respect to the home. But most of these negative factors are believed to have reached a point where silver will be able to retain its share of expanding markets.

The outlook for silver in the 1970 decade is optimistic as soon as the effects of the 1970 recession wear off. A recent study by the U.S. Bureau of Mines projected overall growth for silver at a rate of 3.0 to 3.5 percent per year, paralleling the increase in durable goods manufacture. This appears to be reasonable as long as it is applied to 1970 as a base year to arrive at consumption of 155 to 160 million ounces of silver in 1975.

TABLE II. RECOMMENDED ACTIONS, HIGH PRIORITY GOLD RECYCLING PROBLEMS

Title	Prompt Industrial Scrap	Industrial Wastes and Sweepings	Old Industrial Scrap	Old Consumer Scrap
tions commended	Recycling industry should continue promotional efforts for collecting and recycling small volumes of scrap.	Recycling industry should continue promotional efforts for collecting, segregating and using small volumes of scrap with low gold content.	Recycling industry should continue promotional and training efforts to ensure that scrap with low gold content is collected and recycled.	Recycling industry should continue promotional efforts to encourage ultimate consumer to turn in discarded articles.
Whom (1)(2)(3)	EPA/NASMI	EPA/NASMI	EPA/NASMI	EPA/NASMI
cific ps	1. Continue institutional advertising on value of scrap and probable cost savings by recycling	1. Continue institutional advertising on value of scrap and probable cost savings by recycling	1. Continue institutional advertising on value of scrap and need to recycle to conserve resources 2. Support USBM-DOD training programs for identification and segregation of gold-bearing scraps 3. Support R&D efforts to develop processing of gold-bearing scraps to economic recovery level	1. Continue institutional adve tising on value of scrap an need to recycle to conserve resources 2. Support efforts by service clubs to act as collection agencies for consumer scrap

1) The responsibility for recommended actions shown in this table are based on importance of the action, benefit to the taxpayers, and opportunities for NASMI. They are the best judgments of Battelle.
2) Recommended actions were distributed between high priority and lower priority based on the evaluation with three criteria.
3) It is suggested that NASMI continue its leading role in recycling, recognizing that other organizations such as the Bureau of Mines, Department of Commerce, Council of Environmental Quality, HEW Office of Information, and State, Local, and Federal Legislatures must be involved.

Currently, recycling of silver is at a high level from recent attempts to improve its recovery from salvaged military and industrial equipment. When annual consumption is about 140 million ounces, prompt industrial scrap should be about 30 million ounces and old scrap, including photographic wastes, would add an additional 30 million ounces. In 1968 and 1969 recycled silver exceeded 90 million ounces or over 60 percent of total consumption. There are reasons to believe that little improvement over this level can be achieved. An additional 28 percent of consumption is supplied by domestic mine production of new silver with the balance of about 12 percent derived from imports since the U.S. Treasury Department ceased selling silver in 1970. Expansion of domestic mine output is unlikely at recent silver prices and any increase in recycled silver will be small so that imports will be needed to satisfy future demand levels.

Table III summarizes the problems of silver recycling. The primary obstacle to better recycling of silver has been economics--the economics of collection and segregation of old scrap from private and industrial consumers. Consumer-oriented products--tableware and household decorations, jewelry, dental and medical devices, and mirrors--are purchased with every intention of keeping them for a lifetime. Accidental damage and normal wear produce small quantities of scrap each year that is potentially available for recycling. However, the individual consumer seldom bothers to determine the scrap value of the single article he has unless it is sterling silver and he wants to replace a piece in a set. Silver plated articles or jewelry are more apt to wind up in the trash and disappear into a municipal dump.

Some industrial products have readily identifiable contents of silver and a pattern of usage that encourages recycling. The U.S. Navy uses silver batteries in submarine service and has organized the collection and recycling of discards. Military electronic equipment with silver batteries and/or silver

TABLE III. IDENTIFICATION AND ANALYSIS OF PROBLEMS CONCERNING SILVER THAT WAS NOT RECYCLED IN 1969

	Scrap Categories Where Some Silver Was Not Recycled				
Title	Prompt Industrial Scrap	Industrial Wastes and Sweepings	Old Industrial Scrap	Old Consumer Scrap	Photographic Scrap
Problem Definition	Manufacturing processes often generate unusable materials in small volume in a number of installations, often these are contaminated and are not recycled.	Polishing, buffing, plating operations and metal melting generate wastes with a small silver content. The silver values are not economic to recycle. Thus this scrap silver is not recycled.	Silver content of discarded articles is variable Low silver-content articles usually have other metals, sometimes nonmetallic materials. This is a major area where silver is not recycled.	Service life of consumer goods dependent on factors other than economics. Consumer's idea of value of article to be scrapped is much higher than the materials cost.	Silver recoverable only at certain stages which occur at geographically dispersed locations Economic recovery possible only at certain levels of film processing or disposal
Silver <u>NOT</u> Recycled	1,500,000 ounces annually	270,000 ounces annually	20-25,000,000 ounces annually	2-3,000,000 ounces annually	20-25,000,000 ounces annually
Percent of Available Silver <u>NOT</u> Recycled	5	45	33	50	50
Problem Analysis	1. Recycling is at a high level when scrap can be segregated by alloy and and product form 2. Small shops handling a a few ounces of silver per day have difficulty in collecting scrap economically 3. This is not a promising area because the economically recoverable scrap is being recovered 4. Institutional promotion by the refining industry is desirable to maintain level of recovery now achieved	1. Silver content of wastes and sweepings is variable, from 0.1 percent to 20.0 percent 2. Balance of material has no significant recovery value 3. Efficient collection is difficult because of dilution 4. This is not a promising area because the economically recoverable waste is being recycled 5. Institutional promotion by the refining industry is desirable to maintain level of recovery now achieved	1. Aside from military salvage depots no effective mechanism exists for economic collection of discarded equipment 2. Discarded equipment has variable silver content--some none, others up to 60 percent of gross weight 3. Identification of silver-bearing scrap is difficult at times 4. No effective processes exist to treat bulk scrap for silver recovery 5. Upgrading to recoverable silver level is uneconomic unless large volumes of scrap are collected 6. About two-thirds of economically recoverable silver is being recovered 7. Some improvement is possible via joint USBM-DOD programs now underway	1. Consumer has little economic incentive to recycle silver unless a direct replacement of an article is being made 2. Some recovery is unreported, probably from small manufacturing jewelers 3. No effective mechanism exists to collect discarded articles from individual consumers 4. Improvement in recycling definitely possible but not necessarily economic	1. Silver is recoverable from spent processing solutions and discarded film and prints 2. Large processors are recovering silver effectively, except certain Governmental users 3. Large volume generators of discarded film and prints also recover silver effectively 4. Essential problem for small user is the lack of incentive to collect store, and recycle the small quantities generated 5. About 80 percent of economically recoverable silver is being recycled 6. Improvement is possible and desirable but consumer apathy has to be overcome

contact points is another example that accounts for recent increases in silver recycling. But products such as silver bearings and silver brazing alloys illustrate the situation of continuing loss to recycling because the silver content of the discard is low (less than 5 percent by weight) and uneconomic to collect.

Photographic wastes in processing solutions and used film and paper have received concentrated attention in the past five years from the makers of photographic supplies who recognize the irreplaceable nature of silver in their products. Recovery of silver probably has been doubled over that span by the establishment of a network of collectors and processors of photographic wastes. Virtually all the large and medium-sized users and processors of paper and film are now covered for recycling and nearly half of the silver used by this industry annually is now being recovered. At least one-third of annual silver consumption in photography cannot be recovered because of economic considerations or archival usage. The balance is potentially recoverable but a variety of logistical and legal problems remain to be solved before recovery is accomplished.

Aside from photographic uses, the present level of recycling of silver appears to be approaching the limits of economic feasibility. Actions recommended thus tend to be general in character along the lines of promotion of the recycling concept, including continuation of the programs underway by the U.S. Department of Defense and the U.S. Bureau of Mines. The problems of photographic wastes also merit general promotion of recycling to overcome user complacency as well as legal action to permit federal governmental agencies, other than the Veterans Administration, to deal with private industry for treatment of their photographic wastes.

Table IV summarizes the actions recommended for easing the silver recycling problems.

TABLE IV. RECOMMENDED ACTIONS, HIGH PRIORITY SILVER RECYCLING PROBLEMS

Title	Prompt Industrial Scrap	Industrial Wastes and Sweepings	Old Industrial Scrap	Old Consumer Scrap	Photographic Scrap
Actions Recommended	Recycling industry should continue promotional efforts for collecting and recycling small volumes of scrap	Recycling industry should continue promotional efforts for collecting, segregating and using small volumes of scrap with low silver content	Recycling industry should continue promotional and training efforts to ensure that scrap with low silver content is collected and recycled	Recycling industry should continue promotional efforts to encourage ultimate consumer to turn in discarded articles	Recycling industry should continue promotional efforts to ensure collection and processing of photographic scrap Legislation should be promoted to allow Governmental installations to receive credit for silver recovered
By Whom (1)(2)(3)	EPA/NASMI	EPA/NASMI	EPA/NASMI	EPA/NASMI	EPA/NASMI
Specific Steps	1. Continue institutional advertising on value of scrap and probable cost savings by recycling	1. Continue institutional advertising on value of scrap and probable cost savings by recycling	1. Continue institutional advertising on value of scrap and need to recycle to conserve resources 2. Support USBM-DOD training programs for identification and segregation of silver-bearing scrap 3. Support R&D efforts to develop processing of silver-bearing scraps to economic recovery level	1. Continue institutional advertising on value of scrap and need to recycle to conserve resources 2. Support efforts by service clubs to act as collection agencies for consumer scrap	1. Continue institutional advertising on need to conserve resources 2. Sponsor legislation to allow Government installations to use industrial reclamation services and receive credit for silver recovered 3. Support efforts by service clubs to act as collection agencies for photographic wastes

(1) The responsibility for recommended actions shown in this table are based on importance of the action, benefit to the taxpayers, and opportunities for NASMI. They are the best judgments of Battelle.

(2) Recommended actions were distributed between high priority and lower priority based on the evaluation with three criteria.

(3) It is suggested that NASMI continue its leading role in recycling, recognizing that other organizations such as the Bureau of Mines, Department of Commerce, Council of Environmental Quality, HEW Office of Information, and State, Local, and Federal Legislatures must be involved.

Platinum

Consumption of the platinum group metals in the United States is difficult to pinpoint. Sales to consuming industries are reported annually but since about 1960 the amount of material that is refined for consumers on a toll basis has been nearly equal to or above reported sales. For the 1965-1969 period, for example, reported sales to industry averaged 1.38 million troy ounces annually while toll refining yielded an average of 1.91 million ounces per year that also was available to consumers. In view of this situation it is not surprising to find that more than 84 percent of reported sales were made to consumers who applied the metals in industrial applications over which they had control. The balance of 16 percent of reported sales went to producers of consumer-oriented products such as jewelry and dental and medical devices. Nearly 54 percent of the reported sales were of palladium, platinum accounted for 41 percent and the remaining 5 percent was split among iridium, osmium, rhodium, and ruthenium. The latter four are used predominantly as alloying agents with platinum or palladium.

The electrical and electronics industry received nearly 39 percent of reported sales in the 1965-1969 period, of which 80 percent was palladium. It is used primarily in telephone switching relay contacts to assure reliability of circuit connections for dial telephones. Platinum is used for contact points in voltage regulators and other industrial control equipment and as the points for aircraft sparkplugs.

The chemical industry received a little more than 28 percent of reported sales, of which 52 percent was palladium and 42 percent was platinum. Both palladium and platinum are used as catalysts for hydrogenation-dehydrogenation reactions and platinum catalyzes the oxidation of ammonia to nitric acid. Platinum also is fabricated into laboratory ware and corrosion resistant processing equipment.

The petroleum industry received a little more than 12 percent of reported sales, of which 88 percent was platinum. Platinum catalyzes reforming reactions in hydrocarbons, an efficient way to increase the octane ratings in gasoline.

Other applications for the platinum group metals take advantage of their resistance to corrosive environments at high temperatures, their strength to weight characteristics and chemical inertness, their color and permanence, and other physical properties.

The market outlook for the platinum group metals is hazy. Palladium, long an undesirable byproduct, probably will be back to that status before 1980. Central exchange relays are being replaced by semiconductor switching devices to accommodate touch tone number selection systems. Complete conversion to touch tone would eliminate a demand for at least 0.5 million ounces of palladium per year. In the opposite direction, a ban on lead in gasoline would create an additional demand for platinum for reforming catalysts that could exceed 3.5 million ounces. There appears to be little prospect that lead in gasoline will be phased out before 1975 and in the meantime automobile manufacturers will be adapting their engine designs to accept lower octane ratings in gasoline. If both these conditions prevail, the need for added reforming capacity would be moderated substantially and the new demand could be spread over several years as the facilities are built. Expanding markets in other applications suggest that overall, consumption of the group as a whole will remain in the vicinity of 1.0

to 1.25 million ounces per year through 1975 but shifting gradually toward platinum and away from palladium.

As mentioned earlier, recycling of the platinum group metals is practiced extensively although much of this material does not change ownership in the process. Considering only the reported sales to consumers as a measure of consumption, recycled material that is sold to refiners supplies a little under 19 percent of annual average consumption and domestic mining contributes about 2 percent. The balance is imported. No significant improvement in the output of the domestic mining industry is expected. A few small placer deposits in Alaska are the only known domestic reserves of the platinum group metals. Recycling, which may actually account for over 60 percent of annual usage, already is at a high level with respect to the amount of scrap generated and unlikely to experience significant improvement. A continued dependence on imports is projected.

In the absence of reliable data on recycling of prompt industrial and old scrap, a rationalized flow calculation indicates that consumers use about 3.30 million ounces annually of the platinum group metals, return about 18 percent of this as prompt industrial scrap, and concurrently recycle old scrap and wastes equivalent to 50 percent of consumption. Indications are that less than 60,000 ounces of the group metals generated as prompt industrial scrap miss being recycled, largely because the generators handle such small quantities of the metals that segregation of scrap is uneconomic. Similarly, the recycling of old industrial scrap and waste is believed to include nearly all that is economically recoverable and the consumers seldom relinquish control of the products and can assure their recovery. Old consumer scrap may represent a modest opportunity to increase recycling provided that the general public can be motivated to turn in discarded articles instead of throwing them in the trash can.

Table V identifies and analyses the platinum-group recycling problems. The major obstacle to better recycling of the platinum group metals is economics, the economics of collecting and segregating small quantities of scrap and waste from widely divergent locations. This applies to prompt industrial scrap, old industrial scrap, and old consumer scrap. A solution for this problem is difficult to visualize. The high level of recycle for the platinum group metals already achieved limits recommended actions to the general promotion of the recycling concept.

Table VI summarizes the recommended actions for platinum-group metals.

TABLE V. IDENTIFICATION AND ANALYSIS OF QUANTITATIVE PROBLEMS OF PLATINUM GROUP METALS RECYCLING

Title	Prompt Industrial Scrap	Obsolete Scrap
Problem Definition	Manufacturing processes generate unusable materials in small volume in a number of installations that are often contaminated and not recycled	Platinum content of discarded articles frequently is low, usually masked by other metals Individual consumer goods articles have small amount of platinum. Consumer's idea of value of article is much high than the materials cost
Platinum NOT Recycled	60,000 ounces	40,000 ounces
Percent of Available Platinum NOT Recycled	5	5
Problem Analysis	1. A very high percentage of available scrap is recycled 2. Aside from accidental loss, only small shops find it uneconomic to recover platinum 3. This is not a promising area because the economically recoverable scrap is being recovered 4. Institutional promotion by the refining industry is desirable to maintain level of recovery now achieved	1. Recycling of obsolete industrial scrap is high in spite of low content of platinum at times 2. Recycling of discarded consumer articles is economic only when consumer turns article in 3. Consumer has little economic incentive to recycle platinum unless a direct replacement of the article is being made 4. No effective mechanism exists to collect discarded articles from individual consumers 5. Unreported recovery via small manufacturing jewelers believed to exist 6. Minor improvement may be possible without economic benefit to consumer

TABLE VI. RECOMMENDED ACTIONS, HIGH PRIORITY PLATINUM GROUP METALS RECYCLING PROBLEMS

Title	Prompt Industrial Scrap	Obsolete Scrap
Action Recommended	Recycling industry should continue promotional efforts for collecting and recycling small volumes of scrap	Recyling industry should continue promotional efforts to encourage ultimate consumer to turn in discarded articles even in small amounts
By Whom (1)(2)(3)	EPA/NASMI	EPA/NASMI
Specific Steps	1. Continue institutional advertising on value of scrap and probable cost savings by recycling	1. Continue institutional advertising on value of scrap and need to recycle to conserve resources

(1) The responsibility for recommended actions shown in this table are based on importance of the action, benefit to the taxpayers, and opportunities for NASMI. They are the best judgments of Battelle.

(2) Recommended actions were distributed between high priority and lower priority based on the evaluation with three criteria.

(3) It is suggested that NASMI continue its leading role in recycling, recognizing that other organizations such as the Bureau of Mines, Department of Commerce, Council of Environmental Quality, HEW Office of Information, and State, Local, and Federal Legislatures must be involved.

INTRODUCTION

In June, 1970, Battelle-Columbus undertook a research program for the National Association of Secondary Material Industries, Inc. (NASMI). This work was carried out under a subcontract from an Office of Solid Waste Management grant to NASMI. This report on precious metals is one of a series of eight commodity reports plus a general or summary report.

Background

The Office of Solid Waste Management is responsible for formulating and recommending Federal Government policies in the area of solid waste pollution. This includes pursuing appropriate research to determine the status and problems of solid waste activities, and to develop programs to reduce solid waste pollution.

One approach to the reduction of solid waste pollution is to reclaim waste materials for reuse - the recycling concept. A well established industry--the secondary materials industry--exists to accomplish this recycling. NASMI is the trade association representing the nonferrous metals, paper, and textiles portion of this industry.

The scrap processors, secondary smelters, and other companies that make up the secondary materials industry have developed effective channels and methods for recycling nearly all waste materials of economic value. These companies have performed their difficult and essential functions well in the traditional economic environment.

More recently additional dimensions have been added to this traditional economic environment. These new dimensions are (1) improvement of the environment in which we live, and (2) increased need for conservation of natural resources. These new dimensions provide new challenges and opportunities for the recycling industry. No longer is economic gain the sole driving force for recycling of waste materials. Social gain has been added in the forms of improved living conditions and preservation of resources for future generations. In an economics-based nation this creates problems of interpretation and evaluation of noneconomics-based goals and activities.

The purpose of this series of reports is to identify obstacles to the recycling of nonferrous solid wastes, and to recommend directions for investigation and research to overcome these obstacles.

Objectives

The objective of the study on which this report is based was to identify opportunities for the increased utilization of solid waste. The major sub-objectives were:

(1) To determine the structure and functions of the secondary materials industry, and its relationships to sources of supply and markets

(2) To identify and evaluate problems of recycling - materials, sources, industry, and markets, and

(3) To determine opportunities for increased recycling.

Scope

The major subjects included in the scope of the study are the secondary materials industry, the materials it recycles, the sources of solid wastes, and the markets for recycled materials. Activities peripheral to these major subjects are considered where pertinent to recycling.

The materials included in the study are:

Aluminum	Nickel and Nickel Alloys
Copper and Copper Alloys	Precious Metals (Silver, Gold and Platinum)
Lead	Paper
Zinc	Textiles

Research Methods

The methods and procedures used in the study are discussed under four types of activities. They include (A) literature search, (B) extensive survey, (C) in-depth survey, and (D) analysis and synthesis.

Literature Search

The literature search included reviewing and studying books, Government reports, industry reports, and trade journals covering solid waste handling and problems, recovery and market data, and recycling of valuable materials.

The results of this effort included the accumulation of data and descriptive material, and an organized bibliography dealing with each of the commodities covered in the scope of the study.

Extensive Survey

The extensive survey of the secondary materials industry consisted of a mail survey and personal interviews with management personnel of companies involved with the collection, processing, and sale of secondary materials. About 600 responses were received.

The information developed through the extensive survey included dollar sales, tons of major materials handled, types of solid waste processed, sources of materials, investment, equipment and facilities, number of employees, the amount of space used, and the grades and quantities of secondary materials produced.

The data from the extensive survey provided statistical tabulations of the regional distribution of the secondary materials industries by type of commodity in terms of numbers of establishments, volume of business, and numbers of employees.

In-depth Survey

The in-depth survey of selected members of the secondary materials industries, their suppliers, and the users of their products served to identify the major technical and economic problems facing those companies involved with secondary material utilization. About 200 interviews were completed. Battelle and NASMI commodity specialists jointly selected the companies to be interviewed in depth.

Interview guides for each of the commodities were prepared. The problems and potential solutions for greatest recycling and waste utilization that were developed from the literature search and prior Office of Solid Waste

Management work plus the knowledge of the NASMI commodity specialists provided the basis for designing the interview guide. Sample guides are reproduced in the Appendix.

Analysis and Synthesis

The analysis and synthesis step was concerned with the collation and analysis of data and information derived from both the literature, extensive survey, and in-depth survey. The analysis and synthesis activity covered the following tasks:

(1) Economic Data on the Secondary Materials Industries. The economic data developed through the extensive survey of the secondary materials industries were tabulated and analyzed as to the amount and type of solid waste handled and as to operational data such as number of employees, amount of space required, capitalization, and geographic locations.

(2) Flow Diagrams and Life Cycles. Flow diagrams were developed to indicate the flow of materials from primary production and scrap sources through fabrication. Life cycle estimates of various products were used to develop data on quantities available for possible recycling.

(3) Demand-Supply Relationships. Estimates were made of future demand and supply levels for secondary materials. The relationship between these data provide an indication of potential surpluses or shortages of recycled materials through 1980.

(4) Stability of Flow and Consumption. This analysis is closely related to the supply-demand analysis described above and identifies the ability of the various secondary materials to

compete as source materials for manufacturers. A number of factors were examined such as price changes in the secondary materials, the availability of materials, and the effect of sudden changes in the magnitude of demand.

(5) Direct Impacts of Technological Change. Direct technical and technological factors were examined to determine their effect on rates of processing and recycling. Potential changes that could take place in technology that could decrease or increase the rate of solid waste recovery were examined. This includes the identification of potentially recoverable solid wastes, the problems limiting the recovery to current levels, and the possibilities of technical advances through the use of known technology or through added scientific and engineering research.

(6) Constraints on Expansion of the Secondary Materials Industries. This analysis included consideration of elements critical to expansion of recycling - labor and management availability, laws and regulations, equipment availability, nature of solid waste materials, market needs, etc.

(7) Potentials for Expansion of the Secondary Materials Industries. Based on the constraints identified in the above task, plus examination of various methods for overcoming constraints, this task determined the ability of the secondary materials industries to meet new opportunities for recycling.

(8) Indirect Technological Change. The broad overall technological trends indirectly affecting the secondary materials industries were examined, and their probable impacts determined.

The Gold Industry

Characteristics of Gold

"More than any other metal, gold has symbolized the dreams and aspirations, as well as the greediness, of man. Since the start of recorded history, it has been held in high esteem for its beauty and workability, and the quest for the yellow metal has continued down to the present day"*. Its permanence and density are contributing factors to the role it still plays in international monetary circles both legal and otherwise. But of chief interest to this study are the properties of gold that account for its industrial usage.

Gold is the most malleable and ductile of the metals. It is a good conductor of heat and electricity. It resists attack by common chemical materials or atmospheric components. It alloys readily with silver, the platinum group metals, copper, lead, zinc, nickel, and mercury, and can be tailored to a range of colors without serious loss of tarnish resistance. Although its principal nonmonetary applications traditionally have been in the fields of personal adornment, art, and decoration, gold's physical properties have been exploited increasingly in recent years in strictly utilitarian applications in industrial equipment and technologically sophisticated hardware for communication devices and space exploration.

Gold is widely disseminated in the earth's crust, occurring in virtually all the geologic rocks known but at very low concentrations. By unknown mechanisms, it appears to have been concentrated to some degree in base metal sulfide ores where it still exists as the native metal. During the erosion and weathering of mountain ranges, it has been further concentrated in alluvial basins from which it could be recovered by placer mining. Although more abundant than silver, commercially exploitable deposits have been relatively small in

*Anonymous, "Gold -- symbol of excellence, measure of wealth," Metals Week, Vol. 39 (40), 11 (Sept. 30, 1968)

gold content and size. One authority has estimated that world production of gold to the year 800 A.D. totaled not more than 3.75 million ounces, a quite minor amount in view of the 2.5 billion plus ounces mined since the discovery of the Americas. The point is that gold is relatively scarce and currently known commercial deposits have limited production potentials. However, the gold that is mined is seldom lost irretrievably although it may disappear from the market place.

Newly mined gold is prepared for use by refining to base bullion, an impure form containing a minimum of 90 percent gold. The common form for marketing is refined bullion that is 99.5 percent pure gold, but other commercial grades are available up to 99.99 percent pure. For jewelry and other decorative uses, gold alloys are identified by the gold content on a classification system based on "karat", a term meaning a 24th part. Pure gold is 24 karat (kt); common jewelry alloys are 22 kt (91.6 percent gold), 18 kt (75 percent), 14 kt (58.4 percent), and 10 kt (41.7 percent).

Gold Alloys. Pure gold is so ductile and soft that it has few significant applications. The bulk of the materials issued to industrial users consist of alloys of gold that have been tailored to specific applications with respect to color, hardness, workability, and price.

Pure gold is required for the production of gold leaf. The art of making this product in the United States is confined to two companies that have automated the process and five aging artisians who still use hand beating methods. Simplified, a gold coupon, 1 1/4 inches square and one thousand of an inch thick is beaten out to a sheet about 4 1/2" x 4 1/2"; the sheet is quartered and each quarter is again beaten out, the resulting sheets again quartered and rebeaten. The original area has been expanded by a factor of 64 and the final leaf is about 1/200,000 inch thick. In spite of the apparent fragility of gold leaf it retains its appearance for many years when applied to statues or building domes exposed to the atmosphere.

A wide variety of gold alloys find applications in jewelry, art, dentistry, and strictly industrial uses. The most common jewelry alloys are identified as to gold content by a classification system based on the "karat," a term meaning a 24th part. Jewelry alloys start at 22 karat (kt) or 91.6 percent pure gold and range down to 10 kt or 41.7 percent pure gold. From 18 kt to 10 kt, alloys may be prepared that are reddish yellow, yellow (like pure gold), greenish yellow, or white. In addition, malleability can be controlled to better suit a number of different fabrication techniques and tempered to provide varying degrees of work handening. A detailed elucidation of jewelry alloys would be inappropriate here. The yellow colored alloys usually contain gold, silver, copper, and zinc. For the white colored alloys, nickel replaces the silver.

Dental alloys may have a range of gold content from 60 percent to 92.5 percent. Varying proportions of silver, copper, platinum, palladium, and zinc account for differences in workability to accomodate the various operations performed by the dentist or dental laboratory. The softest alloys contain between 80 and 92.5 percent gold while the hardest are based on 60 to 70 percent gold.

Gold alloys are available in a variety of forms to suit the subsequent fabrication technique. Sheet and strip are provided for stamping and blanking operations, tubing for roll forming, wire for chain manufacture and assembly buildup, and grain for casting. In addition to these solid gold mill products, gold alloys are clad on base metals for sheet, strip, tubing, and wire for

selected end-use products in the field of art and decorative applications. "Gold filled" is the designation for materials consisting of a karat gold layer on base metal in which the gold represents 1/20th or more of the total weight of the composite. "Rolled gold plate" is used to designate composite materials in which the karat gold layer is less than 1/20th of the total weight. Federal Trade Commission regulations require that consumer goods articles be stamped to identify them as gold filled or rolled gold plate and that the marking include the karatage of the gold layer and, in the case of rolled gold plate, the ratio of the gold layer to total weight (i.e., 1/40 10K gold rolled plate).

Special Alloys. Brazing alloys are formulated to give a desired bond strength. Jewelry brazes need rather low bond strength and seldom contain more than 30 to 35 percent gold. Jet engine brazes require high bond strength and a much higher percentage of gold (70 to 80 percent) to assure the metallurgical bond. Alloying elements include silver, copper, and nickel.

"Liquid Gold," used in the decoration of glass and ceramics, and for microcircuitry consists of 22 kt gold powder suspended in a varnish-type vehicle. After application, the article is fired in a kiln which converts the gold to a thin adherent film that is decorative or electrically conductive.

Gold Compounds. The principal gold compounds are plating salts. Substantial improvement in the speed of deposition, integrity of the deposited film, and finish appearance have been achieved in the past few years with proprietary bath formulations and complete plating systems. The major suppliers of plating salts offer extensive technical service as well as system design and engineering and equipment.

Legal Considerations. It is illegal for a private individual in the United States to own or hold gold other than a limited number of coins, commemorative medals, or manufactured articles.

Because of monetary considerations, the United States Government maintains a measure of control on gold by requiring that producers, refiners, dealers, and consumers be licensed and report their gold transactions and stocks. Exceptions are made only for those that handle less than 50 ounces at any given time and less than 350 ounces in any monthly period.

Characteristics of the Gold Industry

Materials Sources. In the United States, gold is mined from placer and lode deposits and recovered as a by-product in the refining of copper, lead, and zinc. Additional supplies are available from the refining of foreign ores and base bullion as well as from consumer and industrial products containing gold that are scrapped for salvage. Further, until March 1968, the U. S. Treasury Department was authorized to sell any excess gold it was holding (that is, not needed for the legal support of currency). These sources frequently were insufficient to satisfy nonmonetary demands in this country and imports of refined bullion from other countries were needed.

Domestic mine production of gold in the United States peaked in 1940 with an output of a little more than 4.8 million ounces. During World War II a number of lode gold mines were closed to divert the mining manpower to more critical needs and many of them have never been reopened. After the war, steadily rising costs for operations and exhaustion of deposits contributed to

a long-term decline in the output of new domestic gold. In contrast to this situation, world production of gold has been increasing rather regularly since 1944, lead by South Africa and Russia to a level of about 46 million ounces. Table 1 presents the recent (1965-1969) production of gold in a number of important producing countries, refinery production in the United States from both primary and secondary sources, and U. S. imports and exports of unrefined and refined gold. The increases in South Africa and Russia barely compensate for declines in other areas that are suffering from the same economic squeeze that is evident in the United States.

Refinery production in the United States after 1966 has to be estimated since the Bureau of the Mint no longer does refining for private industry. Growing industrial consumption suggests an increase in recycled scrap, especially in 1969 when the free market in gold rose to over $44 per ounce.

Import data probably represent a close approximation of the quantities channelled to refiners (ore and base bullion) and into industrial markets (refined bullion). Not too many countries settle international trade deficits with the United States by sending us gold. However, our exports of refined gold reflect almost completely international monetary transactions rather than commercial trade in gold.

Materials Flow. In recent years, the Office of Domestic Gold and Silver Operations, in the Treasury Department, has collected and published data relating to the flow of gold to industrial consumers and back to refiners for reprocessing. No attempt has been made by this or any other official agency to determine the quantitative relationships between supply and demand for gold or the details of receipts by and returns from specific consuming industries. Through 1967, the

TABLE 1. SOURCES OF GOLD, 1965-1969
(in thousands of troy ounces)

	1965	1966	1967	1968	1969	1965-1969 Annual Averages
Mine Production						
United States	1,705	1,803	1,584	1,478	1,733	1,661
Canada	3,606	3,274	2,962	2,688	2,434	2,993
Colombia	319	281	258	240	219	263
U.S.S.R.	5,030	5,370	5,700	5,900	6,250	5,050
Ghana	755	684	763	727	707	727
Rhodesia	544	550	520	500	480	518
South Africa	30,554	30,880	30,535	31,169	31,276	30,883
Japan	265	256	253	239	253	253
Philippines	437	454	491	527	571	496
Australia	878	915	805	787	716	820
Other Countries	2,128	2,100	1,867	1,899	2,259	2,051
TOTAL	46,222	46,567	45,737	46,154	46,418	46,220
United States Refinery Production						
From domestic ores	1,675	1,803	1,526	1,539	1,717	1,652
From foreign ores and bullion(1)	283	322	212	207	229	251
Secondary(2)	1,275	1,712	1,800	2,000	2,300	1,817
TOTAL	3,233	3,836	3,538	3,746	4,246	3,720
United States Foreign Trade						
Imports, ore and bullion	292	333	219	214	237	259
Imports, refined bullion	2,613	867	710	5,731	5,625	3,109
Exports, ore and bullion	50	49	113	181	59	90
Exports, refined bullion	36,667	13,018	28,607	23,781	279	20,470

Source: "Minerals Yearbooks", U.S. Bureau of Mines
Notes: Details may not add to totals because of independent rounding to nearest thousand ounces.

(1) Calculated by Battelle Columbus Laboratories from import data converted at the historic rate of payment for 96.75 percent of the gold content.

(2) 1967-1969 data estimated by Battelle Columbus Laboratories.

published statistics showed net industrial consumption, determined by the total quantity issued less the total quantity returned for reprocessing, and an estimated allocation of net consumption to broad classes of consumers. The cycle obviously includes scraps, wastes, and sweepings generated by manufacturing industries in the course of their conversion of gold received into saleable products as well as old scrap reentering the cycle after use by ultimate consumers But differentiation between these two sources of recycle materials is difficult because the manufacturing industries usually receive the salvaged consumer scrap and combine it with their own conversion scrap for delivery to a refiner. Thus the exact quantities of salvaged old scrap are unknown although they represent a net addition to supply in any given year.

Based on reported statistics for the 1965 to 1969 period and prior Battelle studies of the gold industry, Figure 1 presents an approximate annual flow of gold in industrial uses in the United States. A total of 8.090 million ounces of gold was issued to industrial consumers in addition to which they apparently received 0.320 million ounces in salvaged scrap from consumers. Of these gross receipts, 1.820 million ounces were returned to refiners for reprocessing while 6.590 million ounces were incorporated into saleable or usable products in circulation.

The quantity issued is estimated to have originated from 3.720 million ounces processed by refiners and 3.110 million ounces of imported refined bullion, of which 0.560 million ounces represents a net addition to refiners' and importers stocks to balance reported net consumption of 6.270 million ounces.

It should be noted that the flow diagram shown does not include any allowance for gold reprocessed by refiners for consumers on toll. Refiners contacted during this study admitted that toll refining of gold is increasing since the two-tier pricing system was instituted in 1968. The magnitude of this

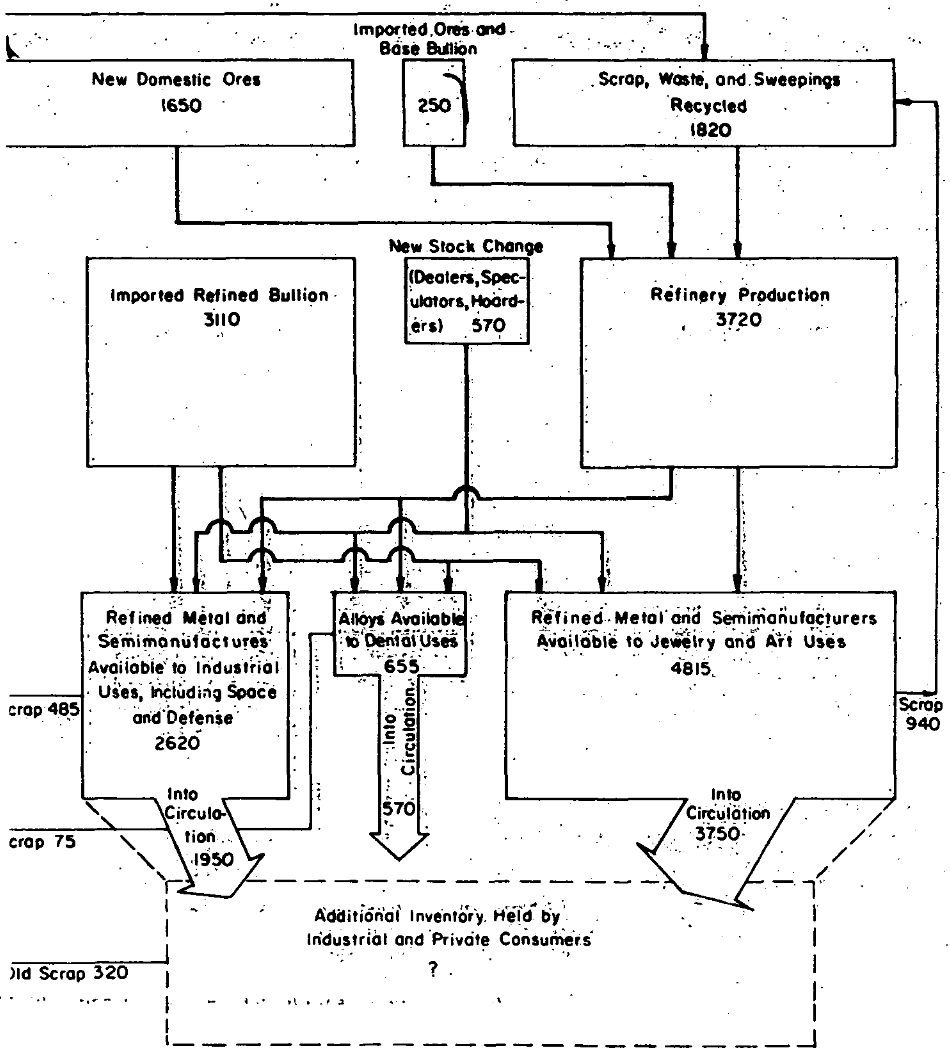


FIGURE 1. APPROXIMATE ANNUAL FLOW OF GOLD, UNITED STATES
(Based on 1965-1969 data, in thousands of troy ounces)
urce: Battelle Columbus Laboratories

facet of the recycling industry is indeterminable from the information received for this study but is believed to be relatively minor and would influence only refinery production since stocks held by consumers are not accounted for in the flow diagram presented.

Gold Producers. The producers of gold in the United States consist of mining companies and refiners with some organizations performing both functions.

Newly mined gold is produced from placer deposits, lode deposits containing primarily gold and silver, and base metal mines for copper, lead, and zinc having recoverable gold. Table 2 presents the production of gold from various types of mines in the 1965-1969 period. Placer mining is declining because of exhaustion of known deposits and rapidly rising labor costs and may soon disappear as a significant source in this country.

Gold lode ores predominantly originate from three large mines that have been able to minimize labor cost increases by mechanization of mining. The roster of small lode mines is decreasing steadily because of economic factors. Homestake Mining Company's deep deposit at Lead, South Dakota, has been the largest single gold producing property in the United States in recent years. This operation produces nearly 600,000 ounces of gold annually and recent development at very deep levels indicates that this mine may have a productive life of 6 to 10 years yet. Carlin Gold Mining Company initiated a large open pit operation in 1965 at Eureka, Nevada, to tap reserves of about 11 million tons of ore containing 0.32 ounces of gold per ton. Peak production was in 1967 with an output of 337,000 ounces but the last several years have been lower because of lower grade ore being treated. The third largest mine is the Lander, Nevada, openpit operation of American Exploration and Mining Company which began operation in 1969.

TABLE 2. SOURCES OF NEWLY MINED GOLD IN THE UNITED STATES, 1965-1969
(in thousands of troy ounces)

Types of Mines	1965	1966	1967	1968	1969	1965-1969 Annual Averages
Placer	99	92	65	37	25	63
Gold lode ores	921	1,031	1,083	927	1,031	999
Gold-silver lode ores	6	7	4	4	2	4
Silver lode ores	4	3	1	3	3	3
Copper ores	567	546	321	406	579	484
Lead ores	3	2	2	1	3	2
Zinc ores	4	3	1	1	1	2
Complex sulfide ores	100	116	106	96	85	101
Old tailings	2	5	4	3	4	4
TOTAL	1,705	1,803	1,584	1,478	1,733	1,661

Source: "Minerals Yearbooks", U.S. Bureau of Mines
Note: Details may not add to totals because of independent rounding to nearest 1,000 ounces.

Gold recovery from base metal mining depends on the level of operation of these properties and the concentration of gold in the ores which ranges from 0.001 ounces to 0.385 ounces per ton. Electrolytic refining of copper, lead, and zinc yield slimes with a high content of gold and silver that are readily treated for recovery of the precious metals. Copper accounts for an average of more than 82 percent of annual gold output from the base metals. Current expansions, especially in Arizona and New Mexico, should boost gold recovery from copper over the 600,000 ounces per year level. Among the top 25 gold producing mines (that accounted for 97.6 percent of total production), 13 were copper mines, 2 were copper-lead-zinc mines, and 2 were lead-zinc mines.

The gold refining industry until 1968 consisted of a handful of companies dealing with base metal recovery circuits, a group of 10 to 15 companies treating recycled scraps, and the U.S. Bureau of the Mint. The latter did virtually all the upgrading of new gold bullion to refined bullion since tolling charges by the Mint were lower than those imposed by private refiners. Since the Mint withdrew from toll refining, a number of the private refiners have added silver-gold parting circuits and refined bullion casting equipment. The current refining industry is believed to be capable of handling between 6 and 8 million ounces of gold per year from all sources--new domestic mine production, imported ores and base billion, and recycled scrap.

Among the companies dealing with new mine production, Homestake Mining, Kennecott Copper Company, The Anaconda Company, American Smelting and Refining Company, and American Metal Climax are important factors. Engelhard Industries and Handy and Harman are the largest of the refiners of scrap, followed by (in alphabetical order) American Chemical and Refining Company, Joseph Behr & Sons, Cincinnati Gold & Silver Refining Company, Eastern Smelting & Refining Company, Martin Metals, Pease and Curren, Sabin Metal Corporation, Sel-Rex Corporation, Simmons Refining Company, Sitkin Smelting and Refining, Spiral Metal Company, United Refining and Smelting, and Wildberg Brothers Smelting and Refining. Any of these are believed to be able to handle any material with a gold content of more than 2 or 3 percent. A few are capable of handling more dilute materials, for example sweepings and wastes.

Table 3 presents reported refinery production of newly mined gold from domestic ores, and Battelle estimates of refinery production from imported ores and base bullion and from purchased recycled materials. The yield from imported ores and base bullion has been calculated at 96.75 percent of the gold content of imports for the given year, the historic basis for determining the price to be paid for such materials. The estimates of output from recycled materials does not include any allowances for process losses. Thus, the total represents the quantity of gold available from refiners for sale to industrial consumers or licensed dealers.

Markets for Gold

Historically, consumer-oriented applications have accounted for more than two-thirds of the gold consumed annually in the United States. Jewelry represented the largest market segment followed by art and decorative uses and dental applications. Gold is valued in these markets for its aura of affluence as well as for its beauty and durability. The strictly utilitarian applications for gold in industrial products have gained prominence only since World War II with the development of sophisticated technology in electronics, aviation, and space exploration.

TABLE 3. REFINERY PRODUCTION OF GOLD IN THE UNITED STATES, 1965-1969
(in thousands of troy ounces)

	1965	1966	1967	1968	1969	1965-1969 Annual Averages
Primary Production						
From domestic ores	1,675	1,802	1,526	1,539	1,717	1,652
From foreign ore and base bullion(1)	283	322	212	207	229	251
Secondary Production						
From recycled scrap, waste, and sweepings(2)	1,275	1,712	1,800	2,000	2,300	1,817
TOTAL	3,233	3,836	3,538	3,746	4,246	3,720

Source: "Minerals Yearbooks", U.S. Bureau of Mines

Notes: (1) Calculated by Battelle Columbus Laboratories from recorded imports converted to production at 96.75 percent of gold content.

(2) Data for 1965 and 1966 from U.S. Bureau of Mines, 1967-1969 estimated by Battelle Columbus Laboratories.

Immediately after World War II, industrial consumption of gold in the United States spurted to new highs as economic prosperity continued without a post war depression. The buying public had disposable funds and jewelry was an outlet for this pent-up purchasing power. From 1946-1950, average annual net industrial consumption was nearly 2.6 million ounces. In the succeeding decade this fell to an annual average slightly under 2 million ounces as consumer buying returned toward normal patterns, with a definite upsurge in the final years of the period. Consumption in 1960 was 3 million ounces, advanced to 4.2 million ounces in 1964 and then continued to rise, as shown in Table 4.

Between 1934 and 1968, the price of gold in the United States was fixed at $35 per ounce by the U.S. Government. When the Treasury Department withdrew from refining and the purchase of newly mined gold in March 1968, a free market in gold was created. Speculators and investors in foreign countries forced prices upward during 1968 and 1969 until the problem of how South Africa would market its current production was solved. At the peak, gold prices in Paris and Zurich exceeded $45 per ounce and rose in the United States to a high of $44.25 per ounce on March 10, 1969. The establishment of Special Drawing Rights (SDR) in the International Monetary Fund and resumption of sales to free markets by South Africa restored confidence in the continued availability of gold for industrial uses and prices declined to the level of $35 to $37 by year end. Minor fluctuation in 1970 toward $39 per ounce reflected short-term availability of industrial supplies in the face of declining demand in the United States.

To date, the price of gold has had relatively little influence on demand for the metal in nonmonetary applications. In the major consumer-oriented

TABLE 4. INDUSTRIAL CONSUMPTION OF GOLD IN THE UNITED STATES, 1965-1969
(in thousands of troy ounces)

	1965	1966	1967	1968	1969	1965-1969 Annual Averages
Issued to Consumers(1)	6,551	7,774	8,094	8,604	9,409	8,086
Returned from Consumers(1)	1,275	1,712	1,800	2,000	2,300	1,817
Net Industrial Consumption	5,276	6,062	6,294	6,604	7,109	6,269
Jewelry, arts and decorative	3,429	3,758	3,840	3,908	3,839	3,755
Dental	369	424	566	771	710	568
Industrial, including space and defense	1,478	1,880	1,888	1,925	2,560	1,946

Source: "Minerals Yearbooks", U.S. Bureau of Mines
Notes: (1) Data for 1965 and 1966 from U.S. Bureau of Mines; 1967-1969 returns from consumers estimated by Battelle Columbus Laboratories.

of gold in the final product determine the decision to buy. In industrially-oriented uses, gold provides vital functionalities that are attainable with substitute materials only after costly research, engineering, and development. Price fluctuations since 1968 undoubtedly have intensified efforts to reduce the quantity of gold needed in industrial applications--efforts initiated when the price of gold was controlled--but where functionality is involved it will continue to be used until a much higher price level is reached and held.

<u>Jewelry</u>. Gold is consumed in the manufacture of rings, pins, brooches, earrings, bracelets, necklaces, cuff links, tie pins, and other articles of personal adornment. All the forms of gold provided by refiners except leaf and pastes and suspensions find applications, led by casting alloys, sheet and strip, and tubing. Casting is an economical means of manufacturing class rings, complex pins and necklace parts, and mounting bases for stones. Stamping and blanking of sheet and strip are used for mounting bases for stones, bracelet and necklace parts, earrings, and cuff links. Roll forming of tubing is used for wedding bands and shanks for ladies fashion rings and men's rings.

An important share of the growth of gold in jewelry since 1958 has to be attributed to the popularity of class rings for college and secondary school students. This rapidly growing market is served by investment casting of 10 karat alloys in a range of colors. An individual ring may contain up to half an ounce of 10 karat alloy, about $7 worth of gold in an article retailing for $18 to $25.

One general trend in the jewelry industry is worth noting; a gradual swing to the alloys of higher gold content. Through the 1950's, about 75 percent of the gold used by the industry was issued in the form of 10 karat alloys. The 12 karat, 14 karat, and 18 karat alloys were found only in more expensive pieces

whose appeal was based primarily on design considerations rather than intrinsic value. During the 1960's, the proportion of 12 karat and 14 karat jewelry increased to the point that they now account for over half of the gold used. Further, there is evidence that 18 karat usage is about to grow substantially, possibly as a result of American consumers' exposure to European jewelry which uses this karatage extensively. Overall, this trend toward the better grade alloys may account partially for increasing gold consumption since 1958 but its impact is difficult to assess in comparison to growth of the total market for jewelry related to population or to expansion of the value of the jewelry market from inflationary factors.

<u>The Arts</u>. This category includes a variety of uses for gold. Gold leaf is used for architectural decoration, on statuary, and for book gilding. Karat gold, gold clad materials, and plated gold in strip and wire form are used to fabricate pens, pencils, lipstick cases, watch bands, watch cases, spectacle parts, and trophies. Gold suspensions and pastes are used to decorate dinnerware, drinking glasses, glass bottles, and household furnishings of glass and ceramic.

This category of gold consumption has had a slow rate of growth in recent years because of the substitution of nongold containing materials for economic as well as fashion reasons. Some facets, such as gold leaf, actually have declined from the incursion of metallized plastics and surface treated metals such as anodized aluminum. However, gold retains its share of these markets based on its automatic association with quality for appearance and durability.

<u>Dental Applications</u>. Gold is unaffected by body fluids and is accepted as a permanent repair for tooth decay in fillings, inlays, caps, and

crowns or as supports for artificial teeth in bridges. Casting alloys constitute the most used form of gold although leaf and wire have specialized applications.

Dental technology and patient preference determine the amount of gold used in dentistry. Recently, dental technology has been swinging toward the retention of natural teeth for as long as possible which increases the opportunity to use gold. Further, certain ethnic groups in American society prize gold for its inferrence of affluence as represented by caps and crowns. Both factors contribute to growing markets for dental gold.

Industrial Applications. Gold is used industrially for electrical contacts, electronic components and conductors, for braze joining of machine components exposed to high temperatures, and as protective coatings for equipment components. About 70 percent of the gold consumed in industrial uses is applied by plating on base metal substrates. Brazing alloys are the next largest form, followed by suspensions and pastes, wire, and sheet and strip.

The corrosion resistance and electrical conductivity of gold assure its place in separable connectors and sockets for low-current, moderate voltage electronic circuits that operate at low signal levels. Reliability of circuit operation is critical and the choice of metals for contact points is gold or platinum or the alternative of nonseparable contacts. For the highest levels of reliability, gold button contacts are used but the usual solution is gold plated contacts. While the number of such contacts has been increasing rapidly in the past five years, gold consumption has not kept pace because manufacturers have continued to refine their plating techniques to be more and more selective of the areas where gold is applied. The trend is toward plating only the potential

contact surfaces which may represent 5 to 10 times as much area as that involved in the actual mating contact surfaces. Further improvements may involve redesign of connectors, an expensive procedure. These connectors are used with electronic equipment such as computers and calculators and semi-portable communications equipment, for example plug-in telephones.

Other uses for gold in electronics include plating of semiconductor components for heat dissipation, conduits on printed circuit boards and micro circuit assemblies, and electroformed thick films and wave guides. Lead wires for semiconductors and electron tubes frequently are gold wire. Brazing alloys make electrical connections in circuit boards and miniature and micro circuitry.

Jet engines for aircraft represent a significant market for brazing alloys outside the electronics field. The large jet engines now in use may contain 20 to 30 ounces of gold to attach seals and manifolds. Even more spectacular is the usage of gold brazing in the rocket engines for Saturn launchers. To cool the thrust chamber, fuel and oxidizer on the way to the engine are routed through tubes brazed to the outside of the chamber. The limited number of Saturn engines built keeps this application in the minor category.

Suspensions and pastes are used to form heat reflective shields for engine shrouds on certain military aircraft, for face masks and other protective equipment for steel workers, for communications satellites, and for cryogenic equipment and jet thrusters on space exploration vehicles. None of these require substantial quantities of gold for individual items but no direct substitute has been discovered.

Gold finds applications in chemical laboratory ware, bolometers, X-ray targets, rayon spinnerets, and in specialized gasketing materials.

Market Outlook

The National Materials Advisory Board* recently projected net industrial gold consumption for 1973 at 8.761 million ounces, an increase of 2 million ounces over their 1968 estimate. This corresponds to an average annual growth rate of 5.3 percent which agrees favorably with projections made by Battelle in previous studies of the gold industry, assuming a price no higher than about $43 per ounce. Preliminary indications are that 1970 will fall below the trend line projection because of the stagnation of industrial expansion in this country. Similarly, recovery in 1971 appears to be slower than expected and a new base for expansion may be appropriate. Unless the American and world economies return soon to the annual growths considered to be normal, it is probable that gold consumption may not approach the 8.5 million ounces level until 1975 or later.

Prospects for increasing the domestic mine production of gold are not encouraging unless a drastic rise in price is experienced. This latter condition appears unlikely in view of the continued commitment of the United States Government to the $35 per ounce price. Although domestic mining and recycling of scraps and wastes will not supply annual demand in the United States, Free World production of new gold will exceed industrial demand and the U.S. deficit can be met by imports. Undoubtedly, the free market price will be higher than the monetary standard set by the United States but levels exceeding $50 per ounce are not anticipated through 1975 in the absence of disruptive political situations.

*Anonymouns, "Trends in Usage of Gold", NMAB-254, National Research Council, National Academy of Sciences - National Academy of Engineering, Washington, D.C., September 1969, p 14

The Gold Recycling Industry

Characteristics of Secondary Gold

Refined secondary gold is undistinguishable from any other refined gold. The value of gold-containing materials, be they recycled scraps and wastes or newly mined concentrates and byproduct recoveries, is based on the gold content with suitable deductions to process it to refined bullion. If the gold value of recycled materials is less than the value of nongold components they are more likely to be reprocessed for the other values without credit for the gold and it may be lost or disappear for years in other material's flow cycle.

Gold-bearing scraps and waste are paid for on the basis of gold content, determined by analytical tests, and the market price for gold on the day that the refined product is available for sale. Processing charges and adjustments for processing losses are deducted from the total value in settling payments. Depending on the type of scrap or waste, the reprocessing cycle may require up to four weeks, an unavoidable delay in settling accounts between seller and buyer.

Aside from the dealer-processors and refiners there are no markets for recycled gold. The requirement of the Federal Trade Commission for karat identification of jewelry alloys effectively forces gold users to know the chemical analysis of the alloys they purchase and gold refiners to separate the constituents of scrap to assure meeting karat standards. In special circumstances of well segregated scrap of known alloy composition, a dealer-processor or refiner may remelt and readjust composition without going through the complete separation of constituents. In this case, the reprocessing charge is adjusted to reflect the minimal work involved.

Refined secondary gold must meet all the specifications for refined bullion. It therefore commands a price equivalent to that for newly refined gold. This is accepted by consumers who do not inquire about the origin of the gold when making purchases.

Characteristics of the Gold Recycling Industry

Materials Sources. Gold-containing materials for recycling consist of scraps, wastes, and sweepings. Scraps usually originate from the fabrication of products or component parts by metal working techniques and retain the essential characteristics of the original metal with respect to gold content and form. Wastes result from secondary metal finishing operations (such as grinding or polishing) on metallic products or component parts, or from residues associated with electroplating operations or the manufacture of brazing alloys or suspensions and pastes. Generally, the gold content of wastes is substantially lower than the materials supplied to the consumers. Sweepings consist of gold-containing residues resulting from cleanup operations in shops or factories where gold is used. The gold content usually is low (1 percent or less) and the balance of the material collected has essentially no recoverable value. Some shops make a practice of burning sweepings to remove combustible materials and concentrate the gold content so that reprocessing charges are lower.

Discarded and obsolete products containing gold usually consist of metallic items in which the gold is readily identifiable. Consumer-oriented products tend to consist of alloys with several precious metals but the gold is easily recognized and frequently the principal value recoverable. Industrially-oriented products tend to consist of composite materials with gold representing a very minor part of the total weight. A printed circuit for a computer illustrates the point. A plastic base supports an etched copper foil to which are connected

metallic, ceramic, and encapsulated components. On one or more edges of the board are gold-plated spring wire contacts. As received from the scrapyard that dismantled the computer, an average circuit board has a gold content value of 6 cents per pound. If the board is trimmed so that only the contact spring assemblies are left as metallic components, the value increases to 60 cents per pound. Further upgrading could be performed by removing the spring assemblies from the board support but the usual procedure would be to burn the board and dissolve the metallic residue in acid leaving a sludge with a fairly high gold content.

Prompt industrial scrap normally includes scraps, as defined above, generated in manufacturing operations and recycled to a refiner or a dealer-processor on a fairly regular schedule. In circumstances where the scrap generator is able to segregate scraps from various alloys (for example, from ring shank production or dental castings manufacture), the material may be either processed on toll or purchased by the refiner with the credit applied toward additional purchases of gold semimanufactures. Old scrap includes industrial wastes and sweepings as well as discarded or obsolete items being returned to the recycle system from consumers. It generally has to be completely refined with separation of the metallic components and is purchased by the dealer-processor or refiner. Frequently, old jewelry scrap is accumulated by manufacturing jewelers and melted, for convenience in handling and assaying, along with prompt industrial scrap. When delivered to a refiner, it is impossible to identify the origin of the scrap leading to uncertainty as to the efficiency of primary manufacturing operations or the actual quantities of old scrap being recycled.

Materials Flow. The basic flow pattern for recycled gold starts with the generation of prompt industrial scrap or industrial wastes and sweepings by consumers performing manufacturing operations or the salvage of discarded old scraps by dealer-processors. Large volume generators of prompt industrial scrap or industrial wastes frequently deal directly with the refiners--acting as dealer-processors--in order to speed the delivery of materials needed in the manufacturing operations. Small volume generators of industrial scraps and wastes may use brokers or local dealer-processors who in turn sell to refiners. Especially in the jewelry industry, the small generator of industrial scrap may act also as a dealer-collector for old scrap. It is believed that virtually all of the old consumer scrap that is salvaged enters the recycle system by way of the small industrial scrap generator rather than flowing to dealer-collector in "over-the-scale" transactions.

From the refiners, who ultimately receive nearly all the scraps, wastes, and sweepings, refined gold is reissued to industrial consumers in the various forms and alloys needed. The recycle circuit is included in Figure 1 (page 16) which shows the approximate flow of gold.

The Recycling Industry. There is essentially no information available to quantify relationships within the recycle chain. Prior to 1968, the U.S. Bureau of the Mint accumulated recycle data from its own transactions and those of the large private refiners processing ores and base bullion. Dealer-processors and small refiners handling secondary materials exclusively were not contacted and the magnitude of their reprocessing and refining operations was not included in reported data. The error introduced by this incomplete coverage was never considered to be serious enough to justify an attempt to canvass all of the generators of scrap or the small secondary refiners. Apparently, it was assumed that remelting jewelry and dental alloys without complete refining represented a minor facet of the industry that had little bearing on the balance of gold supply and demand. However, it does complicate the analysis of the flow of gold and the determiniation of the opportunities to improve recycling of gold in quantitative terms.

The scope of the problem is revealed by the fact that there are about 1500 manufacturing jewelers in the United States, perhaps as many as 50 independent scrap gold brokers, and about 180 secondary refiners or processors of gold chemicals. The extensive survey conducted for this study revealed 193 organizations among the 578 responses received claiming to be dealer-processors, brokers, or refiners of gold, of which 53 were refiners of gold. None of these responses include the manufacturing jewelers that probably are the key to recycling old consumer scrap.

Based on reported data, recycling of gold since 1958 has ranged from a low of 700,000 ounces in 1960 to a high of 1,712,000 ounces in 1966. These data include old scrap, but assuming that they represent only prompt industrial scrap would suggest that 22 percent of the gold issued to industry was recycled promptly. From prior work in the field, Battelle feels that the average prompt industrial scrap return is about 20 percent of the quantity issued in consideration of the manufacturing methods used by consumers and the forms (sheet, strip, tubing, grain, and plating salts) of gold they receive. Using 1965-1969 annual averages, Battelle estimates that deliveries to consumers, scrap returns, and net industrial consumption were as shown in the following tabulation (in thousands of troy ounces):

	1965-1969 Annual Averages
Issued to Consumers	8,086
Returns from Consumers	
Prompt industrial scrap	1,500
Old scrap	317
Net Industrial Consumption	6,269

The prompt industrial scrap represents 18.5 percent of the gold issued. If the 20 percent figure proposed previously is correct, it could indicate that the unreported recycling contains a minimum of 120,000 ounces of prompt industrial scrap and perhaps 300,000 ounces of old scrap.

In the identifiable recycle system, all of the 1,817,000 ounces of scrap pass through the refineries (called dealer-processors). Perhaps 1,350,000 to 1,400,000 ounces of this represents prompt industrial scrap recycled directly from generator to refiner. Some small fraction of prompt industrial scrap plus part of the old scrap reaches the refinery by way of dealer-brokers who may handle 300,000 ounces annually. Further, up to 150,000 ounces per year may reach the refinery by way of dealer-collectors in over-the-scale transactions involving industrial and consumer obsolete scrap.

In the context of the objectives posed for this study, unreported recycled materials do not constitute a problem per se. The assumption of an unreported recycle stream is believed to be valid and constitutes a mechanism for channeling old consumer scrap into the recovery system. The opportunity lies in stimulating the general public to use the existing system whether or not the data get reported.

Markets for Recycled Gold

Markets for recycled gold are the same as those for gold in general. Gold consumers are concerned only that the materials they purchase meet the compositional and physical properties specifications established without regard to the origin of the gold. Admittedly, scrap gold commands a price less than the price of the material they purchased, the difference being the cost to re-process the scrap to usable form. But gold in ores or base bullion also has to be refined and even refined bullion usually requires subsequent processing to become a usable form.

Demand-Supply Analysis

Net industrial consumption of gold has been increasing at an average annual rate of about 13.1 percent since 1958. Since that date nearly 51 million ounces of gold has been funneled into the American economy in consumer and industrial products. The durability of gold suggests that theoretically it all should be available for recovery and recycling at some distant future date. Practically, much of it disappears into what could be described as consumer hoarding--not for speculation but for sentimental value--and some is lost through discard to rubbish piles in wastes that are considered to be uneconomic for recovery.

Future demand for gold for industrial uses is expected to expand but at a rate substantially below that experienced in the past 12 years. This is evidenced by preliminary reports of consumption in 1970, which fell below 1969, and indications that usage in industrially oriented applications may stagnate or decline in the future. The primary determinant of growth in the 1970 decade probably will be the jewelry industry where consumer demand tends to follow gross economic indicators. Overall, annual growth at an average rate of 5.3 percent may be appropriate for the 1971 to 1980 period, taking as the base the final tally for 1970.

Domestic mining is not expected to expand substantially beyond the 1.8 million ounces per year level as long as the price of gold does not exceed $50 per ounce for an extended period of time. The new large open pit mines will compensate for the closing of small lode mines and byproduct recovery from copper ores should increase to over 600,000 ounces per year. However, the potential for a major boost in gold production within five years does not exist even if the price of gold was raised to $70 per ounce tomorrow. Domestic mining will supply not more than one-fourth of projected demand.

Recycling of gold by industrial consumers currently supplies nearly 30 percent of net industrial consumption and includes both industrially generated scraps and wastes and old scrap from consumer and industrial products salvage. More than 80 percent of the 1.8 million ounces recycled annually in the 1965-1969 period originated as prompt industrial scrap and represented nearly 90 percent of that available for recovery. An average of 300,000 ounces originated annually from old scrap, estimated to be less than 40 percent of the amount actually discarded but including most of the economically recoverable material under existing methods of identification and processing. It would be expected that the prompt industrial scrap generated would remain as a resonably constant 20 percent of net industrial deliveries and that recovery would gradually improve toward a level of 95 percent of that generated. Any improvement in the recovery of old scrap from consumer and industrial products will be difficult to achieve. Overall, recycled gold will be insufficient to cover the gap between domestic supply and demand and the United States will have to rely on imports of refined bullion in the period to 1980.

Obstacles and Problems that Reduce the Recycling of Gold

Table 5 summarizes the problems identified and the analyses presented in succeeding paragraphs.

Prompt Industrial Scrap

Prompt industrial scrap results from the conversion of gold-containing materials into usable or saleable products or components. Some fraction of the material purchased does not emerge in products or components because of inefficiencies inherent in the conversion processes used. Predominantly, prompt industrial scrap has the same alloy composition and physical form as the material purchased but is unusable by the purchaser because of size or other considerations.

It is generated primarily by metal working operations such as stamping or coining, cutting, casting, blanking or drawing. The loss from yield depends on the metalworking technique, ranging from about 5 percent for casting to over 40 percent for certain stamping operations. Recycling of this scrap is readily identifiable as an economic means of reducing the materials cost in the product being made and most consumers do segregate and collect it for return to refiners.

This type of scrap originates primarily in the jewelry, arts, and dental industries where metallic gold and gold alloys are handled. All except the smallest shops have established relations with dealer-collectors, brokers, or refiners in order to assure prompt delivery of gold in usable form and a ready outlet for scrap.

The major obstacle to increased recovery of prompt industrial scrap is apathy on the part of the consumer. In small shops, daily production may involve several alloys and a variety of mill product forms (sheet, strip, tubing, wire, casting grain), each of which is used in small quantities. Segregation of scrap, even by alloy only, presents problems because the generator is more concerned about production than about scrap collection. Further, the quantity of scrap

TABLE 5. IDENTIFICATION AND ANALYSIS OF PROBLEMS CONCERNING GOLD THAT WAS NOT RECYCLED IN 1969.

	Scrap Categories Where Some Gold Was Not Recycled			
Title	Prompt Industrial Scrap	Industrial Wastes and Sweepings	Old Industrial Scrap	Old Consumer Scrap
Problem Definition	Manufacturing processes often generate unusable materials in small volume in a number of installations, often these are contaminated and are not recycled.	Polishing, buffing, plating operations and metal melting generate wastes with a small gold content The gold values are not economic to recover. Thus, scrap gold is not recycled.	Gold content of discarded articles is low, frequently less than 1 percent Nongold content is variable, usually other metals and frequently plastics, paper, and cloth This is a major area of gold not being recycled.	Service life of consumer goods dependent on factors other than economics Consumer's idea of article value to be scrapped is much higher than the materials cost Individual article has small amount of gold and variable gold content
GOLD <u>NOT</u> Recycled	100-150,000 ounces annually	20-30,000 ounces annually	400,000 ounces annually	Unknown
Percent of Available GOLD <u>NOT</u> Recycled	10	20	80	Unknown
Problem Analysis	1. Rate of recycling is high when scrap can be segregated by alloy and color 2. Segregation becomes difficult when same worker has to handle several alloys and different product forms in same day 3. Jewelry, arts, and dental industries have many small shops with one or two production workers. 4. In small shops, production of saleable goods represents more economic use of labor than collecting scrap 5. This is not a promising area because the economically recoverable scrap is being recovered 6. Institutional promotion by the refining industry is desirable to maintain level of recovery now achieved	1. Gold content of wastes and sweepings is variable, from 0.1 percent to 5.0 percent 2. Balance of material has no significant recovery value 3. Efficient collection is difficult because of dilution 4. This is not a promising area because the economically recoverable waste is being recycled 5. Institutional promotion by the refining industry is desirable to maintain level of recovery now achieved	1. Aside from military salvage depots no effective mechanism exists for economic collection of discarded equipment 2. Discarded equipment has variable gold content--some none, others up to 1 percent gross weight 3. Identification of gold-bearing scrap is difficult at times 4. No effective processes exist to treat bulk scrap for gold recovery 5. Upgrading to recoverable gold level is uneconomic unless large volumes of scrap are collected 6. About two-thirds of economically recoverable gold is being recovered 7. Some improvement is possible via joint USBM-DOD programs now underway	1. Consumer has little economic incentive to recycle gold unless a direct replacement of an article is being made 2. Unreported recovery believed to be substantial via small manufacturing jeweler 3. No effective mechanism exists to collect discarded articles from individual consumers 4. Improvement in recycling definitely possible but not necessarily economic for consumer

involved may be small so that long-term collection is required to accumulate a saleable amount. The solution to this type of consumer apathy appears to be in the education of management and workers to the value being lost and, if appropriate, training in identifying various kinds of scrap for segregation. The gold refining industry has been promoting the concept of recycling for many years with large consumers and others who request help. Beyond a continuation of the institutional advertising they currently support, no effective programs were discovered.

Industrial Wastes and Sweepings

Metal finishing operations, the production of brazing alloys, and electroplating operations involve procedures that result in gold-containing wastes. The gold content of the waste material usually is considerably lower than that of the material purchased and the physical form frequently is different. Polishing and buffing of jewelry, artware, and dental castings leaves traces of gold in the polishing compound. Fluxes and covercoats for melting brazing alloys may trap some metal. Spent plating baths and wash water recovery systems contain small percentages of gold as salts. Properly handled the gold is recoverable in spite of the fact that it may be less than 1 percent of the weight of the scrap. The problem here is to avoid accidental dumping or discard of the gold-bearing wastes either from carelessness or lack of recognition of value. Again, educational advertising such as that already supported by the refining industry seems to be the most logical approach.

Old Industrial Scrap

Old industrial scrap consists primarily of electronic equipment components and gold brazed jet engine parts that have been scrapped for salvage.

The gold content of the original product usually is less than 2 percent of the total weight and identifiable only by trained inspection or test. Effective recovery of the gold is complicated by the presence of large percentages of aluminum or nickel-based alloys with copper, lead, zinc, tin, and plastic materials as contaminants. Currently available processing methods are not amenable economically to treatment of the scrap in bulk form for isolation of the gold content from the other nonferrous metals.

In electronic equipment--military communication and navigation devices and industrial computers--the gold is present as thin-plated film on connectors, contact points, and semiconductor components. Dismantling of the original instrument or device with segregation of recoverable metals is necessary to upgrade the gold-bearing parts to a level of economic gold recovery. Printed circuit boards for computers are rather readily identifiable as potential gold scrap because most of the gold content is on the connectors mounted on the edges of the boards. Gold-plated transistors and diodes with gold lead wires are more difficult to spot because not all such components contain gold. Furthur, perhaps one component out of a dozen is gold plated and should be segregated to permit gold recovery.

The salvaging of jet engines is practiced routinely because of the value inherent in the metal parts--casings, rotors, turbine blades, etc. Certain models made by one of the two major manufacturers--Pratt and Whitney--have gold-brazed parts such as rotor seals and turbine blades. When such engines are identified, salvagers recover as much of the brazing alloys as they can by "sweating" the parts after disassembly. Complete recovery is difficult because by nature the brazing alloys when melted form a thin film that clings to the

base metal unless wiped off by an expensive hand operation. Bulk melting of the parts results in loss of the gold since the high performance alloys used in jet engine parts are not reprocessed to the pure component metals but diverted into other alloying uses.

The U.S. Bureau of Mines has been working with the Department of Defense for several years to develop techniques for identifying separable components in military salvage. Studies made by the Bureau suggest that military salvage depots currently handle scraps containing about 300,000 ounces of gold, of which an unknown percentage can be recovered by presently available processing techniques. However, it is recognized that the salvage depots represent the most effective approach for solving the logistical problem of accumulating large quantities of gold-containing scraps to justify the development of segregation techniques.

Similarly, there is an evident need to devise collection procedures for nonmilitary electronic equipment discards to permit recovery of gold and other precious metals. The recent establishment of companies specializing in salvage of computer components, working with the large computer manufacturers, is a further attempt to solve this problem. But data are not available to indicate that potential loss because of noncollection or the effectiveness of the collection that is now going on.

Overall, the old industrial scrap being salvaged annually may contain as much as 500,000 ounces of gold. Perhaps as much as 150,000 ounces of this can be segregated and isolated to the point that economic recovery of the gold is feasible but it is doubtful that more than 100,000 ounces actually is being recovered.

Old Consumer Scrap

Old scrap appears to offer an opportunity to improve the recycling of gold. No one knows how much gold is discarded annually by ultimate consumers, the general public. Recent estimates suggest that municipal refuse may contain up to 0.6 ounce of gold per ton, from discarded jewelry, watch cases, and spectacle frame parts. Whether or not these estimates are representative is questionable but there is no question that gold-containing articles do get discarded instead of being returned for recycling. The average individual has difficulty in justifying the time and effort to accumulate gold-bearing scrap and then to find a dealer-collector who will purchase it for a reasonable fraction of the inherent value. Actually, the economics of the recycling system tend to discourage the recovery of individual consumer articles. The consumer places a value on the articles that reflects his purchase price although the contained gold may represent less than 25 percent of that price. When he comes to sell it, the gold content value has to be discounted to compensate for dealer-collector's fees and refinery charges. Refiners calculate that their charges for analysis and reprocessing make it uneconomic for seller and buyer alike to handle anything less than 25 ounces of gold content. Individual consumers seldom accumulate that much gold in a lifetime.

No readily apparent solutions to this problem of collecting consumer gold scrap were suggested by the contacts made during the course of this study. The appeal made during World War II by the U.S. Government resulted in a temporary increase in the recycling of old scrap. The value of the scrap received is believed to have been substantially below the cost of the appeal and currently inflated costs for mass media advertising mitigate against the economics of a similar approach at this time. Perhaps the best alternative would be to enlist the help of service organizations--church groups, Boy Scouts, Rotary clubs, etc.--to act as collection agencies in return for any revenues derived from the sale of the scrap. To be effective, such an effort would have to be promoted for several years by a national organization as a public service.

Problems Not Directly Related to Recycling of Gold

Industry Statistics

The lack of adequate statistics relative to the flow of gold through the manufacturing complex to the American economy complicates any attempt to analyze the magnitude of the problems involved in recycling and determine priorities for their solution. Unquestionably, gold disappears from the flow cycle in many forms and at a wide range of concentration of gold content. It might be possible to quantify some of the more readily apparent areas of loss merely by estimating the effective life cycle of selected products containing gold and the probability of recovery based on the level of contained gold. But such studies would be highly theoretical and impossible to verify in any quantitative sense.

From a practical viewpoint, the value to be derived from having access to complete statistical information is questionable and the cost of collecting and reporting it can be readily determined to be excessive. However, the availability of more detail on the throughput of domestic gold refineries--production from foreign ores and base bullion, sources of recycled gold by the same classifications used for net industrial consumption--would be a welcome addition for industry analysts. Hopefully, the U.S. Bureau of Mines may include such data in its annual canvass of the refinery industry now that it has assumed this reporting responsibility.

Courses of Action Concerning Recycling of Gold

Selection of Opportunities

All the evidence gathered by this study indicates that the major opportunities to improve the recycling of gold involve the collection and processing of old scraps from ultimate consumers and industrial products. By and large, the manufacturing segment of the gold industry is aware of the value of recycling and further improvement from this sector, while possible, will not materially affect the demand-supply situation. Thus, the development of priority rating information appears to be superfluous.

Intuitively, the general public is complacent about recycling gold because the monetary return falls far below the value ascribed to individual pieces by the owner. In the final analysis, the existing system for collecting gold consumer scrap fails to provide an economic incentive to the ultimate consumer for recycling except in those few instances where direct replacement of an article leads to a trade in. From a gross materials flow viewpoint, this does constitute an opportunity to improve recycling but the cost of achieving even a modest increase in recycling may be prohibitive.

In the case of old industrial scrap, the potential for recovery is apparently less than for consumer-oriented products but the probability of effecting improvement is better. Basically, the problem still hinges on economics--the economics of collection and processing for segregation. The precious metals content of the equipment being scrapped is insufficient to justify salvage for that value alone so that concurrent recovery of several values is needed. In general, military and industrial electronic equipment contains steel, copper, and aluminum as salvageable values as well as plastic and textile wastes. The economics of recovery for the base metals favor the handling of large volumes of them by automated or semi-automated means. Currently, only military salvage depots and the large computer manufacturers can accumulate the volume of scrapped equipment needed to setup disassembly lines for segregation of the various metal values. Experiences gained in these installations undoubtedly will be transferable in part to dealer-collectors who could serve as local processors for discarded office equipment (desk calculators, dictation equipment, intercom systems) and consumer appliances (radios and television sets) where suitable arrangements can be made with servicing organizations. The key to such installations will be the ability to identify the various salvageable components and to devise efficient disassembly methods.

Recommended Actions

For the Environmental Protection Agency (EPA), the most apparent action would be the general promotion of recycling for consumer and industrial products containing gold as well as other values. Concurrently, support could be furnished to other governmental agencies, such as the Department of Defense and the U.S. Bureau of Mines, to continue their educational and training programs in scrap recycling, possibly expanding the training programs to private industry on a cost-sharing basis.

Obviously, enlightened self-interest suggests that the recycling industry should continue its educational and promotional advertising on an individual company basis as well as conduct seminars and training sessions under the auspices of NASMI at national and regional associtión meetings. Beyond this NASMI may be in a position to coordinate governmental and private industry efforts to develop more efficient methods for processing multi-metal scraps or disassembly of electronic equipment. Overall, the aim should be to identify and upgrade gold scrap to acceptable range for refining or to develop recovery processes for scraps containing less than 2 percent of gold.

Stimulation of recycling by individual consumers offers formidable problems. One approach suggested by representatives of the recycling industry was the enlistment of local service organizations--Rotary clubs, Boy Scout troops, church groups--to act as collection agents for jewelry and art objects. Revenues derived from the sale of the scrap collected would be used to further the programs of the organizations for the common good. Here, as a public service, NASMI might be able to stimulate such service groups by working with their national offices in the organization and planning of programs to be carried out at the local level. Continued encouragement and support would be needed to sustain interest in such programs because of changing leadership in local clubs.

Table 6 summarizes the actions recommended.

TABLE 6. RECOMMENDED ACTIONS, HIGH PRIORITY GOLD RECYCLING PROBLEMS

Title	Prompt Industrial Scrap	Industrial Wastes and Sweepings	Old Industrial Scrap	Old Consumer Scrap
Actions Recommended	Recycling industry should continue promotional efforts for collecting and recycling small volumes of scrap.	Recycling industry should continue promotional efforts for collecting, segregating and using small volumes of scrap with low gold content.	Recycling industry should continue promotional and training efforts to ensure that scrap with low gold content is collected and recycled.	Recycling industry should continue promotional efforts to encourage ultimate consume to turn in discarded articles
By Whom (1)(2)(3)	EPA/NASMI	EPA/NASMI	EPA/NASMI	EPA/NASMI
Specific Steps	1. Continue institutional advertising on value of scrap and probable cost savings by recycling	1. Continue institutional advertising on value of scrap and probable cost savings by recycling	1. Continue institutional advertising on value of scrap and need to recycle to conserve resources 2. Support USBM-DOD training programs for identification and segregation of gold-bearing scraps 3. Support R&D efforts to develop processing of gold-bearing scraps to economic recovery level	1. Continue institutional ad· tising on value of scrap a need to recycle to conser resources 2. Support efforts by servic clubs to act as collectio agencies for consumer scr

(1) The responsibility for recommended actions shown in this table are based on importance of the action, benefit to the taxpayers, and opportunities for NASMI. They are the best judgments of Battelle.

(2) Recommended actions were distributed between high priority and lower priority based on the evaluation with three criteria.

(3) It is suggested that NASMI continue its leading role in recycling, recognizing that other organizations such as the Bureau of Mines, Department of Commerce, Council of Environmental Quality, HEW Office of Information, and State, Local, and Federal Legislatures must be involved.

The Silver Industry

Characteristics of Silver

Silver is one of the metals known to man before the advent of recorded history. Found as native metal, it was prized for its easy workability, bright appearance and relative permanence. It probably was used first in articles of personal adornment, later extended to household utensils and decoration, and adopted by the Romans as the basis for their monetary system prior to the Christian Era.

The whitest of the metals, silver is the best conductor of heat and electricity and second only to gold in malleability and ductility. It readily forms alloys with gold, the platinum group metals, copper, nickel, lead, zinc, tin, and mercury, and will tolerate substantial amounts of alloying agents without sacrificing its basic appearance or permanence. Both the metal and certain of its compounds exhibit catalytic activity for selected chemical reactions and a number of its compounds, especially the halides, are sensitive to light.

Silver is a scarce metal but durable. It is widely disseminated in the earth's crust, usually associated with other metals. As an indication of its relative abundance, it has been estimated that for every 10 million parts of iron in the lithosphere there are 2 parts of silver. However, it also is believed that most of the silver that has been mined since the evolution of man still exists in metallic form in jewelry, coins, bullion, and art objects held by individuals or institutions for sentimental or hoarding reasons. This does not indicate that any significant portion of the silver hoard is available for use in any given year or at anytime.

Silver for coinage or industrial uses usually is first refined to bullion which may contain gold, copper, lead, or zinc, depending on the original source. This is processed to refined silver containing a minimum of 99.9 percent silver, which is suitable as a starting point for most commercial applications. Because pure silver is too soft for the majority of metallic uses, it is alloyed with copper for common commercial grades such as sterling (92.5 percent silver, 7.5 percent copper) or coinage metal (90.0 percent silver, 10.0 percent copper). These are usually expressed in "fineness", designating the parts per thousand of the silver content. Sterling is 925 fine and coinage metal is 900 fine.

In order to assure flexibility in channeling silver into any of its industrial uses, as well as to isolate the more valuable components of ores, base bullions, scraps, and residues, the refining of silver normally proceeds to the production of commercial silver bullion with a fineness of 999 minimum. Thus, secondary silver is undistinguishable from primary silver and enters the marketplace on an equivalent basis pricewise. This does not preclude the production of alloys such as sterling or coinage metal from secondary sources without the full refining procedure when applicable but such alloys still would command prices equivalent to those changed for newly prepared alloys.

Characteristics of the Silver Industry

Materials Sources. In the United States silver has been available from new mine production, from stocks held by the Treasury Department, from imports, and from recycled scraps. New mine production in this country has failed to meet the demand for coinage and industrial applications for many years. Imports of ores and concentrates and base bullion, for refining in this country, supplemented domestic mine production but still failed to provide all the silver needed.

However, as long as the Treasury Department could release silver from the stockpile accumulated since 1934, industrial consumers were assured of adequate material to meet their requirements.

With the prospect of continuing shortages of new silver production, the United States began to demonetize silver in 1965. The Coinage Act of 1965 provided for the complete removal of silver from newly minted quarters and dimes and the reduction of the silver content of half dollars from 900 fine to 400 fine. In 1967, Public Law 90-29 was enacted providing for a termination date of June 24, 1968, for the redemption of outstanding silver certificates, thus limiting the amount of silver that the Treasury Department needed to hold for the purpose. This legislation also provided for the transfer of 165 million ounces of silver from the Treasury Department to the National Strategic Stockpile with the balance of Treasury holdings available for disposal at a minimum price of $1.29 per ounce at a rate of 2 million ounces per week. During 1969, the rate of Treasury sales was lowered to 1.5 million ounces per week open to all competitive bidders, domestic or foreign, and legislation was proposed for the minting of a commemorative silver dollar that would consume 47.5 million ounces of silver. By November 10, 1970, the 2.1 billion ounces of silver held by the Treasury Department in 1958 had been sold or transferred and the United States silver industry was on its own to get the material it needed. Actually, in the 12 year period from 1958 through 1970, the Treasury Department supplied over 1 billion ounces of silver for coinage and sold at least as much to American industry and private investors. But the essential point is that the United States Government no longer will act as a balance wheel for the silver market and prices in the future are likely to reflect near-term supply-demand balances.

To put the recent supply situation in perspective, Table 7 presents world mine production of silver by countries, refinery production in the United States, and imports into the United States for the 1965-1969 period. For 1969, the U.S. Bureau of Mines estimated that world new silver supply was about 101 million ounces less than consumption (286 million ounces versus 387 million ounces), of which nearly 64 million ounces was supplied from the Treasury stockpile. Concurrently, private investors and speculators outside of India were believed to hold about 400 million ounces that could be available to consumers at prices up to $3 per ounce. In the United States, silver prices peaked for 1969 at over $2 per ounce in January, declined to $1.54 near mid-year and closed at about $1.80 per ounce.

Materials Flow. The flow of silver into and through the American economy remains a matter for conjecture. Reported statistics are incomplete, especially with regard to the transactions of private and institutional investors and speculators, the ultimate destination of monetary silver, and the definitive identification of scrap sources. The demonitization of silver by the United States Government, now essentially accomplished, should clear the decks for more accurate reporting in the future on the physical movement of silver within the industry but it may take several years more to establish an approach that recognizes silver primarily as an industrial commodity and is geared to reporting accurately its flow.

In contrast to the situation for gold, the ownership of silver by private individuals in the United States is legal. Moreover, silver's value is high enough that the physical accumulation of a substantial hoard is not difficult. Silver thus represents an easy way to transport and store relatively large

TABLE 7. SOURCES OF SILVER, 1965-1969
(in millions of troy ounces)

	1965	1966	1967	1968	1969
New Mine Production					
United States	39.8	43.7	32.1	32.7	41.9
Canada	32.3	32.8	37.2	45.4	41.9
Mexico	40.3	42.0	38.3	40.0	42.9
Peru	36.5	32.8	32.1	36.4	34.1
Australia	17.3	18.9	19.8	21.3	24.7
Japan	9.0	10.3	10.8	10.7	10.8
U.S.S.R.	31.0	33.0	35.0	35.0	37.0
Others	51.3	53.2	52.9	53.6	55.2
Total	257.5	266.7	258.2	275.1	288.5
United States Refinery Production					
Primary from domestic ores	39.0[1]	48.4	30.3	42.1	62.7
Primary from foreign ores	45.0[2]	31.1	23.8	31.2	42.0
Secondary	61.0	53.7	58.9	92.1	94.5
Total	145.0	133.2	113.0	165.4	199.2
United States Imports					
Ore and base bullion	47.8	36.0	25.6	28.8	32.3
Refined bullion	6.9	27.0	29.9	41.9	39.5

Source: "Minerals Yearbooks", U.S. Bureau of Mines.

(1) Bureau of the Mint estimate of recovery of silver mined during the year at domestic mines.
(2) Estimated by Battelle Columbus Laboratories.

blocks of funds for investment or speculation. However, no mechanism exists for determining on a regular basis the quantity and value of such silver or the movement of it from and to the marketplace for industrial use.

Silver containing coins have virtually ceased to circulate in the United States. Receipts of such coins at the Treasury Department during the 1965 to 1970 period suggest that private and institutional investors hold large stocks that eventually may be melted and refined for the silver content value. This remelted silver as well as any future repayment of lend-lease obligations in silver could be refined for industrial use if necessary. But here again, a mechanism to trace the flow of such silver outside Government hands is needed.

Prior to 1966, the U.S. Bureau of the Mint was responsible for collecting and publishing data on the refining of silver in its own and industrial refineries. However, the Mint was concerned primarily with new silver and failed to solicit information from most of the secondary industry. The U.S. Bureau of Mines initiated industry-wide collection of refining operations' data late in 1965 and published its findings for 1966 as the first full year. However, the designations adopted for new and old scrap are inconsistent with industry usage and the Bureau makes no attempt to eliminate duplication of reporting that results from the transfer of silver-containing materials from one refiner to another. Through 1965, one of the Mint's refineries and four industrial refineries were the only installations in the United States capable of separating silver alloys into their pure component metals. All the other so-called refiners processed scraps to saleable alloys where possible and sold unusable scrap and waste to the ultimate refiners, who in turn reported it as scrap received from industry. The magnitude of such duplicate reporting is not known, and, hopefully, will be eliminated eventually as the Bureau of Mines improves its data collection and reporting activity.

Granting the imponderables indicated above, Figure 2 presents a synthesized flow diagram for silver in 1969 based on reported statistics. According to these data, 239 million ounces of refined silver were available for sale (199 million from refiners and 40 million from imports). Deliveries to industrial and coinage uses totalled 193 million ounces and 58 million ounces were exported, the implication being that stocks held by investors and speculators had a net outflow of 12 million ounces.

<u>Silver Producers</u>. In recent years, nearly two-thirds of all the new silver mined in the United States has been recovered from the refining of base metal ores--copper, lead, and zinc. From 30 to 35 percent results from the operation of mines primarily for silver and about 1 percent comes from mines operated principally for gold and silver. These ratios have remained relatively constant for the past twenty years.

Production of byproduct silver from base metal ores depends on the level of output of the base metals. Sulfide copper ores in the United States average a little better than 10 ounces of silver per ton of copper. The copper mines of the western states account for the bulk of the 13 to 14 million ounces of silver produced from this type of ore.

Occurrence of silver with lead, zinc, and complex base metal ores is highly variable. The lead ores of Idaho have averaged over 80 ounces of silver per ton of lead in recent years, but the Missouri lead belt contains only about 2 ounces per ton of lead. Zinc ores also are variable and recovery of subsidiary metal values including silver depends on the primary production process used. Electrolytic refining of zinc offers the principal opportunity to isolate silver, and the ores so treated appear to have averaged about 30 ounces of silver per

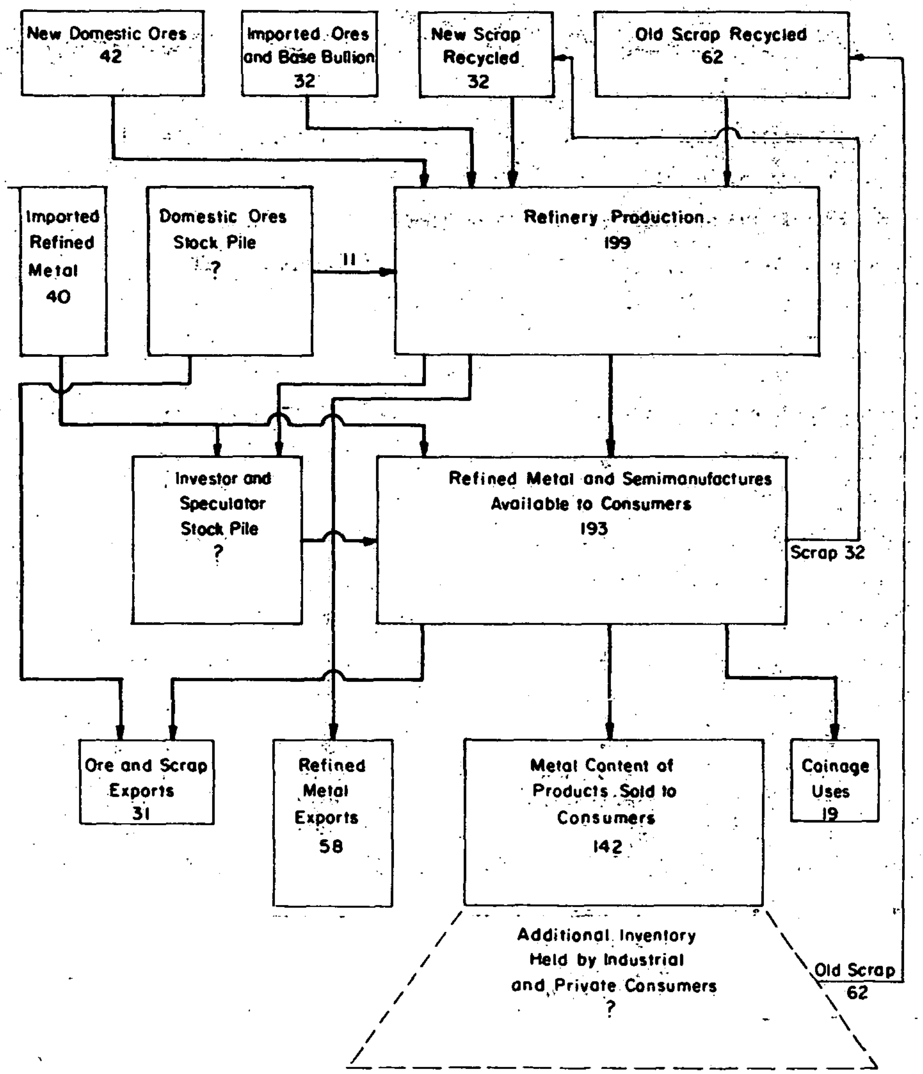


FIGURE 2. APPROXIMATE ANNUAL FLOW OF SILVER, UNITED STATES (based on 1969 data, in millions of troy ounces)*
Source: Battelle Columbus Laboratories

ton of zinc recently. Increasing production from base metal mines in the future seems to assure a rising recovery of silver that could approach 30 million ounces by 1975, in contrast to the 25 million ounces in 1969.

There are perhaps 70 active silver mines in the United States that yield about 15 million ounces of silver per year. Most of these are small, frequently marginal, operations that may or may not produce during a given year. However, there are four big operations in Idaho and Colorado, three of which yielded over a million ounces per year each with all four appearing among the 25 leading silver producing mines. The Sunshine Mine of Sunshine Mining Company is the largest single producer with an output of 8.33 million ounces in 1969. The Galena Mine of American Smelting and Refining Company is the third largest producer, yielding 3.03 million ounces in 1969. The Crescent Mine of The Bunker Hill Company was the seventh largest mine in the United States. Future production from silver mines will depend to a large extent on its price. The deposits generally are deep, narrow-veined and expensive to develop and maintain. At prices up to $3 per ounce, known silver deposits in the United States have a production potential of up to about 2.7 billion ounces of silver, according to a recent study by the U.S. Bureau of Mines.* Expansion beyond the current level of about 15 million ounces annually will necessitate substantial capital investment that is unlikely to occur until firm evidence evolves that silver prices will remain over $2 per ounce for an estended period of time.

Table 8 summarizes the sources of newly mined silver in the United States for the 1965-1969 period. The extended strike in the copper industry reduced production from this source in both 1967 and 1968.

*Banister, D., and Knostman, R.W., "Silver in the United States", Information Circular #8427, U.S. Department of the Interior, Bureau of Mines, Washington, D.C., 1969, Table 1, page 5.

TABLE 8. SOURCES OF NEWLY MINED SILVER IN THE UNITED STATES, 1965-1969 (in millions of troy ounces)

Source	1965	1966	1967	1968	1969
Gold Ore	0.5	0.4	0.4	0.4	0.3
Gold-Silver Ore	0.1	0.1	0.1	0.1	0.2
Silver Ore	13.4	14.4	12.3	12.5	14.8
Copper Ore	12.7	13.1	8.2	9.4	13.6
Lead Ore	5.3	4.0	3.0	2.5	5.2
Zinc Ore	0.5	1.8	0.5	0.5	0.3
Complex Sulfide Ores	7.0	9.5	7.6	6.8	6.9
Old Tailings	0.3	0.6	0.4	0.5	0.6
TOTAL	39.8	43.7	32.1	32.7	41.9

Source: "Minerals Yearbooks", U.S. Bureau of Mines.

Note: Details may not add to totals because of independent rounding to nearest 100,000 ounces.

At the refinery level, the 1965 to 1969 period was one of transition. Until the enactment of The Coinage Act of 1965, the U.S. Mint and four private companies had facilities capable of producing silver bullion. The Mint decided to close its refinery as the need for monetary silver decreased and to give up immediately (i.e., 1966) the refining of scrap and waste for industrial consumers. Between 1965 and 1970, at least 6 private companies installed facilities to refine silver to bullion purity and an unknown number of others equipped themselves to produce high-purity silver chemicals. Thus, currently the capacity to refine silver from ore, concentrates, base bullion, scraps, and wastes (estimated to be 321 million ounces by Charles River Associates) exceeds the level of demand for refined silver originating from domestic sources and foreign sources of unrefined materials. The leading refiners are Engelhard Minerals and Chemicals, Handy and Harman, American Smelting and Refining Company, and Amax Copper, Inc. Major new names in refining include Agmet, Incorporated, Joseph Behr and Sons, Goldsmith Division of NL Industries, Martin Metals, Sabin Metal Corporation, Sitkin Smelting and Refining, Spiral Metal Company, and Wildberg Brothers Smelting and Refining. Eastman Kodak, E. I. duPont, Mallinckrodt Chemical Works, and Sel-Rex Corporation are among the top producers of silver chemicals.

Additionally, there are up to 30 other organizations that participate to some extent in the importation of silver, the collection and processing of scraps and wastes, or the brokerage of silver-containing materials.

Markets for Silver

Silver finds a wide range of industrial and artistic applications based on its malleability and ductility, tensile strength, high electrical and thermal conductivities, acid resistance, melting point, and chemical reactivity. Its durability, color, and polishing characteristics were exploited for many years in coinage and decorative uses. Since the latter part of the 1950 decade, rapidly rising industrial uses based on its physical and chemical properties started to strain the ability of the mining industry to supply enough silver under the controlled price needed to stabilize coinage uses. After much political debate, the decision was taken in 1965 to demonetize silver and let it find its own market level as an industrial commodity.

Prior to World War II, industrial consumption of silver was largely in the field of the decorative arts and photography and ranged up to a maximum of about 40 million ounces annually. During and after World War II, technological advances in electrical and electronic equipment and in the application of industrial and medical photography more than doubled silver usage to the 100 to 130 million ounces level annually. Further advances in technological sophistication, including electrical batteries and metals joining techniques, initiated another boom in industrial silver consumption after the recovery from the recession year of 1958. According to statistics compiled by the U.S. Bureau of the Mint, noncoinage uses in the United States received over 204 million ounces of silver in 1963 from refiners and importers, the largest quantity ever issued. Actual industrial consumption in saleable products is not known because the method of reporting scrap returns from industry and other sources did not differentiate between a prompt scrap return and the recycling of old scrap. This procedure for reporting industrial usage continued through 1965, at which time a net industrial consumption of 137 million ounces (198 million ounces issued and 61 million ounces returned) was reported. Further, the breakdown of industrial consumption by end use was published only at irregular intervals and year to year comparisons of selected end uses were difficult.

Starting in 1966, the U.S. Bureau of Mines began the publication of industrial consumption based on their own collection of data from refiners and other marketers of silver. The extent of coverage and accuracy of returns of these data are undefinable. Informed industry sources feel that the first several years of reporting may contain irreconcilable duplications that distort net consumption (the purported basis) by as much as 25 percent. In any event, by 1968 and 1969 both the Bureau of Mines and industry were in substantial agreement that net industrial consumption was about 140 to 145 million ounces per year as shown in Table 9. Preliminary indications are that 1970 consumption will be lower.

Consumer-Oriented End Uses. Silver usage in consumer oriented products--electroplated and sterling ware, jewelry, dental and medical, and mirrors--tends to follow economic prosperity. It rises in periods of increasing personal disposable incomes and contracts when incomes plateau or decline. Both plated and sterling tableware markets are being eroded by stainless steel but the "elegance" of silver still preserves a minimum market that probably will never disappear.

Overall, these five categories of end use account for about 25 percent of silver consumption and should increase at a rate at least equal to that for population growth, or between 1.5 and 2.0 percent.

Industrially-Oriented End Uses. Silver usage in industrially-oriented end uses--brazing alloys, electrical and electronic products, catalysts, and bearings--depends on a price-performance relationship. Silver fulfills a physical function that is important, if not vital, to the intended use of the ultimate product whether this be industrial equipment or consumer goods. Alternative ways

TABLE 9. INDUSTRIAL CONSUMPTION OF SILVER IN THE UNITED STATES, 1966-1969 (in millions of troy ounces)

End Use	1966	1967	1968	1969
Electroplated Ware	21.5	17.9	15.3	12.7
Sterling Ware	30.9	30.3	28.3	20.3
Jewelry	6.3	5.8	4.5	3.0
Photographic Materials	48.4	50.3	41.6	41.4
Dental and Medical Supplies	2.5	2.7	3.1	1.6
Mirrors	2.9	2.2	1.7	1.5
Brazing Alloys and Solders	18.4	15.4	15.1	16.5
Electrical Batteries	12.5	11.4	5.8	3.8
Electrical and Electronic Contacts and Conductors	33.7	26.8	25.8	34.6
Catalysts	2.7	5.8	2.3	4.1
Bearings	0.6	0.6	0.5	0.5
Miscellaneous	3.2	1.9	1.2	1.6
TOTAL	183.7	171.0	145.3	141.5
As Reported by Industry	150.0	145.0	145.0	147.0

Source: "Minerals Yearbooks", U.S. Bureau of Mines; Handy and Harman

Note: Details may not add to totals because of independent rounding to the nearest 100,000 ounces.

are available to achieve technologically equivalent results in virtually all these applications but the solutions based on silver represent the most economic ones at present. This could well hold true for most of the applications even if the price of silver should double in a few years. The research and engineering cost and new capital investment for alternative materials or manufacturing procedures suggest a relative inelastic demand-price relationship. For example, silver contact points in a step relay for a TV set might be replaced by palladium-plated beryllium copper without loss in reliability or signal transfer efficiency. But the cost to redesign the relay and to set up the equipment to fabricate it become prohibitive until the materials cost for the silver containing relay far exceeds the materials cost for the alternative relay.

Overall, these uses accounted for about 40 percent of annual silver consumption recently and are expected to grow at only a modest rate in the future. Ways to conserve the amount of silver needed to satisfy the performance requirement have been and are being sought--for example, bimetallic contact points instead of solid silver--but the number of applications continues to increase. A growth rate of 4 to 5 percent per year appears reasonable.

Other End Uses. To date, silver in photographic uses has been irreplaceable. Other light sensitive chemicals are known but nothing has been discovered that compares to the silver halides--silver chloride, silver bromide, and silver iodide--in speed, range of response, and ease of subsequent processing. So in spite of large research expenditures to displace it, silver seems assured of these markets for another five to ten years at a minimum. Further, the markets for industrial, commercial, and medical photography continue to increase and amateur photography also grows.

This use accounted for 29 percent of silver consumption in 1969, slightly below the historic proportion. A return to about one-third of industrial usage is expected with future growth at a rate of about 4 percent.

Prices. Silver prices in the United States have been influenced by governmental policies with respect to its value as money for many years. In the 1930's legislation authorized unlimited purchase of newly mined domestic silver at $0.6464 per ounce (one half the $1.293 per ounce that represents the monetary equivalent of the silver content of silver dollars and subsidiary coinage). Newly mined silver flowed to the Treasury Department and industrial users had to go to foreign sources for their needs, usually at lower prices.

In 1946, to stimulate the domestic mining industry, which had been drastically curtailed during World War II, the price for newly mined silver was raised to $0.9050 per ounce, still above the market price for foreign silver. By 1955, the market price approached the support price and purchases from Treasury stocks were needed to supplement domestic production that was going into industry. Treasury's "free" stocks--the portion of total inventory not needed to support outstanding silver certificates--were sold at $0.9050 per ounce plus a handling charge and effectively placed a ceiling on silver market prices until 1961 when they were exhausted. Between 1961 and 1963, the market price advanced to $1.293 as domestic production was channeled to industry and coinage requirements were met by retiring $5 and $10 silver certificates thus freeing some Treasury stock.

The Coinage Act of 1965 resulted in freeing further Treasury stocks no longer needed for coinage and subsequent downward revisions in the support stocks held for silver certificates permitted Treasury sales at $1.293 per ounce into 1967. On May 18, 1967, Treasury announced a limitation on sales to domestic

users only and the prohibition of private melting and export of silver coins, which stimulated a two-tier pricing for silver. Prices jumped sharply on the nongovernmental markets but the dual pricing situation was eliminated on July 14, 1967, with the announcement that future Treasury sales would be at auction rather than the fixed monetary equivalent of $1.293. However, prices continued to rise and reached a peak of $2.565 per ounce in mid-June, 1968. Thereafter, a gradual decline set in as the market reacted to short-term supply and demand relationships and during 1969 silver ranged from a high of $2.025 early in the year to a low of $1.540 near mid-year before closing at a little over $1.800. There was little speculation activity during 1970 and with supplies relatively free, even the end of Treasury's sales during November did not stimulate the market which ranged from a high of $1.900 to a low of $1.600, winding up the year at the lower end of the range.

Market Outlook. During 1969, the U.S. Bureau of Mines published a study that related consumption of silver with the index of durable goods manufactured for the 1954 to 1965 period. The correlation developed in this study*, which would have predicted a silver consumption of 163 million ounces in 1969 (versus a reported 141.5 million ounces), appears to require some modification. Preliminary indications are that 1970 will be even farther below the trend line, probably establishing a new base from which future calculations can be made.

Without question, the current applications for silver suggest rising consumption in the decade ahead and a continuation of the supply deficit. Industry sources stress the latter aspect as justification for the predication that prices about $2.00 per ounce are inevitable with the big question being what

*Banister, D. and Knostman, R.W., ibid, Table 7, page 25.

price will bring significant quantities on the market from speculators' hoards. Assuming a gradual recovery from the depressed industrial activity of 1970, demand for silver in the United States could increase at a rate of about 3 to 3.5 percent per year until 1975. This would suggest a demand level of 155 to 160 million ounces annually at that time (up from the 135 million ounces of 1970) and the prospect that prices would range from $2.25 to $2.75 per ounce.

The Silver Recycling Industry

Characteristics of Secondary Silver

As mentioned previously, secondary silver is undistinguishable from new silver with respect to purity, performance, or price. Selected scraps, for example the stamping waste from sterling ware production, may be remelted and rerolled to strip without isolation of the component metals, but the price for this material to consumers is the same as that charged for newly made alloys.

Essentially, the specifications for industrial silver alloys or compounds are rigid within limits so narrow that only the equivalent of complete refining is tolerable regardless of the source of the silver. There are no markets for "off grade" or impure silver alloys or compounds, except to the refiners for recycling.

Characteristics of the Silver Recycling Industry

Materials Sources. Silver-containing materials for recycling consist of scraps, wastes, and sweepings. Scraps normally originate from the fabrication of products or component parts by metal working techniques and usually retain the essential characteristics of the original metal with respect to silver content and form. Wastes result from secondary metal finishing operations (such as grinding or polishing) on metallic products or component parts, or from residues associated with electroplating operations or the manufacture of brazing alloys and solders or silver chemicals. Generally, the silver content of wastes is significantly lower than the materials supplied to the consumer. Sweepings consist of silver-containing residues resulting from cleanup operations in shops or factories in which silver is used. The silver content frequently is low

(1 percent or less), and the balance of the material collected has essentially no recoverable value.

Discarded and obsolete products containing silver usually consist of metallic items in which the silver content is readily identifiable. Unless other precious metals are present, this old scrap normally has a relatively high silver content. Discarded jewelry, worn out silver batteries, obsolete or damaged contact points, junked bearings, and spent catalysts illustrate the principal sources of old scrap. Broken mirrors and silver-brazed industrial machinery parts illustrate potential sources of old scrap whose low silver content frequently precludes their recycling.

For convenience in subsequent discussions, prompt industrial scrap is considered to be the high metallic content scrap resulting from metal working operations mentioned above. Old scrap is considered to be the wastes and sweepings originating in industrial plants and the discarded products or components that have outlived their usefullness by individual or industrial consumers.

The data reported by the U. S. Bureau of Mines for 1966 to 1969 on refinery production from new and old scrap represent the best available information. As shown in the accompanying tabulation, old scrap is the more important source.

Year	Refinery Production of Silver, Millions of Ounces From Old Scrap	From New Scrap	Total Scrap
1966	36.6	17.0	53.7
1967	33.5	25.4	58.9
1968	57.5	34.6	92.1
1969	62.5	32.0	94.5

Source: "Minerals Yearbooks", U. S. Bureau of Mines.

However, in view of reported industrial consumption in the same years, the figures given for new scrap are subject to question. Two explanations are immediately obvious: (1) consumers tend to hold prompt industrial scrap when the prospect of a price rise is imminent, as in 1966 and 1967, or (2) the first few years of reporting by a new agency contain unresolved discrepancies until the respondents become acquainted with the forms and definitions. The former appears more probable, and consolidating the four years would suggest the issuance of about 750 million ounces to industry from which the prompt industrial scrap return was nearly 110 million ounces, a loss to yield of slightly less than 15 percent which is within reason.

The increase from 33.5 million ounces in 1967 to 57.5 million ounces in 1968 for old scrap may or may not be related to the price rise. The recycling of old scrap has tended to be rather variable in the past and largely dependent on consumer oriented products. Intensified emphasis on recovery and recycling of obsolete military and industrial electrical and electronic equipment as well as the uncontrolled price probably account for the jump.

<u>Materials Flow</u>. Industrial and consumer generated silver refuse follow slightly differing paths to the ultimate recipient, the refiner. Prompt industrial scrap, old industrial scrap, and wastes and sweepings reach the refiner by way of a dealer-collector or dealer-processor. Many of the refiners act as dealer-collectors, especially for large industrial generators, while the smaller generators usually are serviced by dealer-processors who consolidate various types of scrap and waste from several sources. Industrially generated scrap and waste seldom passes through more than two hands en route to the

refiner. Refiners pay for scraps and wastes on the basis of an analysis of a sample for silver content.

Consumer generated scrap normally enters the recycle chain at a small dealer-collector who may be a retail jeweler, a dental laboratory, or an "over-the-scale" dealer. Brokers specializing in precious metals visit the dealer-collectors on a fairly regular basis, fulfilling the function of consolidating small quantities of scrap into shipments to refiners that can be handled economically. Refiners pay for scrap only after analyzing the material for silver content, which may entail a bulk melting of the shipment to assure a representative sample. The broker pays on the basis of his estimate of the silver content, as does the dealer-collector, although both will discount either the weight or the price of silver in order to assure a profit on the transaction.

The Recycling Industry. There is virtually no information available on the quantitative relationships in the recycle chain. Refiners, of course, eventually treat all recycled silver and there probably are at least 70 companies that claim to be refiners. Beyond this, the number of brokers and dealer-collectors is unknown and the quantities of silver scrap passing through their control is not reported. The intensive survey conducted for this study identified 111 organizations that handle silver out of the 578 responses, of which 67 claim to do some refining. These obviously include large dealer-collectors, some of the larger brokers of industrial scraps and wastes, and the principal refiners but few of the small retail outlets or laboratories that serve as dealer-collectors for consumer generated scrap, or the brokers that service them. Battelle estimates that the primary collection and accumulation function is performed by over 500 companies or shops, including the ones identified by the intensive survey, and that industrially generated scrap

and waste, both prompt and old, accounts for at least 75 percent of the 94.5 million ounces recycled in 1969.

It should be noted that the recycling of silver from photographic uses is considered to be an industrial rather than a consumer oriented situation. Moreover, at least a part of the 70 refiners identified by the intensive survey are believed to be dealer-processors in the context that they buy old film and paper and process it to a silver containing ash, if not carrying the refining to the ultimate stage of purified silver compounds or metal.

Markets for Recycled Silver

Markets for recycled silver are the same as those for silver in general. This results from the fact that the silver industry makes no distinction between primary or secondary sources for the materials sold. While it is true that silver-containing scraps and residues do not yield the full silver price to the seller, the pricing basis is the prevailing price for silver less a charge for the reprocessing and refining. And, the recovered silver commands full price when reissued to consumers. Thus, the usage pattern for secondary silver is coincident with the pattern for primary silver.

Demand-Supply Analysis

Nonmonetary net consumption of silver has exceeded 100 million ounces annually since 1955. This represents the disappearance of more than 2 billion ounces of silver into the American economy in consumer and industrial products. Aside from accidental loss, this material theoretically should be available for recycling at some time in the future when the products have outlived their usefulness. Much of it never will actually be recycled because of sentimental attachment, archival considerations, or the difficulty of economic collection and processing. From the viewpoint of logic, the potential recovery of old scrap should exceed 100 million ounces annually if the problems of logistics and economics of collection could be solved. Indications derived from recent data suggest that the probable achievable level under current pricing is about 75 million ounces annually which might be increased to 80 to 85 million ounces if the price goes to $3 per ounce.

Prompt industrial scrap, currently in excess of 30 million ounces annually, represents an area where improvement is possible under present pricing for silver. Representatives of the recycling industry contacted during this study believe that a 10 to 15 percent increase could be achieved at an annual consumption level of about 145 million ounces.

Overall, recycled silver might supply about 100 million ounces and new domestic mine procution about 40 to 50 million ounces versus a demand of 150 million ounces or more. This would leave a deficit to be furnished by imports and dehoarding of investor and speculator stocks that appears to be manageable. Considering established import-export trade relationships, the projected supply-demand balances for the next five to ten years will not exert substantial pressures to increase the recycling of silver. More likely would be a decline in old scrap return to a level of about 50 to 60 million ounces per year with a consequent net increase in imports of refined metal to fill the deficit gap.

Obstacles and Problems that Reduce the Recycling of Silver

Problems identified and the analyses contained in succeeding paragraphs are summarized in Table 10.

Prompt Industrial Scrap

As used here, prompt industrial scrap consists primarily of metallic waste of relatively high silver content generated by the application of metal working processes to sheet, strip, tubing, wire, and casting alloys. The mill product forms used may be solid silver alloys or bimetallic composites in which silver is clad on a base metal. Stamping, blanking, drawing, and casting operations result in unusable wastes ranging from 5 percent to over 40 percent of the metal purchased by consumers. Recycling of this scrap is readily identifiable as an economic means of reducing the manufacturing cost of the end product and most consumers do segregate and collect it.

This type of scrap originates primarily in the sterling ware, jewelry, dental and medical, electrical and electronic industries. Sterling ware producers, jewelry manufacturers, and dental and medical laboratories maintain close ties with the refiners of silver and have recycled scrap for many years. Only the smallest consumers who work infrequently with silver may be lax in segregating their scrap for efficient recycling but the materials usually are collected with other precious metals and eventually returned.

The electrical and electronic industries also are well aware of the value of silver and the need to recycle it for assurance of future supplies. In contact points in particular, manufacturers have been active in adapting clad metals to replace solid silver in order to reduce the cost of materials. The lower silver content of bimetallic components introduces problems in segregating this scrap from solid silver scrap for efficient recycling and the reduced value of the scrap per unit weight may lead to carelessness in handling

TABLE 10. IDENTIFICATION AND ANALYSIS OF PROBLEMS CONCERNING SILVER THAT WAS NOT RECYCLED IN 1969

Title	Scrap Categories Where Some Silver Was Not Recycled				
	Prompt Industrial Scrap	Industrial Wastes and Sweepings	Old Industrial Scrap	Old Consumer Scrap	Photographic Scrap
Problem Definition	Manufacturing processes often generate unusable materials in small volume in a number of installations, often these are contaminated and are not recycled.	Polishing, buffing, plating operations and metal melting generate wastes with a small silver content. The silver values are not economic to recycle. Thus this scrap silver is not recycled.	Silver content of discarded articles is variable Low silver-content articles usually have other metals, sometimes nonmetallic materials. This is a major area where silver is not recycled.	Service life of consumer goods dependent on factors other than economics. Consumer's idea of value of article to be scrapped is much higher than the materials cost.	Silver recoverable only at certain stages which occur at georgraphically dispersed locations Economic recovery possible only at certain levels of film processing or disposal
Silver NOT Recycled	1,500,000 ounces annually	270,000 ounces annually	20-25,000,000 ounces annually	2-3,000,000 ounces annually	20-25,000,000 ounces annually
Percent of Available Silver NOT Recycled	5	45	33	50	50
Problem Analysis	1. Recycling is at a high level when scrap can be segregated by alloy and and product form 2. Small shops handling a a few ounces of silver per day have difficulty in collecting scrap economically 3. This is not a promising area because the economically recoverable scrap is being recovered 4. Institutional promotion by the refining industry is desirable to maintain level of recovery now achieved	1. Silver content of wastes and sweepings is variable, from 0.1 percent to 20.0 percent 2. Balance of material has no significant recovery value 3. Efficient collection is difficult because of dilution 4. This is not a promising area because the economically recoverable waste is being recycled 5. Institutional promotion by the refining industry is desirable to maintain level of recovery now achieved	1. Aside from military salvage depots no effective mechanism exists for economic collection of discarded equipment 2. Discarded equipment has variable silver content--some none, others up to 60 percent of gross weight 3. Identification of silver-bearing scrap is difficult at times 4. No effective processes exist to treat bulk scrap for silver recovery 5. Upgrading to recoverable silver level is uneconomic unless large volumes of scrap are collected 6. About two-thirds of economically recoverable silver is being recovered 7. Some improvement is possible via joint USBM-DOD programs now underway	1. Consumer has little economic incentive to recycle silver unless a direct replacement of an article is being made 2. Some recovery is unreported, probably from small manufacturing jewelers 3. No effective mechanism exists to collect discarded articles from individual consumers 4. Improvement in recycling definitely possible but not necessarily economic	1. Silver is recoverable from spent processing solutions and discarded film and prints 2. Large processors are recovering silver effectively, except certain Governmental users 3. Large volume generators of discarded film and prints also recover silver effectively 4. Essential problem for small user is the lack of incentive to collect store, and recycle the small quantities generated 5. About 80 percent of economically recoverable silver is being recycled 6. Improvement is possible and desirable but consumer apathy has to be overcome

that results in losses.

Overall, the refiners feel that these industries are recovering more than 95 percent of the prompt industrial scrap generated and that the remainder would be difficult and expensive to get. Improperly trained labor and carelessness are cited as the principal problems of collection and to alleviate them the refiners conduct educational and promotional advertising campaigns and shop practice training for consumers' personnel, if so requested.

Industrial Waste and Sweepings

Metal finishing operations, the production of brazing alloys and solders, electroplating operations, and mirror manufacture involve procedures that result in silver-containing wastes. These may range from a low of several percent of silver content up to about 20 percent and be produced continuously or sporadically.

Polishing and buffing of sterling or electroplated ware and jewelry illustrate metal finishing from which spent polishing compounds accumulate. Such waste has a low silver content but tends to be collected to prevent a health hazard in the factory. In shops where the silver polishing can be isolated, the segregation of silver waste is readily accomplished and returned to a refiner when a convenient quantity has been collected.

The manufacture of brazing alloys and solders involves metal melting and casting with their inherent opportunities to lose metal into slags and cover coats, by spillage, and reject products. Silver content of the alloys is variable although higher than in the slags and melting pot cover coats but all sources of waste present problems of segregation and collection. From their knowledge of this industry, the silver refiners believe that less than 80 percent of the available waste is being returned for recovery. They have attempted to make the industry aware of the desirability of better collection through institutional advertising and sales contacts to little avail. Few of the companies in this industry can afford to have labor continuously available to specialize in waste recovery and the emphasis for production labor is production rather than "housecleaning."

Electroplating and mirror manufacture involve the handling of silver chemicals and large volumes of solutions and wash waters. Spent plating solutions and metallic wash water recovery units are the usual wastes that are recycled. Careless handling of solutions and inattention to the recovery unit account for most of the loss of silver that does not go out with the product. The refiners provide metallic recovery units and manuals of instruction for their operation which has resulted in significant savings to the consumers operating them. But again, production labor is concerned primarily with production while the value of spent solutions and recovery units is difficult to see. The larger shops and facilities that have continuous plating do a more effective job of salvage than the small shops. For this reason it is probable that more than 90 percent of the recoverable silver is recovered. The economics of trying to recover the balance do not appear favorable to the consumer and there is little more that the refiners can do. There are unavoidable losses from very dilute wash waters for which no practical recovery methods are presently available. Potentially, ion exchange techniques offer the best hope for treating very dilute solutions for complete removal of silver. If necessary, a technically acceptable unit could be developed rather quickly but the economics will remain unfavorable if they depend on the value of the silver recovered.

Old Industrial Scrap

Old industrial scrap consists predominantly of worn-out silver batteries, discarded silver bearings, contact points in military and industrial electrical or electronic equipment, and spent chemical catalysts. Having served their intended purposes, they become available for the recovery of silver.

In the past five years, military disposal agents have become well aware of the value left in discarded silver batteries and contact points. Intensive efforts are being made to recover batteries and points from field communication equipment and submarine service in order to assure a continuing supply of silver for defense applications. By 1969, the U. S. Bureau of Mines estimated that military salvage depots around the world were recovering silver at a rate of 12 million ounces annually. Undoubtedly, this does not represent the total silver content of the equipment withdrawn from service in any given year. Battlefield losses and salvage at remote isolated locations present difficult collection problems logistically and the very low silver content of certain types of aircraft and electronic equipment scrap virtually preclude its segregation and collection. Minor increases in the quantity of recycled silver probably are possible under current conditions of collection and identification but the limit of economic recovery is believed to be fairly close to actual recovery.

Discarded bearings, industrial control equipment, and commercial communications equipment are a source of recovered silver. The amount of silver actually recovered is less than the amount available, although both quantities are not known with any degree of accuracy. The logistics of collecting such scrap and the segregation of the silver content to a level of economic recovery are the major obstacles to recycling of this scrap.

Silver catalysts are recycled from the chemical industry at a high level of recovery. The materials are readily segregated, have an identifiable silver content, and need to be replaced with a similar product. Losses in this recovery cycle tend to be the accidental spills and careless materials handling that is difficult are difficult to eliminate. Little improvement is possible.

No data are available to even suggest the magnitude of the problem of recovering more silver from old industrial scrap. In recent years, the consuming industries that account for most of the products that would be classified as industrial scrap have used between 35 and 40 percent of the net consumption of industrial silver. This would suggest that, since 1955, between 600 and 700 million ounces of silver was funneled into end products that had an effective useful life ranging from one year to over 10 years. The assumption that annual production of these industrial products in recent years has merely replaced those scrapped indicates that 60 to 70 million ounces of silver would be the amount scrapped annually. In view of attempts to reduce the silver content of electrical and electronic components, a figure nearer 70 million ounces per year appears to be more reasonable. However, reported recovery from all old scrap -- including all the discarded consumer-oriented products -- averaged only 47.5 million ounces annually in the 1966 to 1969 period. Thus, it appears that at least 20 million ounces per year is not being recycled, in spite of continuing efforts by the refiners to promote recovery and reuse.

Old Consumer Scrap

Old consumer scrap includes jewelry, tableware, flatware, trophies, artware, mirrors, and dental and medical products that have been discarded because of damage or obsolescence. It consists of sterling alloys, coinage alloys, silver plate on copper- or nickel-base alloys, dental amalgams, special alloys for dental or medical use, and silver on glass.

Sterling jewelry, table and flatware, and dental and medical products that are discarded by individual consumers usually find their way into the recycle system because the silver value is recognized. Retail jewelers frequently will pay some fraction of the metal value of articles presented for their appraisal and, thus, function as a dealer-collector in the recycle chain. Dentists and hospital medical personnel also collect (with or without payment) silver-containing alloys, pins, supports, and other devices that patients no longer need. These then are returned to refiners by way of brokers, dental laboratories, or dealer-processors. However, very little of the outstanding inventory of these products in the hands of individual consumers is returned for recycling. The majority is kept for sentimental reasons and frequently passed from one generation to the next with no thought of salvage. The chief obstacle to recycling usually is apathy to the inherent value, once the sentimental attachment has been broken. A single piece of jewelry or even several pieces offer little incentive to the average American to collect them and take them to someone who is willing to pay for them. Many times, the first unresolved question for the consumer is "who will give me a fair price?" The demise of the itinerant "junk collector" has removed a vital link in the recycling of precious metals including silver, and no one is making a concerted effort to replace him.

Mirrors and silver plate ready for discard are more likely to be thrown out as refuse than to be presented for reclamation. In the case of mirrors, the salvage value of the silver is less than the time and inconvenience of trying to find a suitable buyer. In the case of silver plate, individual items encounter the same resistance to sale as mirrors, but if the owner will tolerate the inconvenience of storage eventually he may accumulate enough silver to make recovery worthwhile. The problem for these items is that their salvage value is much less than appearance would indicate and even the most reputable dealer-collector has difficulty explaining the discrepancy. Dealer-collectors also encounter difficulty in making their services known to the general public despite the local advertising they do.

Again, no data are available to indicate the quantity of old consumer scrap recycled in any given year or its specific source. Moreover, the need of both dealer-processor and refiner for accurate knowledge of the metallic composition of the scrap leads to bulk melting of the material which destroys the identity of the source. Further, the useful life cycle of the products is not predictable. In the 1966-1969 period, the average net consumption of silver in these products has been nearly 54 million ounces annually. It is probable that not over 1 percent of this represented the direct replacement of articles damaged or discarded during the course of a given year. Assuming that articles are discarded several years after their utility has expired on the average, Battelle estimates that between 1.5 and 2.5 million ounces of silver were reclaimed annually from old consumer scrap during the 1966-1969 period.

For certain sectors of the general public, economics will play a major role in determining the useful life cycle of silver-containing jewelry and household decorative items. They are purchased in good times and sold during hard times. But this type of transaction represents a minor percentage of the silver going into consumer-oriented products and recycling can be increased only by appealing to motivations other than economic for the bulk of the general public.

Photographic Scrap and Waste

Photographic scrap and waste consists of solutions from the processing of film and paper and used film and paper. Recognizing the impending silver shortage, the major producers of photographic supplies initiated promotional and educational program as early as 1965 in an attempt to recover and recycle as much as possible. Substantial progress has been made but this category of silver consumption still represents a major opportunity to decrease the disappearance of material that potentially could be recycled.

Depending on the end use, photographic film and paper may contain from 0.01 to 0.70 ounces of silver per pound. The developing and fixing processes remove a part of this but the residue is left in the film or paper. When discarded, these materials could have a silver scrap value of 15 to 35 cents per pound with silver at the $1.50 to $2.00 per ounce price level.

During processing, the silver not needed to form the image concentrates in the fixing bath and wash waters. Under controlled conditions, exhausted fixing solutions could contain up to 1 ounce of silver per gallon although wash waters would be much more dilute.

Overall, the photographic industry estimates that two-thirds of the silver contained in film and paper could be recovered. The balance is lost in archival records (industrial, commercial, and family snapshots) or occurs in such small quantities at such dispersed locations (logistical loss) that collection is uneconomical. In the 1966 to 1969 period, the amount recovered in the United States has risen from about 30 percent of the total consumed to something over 40 percent and may reach 45 percent in 1970. The steady increase in recovery is attributed to the efforts of the photo supply industry aimed at commercial film and paper processors and the industrial, commercial, and institutional users of X-ray and business record films. In addition to direct mail and institutional advertising promotions that stress the economic opportunities for recovery, they have offered technical service help in connection with proprietary systems (metallic or electro-chemical) for removing silver from fixing baths and wash waters, and encouraged the formation of a network of film and paper collector-processors that now blanket the country to service the user who could not afford his own separate recovery system. For example, the basic publication on photographic silver recovery from Eastman Kodak Company (Publication J-10), lists 98 installations nationwide that handle one or more facets of recovery.

Several classes of photographic supply users are recognized by the supply producers as opportunities for increased recovery within the two-thirds limit of economic recovery. A major class is government installations other than the Veterans Administration (VA). Several years ago, enabling legislation was enacted to permit the VA to use industrial firms rather than governmental agencies to recover and refine its silver-bearing wastes with the credit therefrom accruing to the VA. All other federal government installations have to send their scraps and wastes to governmental installations with the value of the recovered silver going into general revenue funds. Many state and local governmental installations have similar restrictions. These procedures minimize the incentive for agency and departmental heads to actively promote efficient recovery and recycle since they do not benefit directly.

Another major class is the small industrial or commercial installation handling classified information but unable to support a separate incinerator for photographic waste. The photographic waste usually is burned with paper and the silver content of the resulting ash is too low to permit economic recovery.

A third major class of user is business firms who record technical and scientific information on special sensitized papers for analytic and records work. Exploration areas for petroleum or mining companies illustrate one aspect of this class. The papers they use have a high content of silver but usually get discarded as refuse because the information recorded has temporary usefulness, frequently at quite remote locations. Even at centralized locations, the time and effort to collect and recycle small quantities appears unwarranted.

User complacency also is a major contributor to photographic silver loss. This area has a bearing on the three classes discussed above but is applicable specifically to many small commercial and industrial photographic departments operated in connection with other activities. In general, the darkroom of such installations is operated intermittantly and current solution recovery systems are not applicable. Film and paper waste also is small in volume and inconvenient to store for any length of time. The economic incentive for the operator of such an installation to recover silver is far less than the incentive to get more business and it is unlikely that what he would recover from silver would have much effect on profit or loss.

In connection with reprocessing used film and paper, the economics of recovery could be improved significantly if markets could be found or developed for the film or paper base and for the emulsions in which the silver is held. To date, these nonsilver values are recovered only in highly specialized situations, for example, by the producers of film and paper treating large quantities of wastes of known composition. Other processors of used film and paper incinerate film and paper scrap because the variability of composition precludes economic handling of the nonsilver values. A solution to this problem would have to include quite imaginative approaches to finding uses for relatively low-valued products as well as extensive research and development for efficient methods of separating the components from small quantities of diverse waste materials.

In connection with solution wastes, there are three principal methods for treating exhausted fixer baths. Metallic recovery units, called "silver filters" or "silver savers", consist usually of steel wool in canisters through which the solution is passed with the silver depositing on the steel wool. The loaded steel wool is treated by refiners for silver recovery. Electrolytic systems use an electrical current to deposit the contained silver on plates which are then recycled to the refiner. Precipitation systems use chemicals to reduce the silver content to metal which is then filtered and sent to refiners. Any of these systems are effective as long as the silver content of the spent fixer bath is about 0.5 gram per liter or more.

However, wash waters are more dilute than this, perhaps of the order of 0.05 grams of silver per liter. At these low concentrations, none of the available commercial systems are selective enough to recover silver economically. Ion exchange systems appear to offer some hope for solving this problem if the production cost of the resins can be reduced by several orders of magnitude through the discovery of suitable materials. Research is being carried out in this area in the hope of having technically and economically feasible systems if stringent controls are placed on the discharge of silver to public sewers. No near-term breakthrough is anticipated.

As a rough approximation, recovery of silver from photographic wastes in the United States in 1969 is estimated by Battelle to have been between 15 and 20 million ounces. Intensified efforts by the photo supply industry may result soon in an increase of 2 to 3 million ounces per year but a minimum of about 20 million ounces are being lost, of which less than 5 million ounces is considered to be potentially recoverable.

Problems Not Directly Related to Recycling of Silver

Industry Statistics

One difficulty in any analysis of the problems and opportunities in recycled silver is the lack of adequate statistics on the flow of silver into and out of the industrial manufacturing complex and through the hands of industrial and private consumers. The available data fall far short of those needed to measure the potential for recovery in any given end use, to allocate actual recovery to end uses, and thereby to assess the magnitude of the scrap recovery problem. Of course, studies such as this help to highlight gross problem areas and a tentative order of magnitude for those problems. In lieu of better data, Battelle presents a rationalized flow of silver in industrial applications in the United States based on available data for 1969 in Table 11. It should be noted that this presentation ignores losses in processing recycled silver by equating refinery production from scrap sources with the quantities received by refiners. Further, it is assumed that net industrial consumption represents the quantities of silver converted into saleable products for the year, an addition to the amount in circulation.

A further difficulty with the statistics lies in the possible duplication of data in the recycle system. The existence of several levels of refining complicates the task of following recycled silver through the system. For example, a dealer-processor specializing in photographic wastes will report the recovery of silver even though the silver is contained in an ash having no commercial use. The ash is sold to a refiner, who reports receipt of silver waste from industry and the production of refined silver suitable for use by consumers. Unless the scrap nature of the dealer-processor's product is identified by the statistical reporting agency and eliminated from the recovery data, the data will contain duplication of information. In actuality, the situation is much more complex than the illustration cited because some refiners generate wastes and sweepings in the course of their operations that are sold to other refiners who are better able to handle these wastes, but the transfer may be treated as a new increment of scrap generation and recovery. The magnitude of error arising from duplicate counting is unknown and not critical to the continued functioning of the recycle industry.

TABLE 11. RATIONALIZED FLOW OF SILVER IN INDUSTRIAL USES IN THE UNITED STATES, 1969
(in millions of troy ounces)

Use Category	Issued To Industrial Consumers	Prompt Industrial Scrap Generated (1)	Reported Net Industrial Consumption	Old Industrial Scrap Recycled (1)	Old Consumer Scrap Recycled (1)	Prompt Industrial Scrap Recycled	Total Scrap Recycled
Industrial Products							
Brazing Alloys	17.0	0.5	16.5	1.5	--	0.3	1.8
Electrical Batteries	6.0	2.2	3.8	10.0	--	2.0	12.0
Electrical Contacts	51.4	16.8	34.6	24.0	--	16.0	40.0
Catalysts	4.3	0.2	4.1	3.5	--	0.2	3.7
Bearings	0.9	0.4	0.5	1.0	--	0.3	1.3
Miscellaneous	1.9	0.3	1.6	0.5	--	0.2	0.7
Consumer Products							
Electroplated Ware	13.3	0.6	12.7	--	0.5	0.5	1.0
Sterling Ware	30.7	10.4	20.3	--	0.5	10.0	10.5
Jewelry	4.7	1.7	3.0	--	0.5	1.5	2.0
Dental and Medical	2.0	0.4	1.6	--	0.5	0.3	0.8
Mirrors	1.7	0.2	1.5	--	...	0.2	0.2
Photographic Materials	41.9	0.5	41.4	20.0	--	0.5	20.5
TOTAL	175.8	34.2	141.5	60.5	2.0	32.0	94.5

Sources: "Minerals Yearbooks", U.S. Bureau of Mines; Battelle Columbus Laboratories.

Note: ... indicates less than 50,000 ounces.

(1) Total and allocation to consuming industries estimated by Battelle Columbus Laboratories.

Courses of Action Concerning Recycling of Silver

Selection of Opportunities

Without question, substantial quantities of silver are being lost each year because scraps and wastes are not returned to the recycle system. All the evidence accumulated during the course of this study suggests that the primary opportunity for increasing recycling lies in the area of reclaiming old scrap that has been in the hands of individual and institutional consumers as products that contain some silver. By comparison, the recovery of silver from prompt industrial scrap represents a minor opportunity for improvement. Qualitatively, top priority should be assigned to all the problems associated with the reclamation of old scrap.

Prompt Industrial Scrap. As suggested in Table 8, the generation of prompt industrial scrap exceeded recovery by a minimum of 2.2 million ounces in 1969. Actual recovery of 32 million ounces in that year may include some scrappage from prior years that was held by generators for a better silver price. Nevertheless, the amount generated but not recovered in any given year probably is less than 10 percent of the reported recovery. Achievement of the 90 percent level of recovery is attributable to growing recognition by consumers of the value of their scraps from continuing promotional and educational programs supported by the recycling industry. In those consuming industries where silver represents a major share of the materials cost in products--jewelry, sterling ware, dental and medical, and mirrors--recycling has been practiced for many years. In all probability, further improvement in recycling is economically infeasible because of the difficulty in overcoming consumer indifference or the inability to resolve the logistics problems of collection of small quantities of scrap.

For those consuming industries where silver represents a minor materials cost but filfills a vital performance function--electric batteries, electrical

and electronic contacts and conductors, catalysts, and bearings--good recognition of the value of silver recycling now exists as a result of efforts by the recycling industry. Here again, consumer indifference and the logistics of small-volume collection remain the principal obstacles to improved recycling.

Aside from continued education and promotion by the recycling industry and governmental agencies such as the Bureau of Mines, General Service Administration and the Defense Department, there appears to be little that could be suggested as a worthwhile program. Assuming that the 2.2 million ounces loss figure is correct the American economy is wasting nearly $4 million (silver at $1.80 per ounce) but the cost of recovery is likely to be more than the value.

Old Industrial Scrap. The problem with old industrial scrap is that no one has a firm idea of the amount of silver contained in discarded, worn-out, or obsolete industrial equipment. Studies of military and space equipment salvage by the Bureau of Mines suggests that at least 12 million ounces of silver are contained in the materials scrapped annually. Sources in the recycling industry feel that the largest single consumer of silver batteries, the U.S. Navy Department, has done an excellent job of recovering and reclaiming this specific source. Here, the silver content is readily identifiable and sufficiently concentrated to support the economics of recycling. But the silver content of airborne electronic equipment or field communication equipment is much lower than in batteries and complicated by the presence of other nonferrous metals and nonmetallic materials. Segregation solely for the value of the silver probably is uneconomic and the military seems to be the principal institutional agency capable of accumulating the large volumes necessary to make simultaneous recovery of aluminum, copper, gold, silver, and iron economically feasible.

Programs for training military salvage experts in the identification and segregation of precious metals scrap have been underway for several years now and can be credited with some part of the recent increase to over 60 million ounces reported recovered from old scrap. In addition, the recycling industry has supported educational and promotional campaigns aimed at nonmilitary industrial salvage concerns in the hope of increasing recovery and reclamation of silver.

Industrial Wastes and Sweepings. Very little is known about the quantities of industrial wastes and sweepings that are generated or recycled in any given year. Electroplating and polishing wastes from consumer-oriented products and electrical contacts and conductors probably account for the bulk of this potential. The brazing alloys and bearings industries also generate some of this type of material.

The recycling industry feels that only brazing alloys and bearings offer much opportunity to substantially improve recycling on a percentage basis, although the absolute quantities involved will be small. Currently recycling about 3.1 million ounces of silver per year, an increase of about 0.6 million ounces is believed to be possible. The other industries are estimated to be recovering nearly 90 percent of their potential with the losses attributed primarily to operator carelessness, accidental spills, and dilute wash waters. These are difficult to prevent and may be considered to be economically infeasible.

Overall, no specific programs offering logical solutions to the problems of this category of waste were discovered during this study. At best it represents a minor opportunity for increased recycling.

Old Consumer Scrap. The products that are the source of this scrap--plated and sterling tableware and flatware, household decorations, trophies and medals, and dental and medical devices--usually have values associated with them that exceed the value of the silver content. By nature they represent the achievement of affluence or excellence in some specific field and are considered by the owners to be permanently removed from the recycle system. Whether or not they are fulfilling a functional or aesthetic need currently is insufficient justification to consider that they are or are not available for recycling. The quantities actually discarded annually because of damage, obsolescence, replacement, or economic necessity are unknown. However, scrappage is likely to occur on single items more frequently than on large collections of articles and the primary problem for the recycling industry is one of collection. The demise of the itinerate "junk man" removed the initial link in the recycle system that has not been replaced to date.

The response to governmental appeals for scrap silver during World War II demonstrated that some individual owners could be stimulated to search for and turn in unused silver articles. The appeal then was to patriotism. In the absence of a similar motivation, it is doubtful that any appeal to the general public will be effective in increasing the flow of old consumer scrap for recycling.

Photographic Scrap and Waste. Photographic scrap and waste appears to offer the best opportunity to increase substantially the recycling of silver. Theoretically, perhaps as much as 90 percent of the quantity consumed in any given year should be available for recycling within a two or three year period; the balance going into permanent archival record uses. This suggests that the potential for recovery in 1969 was about 37 million ounces, not including any materials in consumers' hands from prior years. In contrast, recovery was estimated to be 20 million ounces total of which an unknown quantity came from the 41 million ounces supplied to consumers in 1969.

Consumer apathy is the underlying cause for failure to recycle photographic silver scrap and waste. Various rationalizations are used to explain the lack of consumer motivation for recycling but the principal one is economic in the context that the cost of collection and processing exceeds the value to be credited to the consumer for the silver recovered. Small industrial, commercial, and medical photographers account for most of the loss. There is virtually no existing mechanism by which they could be reimbursed even if they were willing to bring their scrap and waste to a central collection point because analysis of the silver content of small lots is prohibitively expensive. Eastman Kodak* suggests that the minimum economic level for recycling used film and paper may be 25 pounds per week if the silver content is 0.10 ounces per pound. Even then, several weeks accumulation is desirable in order to minimize the charge per pound for analysis.

<u>Recommended Actions</u>.

For the Environmental Protection Agency (EPA), the only apparent action would be the general promotion of recycling of industrial scraps and wastes emphasizing the advantages of recycling over solid waste disposal. Some selected programs aimed at other governmental agencies, such as the Department of Defense or the National Aeronautic and Space Agency could be implemented to support the existing training and educational programs. Also, EPA might take the lead in sponsoring legislation that would permit governmental agencies other than the

*Anonymous, "Recovering Silver from Photographic Materials", Kodak Publication J-10, Eastman Kodak Company, Rochester, New York, 1969, p. 6.

VA to receive credit for silver recovered from photographic wastes.

The recycling industry obviously will continue its institutional advertising and promotional campaigns for recycling. Concerted or joint action in this area is not recommended. But through NASMI, support might be generated to stimulate the formation of service club collection agencies for photographic wastes.

Several suggestions were advanced by representatives of the recycling industry contacted during this study in this connection. The tenor of them was that service organizations--for example, Rotary International, Boy Scouts of America, church groups, or professional or trade associations--might be persuaded to act as the accumulation center for local photographers and use any funds derived from the sale of the scrap in furthering the programs of the organization. The photographer consumer would derive no economic benefit other than the possible lessening of his contribution in support of the organization's program. Alternatively, a local governmental unit might serve as the accumulator with the revenues received going to defray specified expenses (for example, school supplies) for which the taxpayer would then not be liable. Experience along these lines indicates that interest in such programs is hard to sustain in service organizations because of changing leadership. This should not deter the suggestion that such programs be tried and continued as long as possible, but the stimulus for them will have to involve a philanthropic group willing to invest annually in a venture of questionable durability.

Table 12 summarizes the recommended actions.

TABLE 12. RECOMMENDED ACTIONS, HIGH PRIORITY SILVER RECYCLING PROBLEMS

Title	Prompt Industrial Scrap	Industrial Wastes and Sweepings	Old Industrial Scrap	Old Consumer Scrap	Photographic Scrap
Actions Recommended	Recycling industry should continue promotional efforts for collecting and recycling small volumes of scrap	Recycling industry should continue promotional efforts for collecting, segregating and using small volumes of scrap with low silver content	Recycling industry should continue promotional and training efforts to ensure that scrap with low silver content is collected and recycled	Recycling industry should continue promotional efforts to encourage ultimate consumer to turn in discarded articles	Recycling industry should continue promotional efforts to ensure collection and processing of photographic scrap Legislation should be promoted to allow Governmental installations to receive credit for silver recovered
					credit for silver recovered
By Whom (1)(2)(3)	EPA/NASMI	EPA/NASMI	EPA/NASMI	EPA/NASMI	EPA/NASMI
Specific Steps	1. Continue institutional advertising on value of scrap and probable cost savings by recycling	1. Continue institutional advertising on value of scrap and probable cost savings by recycling	1. Continue institutional advertising on value of scrap and need to recycle to conserve resources 2. Support USBM-DOD training programs for identification and segregation of silver-bearing scrap 3. Support R&D efforts to develop processing of silver-bearing scraps to economic recovery level	1. Continue institutional advertising on value of scrap and need to recycle to conserve resources 2. Support efforts by service clubs to act as collection agencies for consumer scrap	1. Continue institutional advertising on need to conserve resources 2. Sponsor legislation to allow Government installations to use industrial reclamation services and receive credit for silver recovered 3. Support efforts by service clubs to act as collection agencies for photographic wastes

(1) The responsibility for recommended actions shown in this table are based on importance of the action, benefit to the taxpayers, and opportunities for NASMI. They are the best judgments of Battelle.

(2) Recommended actions were distributed between high priority and lower priority based on the evaluation with three criteria.

(3) It is suggested that NASMI continue its leading role in recycling, recognizing that other organizations such as the Bureau of Mines, Department of Commerce, Council of Environmental Quality, HEW Office of Information, and State, Local, and Federal Legislatures must be involved.

Platinum-Group Metals Industry

Characteristics of the Platinum-Group Metals

The metals of the platinum group consist of platinum, palladium, iridium, osmium, rhodium, and ruthenium. These metals are characterized by high density, hardness, and relatively high melting points. Their usefulness in industry and the decorative arts derives from excellent resistance to corrosion at atmospheric conditions or at high temperatures, moderately good electrical conductance coupled with abrasion and corrosion resistance, catalytic activity for a variety of chemical reactions, and maintenance of a bright, tarnish-free appearance.

Usually found in conjunction with other metals -- gold in placer deposits, copper and nickel in the Canadian sulfide deposits, and chromium in the South African Merensky Reef district -- the platinum-group metals are produced as by-products or co-products with all members of the group represented. Platinum and palladium are relatively far more abundant than the other metals of the group, usually representing more than 90 percent of the group's total occurrence. However, the platinum to palladium ratio is subject to rather wide variation -- from 3:1 to 1:3 -- depending on the deposit. Initially isolated as a crude platinum or palladium, the individual metals are separated by chemical methods and purified for use. Commercial platinum has a purity of 99.7 percent but many of its end-use products require 99.9 or 99.99 percent purity. Thermocouples and resistance thermometers need 99.999 percent purity. Palladium and the other group metals usually are refined to 99.9 percent purity. These high levels of purity as well as relative scarcity -- total world production of platinum group metals in 1969 was about 220 tons -- accounts for the high prices these metals command.

The platinum-group metals are used principally in metallic form. Unalloyed platinum and palladium are readily malleable and soft and the other group members are used as alloying agents to improve hardness, abrasion resistance, and stiffness. Also, the various members of the group exhibit slight differences in catalytic activity and, recently, platinum-rhenium combinations have been found to be more effective than platinum alone in petroleum reforming. For the purposes of this discussion, however, the platinum-group metals can be considered to consist of platinum and palladium and their alloys.

<u>Characteristics of the Platinum-Group Metals Industry</u>

<u>Materials Sources</u>. Since 1965, the United States has produced less than 1 percent of the newly mined platinum-group metals output of the world but has consumed 43.4 percent of that output. Thus, the United States is dependent on foreign sources for new metal. However, the uses to which these metals are put are predominantly nonconsumptive -- in the usual context of that term -- and annual supplies available to users include substantial quantities of old metal rerefined by a domestic recycling industry. Table 13 presents world mine production of new metal, details of refinery production of new and secondary metal in the United States, and imports into the United States of refined metal and semimanufactures for the period 1965 through 1969.

<u>Materials Flow</u>. The basic source of platinum-group metals that are used by consumers in the United States has been imports for many years. Recovery of the metals from domestic mining operations -- some Alaskan placer deposits and selected gold and silver by-product separations -- has supplied negligible quantities of new metal in comparison to annual needs. For the 1965 through 1969 period, domestic mining output averaged slightly over 27,000 troy ounces annually while imports of refined metals for consumption averaged 1,250,000

TABLE 13. SOURCES OF PLATINUM-GROUP METALS, 1965-1969
(in thousands of troy ounces)

	1965	1966	1967	1968	1969	1965-1969 Annual Average
Mine production of New metal						
United States	35	51	16	15	22	28
Canada	463	396	403	486	266	403
Union of South Africa	754	783	828	864	964	839
U.S.S.R.(1)	1,700	1,800	1,900	2,000	2,100	1,900
Other countries	17	9	7	29	35	19
World total	2,969	3,039	3,154	3,394	3,387	3,189
United States Refinery production						
New metal	62	74	30	12	18	39
Secondary metal(2)	109	103	366	329	372	256
Toll refining	1,194	1,750	2,014	2,337	2,246	1,908
Total	1,365	1,927	2,410	2,678	2,636	2,203
United States imports for consumption						
Unrefined materials	53	87	42	120	195	99
Refined metals	1,115	1,265	1,177	1,654	1,031	1,248
Total	1,168	1,352	1,219	1,774	1,226	1,348
Of which from United Kingdom	311	432	500	872	608	545
U.S.S.R.	505	468	208	511	290	396
Canada	199	164	211	127	75	155

Source: "Minerals Yearbooks", U. S. Bureau of Mines
Note: Details may not add to totals because of independent rounding to nearest thousand ounces
(1) Estimated by U. S. Bureau of Mines.
(2) From purchased sweepings, waste and scrap.

ounces. Since preparations for World War II began in 1940 in this country, the United States has produced less than 800,000 ounces from domestic sources but has imported over 21,250,000 ounces, against which exports have been about 2,680,000 ounces.

Theoretically, the current inventory of the platinum-group metals in the United States is about 20,000,000 ounces, assuming that none has been lost in products or in recycling. Undoubtedly, products containing platinum-group metals (jewelry, dental and medical items, electrical and electronic equipment) have been exported from the United States or shot into space and losses due to accidents and reprocessing are inevitable. No reliable data regarding the current inventory of readily reprocessable platinum-group metals were discovered in the course of this study, but Battelle estimates that it is between 6,000,000 and 8,000,000 ounces. It is held principally by companies that produce chemicals, the petroleum refiners, manufacturers of glass, and the telephone companies. But the important point is that this inventory provides more platinum-group metals for reclaimation annually than the quantity of new metal added to that inventory.

Based on the statistics for 1965 through 1969, the approximate annual flow of platinum-group metals in the United States is presented in Figure 3. In brief, annual refinery production of new metal averages about 40,000 ounces, purchased scrap and waste averages nearly 260,000 of which 190,000 ounces are generated by consumers and 70,000 ounces are imported, and toll refining of spent catalysts and obsolete equipment averages 1,900,000 ounces, a refinery throughput of about 2,200,000 ounces. In addition, about 1,300,000 ounces of refined metals are imported to make a total of 3,500,000 ounces of refined metal or semimanufactures available to consumers. Approximately, 3,000,000

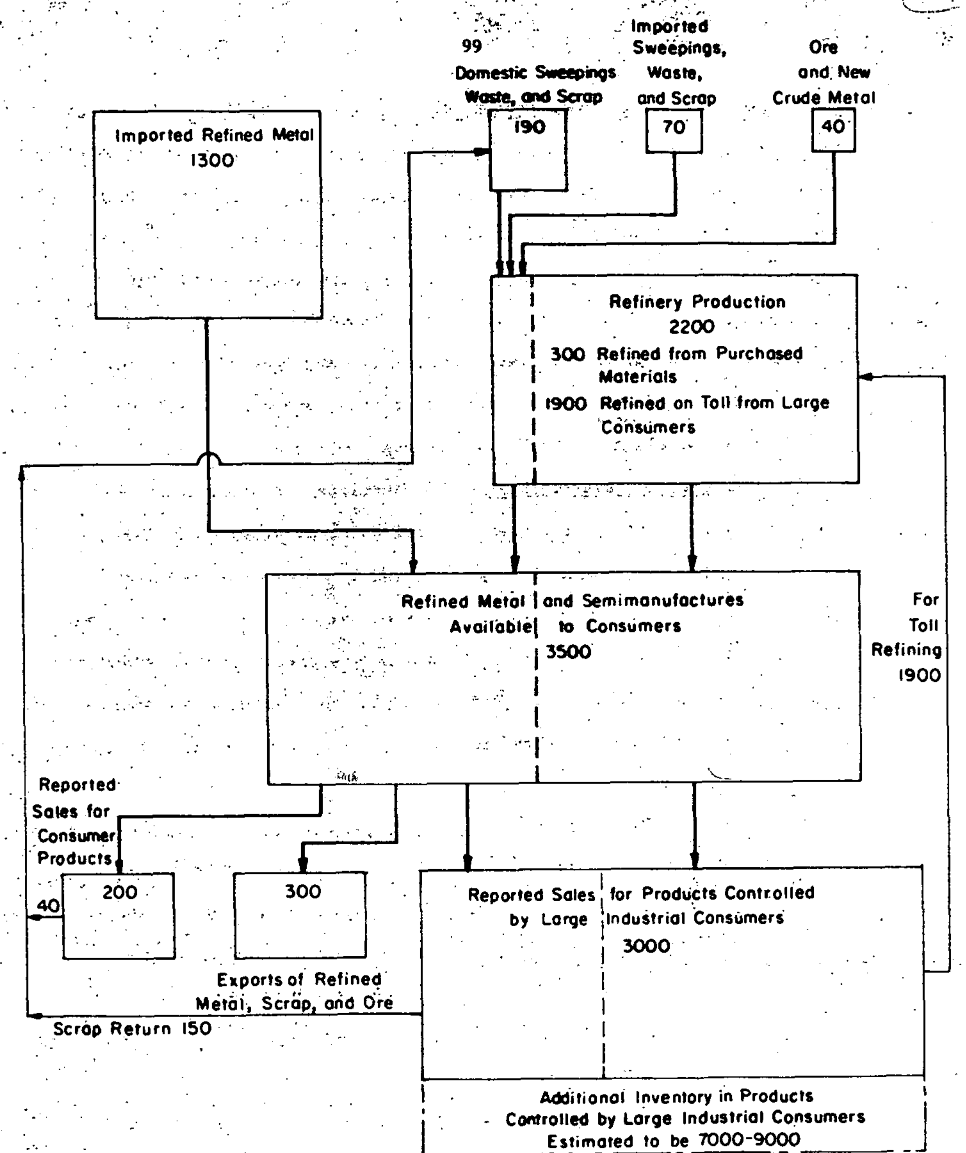


FIGURE 3. APPROXIMATE ANNUAL FLOW OF PLATINUM-GROUP METALS, UNITED STATES (Based on 1965-1969 Data, in thousands of troy ounces)

Source: Battelle's Columbus Laboratories ounces of this supply is used by the chemical, petroleum, glass, and electrical companies with the bulk of it remaining under their control because of the nature of the products produced. Some 300,000 ounces gets exported from the country in the form of crude metals, refined metals, semimanufactured metal forms, and waste and scraps. The balance of 200,000 ounces disappears (less a scrap recovery of about 40,000 ounces) into dental and medical devices, jewelry, and miscellaneous industrial products usually containing minor quantities of the group metals. These products are sold and represent an addition to the unreported inventory of metals held by ultimate consumers.

Platinum-Group Metals Suppliers. The suppliers of platinum group metals fall into two distinct categories: those that have access to primary sources of the metals, and those that depend primarily on secondary sources. Currently, there are between 30 and 40 companies in the United States that claim to be able to refine these metals. Four of these are affiliated or have working arrangements with companies that mine ores containing the metals. The remainder process scraps and waste of all the precious metals including the separation and recovery of the platinum group metals.

Matthey Bishop, Inc., Engelhard Minerals and Chemicals Corporation, Amax Copper, Inc., and American Smelting and Refining Company (ASARCO) have access to primary sources of the metals.

Matthey Bishop is an affiliate of Johnson, Matthey & Company, the English organization that refines the output of the Rustenberg platinum mine in South Africa. Its refining operation is supplemented by metal working facilities to produce a full range of pure or alloyed metals in grain, strip, tube, or wire form as well as chemical compounds for plating or catalysts. Imports of refined metals from the parent company for industrial uses are channelled through Matthey Bishop but imports for the jewelry trade are handled by the parent

company directly. The Rustenberg mine is the largest producer of platinum in the Free World.

The Engelhard refinery handles crude primary platinum and palladium and all forms of secondary materials. It is supplemented by metal working facilities and special chemical facilities to produce a full range of pure and alloyed metals, plating solutions, and catalysts. This refinery handles a part of the crude primary platinum recovered by International Nickel Company from their Canadian nickel-copper operations. In addition, Engelhard imports refined metals for conversion to semimanufactured products -- strip, tubing, or wire.

Amax and ASARCO recover the platinum group metals in the course of their refining of both primary and secondary copper, gold, and silver. Both are capable of handling virtually any form of ore, concentrate, scrap, waste, or sweepings. Both tend to specialize in metal recovery, largely as the pure metals.

Among the refiners dealing primarily with secondary materials, the more important companies include (listed alphabetically): Joseph Behr and Sons; Handy and Harman; Martin Metals; Sel-Rex Corporation; United Refining and Smelting Company; and Wildberg Brothers Smelting and Refining Company.

Markets for the Platinum Group Metals

The platinum group metals are fabricated into specialized processing equipment for the chemical and glass industries, into wire and formed contact points for the electrical and electronics industries, into cast and built up support parts for the dental and medical professions, and into cast and stamped findings for the jewelry manufacturing industry. Salts of the various metals also are made in the preparation of catalysts for the chemical and petroleum refining industries, as well as for plating baths that are used by the electrical and jewelry manufacturing industries.

Actual consumption of the platinum group metals is difficult to assess. Sales to consumers are reported annually by the refiners and metal trading firms to the U. S. Bureau of Mines but there is evidence that, at times, some purchased materials go into consumers' inventories rather than being utilized immediately. Further, as shown in the flow diagram (Figure 3, page 99), toll refining of consumer-owned materials provides additional supplies for which no use classification is available. Moreover, the reported data for refinery production, imports for consumption, exports, and changes in suppliers' stocks do not balance statistically with reported sales to consumers. Aside from the problems of accounting for net changes in consumers' inventory stocks (for which no data are reported), the principal obstacles to a statistical balance appear to lie (1) in the amount of foreign crude metals absorbed by consumers, and (2) in the distribution of the exports of ores, scrap, and refined metals. The best approximation of consumption apparently is the reported sales to consumers, which, as shown in Table 14, averaged 1,380,000 ounces annually in the 1965-1969 period.

The electrical and electronics industries took 38.8 percent of reported sales, an average of 535,000 ounces per year. The chemicals industry purchased 28.2 percent of the available metals, an average of 390,000 ounces per year. These two plus the petroleum and glass industries, accounted for 84.4 percent of sales, and probably represent at least an equivalent percentage of the material refined annually on toll.

Brief discussions of the individual consuming markets follow.

TABLE 14. REPORTED SALES OF PLATINUM GROUP METALS TO CONSUMING INDUSTRIES, 1965-1969

(in thousands of troy ounces)

Consuming Industry	1965	1966	1967	1968	1969	1965-1969 Annual Average (000 ounces)(1)	1965-1969 Annual Average (Percentage)
Chemicals	308	435	380	406	424	390	28.2
Petroleum	119	233	250	185	64	170	12.3
Glass	32	126	57	55	78	70	5.1
Electrical and electronic	551	661	440	461	558	535	38.8
Dental and medical	77	94	82	88	76	80	5.8
Jewelry and decorative	65	85	65	72	68	70	5.1
Miscellaneous	35	42	61	101	89	65	4.7
Total	1,187	1,676	1,334	1,368	1,357	1,380	100.0

Source: "Minerals Yearbooks", U. S. Bureau of Mines

Note: Details may not add to totals because of independent rounding to the nearest thousand ounces.

(1) The 1965-1969 averages have been rounded to the nearest 5,000 ounces for convenience.

<u>Chemical Industry Markets</u>. The chemical industry uses the platinum group metals directly as catalysts and as specialized equipment. Platinum laboratory ware, especially ignition crucibles, has long been recognized as an outstanding example of the high-temperature corrosion resistance of these metals. These same properties are important also in applications such as spinnerettes for artificial fibers, anodes for electrochemical processing, rupture discs for processing operations, and highly resistant processing equipment. Products such as these are fabricated from sheet and strip platinum with minor additions of rhodium, ruthenium, or iridium for improved abrasion resistance or high temperature performance.

In the catalysis area, platinum and palladium are used to promote oxidation reactions (ammonia to nitric acid), and hydrogenation or dehydrogenation reactions (for vegetable oils and specialty organic chemicals). A platinum-rhodium alloy is fabricated into wire gauze for use in the production of nitric acid, while palladium has been gaining favor as the catalyst for hydrogenation reactions.

The larger chemical companies try to retain control of their equipment and catalysts containing the platinum group metals by returning their worn out or damaged equipment and spent catalysts to the refiners for reprocessing on a toll basis. Table 15 presents sales of the individual platinum group metals to the chemical industry for the 1965-1969 period. Battelle estimates that the chemical industry has between 1,000,000 and 2,000,000 ounces of platinum group metals tied up in equipment and catalysts, and that about 250,000 to 300,000 ounces of the annual sales to the industry are used to maintain that inventory. Annual additions to the inventory probably average less than 100,000 ounces.

TABLE 15. REPORTED SALES OF PLATINUM GROUP METALS TO THE CHEMICAL INDUSTRY, 1965-1969

(In thousands of troy ounces)

Metal	1965	1966	1967	1968	1969	1965-1969 Annual Average
Platinum	132	191	159	158	175	163
Palladium	157	222	192	228	215	203
Iridium	3	4	5	2	6	4
Osmium	1	1	1	1	1	1
Rhodium	12	14	18	15	18	15
Ruthenium	3	3	5	3	9	5
Total	308	435	380	406	424	391

Source: "Minerals Yearbooks", U. S. Bureau of Mines

Note: Details may not add to totals because of independent rounding to the nearest thousand ounces.

Petroleum Industry Markets. The petroleum industry uses the platinum group metals primarily as catalysts based on platinum. A recent minor use for palladium is developing as a diffusion membrane for the purification of hydrogen.

Platinum deposited on inert substrates is used for reforming operations in petroleum refining, usually involving hydrogenation. The products of this operation are blended into gasoline where they increase the octane rating. Unalloyed platinum still accounts for the bulk of this application, but starting in 1968 a platinum-rhenium alloy was commercialized on the basis of improved yields of aromatic reformate compounds and significantly longer catalyst life. Both factors will contribute to a decrease in the amount of platinum needed to produce a given quantity of reformate. However, demand for platinum reforming catalysts could increase by a factor of 15 if the petroleum refining industry is forced to remove lead antiknock compounds from gasoline to comply with anti-pollution regulations.

Crude hydrogen, available in petroleum refineries from several catalyzed reactions, can be purified by diffusing the hydrogen through thin membranes of palladium metal. This is likely to remain a rather small market for palladium since the membranes are quite thin and last for a long time before requiring replacement.

Virtually all the catalysts used by the petroleum industry are reprocessed by the refiners on a toll basis. The high level of sales in 1966 and 1967, as shown in Table 16, is believed to reflect a deliberate buildup of inventory by the petroleum companies, who would have purchased more in 1968 and 1969 if it had been available. Battelle estimates that the petroleum industry has between 2,000,000 and 2,500,000 ounces of platinum tied up in catalysts, both installed and held as replacement charges.

TABLE 16. REPORTED SALES OF PLATINUM GROUP METALS TO THE PETROLEUM INDUSTRY, 1965-1969

(in thousands of troy ounces)

Metal	1965	1966	1967	1968	1969	1965-1969 Annual Average
Platinum	81	202	246	161	59	150
Palladium	37	29	4	23	1	19
Iridium	**	1	1	1	1	1
Osmium	**	-	-	-	-	**
Rhodium	**	1	**	2	2	1
Ruthenium	-	**	**	**	**	**
Total	119	233	251	64	64	170

Source: "Minerals Yearbooks", U. S. Bureau of Mines.

Notes: Details may not add to totals because of independent rounding to the nearest thousand ounces.

** Less than 500 ounces

- None

Glass Industry Markets. The glass industry uses platinum and its alloys in sheet and tubing forms for its high temperature corrosion resistance.

Optical glasses and laser glass formulations are prepared in platinum-lined crucibles to assure the chemical composition of the products. Glass melting furnaces for selected formulations -- borosilicate glasses, textile grade fiber glass, and similar compositions -- may have platinum-lined stirring equipment as well as platinum sheet linings at the liquid level line in addition to platinum thermocouple wells. For fiber glass, forehearths may have platinum linings on the refractories and the fiber forming bushings are fabricated from a platinum-rhodium alloy. Various levels of rhodium have been tried in an attempt to extend the life of the bushings, starting with a 90 pt-10 Rh alloy and ranging up to 70 Pt-30 Rh. Rhodium increases the abrasion resistance but also makes the material more difficult to work in fabrication of the bushings. An 80 Pt-20 Rh alloy appears to be a reasonable compromise between performance and workability.

The glass industry tends to retain ownership of the platinum it has and uses and the high level of purchases in 1966 as shown in Table 17 is believed to have added to the inventory held for future use. The five-year average purchase of 70,000 ounces probably represents about 50,000 ounces for maintenance of an inventory estimated at 500,000 to 750,000 ounces plus about 20,000 ounces annually for additional new equipment and fittings.

Electrical and Electronics Industry Markets. The electrical and electronics industry uses the platinum group metals as contact points in relays, magnetos, thermostats, voltage regulators, and control devices, as thermocouple wire, as sparkplug electrodes, as temperature or current limiting fuses, as protective coatings on resistance heating elements, in metal to glass seals,

TABLE 17. REPORTED SALES OF PLATINUM GROUP METALS TO THE GLASS INDUSTRY, 1965-1969

(In thousands of troy ounces)

Metal	1965	1966	1967	1968	1969	1965-1969 Annual Average
Platinum	20	91	45	48	63	53
Palladium	1	1	::	::	4	1
Iridium	::	::	::	::	::	::
Osmium	-	-	-	-	-	-
Rhodium	10	34	11	7	11	15
Ruthenium	-	-	::	-	-	-
Total	32	126	57	55	78	70

Source: "Minerals Yearbooks", U. S. Bureau of Mines

Notes: Details may not add to totals because of independent rounding to the nearest thousand ounces

:: Less than 500 ounces

\- None

and in sophisticated electronic circuitry. Table 18 presents reported sales to these markets for 1965-1969. Strip and wire mill products probably are the most commonly used forms, although plating of contact parts and resistance heating wire is important and paste formulations are made for seals and electronic circuitry.

Since the introduction of the dial telephone in the late 1940's, the communications industry has been the major consumer of the palladium supplied to the electrical and electronic industry. Palladium contact points in central exchange switching relays assure reliability of current flow for trouble-free operation. Expansion of dial telephone systems continued through 1969 but further increases in the annual sales of palladium to this segment of the industry appear unlikely because of the growing popularity of touch-tone dialing for which the central exchange depends on solid-state switching devices rather than relays. Metals Week (volume 42, No. 4, January 25, 1971, page 25) recently suggested that this market for palladium may disappear within a few years while the scrapping of relayed central exchanges will throw large quantities of secondary palladium on the shrinking market.

Platinum (frequently alloyed) is favored for spark plug electrodes, thermocouple wire, magnetos, voltage regulators, resistance heating elements, relays for control devices, and electronics circuitry. Pastes based on either platinum or palladium are used for glass to metal seals for electronic vacuum tubes and for printed circuits and thick film devices.

Central exchange equipment usually remains under the ownership of the telephone companies who recycle manufacturing scrap and obsolete contact points to a refiner for processing on toll. The quantity of palladium tied up in

TABLE 18. REPORTED SALES OF PLATINUM GROUP METALS TO THE ELECTRICAL AND ELECTRONICS INDUSTRY, 1965-1969

(In thousands of troy ounces)

Metal	1965	1966	1967	1968	1969	1965-1969 Annual Average
Platinum	107	117	100	117	113	111
Palladium	430	532	325	329	430	409
Iridium	3	2	3	3	2	3
Osmium	"	"	"	"	"	"
Rhodium	8	9	12	10	11	10
Ruthenium	3	1	1	2	2	2
Total	551	661	440	461	558	534

Source: "Minerals Yearbooks", U. S. Bureau of Mines

Notes: Details may not add to totals because of independent rounding to the nearest thousand ounces

" Less than 500 ounces

— None

central exchange equipment is unknown but could be between 3,000,000 and 5,000,000 ounces. The platinum-containing products tend to be sold to industrial, commercial, or military users where the probability of effective scrap recycling is lower.

Other Markets. Dental and medical uses include cast metals for special dental fillings and caps from platinum-palladium-gold-silver-copper alloys, bridges, tooth pins, anchors, cone pins, plates, hinges, and other prosthetic devices from strip and wire forms of several alloy combinations of platinum group metals with gold and silver, and platinum or palladium wire reinforcement for dental porcelains. Platinum electrodes are incorporated into a heart pacing device designed for implanting within the body for certain types of heart failure. Palladium usually accounts for two thirds of these applications, as illustrated in Table 19.

The jewelry and decorative industries take platinum and palladium alloys in grain, strip, and wire forms for cast and fabricated mountings for precious stones and for complete rings, pins, pendents, bracelets, and necklaces. Electroplated rhodium provides a bright, tarnish-free finish for jewelry findings and high quality reflectors. Palladium brazing compounds with gold are used to assemble jewelry and other art objects.

Among the miscellaneous uses for the platinum group metals, galvanic corrosion protection systems, platinum-edged razor blades, antipollution devices, and brazing alloys deserve mention. Platinum-coated electrodes provide the nonfouling contact for introduction of the low-voltage, low-amperage current that can protect metallic boat hulls from corrosion in salt water or dissimilar metal parts in industrial equipment exposed to conducting liquids. A number of such systems have been designed and installed on large ocean boats and floating dry docks, as well as in the condenser water headers of large industrial boilers.

TABLE 19. REPORTED SALES OF PLATINUM GROUP METALS TO MINOR CONSUMING INDUSTRIES, 1965-1969

(in thousands of troy ounces)

Metal	1965	1966	1967	1968	1969	1965-1969 Annual Averages
Dental and Medical						
Platinum	27	24	25	25	22	25
Palladium	50	67	56	62	52	57
Iridium	"'	1	"'	"'	1	"'
Osmium	"'	"'	1	1	1	"'
Rhodium	"'	"'	"'	"'	"'	"'
Ruthenium	"'	1	"'	"'	"'	"'
Total	77	94	82	88	76	84
Jewelry and Decorative						
Platinum	35	41	33	40	36	37
Palladium	18	32	19	18	22	22
Iridium	3	3	3	3	3	3
Osmium	-	-	-	"'	-	"'
Rhodium	7	9	9	7	6	8
Ruthenium	1	"'	1	4	2	2
Total	65	85	65	72	68	71
Miscellaneous						
Platinum	10	25	26	31	47	28
Palladium	23	12	26	62	35	32
Iridium	"'	1	1	1	1	1
Osmium	"'	"'	"'	"'	"'	"'
Rhodium	"'	2	5	6	2	3
Ruthenium	1	2	2	1	4	2
Total	35	42	61	101	89	66

Source: "Minerals Yearbooks", U. S. Bureau of Mines.

Notes: Details may not add to totals because of independent rounding to the nearest thousand ounces.

"' Less than 500 ounces

The latter use significantly reduces the clean out needs and maintenance shutdowns resulting from condenser tube fouling and corrosion-induced failure.

A platinum-chromium alloy applied to stainless steel razor blades is claimed to provide the most durable edge ever achieved. The alloy, principally platinum, is applied by vapor deposition techniques only along the edge of the blades in quite thin films. Although one of the more "exotic" uses for platinum, this application consumes quite modest quantities of the metal.

Platinum is one of the catalytic agents being used in devices and systems now being offered commercially or under test to convert obnoxious and poisonous effluents to harmless gases. Systems based on platinum have been installed on a few plants to decolorize the tail gases from nitric acid production facilities. Somewhat similar systems are under test on exhaust stacks for spray painting booths to convert organic solvents to carbon dioxide and water, eliminating an odorous nuisance. Platinum also is being tested as a catalyst for cleaning up the exhaust of internal combustion engines, especially for automobiles. Here, the catalyst promotes oxidation of the unburned hydrocarbons, carbon monoxide to carbon dioxide, and nitrous oxides to nontoxic nitric oxides. To date, platinum-based catalyst systems rapidly lose efficiency because of poisoning from the lead residues of antiknock compounds. Further, the automotive industry has considered them to be too expensive for use on current models of cars. Both objections appear to be well founded. However, research is being continued, and the probability of platinum based exhaust converters for automobiles is undeterminated today.

Brazing alloys based on palladium or platinum are finding increasing use in high temperature situations. They are particularly suitable for joining thin-walled tubing to headers, for example in rocket engine cooling systems.

However, the experience gained in this application is now being applied in less severe service where extended service life is desirable, as in nuclear reactor installations.

Platinum Group Metal Prices

The platinum group metals are relatively expensive and prices are sensitive to the supply-demand balance. Moreover, a two-tier pricing system has been in effect for many years in the Free World. Free World sources for platinum have been unable to supply all the metal desired by consumers for many years until 1970 but the major producers have followed conservative pricing policies consistently for dealing with large established customers. Metals reaching Free World markets from Russia and small quantities supplied by minor Free World producers have been marketed by brokers at prices variably above the producer-quoted prices depending on the severity of the unbalance of supply and demand. This is usually referred to as the "dealer price".

In 1965, the platinum group metals were priced as follows, in dollars per troy ounce:

Metal	Producer Quotations	Dealer Quotations
Platinum	$97 to $100	$135 to $140
Palladium	$32 to $35	-
Iridium	$100 to 105	-
Osmium	$230 to $250	-
Rhodium	$182 to $185	-
Ruthenium	$55 to $60	-

By the end of 1965, Free World supplies were definitely lagging behind demand and continued to do so until about the second quarter of 1970. During the intervening period, the producer price for platinum moved upward gradually to a high of $130 to $135 per ounce late in 1969 while the dealer price peaked at about $300 per ounce in mid 1968. By the end of 1969, the premium charged by dealers had fallen from $160 per ounce to about $47 per ounce with the dealer quote at $177. In 1970, the premium disappeared entirely and although producers maintained the $130 to $135 quotation they were conceding discounts of $10 to $15 per ounce.

Prices of palladium, consistently in an excess supply situation, remained relatively stable over the 1965-1969 period. Slight increases in 1966, 1967, and 1968 raised the producer price to $45 to $47 per ounce by mid 1968, returning to $37 to $39 near the end of 1969. Dealer prices reflected a premium that peaked at $12 per ounce when the dealer quotation reached $56 in mid March 1968. By the end of 1969, dealer quotations were below producer quotes at $35.50 to $36 per ounce.

For the minor metals, prices increased irregularly from the 1965 quotations and then declined toward the end of 1969. Iridium advanced to a producer price of $185 to $190 during 1967, nearly double the 1965 opening of $100, then retreated to $160 to $162. Osmium jumped to a producer quote of $300 to $450 in 1967 and 1968, falling back to the $200 to $250 level in late 1969. Rhodium rose from $185 in 1965 to the range of $245 to $250 by late 1967 but was back down to $215 to $220 in 1969. Ruthenium maintained the producer price of $55 to $60 until 1969 when a drop to about $45 was noted.

Prices for platinum-group metals scrap are not listed by any of the metal trade journals. However, the usual practice of scrap purchasers is to determine the specific metallic content of the scrap, deduct probable reprocessing losses, and pay for the probable recovered metals at prevailing new metal prices less the processing charge. Depending on the form and content of metal, processing charges may range from $5 to $15 per ounce.

Market Outlook

Future markets for the platinum group metals present a series of enigmas. Certain applications for platinum appear to have good growth prospects without serious threats of replacement or discontinuance. This situation would be applicable to hydrogenation catalysts and processing and laboratory equipment in the chemicals industry, to glass industry uses, to electrical industry uses for platinum, and to the minor markets for all the metals.

Platinum-based catalysts for nitric acid are threatened by the recent commercialization of nonplatinum catalysts. At best, the growth of platinum-using systems will be slowed from the rapid expansion of the 1963-1968 period; at worst, the market for platinum catalysts in nitric acid could disappear by 1980. Most probable is a modest growth based on continued use of platinum catalysts but more efficient utilization of the metal charged to the reactor.

In the petroleum industry, the service life of reforming catalysts is being extended by the platinum-rhenium alloys which require less platinum per barrel of throughput. Reforming requirements will continue the 10 percent per year growth pattern of the past ten years if lead is not legislated out of gasoline. Under this assumption, platinum demand in petroleum will probably remain above 100,000 ounces per year. If, however, lead is removed from gasoline, platinum demand for reforming catalysts could skyrocket to more than 2,250,000 ounces. New plants would have to be built to handle the increased reforming load and it is difficult to visualize this occurring in less than a 5-year period after the decision is reached. Still, the potential new demand of 700,000 ounces per year is believed by some industry observers to have been the motivation for the recent expansion in production capacity for platinum in South Africa. Based on the assumptions that lead will be phased out of gasoline gradually in the 1975 to 1985 period and that further improvements in reforming catalysts can be achieved. Battelle believes that the reforming catalyst demand will not create a shortage of platinum in the foreseeable future.

Palladium demand in the electrical and electronic industry, as mentioned earlier, appears to be headed toward lower annual levels with the continuing conversion to touch-tone dialing. The currently installed switching equipment based on palladium contact relays eventually will be scrapped, but reclaimation of the palladium may well depend on the development of new markets for this metal that cannot be visualized at this time. Other markets for palladium appear to have some growth potential.

Overall annual sales of the platinum group metals could continue at the 1,000,000 to 1,250,000 ounce level for several years, perhaps beyond 1975, but with increasing emphasis on platinum at the expense of palladium.

Characteristics of the Platinum Group Metals Recycling Industry

Materials Sources. The source materials for secondary platinum group metals consist of scrap, wastes, and sweepings. These materials originate from the processing of the metals into usable parts for industrial, commercial, or consumer products or from the dismantling of damaged, worn out, or obsolete equipment and the discarding of consumer items containing the metals. These sources may be classified as "prompt industrial scrap" and "old scrap" for convenience in following the flow of the platinum group metals through the recycling industry.

Prompt industrial scrap includes the waste material generated in the course of the fabrication of equipment or the manufacture of component parts for inclusion in industrial, commercial, or consumer products. It originates in the factories and shops of consumers of the platinum group metals and thus

excludes the "in-house" scrap generated and recycled by the refining industry. It consists primarily of metallic wastes resulting from the conversion of sheet, strip, tubing, wire, or grains to fabricated parts by metal working processes including casting. In general, it is readily segregated from other metallic and nonmetallic scraps and contains the same percentage of platinum group metal content as the material purchased. Depending on the amount of platinum group metals handled, it may be returned to the refiner for reprocessing on toll or sold to the refiner as scrap. Examples of prompt industrial scrap include the trimmings from stamping and blanking operations; sprues, gates, and risers from casting operations; trimmings from sheet, tubing, and wire in fabrication of equipment or assemblies; and reject subcomponents or parts that cannot be reworked.

Old scrap consists primarily of consumer articles that have been discarded, industrial equipment that is damaged or worn out, parts salvaged from obsolete commercial, industrial, or military equipment, and spent catalysts from the chemical or petroleum industries. It also includes wastes such as spent plating solutions, polishing compounds containing metallic particles, and floor sweepings from shops where the metals are processed. The platinum group metals content of old scrap ranges from nearly 100 percent to less than 1 percent depending on the source and extent of segregation effected by the collector. It may represent part of the processing loss incurred in treating metals purchased in the current year or the return to the recycling system of products sold many years in the past. Examples of old scrap include discarded jewelry; spent catalysts; worn out aircraft sparkplugs; damaged laboratory or production equipment; contact points from obsolete switching equipment or control devices; polishing wastes; floor sweepings; even worn out wooden floors.

Materials Flow. The platinum group metals are returned to the recycling industry by a variety of routes. A large percentage of the prompt industrial scrap follows the relatively short route of generator to dealer-collector. The dealer-collector may also be the refiner or he may be a broker handling several types of metallic scrap. In either event, the scrap ultimately reaches a refiner for reprocessing to saleable forms of the pure and alloyed metals and chemical compounds.

A substantial share of the old scrap appears also to follow the route of generator to dealer-collector, especially from sources in the chemical, petroleum, glass, and electrical and electronics industries. This is evidenced by the quantity of material that is rerefined on a toll basis for the consumer-generator. However, old scrap is sold by certain generators to dealers, dealer-collectors, and industrial generators for entry into the recycling system. This may be illustrated by the example of platinum-or palladium-containing jewelry that is turned in to a manufacturing jeweler at the time of a new purchase. Accumulations over a period of time at this level may be sold to dealers having no processing facilities as a part of their purchases of all the precious metals. In turn, they sell the scrap jewelry to refiners for reprocessing. Similarly, generators of wastes that have a low content of platinum group metals -- for example, used polishing compounds, spent plating baths, and floor sweepings -- are more likely to sell these materials to dealer-collectors than to try to retain ownership by toll refining.

The available data on recycled platinum group metals are presented in Table 20. From information received from refiners in the course of this study, Battelle estimates that the reported recovery represents about 98 percent of the material received by the refiners and probably represents about 95 percent of the material available for recycling. In other words, prompt

TABLE 20. REFINERY OUTPUT OF RECYCLED PLATINUM GROUP METALS, 1965-1969
(in thousands of troy ounces)

Item	1965	1966(1)	1967	1968	1969	1965-1969 Annual Averages
Refinery production						
From purchased scrap	109	103	366	329	372	256
On toll	1,194	1,750	2,014	2,337	2,246	1,908
Total	1,303	1,853	2,380	2,666	2,618	2,164
Distribution by metals						
Platinum	996	1,060	1,347	1,301	1,335	1,208
Palladium	253	705	925	1,250	1,173	861
Other group metals	54	88	108	115	110	95

Source: "Minerals Yearbooks", U. S. Bureau of Mines

Notes: (1) Toll refining in 1966 estimated by Battelle Columbus Laboratories from 1967-1966 comparisons prepared by the U. S. Bureau of Mines.

industrial scrap and obsolete products discarded had an annual average platinum group metals content of perhaps 2,300,000 ounces, of which 2,200,000 ounces were recycled with a recovery of about 2,160,000 ounces.

From the reported data relating to recovery of the various metals and opinions expressed by dealer-collectors and refiners, Battelle further estimates that prompt industrial scrap accounted for approximately 600,000 ounces of the 2,200,000 ounces actually recycled, heavily weighted in favor of palladium used by the electrical industry. By inference, this indicates that much of the platinum was recovered from old scrap, probably spent catalysts used by the chemical and petroleum industries. Table 21 presents Battelle's rationalization of the flow of platinum group metals for an average year in the 1965-1969 period. It should be noted that the amount of purchased scrap recycled in the last three years of the period increased substantially during the height of the shortage of supplies. This suggests that recovery of the platinum group metals from old scrap represents an opportunity to improve the supply situation if suitable economic incentives are provided.

The Recycling Industry. The recycling industry for the platinum group metals consists of at least 49 companies that refine the metals and an unknown number of collectors and brokers that serve to link the generators of scrap to the refiners. The extensive survey for this study identified 193 organizations (out of 578 responses) that handle all the precious metals. The responses suggested that 112 of these have no refining facilities while 73 claim to refine one or more of the precious metals, including 49 that refine the platinum group metals.

TABLE 21. RATIONALIZED FLOW OF PLATINUM GROUP METALS, ANNUAL AVERAGES BASED ON 1965-1969

(in thousands of troy ounces)

Industry	Reported Sales to Consumers	Toll Refined for Consumers	Available to Consumers	Incorporated in Usable Products	Prompt Industrial Scrap	Old Scrap Recycled	Total Scrap Recycled	Purchased Scrap
Chemicals	390	425	815	785	30	425	455	30
Petroleum	170	550	720	715	5	555	560	10
Glass	70	60	130	115	15	60	75	15
Electrical and Electronics	535	850	1,386	870	515	420	935	85
Dental and Medical	80	5	85	75	10	10	20	15
Jewelry and Decorative	70	5	75	60	15	10	25	20
Miscellaneous	65	5	70	60	10	70(1)	80	75(1)
Total	1,380	1,900	3,280	2,680	600	1,550	2,150	250

Source: Estimated by Battelle Columbus Laboratories

(1) Includes 70,000 ounces of imported scrap, waste, and sweepings, unassignable by industrial generation source.

Dealer-collectors who also refine form the backbone of the recycling industry. They service the major industrial consumers, many on a toll refining basis, and purchase crude metals from collector-processors that perform a segregation function. There are between 12 and 15 established refiners including the companies listed in the section dealing with platinum group metals suppliers. Matthey Bishop and Engelhard are the largest integrated refiners, probably accounting for 75 percent of refined metals capacity. The top 15 may process as much as 90 percent of the total.

In terms of the quantity of platinum handled, the collector-processors dealing with electrical and electronic scrap are the most important. They supplement the integrated dealer-collectors on the collection side and sell to the refiners. Numerically, the largest group of collector-processors is the manufacturing jewelers, especially the small shops associated with retail outlets. The discarded jewelry they purchase or take in trade is readily segregated and usually melted down into gold, silver, or platinum crude ingots. These are returned, frequently through brokers, to the refiners. Although the volume of such activities is not large--estimated by Battelle to be about 10,000 ounces per year--it is a fairly steady source of recycle material.

Demand/Supply Analysis

In spite of the extensive recycling that occurs regularly with the platinum group metals, the supply of secondary material falls far short of total demand in the United States. As measured by reported sales to consumer, demand has increased steadily since 1940 with most of the new supply being furnished by imports. There is a distinct possibility that this pattern will be reversed with respect to palladium in the next five years whereby secondary sources (largely telephone switching equipment) will be able to supply more than enough material to satisfy continuing needs in the chemical, electrical, and consumer-goods markets. However, increasing demands for platinum will continue to depend on imports of foreign metal although secondary refining also will expand to handle toll reprocessing of industrial materials.

Obstacles and Problems that Reduce Recycling of Platinum Group Metals

Table 22 presents the problems identified and analyses discussed in succeeding paragraphs.

Prompt Industrial Scrap

The prices of the platinum group metals always have encouraged their recycling when their functionality has been lost. The relative sizes of the toll reprocessing and secondary recovery activities indicate the awareness of industry to the value in platinum group metals scrap. Whereas about 250,000 ounces of secondary metals are produced annually at the present time, 1,900,000 ounces are processed without change in ownership of the metals. To a considerable extent, this relationship is possible because the principal applications for the metals lie in industrial products that never leave the control of the primary industrial consumer. Catalysts for the chemical and petroleum industries, and contact points for telephone switching relays illustrate this situation. The products used by these industries are expected to fulfill an important function and when that function no longer is efficiently performed the products are returned for reworking or reactivation. This is not to say that the ultimate in recycling has been achieved. Accidental spills, careless handling of materials, fires, hurricanes, or other disasters can result in disappearance of the platinum group metals. Although such losses are known to occur, their incidence is minor in comparison to the careful handling of the metals and the products they are in.

To counter these losses, the refiners have been conducting institutional advertising aimed at the industrial consumer for many years and supplementing this with technical services for operating personnel and discussions with financial and top management personnel of consumers. As expressed by one refiner interviewed, "If we can get top management, the financial people, and factory foremen aware of the possibilities for scrap recovery, we usually have an excellent

TABLE 22. IDENTIFICATION AND ANALYSIS OF QUANTITATIVE PROBLEMS OF PLATINUM GROUP METALS RECYCLING

Title	Prompt Industrial Scrap	Obsolete Scrap
Problem Definition	Manufacturing processes often generate unusable materials in small volume in a number of installations that are often contaminated and not recycled.	Platinum content of discarded articles frequently is low, usually masked by other metals. Individual consumer goods articles have small amount of platinum. Consumer's idea of value of article is much higher than the materials cost Some of this platinum is not recycled.
Platinum NOT Recycled	60,000 ounces	40,000 ounces
Percent of Available Platinum NOT Recycled	5	5
Problem Analysis	1. A very high percentage of available scrap is recycled 2. Aside from accidental loss, only small shops find it uneconomic to recover platinum 3. This is not a promising area because the economically recoverable scrap is being recovered 4. Institutional promotion by the refining industry is desirable to maintain level of recovery now achieved	1. Recycling of obsolete industrial scrap is high in spite of low content of platinum at times 2. Recycling of discarded consumer articles is economic only when consumer turns article in 3. Consumer has little economic incentive to recycle platinum unless a direct replacement of the article is being made 4. No effective mechanism exists to collect discarded articles from individual consumers 5. Unreported recovery via small manufacturing jewelers believed to exist 6. Minor improvement may be possible without economic benefit to consumer

response and get nearly everything available". He also reported that their own studies indicated that about 90 percent of the prompt industrial scrap generated was being recycled with most of the losses concentrated in small factories and shops that handle modest quantities of platinum group metals annually. His solution includes a continuation of present efforts to educate all levels of personnel at consumers' installations with the expectation that the improvement noted in recycling during the past five years will be continued.

Without question, the shortage of primary new metals that developed in 1965 and intensified through 1968 accounted for the sudden increase in reprocessing of consumer-owned metals starting in 1966 and in purchased scrap from 1967 on. Aside from the increased value of scrap--as reflected by rising prices for refined metals--many consumers had to search for material to be reprocessed in order to assure at least part of their needs. The latter aspect probably was the dominant factor in view of limited opportunities to substitute for platinum and palladium in most uses. Thus, the actual effectiveness of the refiners' efforts to boost recycling may be questionable from the strictly economic viewpoint but certainly valid from the viewpoint of improving the overall supply picture.

As noted in Table 21, Battelle estimates that an average of about 600,000 ounces of prompt industrial scrap was recycled annually in the 1965-1969 period. Over 85 percent of this is believed to be originating from the fabrication of contact points and other components of telephone switching systems, industrial control devices, voltage regulators for automotive use, aircraft spark plugs, and wire-based products such as thermocouples and resistance heating elements. Nearly all the balance also resulted from the manipulation of sheet, strip, tubing, and wire (i.e., mill product forms) into the desired products. Very little direct loss is believed to occur in the conversion of compounds to catalysts, plating solutions, brazing compounds, or other non-mill product forms. The total represents less than 20 percent of the amount of the platinum group metals that was available to consumers (3,280,000 ounces) for processing into usable products. It may account for about 30 percent of an estimated delivery of 2,000,000 ounces of platinum group metals in mill product form, a reasonable rate of scrap and waste generation by the metal working processes.

The refining industry feels that small shops handling less than a few thousand ounces of platinum group metals annually are responsible for most of the loss of prompt industrial scrap. There are many one-or-two man shops in jewelry manufacture, dental laboratories, and specialty electrical concerns where the secondary metal processing operations (machining, grinding, polishing, and plating) produce such small volumes of waste that segregation and collection becomes a major problem. The craftsmen who perform these operations are concerned primarily with the output of usable products whose value is many times that of the value of platinum group metals in the scrap. Even optimun recovery of the waste would not significantly affect the final cost of the products and there is thus little economic incentive to divert high-priced labor to segregating and collecting it. There is little that the refining industry or scrap dealers can do to overcome this problem beyond the institutional promotion they are maintaining.

<u>Obsolete Scrap</u>

Obsolete scrap is believed to account for 1,550,000 ounces annually of refined platinum group metals in the 1965-1969 period (see Table 20). The chemical, petroleum, and electrical and electronics industries were responsible

for 90 percent of this and virtually all was toll refined and returned to the consumer-generators. Platinum and palladium catalysts--deposited on inert substrates--for the petroleum and chemical industries may have accounted for nearly half of the total, about 700,000 ounces, returned for reprocessing after 1 to 2 years of service. Platinum gauze catalysts for chemicals and petrochemicals (largely nitric acid) probably accounted for an additional 200,000 ounces. A majority of the old scrap from the electrical and electronics industry is believed to consist of telephone relay contacts from obsolete or damaged central exchanges, with minor quantities originating from discarded aircraft sparkplugs, military hardware, industrial control devices including thermocouples, and automotive voltage regulators. Other significant sources of obsolete scrap were chemical laboratory and process equipment, glass tank equipment and linings, fiberglass bushings, and imported scrap for rerefining.

The potential volume of old scrap that could be available for recovery of the platinum group metals is uncertain. From discussions with consumers and refiners, Battelle estimates that a minimum of about 7,000,000 ounces of platinum group metals are being used or held in inventory by the large industrial companies. The actual figure may be closer to 9,000,000. Since 1940, when industrial expansion boomed to support the prosecution of World War II, new domestic production and imports of the platinum group metals have totalled over 22 million ounces. Exports of refined and unrefined metals over the period would reduce the net inflow into the system by about 2.7 million ounces to 19.3 million ounces. Further, perhaps as much as 4 million ounces have been converted into consumer held products by the jewelry and dental and medical industries, leaving about 15.3 million ounces channelled into industrial uses. Undoubtedly, there have been exports of industrial products and equipment containing the metals and an allowance must be made for accidental disappearance and reprocessing losses.

But the nearly 7 million ounces of new supplies made available between 1965 and 1969, less the 1.5 million ounces of exports suggests that the potential recoverable amount is between 7 and 9 million ounces, of which not over 2 million ounces represents unused inventory held by the chemical, petroleum, and glass industries partly in product form and partly as ingots of refined metals. Theoretically, all of the 7 to 9 million ounces could be returned eventually for reprocessing. Battelle's rationalized flow of the metals suggests that a little over 1.5 million ounces were returned annually in the 1965-1969 period. However, declining prices during 1970 that reflect a change to surplus supplies may also reflect a lower level of recycle for old scrap both purchased and toll refined.

One of the major problems associated with old scrap is the segregation of the platinum group metals. Electrical control devices, relays, and industrial and military electronic equipment frequently contain base metals and/or nonmetallic materials in addition to the platinum group metals. In many instances, the platinum group metals account for less than 1 percent of the weight of the item being discarded. The cost of segregating the precious metals content to the point that it represents over 50 percent of the recycle weight may be prohibitive under current approaches to recycling which start with manual disassembly. Bulk melting is a possible alternative approach as long as the base metals consist principally of copper. Appreciable quantities of iron or aluminum, however, preclude this approach because methods for treating such scrap are not conducive to recovery of the platinum group metals or the economic separation of aluminum from copper or iron from aluminum and copper.

Generalizations about this problem tend to be meaningless beyond the comments given above. Each salvage operation for these industrial-type scraps presents specific and frequently unique problems. Usually, an effective

segregation can be achieved if the volume of scrap is large, for example with thousands of relays. The real problem arises when the units being salvaged arrive at a collection point a few at a time, at irregular intervals, or mixed in with other items for reclamation. No ready solutions for this problem are known to exist but the refiners can offer helpful suggestions in many instances if they are made aware of the opportunities.

With respect to old scrap from the jewelry and dental and medical industries, collection and segregation is less of a problem because the gold and silver also present is recognized as economically recoverable. The major obstacle to increased recycling of these obsolete products is the reluctance of consumers to turn the articles in for reclamation. Aside from speculative hoarding--believed to be minimal in the United States-- sentimental attachment to the article and indifference to the reclaim value result in wastage and loss of all the precious metals. Nationwide campaigns aimed at consumers have temporarily boosted recycling of the precious metals in the past with the primary stimulus of patriotism. Similar campaigns based on antipollution objectives might persuade some consumers to search for reclamable articles but the lasting effects of such promotions was questionable.

<u>Problems Other Than Supply and Economics</u>

Representatives of the recycling industry for platinum group metals failed to identify any significant problems in areas other than those noted in the preceding section. The collection, processing, segregation, and refining of the platinum group metals require minimal space, virtually no hazardous or offensive treatment methods, and no unusual labor skills. The refiners are faced with tightening requirements for air and water effluent treatments but these have no specific hazards or complexities unique to the platinum group metals.

Courses of Action Concerning Recycling of the Platinum Group Metals

The problems of the platinum group metals recycling industry have a predominant economic orientation. The supply of scrap available in any given year falls far short of demand for the metals but the quantities collected and reprocessed represent nearly the maximum economic recovery under present conditions. The experience of the 1965-1969 period demonstrates that consumers and scrap collection agencies can increase the annual recycle of the platinum group metals under the impetus of a severe supply shortfall. However, less than 20 percent of the increase came by way of purchased scrap that represented a real increase in the available supply and even a part of that increase was generated by foreign consumers.

Fundamentally, courses of action are needed to stimulate the flow of scrap containing the platinum group metals to the refiners. In terms of priorities, there is little difference in the magnitude of improvement to be achieved between the recycling of prompt industrial scrap and that of old scrap. Both represent opportunities for consumers and recyclers alike. However, from the viewpoint of the consumers, the problem is most severe in small shops and factories and the general public, an audience that is difficult to reach and uneconomic for the refiner to cultivate extensively. Programs aimed at these low-volume generators of scrap will undoubtedly benefit from indirect education of some of the large-volume generators who also will see the promotional materials.

Recommended Actions

Environmental Protection Agency. Battelle recommends that the Environmental Protection Agency initiate a promotional campaign to stimulate the recycle of all solid waste materials, including a series for the precious metals. The

emphasis should be on the need to conserve these metals to reduce the dependence of the United States on foreign sources. Inputs for the precious metals series, by way of illustrating what to look for, could be provided by the refining industry working through their subcommittee of the NASMI Committee on Solid Wastes. The campaign should have an intensive phase with broad use of all communication media -- radio, television, newspapers, trade journals, and general readership magazines -- and an extensive phase that repeats the basic message over several years.

Recycling Industry. Battelle recommends that the recycling industry continue the individual company-sponsored promotional and educational advertising and technical service activities that currently are being carried out. They can supplement the EPA campaign, especially for the larger-volume consumers of the platinum group metals, by detailing specific instances or opportunities for recycling.

Table 23 summarizes the recommended actions.

TABLE 23. RECOMMENDED ACTIONS, HIGH PRIORITY PLATINUM GROUP METALS RECYCLING PROBLEMS

Title	Prompt Industrial Scrap	Obsolete Scrap
Action Recommended	Recycling industry should continue promotional efforts for collecting and recycling small volumes of scrap	Recyling industry should continue promotional efforts to encourage ultimate consumer to turn in discarded articles even in small amounts.
By Whom (1)(2)(3)	EPA/NASMI	EPA/NASMI
Specific Steps	1. Continue institutional advertising on value of scrap and probable cost savings by recycling	1. Continue institutional advertising on value of scrap and need to recycle to conserve resources

(1) The responsibility for recommended actions shown in this table are based on importance of the action, benefit to the taxpayers, and opportunities for NASMI. They are the best judgments of Battelle.

(2) Recommended actions were distributed between high priority and lower priority based on the evaluation with three criteria.

(3) It is suggested that NASMI continue its leading role in recycling, recognizing that other organizations such as the Bureau of Mines, Department of Commerce, Council of Environmental Quality, HEW Office of Information, and State, Local, and Federal Legislatures must be involved.

APPENDIX A

PRECIOUS METALS RECYCLING INDUSTRY DATA

FROM EXTENSIVE SURVEY

TABLE A-1. AVERAGE SIZE OF PRECIOUS METALS SCRAP PROCESSORS, ANNUAL TONS, BY REGION

Region	Number of Companies	Tons Per Year, Gross Weight
Total United States	115	6.6
New England	9	8.0
Middle Atlantic	29	10.3
South Atlantic	11	7.9
East North Central	27	3.6
East South Central	1	1.0
West North Central	4	3.5
West South Central	2	1.0
Mountain	5	1.6
Pacific	26	6.9
Unknown	1	1.0

TABLE A-2. AVERAGE SIZE OF PRECIOUS METALS SOLUTIONS PROCESSORS, ANNUAL GALLONS, BY REGION

Region	Number of Companies	Gallons Per Year
Total United States	42	1656
New England	5	2720
Middle Atlantic	18	2508
South Atlantic	0	0
East North Central	9	761
East South Central	0	0
West North Central	1	50
West South Central	0	0
Mountain	0	0
Pacific	9	433
Unknown	0	0

TABLE A-3. AVERAGE SIZE OF PRECIOUS METALS SMELTERS, ANNUAL TROY OUNCES, BY REGION

Region	Gold: Number of Companies	Gold: Troy Ounces Per Year	Silver: Number of Companies	Silver: Troy Ounces Per Year	Platinum Group: Number of Companies	Platinum Group: Troy Ounces Per Year
Total United States	53	7915	71	11694	49	4990
New England	5	14150	5	21450	4	250
Middle Atlantic	18	12750	22	16636	18	9514
South Atlantic	2	250	4	12750	2	250
East North Central	9	5750	15	7167	8	4750
East South Central	0	0	0	0	0	0
West North Central	1	3300	1	1500	1	250
West South Central	1	250	2	17875	1	250
Mountain	2	500	3	12917	1	250
Pacific	14	4196	18	5972	14	2357
Unknown	1	3500	1	15000	0	0

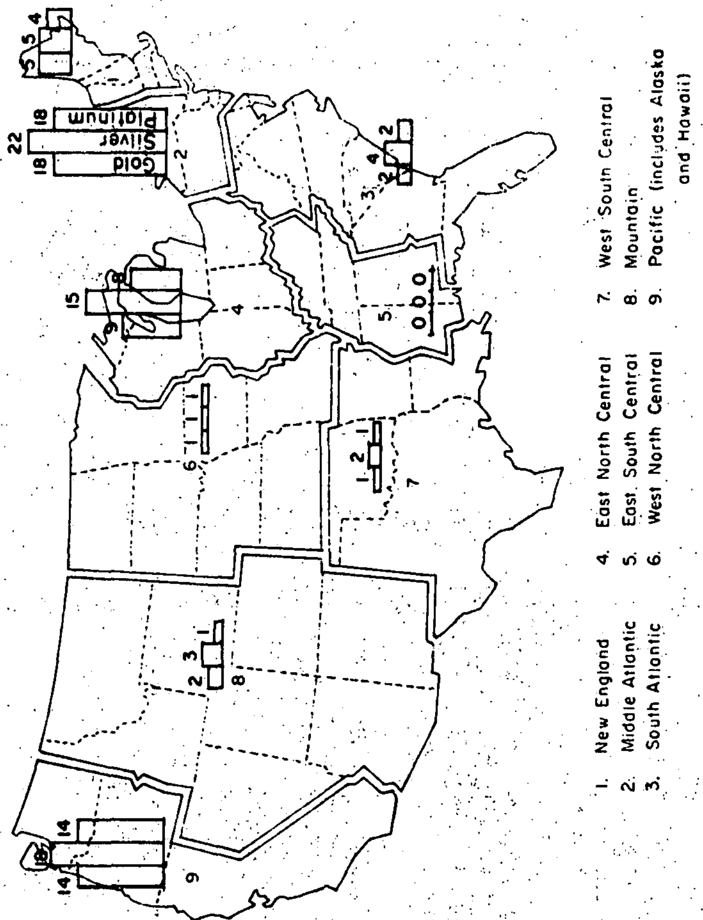


FIGURE A-1. REGIONAL DISTRIBUTION OF PRECIOUS METALS REFINERS

APPENDIX B

EXTENSIVE SURVEY

APPENDIX B

EXTENSIVE SURVEY

The extensive survey of the secondary materials industry consisted of a mail survey and personal interviews with management personnel of companies involved with the collection processing, and sale of secondary materials. About 600 responses were received.

The information developed through the extensive survey included dollar sales, tons of major materials handled, types of solid waste processed, sources of materials, investment, equipment and facilities, number of employees, the amount of space used, and the grades and quantities of secondary materials produced.

The data from the extensive survey provided statistical tabulations of the regional distribution of the secondary materials industries by type of commodity in terms of numbers of establishments, volume of business, and numbers of employees.

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