Technical Report

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The U.S. Copper-base Scrap Industry and Its By-products – 2002

Copper Development Association Inc.

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The U.S. Copper-base Scrap Industry And Its By-products

An Overview

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PREFACE

The purpose of this report is to provide a brief background paper on the U.S. copper and copper alloy secondary processing industry. It was felt that policy and decision makers could use a ready reference on an industry that is generally so little understood. The industry has undergone many evolving changes over the past few decades and has been in decline in the last few years. During the research, several problems of recent origin for the industry became apparent, as well as several approaches to solutions for some of these problems. While the coverage is not comprehensive, a brief mention is made of them. The secondary industry and the Government agencies most concerned with legislation affecting the collection, processing and markets for scrap are both working to overcome some of the current difficulties. Nevertheless, for some sectors of the secondary copper industry, the outlook looks particularly difficult, given the restrictions within which they currently operate, the potential for new restrictions, and the current copper market.

The author would particularly like to thank those in the industry who were kind enough to host informative visits to their plants and to provide much of the information contained in this report. In particular, Alan Silber of RECAP was of tremendous help not only in outlining and reviewing the report, but also in giving freely of his solid background in the industry. Daniel Edelstein, Copper Specialist with the U.S. Geological Survey, also provided substantial help and advice. Thomas Baack, Chief Statistician for the International Copper Study Group, was of great assistance in providing world statistics for direct melt and ingot production as requested. The research for this report was supported by the Copper Development Association. This third edition presents updated data and observations made since the first report was written in 1999.

ABOUT THE AUTHOR

Janice L.W. Jolly has had more than 30 years experience in both the primary and secondary copper industries. She first spent 14 years as a research geologist with the U.S. Geological Survey and with Roan Selection Trust in the Zambian Copperbelt and, second, spent 18 years as a foreign mineral and commodity specialist with the U.S. Bureau of Mines. She was the copper commodity specialist for the Bureau of Mines over 10 years, responsible for that agency’s data collection and reports on copper and copper scrap. She also worked briefly with the Armed Services Committee of the House of Representatives and the World Bank. She is author of many articles and reports on copper and copper scrap and is especially familiar with the statistics relating to these subjects. She spent almost 4 years in Portugal with the International Copper Study Group as its first Chief Statistician. She was instrumental in helping the ICSG establish its statistical collection and publishing effort on copper. She retired from the U.S. Bureau of Mines in 1993 and from the International Copper Study Group in 1997.

TABLE OF CONTENTS

CHAPTER 4 — ENVIRONMENTAL OVERVIEW

CHAPTER 5 — PROBLEMS AND SOLUTIONS

ILLUSTRATIONS:

CHAPTER 1 FIGURES

CHAPTER 2 FIGURES

TABLES:

CHAPTER 1 TABLES

CHAPTER 2 TABLES

CHAPTER 3 TABLES

EXECUTIVE SUMMARY

Surplus world copper production, lower copper prices and increasing environmental compliance costs continued to impact U.S. secondary copper-base scrap collection and processing capacity during 2001. Lower copper prices and higher environmental costs over the past several years have created a cost squeeze that contributed to the closure of all U.S. secondary smelters and associated electrolytic refineries. Of the 4 secondary smelting and 2 electrolytic refining firms operating in 1996, none remained in 2001. Fire refining, which requires a better grade of scrap, seemed to be holding its own. Plant closures also have occurred in the ingotmaking and foundry sectors of the industry.

Copper prices continued to drop through 2001 as copper inventories, at 2.1 million tons, reached the highest levels in many years. According to the International Copper Study Group, inventories at the end of 2001 were about 800,000 tons of copper higher than that of yearend 2000. The accumulated stocks represented almost 2 months of supply at current rates of consumption. In an attempt to correct the situation, several mines in Chile and the rest of the world continued to cut back on production through 2002.

A significant upturn in copper prices is needed to compensate for higher collection, processing and disposal costs. A further contraction of the industry could also be expected with any new legislation that might further control and hinder the easy flow of secondary materials between firms.

Without a basic domestic secondary-processing infrastructure, more valuable metals will reach the landfill as the most reasonable remaining choice. Export is always possible for the higher grades of scrap, but the lower-grade copper by-products, which currently are traded, could become impossible to market. The recent trend of higher exports of U.S. copper scrap continued unabated through 2001.

Refined copper consumption in the United States increased about 10.4% since 1994 to about 3 million tons in 2000. Over the same period world copper consumption increased nearly 32% to over 15 million tons. In 2001, however, U.S. copper consumption fell by about 13.5% to about 2.6 million tons, and world copper consumption fell by 3% to 14.8 million tons. Even so, the United States remained the leading consumer of copper from copper-based scrap with 20% of the world's total in 2001. In 2001, the United States had an estimated copper consumption from all sources of about 3.1 million tons, including 1.1 million tons from refined and direct melt scrap.

While copper recovered from new, manufacturing scrap sources has been increasing in the United States, copper recovered and consumed by industry from "old," used product scrap sources has been decreasing. Copper recovered, and consumed by the U.S. industry from old scrap reached 613,000 tons in 1980, but was only 309,000 tons in 2001, despite large gains in overall copper consumption over the same period. However, if net scrap exports are classified as old scrap and are included in an estimate for all "old" scrap recovered, the amount of copper in all old scrap collected in 2001 totaled 691,000 tons. This would seem to imply that the rate of old scrap copper recovered from the end-use reservoir has not really diminished as much as the reported consumption data would indicate.

World trade in copper-base scrap has more than doubled between 1989 and 2000, largely in response to the increased industrial growth in the Far East and Europe. The United States was the largest exporter of copper scrap in the world, exporting 16% of the world's total copper-base scrap exports in 2000 and an estimated 20% in 2001. China was the largest importer of copper-base scrap in 2001 with 63% of world copper scrap imports of 5 million tons. By 2002, however, China began to take a harder stance toward the imports of scrapped electronics and the lower grades of copper scrap. The environmental concerns these scrapped materials presented were becoming more important for the Chinese government. Import controls were implemented.

Trade restraints on scrap, such as import quotas, export licenses, price controls and other mechanisms have been used many times over the past 30–40 years in the United States and other countries. These have been applied specially during times of national emergency and supply shortage. The entire U.S. secondary copper processing industry has been treated as a critical and strategic industry during these tight supply periods. The United States has had no trade restrictions on copper-based scrap since 1970. All of the remaining copper in the National Defense Stockpile was sold in 1993.

The U.S. secondary copper processing industry currently consists of 6 fire-refiners, 24 ingotmakers, 50 primary brass mills, and about 600 foundries, chemical plants and other manufacturers. Wire-rod mills do not consume much scrap directly. Most of the chemical plants are hydrometallurgical plants that have created businesses based on using secondary by-products produced by other metal production and metal finishing. Most copper chemicals, such as cupric oxide, copper sulfate and others are produced from scrap in the United States.

The EU-15 as a group of countries is the largest ingot-producing entity in the world. However, the United States, followed by Italy and Japan, is the world's leading ingot maker country, providing the domestic foundry and brass mill industries with special alloys for casting and milling.

Ingotmaking is, in particular, a very scrap intensive industry, using mostly scrap as its raw material. Even so, the brass mill (67% of 2000 copper-base scrap consumption) industry consumes most of the copper-base scrap recycled in the United States. Several copper tube and wire rod mills have had secondary smelters or refineries associated with them because of their requirement for high-purity copper. Unfortunately, most of these plants have closed, owing to the recent poor economic environment for processing scrap and the easy availability of low-priced primary refined copper.

In 2000, recycled copper consumed in the United States was derived 74% from purchased new copper-base scrap generated in the process of manufacture and 26% from old scrap derived from used products. Purchased new scrap yielded about 906,000 tons of contained copper in 2000, 91% of which was consumed at primary brass, tube and wire-rod mills. A manufacturer may generate up to 60% scrap in the form of slippings, trimmings, stampings, borings and turnings during the manufacture of finished articles. This new, or mill-return, scrap is readily used by the industry in making new semifabricated products. A secondary material becomes "purchased" scrap when it is traded or otherwise sent to market. Home scrap, or runaround scrap, is used in-house, not marketed and not counted in consumption statistics.

In addition to the better known classes of purchased scrap there is a smaller group of lower-grade, copper-based scrap known generally as "low-grade ashes and residues," or as secondary "by-products." By current definition, these materials are comprised of copper-bearing ashes, residues, drosses, skimmings, dusts, slags and other materials containing less than 65% copper, and are derived as by-products of other copper-base metal processing. According to the U.S. Geological Survey, which has long tracked the purchased scrap market for this material, about 89,000 tons of "low-grade ashes and residues" were purchased and consumed domestically for their metal content in 2000. This is down considerably from the 300,000 tons to 500,000 tons that was marketed in the 1970s. The downturn in domestic consumption of this material coincides with cutbacks in the domestic smelter industry, the decrease in use of reverberatory furnaces by the copper industry, and the closure of secondary smelters and ingotmakers.

Though most firms prefer to ship high-grade slags and skimmings (up to 65% copper) to other domestic or foreign firms for further processing, about 28% of the slag and skimming by-products produced are processed in the plant of origin. In addition, pickling solutions may also be reprocessed in house to produce copper cathode. A significant proportion of these higher-grade products is exported to Canada or Mexico.

In addition to the copper-bearing ashes and residues, the copper-base secondary industry also produces significant quantities of zinc oxide as a by-product of its metal processing. The USGS estimates that about 30% of the world's zinc is produced from secondary materials, some of which is from the flue dust collected during copper alloy processing. While some of the production is suitable to be used directly as animal feed and agricultural products, most is sent to zinc smelters and processors for treatment and zinc recovery. Only the poorest grade reaches as landfill.

Spent furnace linings used in pyrometallurgical copper and copper alloy processing are also by-products that sometimes have further value. The type of lining used varies from chrome-magnesite brick to various types of ceramic-like materials that are applied like cement. While some spent linings are recycled for their metal content or used for concrete and other construction material, some ends up in the landfill. Spent furnace brick containing appreciable cadmium or lead are shipped as hazardous material. All products sent to landfill must pass the USEPA hazardous material test, the Toxicity Characteristic Leaching Procedure (TCLP).

The TCLP has been challenged in court in recent years for its inherent difficulties in predicting all disposal situations. The TCLP was not intended to be representative of in situ field conditions, but rather of a generic municipal solid waste (MSW) landfill worst-case scenario. In February 1999, the Science Advisory Board's Environmental Engineering Committee (EEC) called for the need to review and improve EPA's current leachability testing procedure. The U.S. mining industry and others have also challenged the applicability of the TCLP based on the physical and chemical differences between municipal waste sites and those used for large volume mine wastes, among other uses.

Many problems have been derived from the application of CERCLA (the Superfund Law), passed in 1980, and RCRA, passed in 1976. Most problems stem from the reporting, permitting, and other paperwork requirements, as well as from the legal liabilities stemming from application of these laws. For example, liability concerns have been enormous barriers to "brownfield" cleanup technologies. A "brownfield" is a site, or portion thereof, that has actual or perceived contamination and an active potential for redevelopment or reuse. Because financial institutions can be liable for cleanup costs when they acquire the properties through default, they are unwilling to provide loans for development. Problems also emanate from the potential responsible party (PRP) aspects of CERCLA. The potential here is to be named liable for expensive cleanup solely because you may have done business with a firm named as a superfund site. This approach to superfund financing has caused businesses to think twice about shipping materials to certain firms.

In addition, restrictions on shipping products are increasing. Once a product is classified as hazardous and/or is controlled as to market, handling and shipping, costs rise. Higher costs have resulted from rulings that dictate how much can be stored in one place or another, what must be classified as hazardous, who may receive the material, and what procedures must be followed through the entire production and marketing process. The permitting procedures and handling restrictions have not only added to the costs of shipping, but have also reduced the potential for by-product sale to other processors. Further tightening of regulations through reclassification of secondary products currently traded will result in higher costs and more products sent directly to the landfill.

Those firms that can have opted to invest money in becoming more internalized with increased in-house treatment of products. Many have adopted unique cost-saving devices and policies. Some also are instituting formalized, self-policing management systems to improve their processes and products, via the ISO 9000 and ISO 14000 standards. Some parts of the government are also taking a harder look at the regulations that affect the smooth marketing of products and, in particular, the development of brownfield sites. Nevertheless, the current economic situation continues to look more difficult for some parts of the secondary copper industry. This segment of the economy seems to be laboring under significant stress, caused in part by changing and more stringent government regulations.

CHAPTER 1 – INDUSTRY PERSPECTIVES

Global Industry Perspective

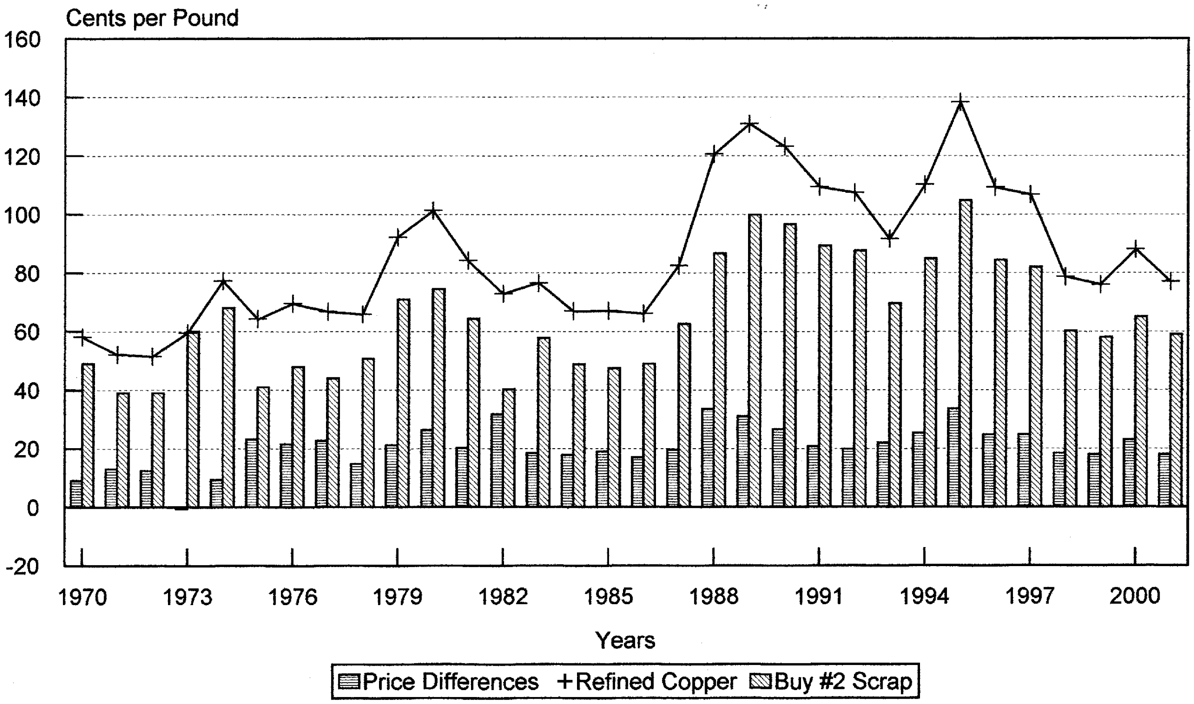
World Copper Consumption and Production. Copper ranks third in the world consumption of metals, after steel and aluminum. According to the International Copper Study Group (ICSG), refined copper consumption was 14.8 million tons in 2001, down from 15.2 million tons achieved in 2000. The major refined copper consuming nations of the world were the United States (17.8%), China (15.2%), Japan (7.8%) and Germany (7.4%), with China surpassing Japan since 1998. Although world refined copper consumption has increased by 17.4% between 1996 and 2001, the higher rate of new copper production (20.3% increase) has resulted in market surpluses, largely owing to the significant new mine capacity that came on stream since 1996. Coincidental to this new capacity, and compounding the surplus, was a world industrial recession that was particularly difficult in 2001. Total world copper stocks at producers, consumers and the exchanges were estimated to be in excess of 2 million tons, or about 8 weeks of consumption, according to data published by the ICSG. Copper inventories on the world's metal exchanges, alone, were in excess of 1 million tons of copper by yearend 2001, and had reached 1.5 million tons by April 2002. These surpluses occurred despite efforts by the world's major producers to trim back copper mine production.

As a result of the more than adequate world supply of copper over the period, world copper prices have steadily decreased since 1995 (**Table 1**) and, in 2001, reached low levels not seen since the early 1980s. Lower prices, in turn, have prompted a decrease in the supply of copper scrap. The use of copper scrap as a component of world refined copper has decreased from 16% in 1996 to about 12% in 2001.

A reasonable spread in price must be present between the current refined copper price and that for purchased scrap, in order for processing to be profitable. The price spreads between No. 2 scrap and refined copper are lower in coincidence to the decreasing refined copper price in recent years, as shown in **Figure 1.** For example, the price spread in the United States was as high as 32 cents in 1995, but reached about one-half that amount during 1998, 1999 and 2001. The price spread for these years was similar in range to that experienced during the recession years of 1982-1984. With increasingly stringent environmental regulations and requirements, the costs to process scrap at all levels, from low-grade scrap to pure metal scrap have escalated. The current cost squeeze has caused many secondary processors to rethink doing business.

Since 1965, copper recovered from scrap, as a percent of total world copper produced, has ranged between the current low of 31% to as high as 41% during 1995, as shown on **Table 2A** and in **Figure 2**. The periods of low scrap recovery, such as those in 1975-1978, 1983-1984, and again in 2001, coincide with low copper prices and surplus copper supplies. Copper recovered from all forms of scrap in 2001 (refined and direct melt) is about 500,000 tons lower than the high point achieved in 1995. The United States

Figure 1. Price Spreads Between Refiners No.2 Scrap and U.S. Producers Refined Prices, 1970–2001



Source: AMM and Metals Week

(20% of all world copper recovered from scrap in 2001) is the largest copper base scrap-consuming nation in the world. However, the Western European countries (37%) make up the largest single market for copper-base scrap in the world **(Table 2D)**. Germany, Italy, France and the United Kingdom are the leading consumers of copper scrap in Western Europe.

Asia (including the Middle East) (31%) forms the second largest copper-base-scrap-consuming region of the world, led by Japan (13%), Mainland China (7%), and South Korea (7%). Scrap consumption in Asia grew from about 723,000 tons in 1980 to 2.7 million tons in 1995-1996, but then during an industrial contraction in 1997-1998, it experienced a 12% drop to around 2.3 million tons of copper in scrap. North and South America (23%) is the third largest copper scrap-consuming region after Western Europe and Asia.

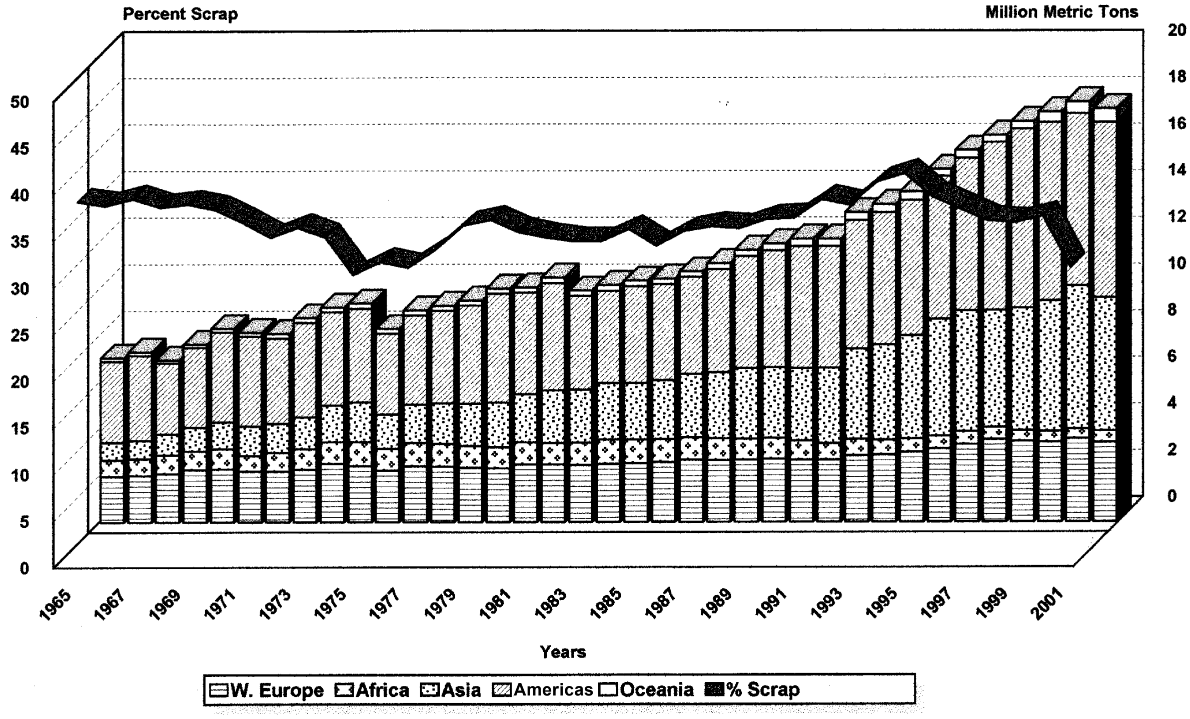
World Trade in Copper Scrap. The United States (16% of world copper-base scrap exports in 2000) is the largest exporter of copper scrap in the world. U.S. exports of scrap increased significantly in 2000, compared with 1998 and 1999. Russia's exports of copper-base scrap increased three-fold between 1993 and 1998 to around 357,000 tons, but they have since dropped sharply to little more than a trickle (about 19,000 tons in 2000), owing to new export duties. Germany (9.6%), France (6.7%), United Kingdom (5.7%), Belgium (5%), and Netherlands (4.4%) are also large exporters of copper-base scrap, as shown in **Table 3**.

World imports of copper-base scrap more than doubled over ten years, 1989-1999, in response to the significant industrial growth in the Far East and Europe. China, including Hong Kong and Taiwan, is the largest recipient of U.S. scrap. The Asian region has shown a significant increase in copper-base scrap imports from 1989 through 2000. In 1989, Asia accounted for only a 24% share, while Europe (61%), had a higher share of the world's imports of scrap. In 2000, as shown in **Figure 4**, Asia accounted for about 65% and Europe (West and East Europe) accounted for 29% of global scrap imports. The countries in the Americas (North and South America) have seen their share of world scrap imports diminish over this period.

China has had the most significant growth in scrap imports over the period 1995 through 2001, as shown in **Table 4.** Although Mainland China apparently suffered a marked collapse in amount of scrap imported in 1996 and 1997, owing to import restrictions, copper-base scrap imports were again higher in 1998. By 2001, China's imports of copper-base scrap was three-times that of 1995. South Korea, Taiwan, Hong Kong, Japan and India also are significant importers of copper-base scrap. The availability of copper scrap was reported as especially tight in the United States in early 2001, owing to the high exports to the Far East. Birch/cliff and berry/candy grades are in particular demand. There are no longer any secondary copper smelters in the United States, and China has emerged as the major outlet for No. 2 scrap.

In Europe, exports of copper scrap to the Far East also were increasing dramatically at a time when local availability in the European Union (EU) was lower, creating problems for European refiners. Some felt that unfair customs regulations, as well as lower labor and environmen-

Figure 2. World Copper Recovery from All Sources[1] and Percent Copper from Scrap, 1965-2001



[1] Include copper in primary and secondary refined production and direct melt scrap consumption.
Data Source: ICSG, 2001

tal costs in some Asian countries, enabled them to pay higher prices for scrap. If Europe's refiners fail to cover costs, closures could occur on the same scale as in the United States (Recycling Today, 6/15/2002).

Another issue of concern is the U.S. export of low-grade copper scrap derived from electronic products such as computers. China is tightening its rules on importing electronics scrap, but other poor countries may still be willing to accept these materials. According to some reports (Recycling Today, Feb. 2002), Pakistan is becoming a bigger market for electronic scrap and used computers. China was reported as tightening its import restrictions on low-grade copper scrap in 2002 and closing down factories where toxic chemicals are being released by improper recycling of electronic trash. A substantial tariff was instituted in May 2002 on what China refers to as "Class 7" copper scrap. This class includes lower grades of copper scrap such as unprocessed wire and die cast alloyed parts. Some believe that the tariff has been enacted to force the smelting industry to use higher grades of scrap as a pollution measure.

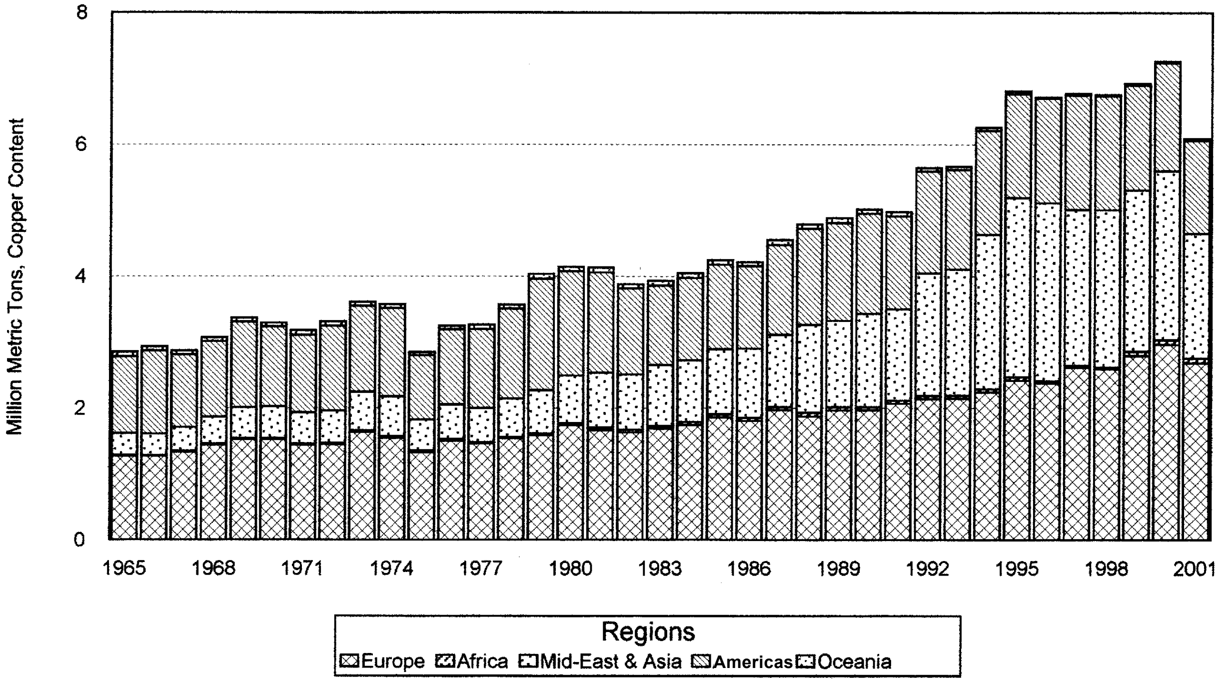
Historically, copper-base scrap has been a highly prized raw material, especially in Asian and European nations with scarce natural raw material sources for copper. As a result, export controls on scrap have been commonly applied in many nations in the world. Because these can affect U.S. producers unfairly, a 301 petition concerning the trade of copper and zinc scrap was submitted to the U.S. Trade Representative on Nov. 14, 1988, by the U.S. Copper and Brass Fabricators Council, representing domestic brass mills. Domestic semifabricators asserted that European (EU) and Brazilian brass mills had been able to maintain materials cost and product price advantages since the middle 1970s, largely through export controls on the flow of copper and zinc scrap. In 1992, the European Commission terminated the export controls on copper and copper alloy scrap. Several Asian nations also have maintained scrap market controls in recent years.

The Bureau of International Recycling (BIR), a European recycling organization, recently assisted Romanian companies in opposing a Romanian governmental decree to impose 20% to 30% export taxes on nonferrous and ferrous scrap. The European Commission was also holding talks with Romania on this issue in 2002.

World Production and Trade in Copper Alloy Ingot. Because the ingot makers of the world are heavily reliant on scrap, especially old scrap returned from manufactured and used products, it is important to put the industry in world perspective. While copper and copper alloy ingot production and trade are not large in volume compared with other copper products, they form the foundation blocks for important specialty metal fabrication industries. Many foundries, brass mills and other parts of the world's manufacturing industry are dependent on these special alloys. The United States (35%) is the world's leading producer of copper and copper alloy ingots from scrap (**Table 5** and **Table 10**), producing between 145,000 tons and 160,000 tons per year. Italy, Japan, Germany and the United Kingdom are also significant producers of copper alloy ingots.

World trade in ingot also is very active. In 2000, the most complete year available in the ICSG Copper

Figure 3. World Consumption of Copper of Direct Melt and Refined Scrap, by Region, 1965-2001



Source: International Copper Study Group and USGS.

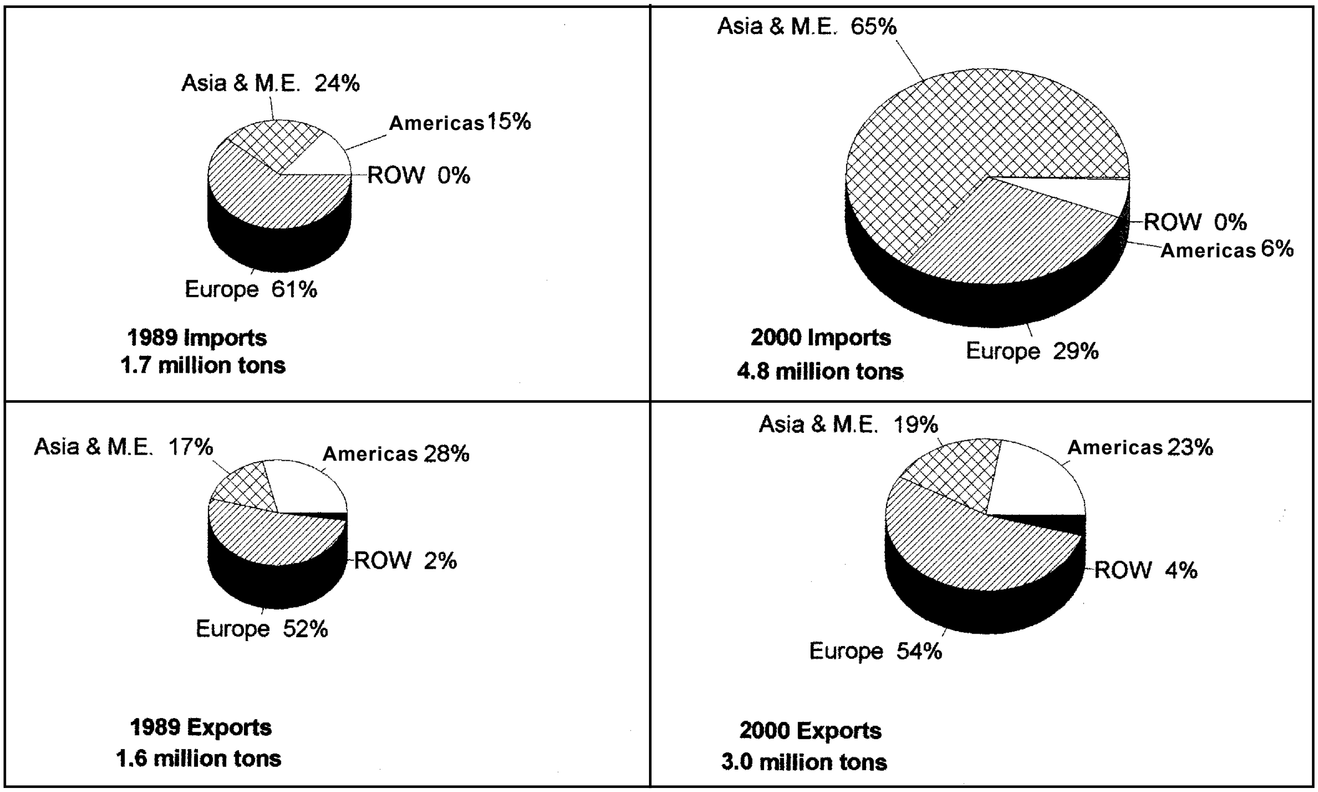
Bulletin, world ingot imports were 253,000 tons and exports were 299,000 tons. During this period, Germany (17.5%), France (8.3%), Italy (8%), China (7.8%) and Taiwan (5.2%) were the largest importers of ingot. Germany (35,600 tons), Japan (28,700 tons), the United States (25,800 tons) Belgium (24,800 tons), and the United Kingdom (21,300 tons) were the leading exporters of ingot. Over the past 5 years, U.S. ingot exports were between 19,000 tons and 32,000 tons, reaching a peak in 2001. U.S. ingot imports were between 7,000 tons and 22,000 tons, reaching the lowest point in 2001.

Domestic Industry Perspectives

Domestic Uses for Copper. About 75% of the copper consumed in the United States is for electrical and electronic uses, finding widespread application in all end-use sectors of the economy. According to the Copper Development Association Inc. (CDA), 8,350 million pounds (3.8 million metric tons) of copper and copper alloy mill products were produced for 2001 end-use markets, as follows (electrical is distributed through all end-use markets): Building Construction (44.3%), Electrical and Electronic Products (25.2%) Industrial Machinery and Equipment (9.1%), Transportation Equipment (11.2%) and Consumer and General Products (10.2%). Copper mill production has increased in all sectors, but the increase in copper mill products for electrical and electronic products since 1991 has been particularly significant. CDA reports an increase from 1,537 million pounds of copper products shipped in 1991 to about 2,661 million pounds in 2000 for this market sector. Although smaller in total tonnage, the copper powder and chemical industries also provide important products. Copper and copper alloy powders are used for brake linings and bands, bushings, instruments and filters in the automotive and aerospace industries, for electrical and electronic applications, for antifouling paints and coatings, and for various chemical and medical purposes. Copper chemicals, principally copper sulfate and the cupric and cuprous oxides, are widely used as algaecides fungicides, wood preservatives, copper plating, pigments, electronic applications and numerous special applications.

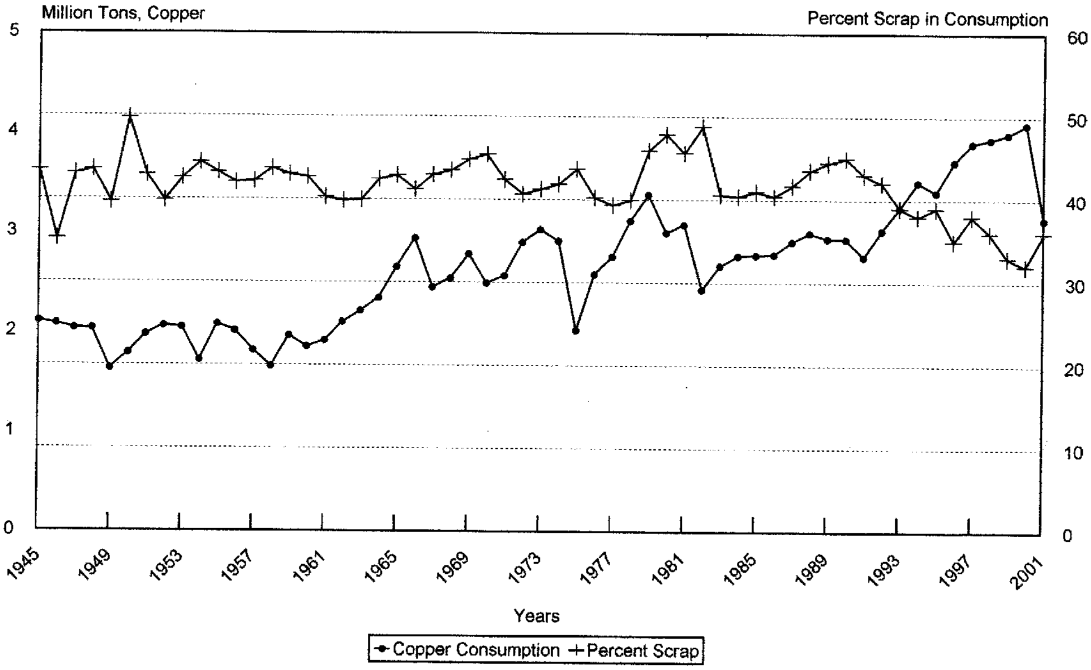
U. S. Consumption of Copper. The United States consumes copper derived from both primary copper and scrap copper. Copper may be derived from either refined or direct-melt copper and copper alloy scrap. The industrial sector of the United States consumed about 2.6 million tons of refined copper in 2001, according to the U.S. Geological Survey (**Table 6**). Reflecting the impact of the economic slowdown in 2001, this represented a decrease in copper consumption of about 400,000 tons compared with 2000. Of the total consumed in 2001, only 158,000 tons (or 6% of refined copper consumption) was derived from scrap (**Table 6**). This is down considerably from the 480,000 tons (22% of refined consumption) of copper from refined scrap reported for 1989. In addition, the United States consumed about 1 million tons of copper in 2001 derived from 1.3 million tons of direct-melt, copper-base scrap (**Table 2C**). The range in annual average copper content for direct-melt

Figure 4. Trade in Copper and Copper Alloy Scrap, by World Region, 1989 and 2000



Source: International Copper Study Group

Figure 5. U.S. Total Copper Consumption[1] Including All Scrap, 1945 to 2001



Source: U.S. Bureau of Mines and U.S. Geol. Survey.

[1]Total Copper Consumption = Primary refined, secondary refined + copper in direct-melt scrap.

scrap in the United States has been 83% to 85% of the gross weight over the past 10 years. Total copper from scrap (refined plus direct-melt and other-than-copper-base scrap) amounted to about 1.2 million tons. Copper from old and new copper-base and other metal-based scrap was valued at $1.5 billion and made up 38% of total U.S. copper consumption.

Old scrap copper recovery in the United States is largely related to the variability in the copper price, the domestic industry demand for this type of raw material, and the availability of primary copper. Copper from scrap refining was 78% derived from old scrap sources in 2001, according to the U.S. Geological survey. Ingotmaking also consumes large quantities of copper from *old* scrap (75% derived from old scrap in 2001). Scrap used in refining and smelting is made up mostly of *old* scrap, while the purchased direct-melt scrap used by brass mills is mostly *new,* customer-returned scrap. Some copper tube mills also use a high proportion of old scrap when purchased from dealers as good, clean, number 1 copper scrap.

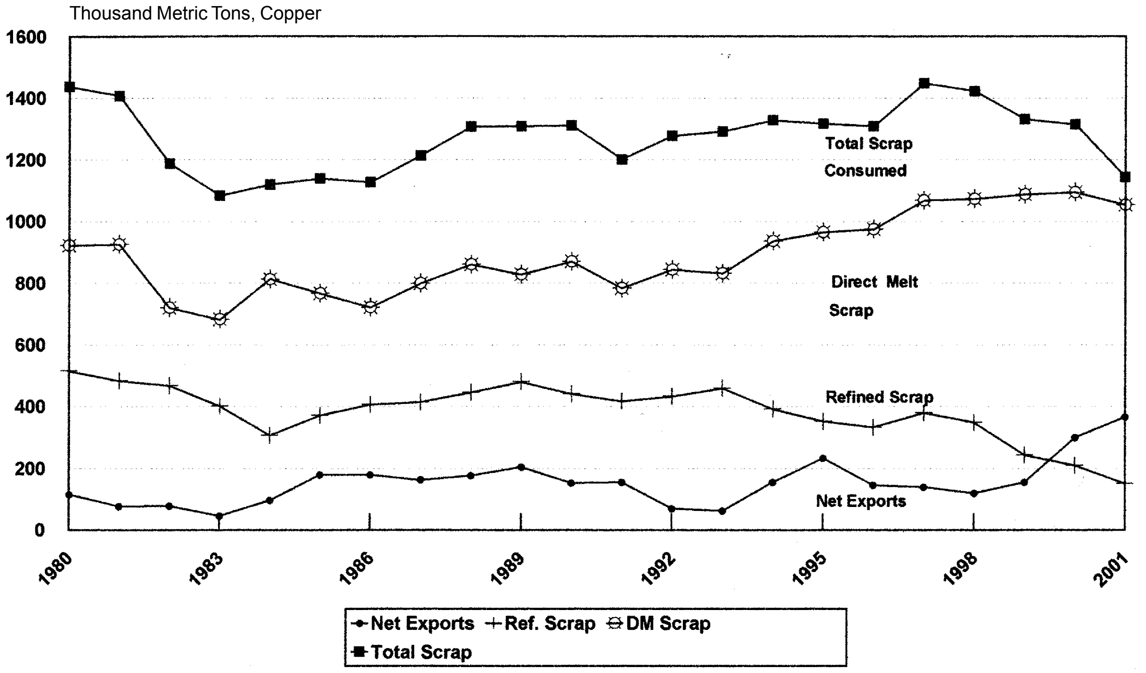
U.S. scrap statistics (**Table 6**) represent consumption as reported at the industry plant and, thus, do not reflect the total amount of material collected at scrap dealers and sellers. On the assumption that most internationally traded copper scrap may be derived from used materials, the addition of U.S. Scrap exports to old scrap consumed by the industry may provide an estimate of the total recovered in a particular year. This assumes, of course, that most new scrap is returned to the domestic mill of material origin and is not sold abroad.

Old scrap recycling and its contribution to U.S. refined copper production has fallen in recent years, despite a rise in total U.S. copper consumption. U.S. recovery and consumption of *old* scrap was highest in 1979 and 1980, years of high copper demand and high prices. It was also high during the Great Depression years, when mine production was severely curtailed. As a percent of total copper consumed, (**Figure 5**) scrap consumption has declined from 49% since the early 1980s to around 38% in 2001. Despite the robust U.S economy in the 1990s, copper from *old* scrap and refined from scrap, in particular, have seen a significant decline over this period (**Tables 6 and 7**). For example, copper from old scrap recovery was as high as 613,000 tons in 1980, but was only about 309, 000 tons in 2001. Exacerbating the decline in collection and processing of old and low-grade scrap in the United States has been the closure of U.S. copper scrap smelting and refining plants and ingot makers, owing to the higher costs associated with tight environmental and worker safety standards. In addition, some of the *old* scrap collected has been exported, as suggested by the increase in U.S. scrap exports in recent years.

While the domestic recycling of copper from old scrap has suffered owing to the shutdown of facilities that processed this material, recovery of copper from new purchased scrap (manufacturing scrap) has been increasing over time (see percent new scrap in **Table 6**). This is the result of a steadily increasing industrial base from which more customer-returned scrap is generated. Customer-returned new scrap tends to be recirculated to the plant of domestic origin.

In 2001, 98% of scrap consumed at brass and wire rod mills was new scrap, according to the U.S. Geological Survey. While this sector of the U.S. secondary-based industry has been expanding its capacity, its consumption of scrap copper relative to primary copper has been decreasing. Still, copper derived from purchased copper and copper alloy scrap tends to form a very large percentage of the total

Figure 6. Trends in U.S. Net Export and Consumption[1] of Copper in Copper-base Scrap, 1980-2001



Source: U.S. Geological Survey.

[1] Revised to include copper from copper-base and other-base scrap.

copper consumed each year in the United States. Until 1982, copper from all scrap sources had grown each year in the United States, as a percent of total copper consumed, varying between 7% (in 1906) to 50% (in 1950). However, from a peak of around 49% in the early 1980s, the contribution of copper from scrap has gradually been decreasing to around 38% in 2001. This decline was particularly significant in 1999 and 2000 (to 33% and 32%, respectively).

Copper consumption from scrap (**Table 6**) does not include a significant amount of runaround or home scrap. From 15% to 40% of raw material consumed remains in the production cycle of some brass mills and is recycled again and again. To include this material in consumption statistics each year, however, would be to double count the material each time it passed through the production process and was scrapped. Yet, this material is available and very necessary for the complete production cycle. Few statistics are available to quantify runaround material.

Owing to the increase in manufacturing scrap, there has been a gradual increase in total purchased scrap marketed in the United States since 1982, as shown in **Table 6** and in **Figure 6**. Scrap is a necessary raw material ingredient in the U.S. manufacturing cycle. Not only does the U. S. industry generate many tons of copper-base scrap, but it also needs and uses many thousands of tons each year in the process of new manufacture.

U.S. Trade in Copper and Copper Alloy Scrap.

U.S. derived copper and copper alloy scrap of all types has significant intrinsic value both to the U. S. and World manufacturing industries. Secondary copper-base scrap, including lower-graded copper materials with by-product metal value, are all commodity-like materials that are traded (bought and sold) and used just like other raw materials and, as such, form a significant part of U.S. copper exports and imports.

The United States is a significant exporter of copper and copper alloy scrap, as shown on **Table 8**, and is the world's largest exporter of copper-base scrap since 1999. The most significant U.S. scrap export destinations are in Western Europe and Asia. The United States also imports significant quantities of scrap. The most important sources in 2001 for U.S. copper and copper alloy scrap imports were Canada (35%) and Mexico (44.6%). Scrap exports generally have been increasing since the early 1970s, reaching peaks in 1989, 1995 and again in 2000 and 2001. U.S. scrap imports and exports were down significantly in 1998 and 1999, as a result of the worldwide depressed prices for copper and the strong U.S. dollar. The lower scrap price and stronger dollar combined to make U.S. scrap scarce for domestic buyers and expensive for foreign buyers. Primary copper at bargain prices has provided a ready substitute for those who can utilize it. However, owing to the types of furnaces used, size of charge needed and chemical requirements for certain alloys, this is not possible for all secondary metal users, and the market has become difficult for these industries.

The trend in U.S. net scrap exports appears as a mirror image to the trend of copper recovered from refining scrap, as shown in **Figure 6**. When refining from scrap (largely *old* scrap) is high, net exports (exports less imports) are lower. Lower exports and higher imports of scrap in the early 1980s were, in part, owing to the stronger dollar of the period.

Trade in low-grade, copper-containing ash and residues has been recorded by the Bureau of the Census under HTS 262030 since 1989, when the harmonized code was instituted in the United States. Prior to this date, the TSUS standards and nomenclatures were used. For exports, the TSUS number is 6030010, and, for imports, it is TSUS 6035040. Exports of "ashes and residues containing mainly copper" are reported in gross weight of material. The import data are in copper content, but it can be extrapolated to gross weight, for comparison with the USGS reports for consumption of low-copper ashes and residues. Although the material may contain up to 65% copper, an average copper content of 35% was used in estimating the gross weight for exports and imports in **Table 9**.

The major trading partners receiving ashes, residues and slag from the United States for further processing are Belgium, Canada, Germany, Mexico, the United Kingdom and, more recently, China. Major import sources are the copper producers of Botswana, Chile, Mexico, Canada and Australia. Copper ashes and residues exports increased from the early 1980s to reach 28,110 tons in 1995, but they have since decreased to as low as 8,340 tons in 2001. Imports have been decreasing from 5,400 tons (copper content) in 1988 to less than 630 tons in recent years (**Table 9**.)

Because many of these materials are associated with the brass and bronze making process, trade in zinc dross, skimmings, ashes and residues are also shown in **Table 9**. As measured in zinc content of zinc ash and residues (26201960), exports reached a peak in 1992, declined through 1999, but increased significantly in 2000 and 2001. Zinc ash and residues imports steadily increased to around 24,300 tons as measured in contained zinc in 1998, but, since then, they have decreased to about 13.7 thousand tons in 2001.

U. S. Export Controls on Scrap. Copper and copper-base scrap has been in such tight demand and scarce supply during periods of high military excursion and/or difficult economic conditions that U. S. export controls and other restrictions have been placed on the use of scrap. During the tight supply periods of the 1960s and early 1970s which were occasioned not only by the Vietnam War but also by extended labor strikes, releases of more than 1 million tons of copper from the National Defense Stockpile and price controls were required. A brief review of the historical events surrounding the use of export and price controls relative to the copper market and the need for copper scrap is instructive. The reader may refer to **Appendix A** for a more detailed accounting of events prompting the need for export controls. Given the propensity for military efforts to use large amounts of copper and its alloys, as well as to cut off major sources for copper around the world at times, it is highly possible that export controls and the pressure for increased use of secondary copper can occur again. All of the remaining copper in the National Defense Stockpile was sold in 1993.

Products and By-products Produced from Scrap

Wrought Copper and Copper Alloys. The making of brass and bronze wrought metal alloys for brass mills accounts for the largest share of copper recovery from scrap. Wrought copper and copper alloys are produced from purchased scrap, home scrap, refined copper and other metal alloying additives. These alloys are then fabricated into products such as sheet, tube, rod and pipe. Wire-rod mills produce continuous cast pure copper rod for making wire that is then drawn down to various types of coated and uncoated wire.

Because of the stringent requirements for making copper wire, wire-rod mills use mostly refined copper in making rod. The small amount of scrap that is used by wire-rod mills must first be refined. Only one wire-rod mill in the United States has a continuous system for fire refining, melting and rod casting from scrap. This mill uses the company's own customer-returned scrap from its wholly owned wire mills in the fire-refining plant. For 2001, the combined semifabricate production of brass and wire mills amounted to nearly 3.5 million tons of copper and copper alloy products, according to the ICSG (May 2002). This achievement represents a significant increase compared with a total of 2.8 million tons of semifabricated products produced in 1989, as shown in **Table 10.** The commensurate increase in U.S. copper consumption statistics is a reflection of this increased brass and wire mill activity and, therefore, does not represent an accurate statistic for the entire U.S. community's consumption of copper. Copper in imported goods must also be considered.

Brass and Bronze Ingots. According to the U. S. Geological Survey, ingot production in the United States was about 164,000 tons in 2000 and has been less than 200,000 tons over the past 10 years. This is down considerably from the 300,000 tons to 380,000 tons produced in the 1960s and 1970s. It is interesting that U.S. ingot exports have increased significantly in recent years, while imports have dropped off sharply since 1999. Ingot making was a critical industry during World War II. This was so much the case, the Defense Production Act required that, among all other government copper surveys, only the ingotmaker, foundry and brass mill data surveys were mandatory under penalty of law. Special alloys and the special castings, fittings and parts made for military uses are dependent upon domestic production from ingotmakers and foundries.

Ingot makers produce a wide range of cast copper alloys for the nonferrous foundries. Ingots weigh about 30 pounds each when cast, being of a small enough size to suit foundry furnaces. **Table 10** indicates production trends for several broad ingot groups. The most important of these are the red brass, bronze and yellow brass groups. **Figure 7** clearly shows the gradual decline in U.S. ingot production since the middle 1980s. The leaded and semi-leaded red brass and the tin bronze categories of ingot seem to show the most volume decrease over this period. For a general range in ingot compositions, see **Table 11.** There are actually hundreds of ingot metal compositions designed for special tasks. The groups shown in **Table 10** are very general.

Individual grades of copper and copper alloys were designated in the past by a three-digit number series developed by the industry. More recently, however, this series has been incorporated into the Unified Numbering

System (UNS) for Metals and Materials developed by the American Society for Testing and Materials and the Society of Automotive Engineers. This system designates each alloy by 5 digits preceded by the letter C. The UNS system is administered by the Copper Development Association Inc. There are about 460 types of copper and copper alloys divided into the broad categories of wrought and cast metals. Within these two categories, the metals are further subdivided into classes as follows:

Coppers: Metals containing at least 99.3% copper. There are 54 numbered coppers, including oxygen-free, tough-pitch, and deoxidized varieties.

High-copper alloys: Copper content of cast alloys is at least 94%; copper content of wrought alloys is 96% to 99.3%. This class includes the cadmium, beryllium and chromium copper alloys.

Brasses: Copper alloys containing zinc as the principal alloying element. There are 3 families of wrought brasses and 6 families of cast brasses. EnviroBrasses 1, II and III were recently introduced as lead-free alternatives to the leaded-red brasses used in plumbing. These lead-free cast red brasses contain bismuth and selenium as principal additives.

Bronzes: Copper alloys in which the principal alloying element is usually tin, and which contain other metals such as aluminum, lead, phosphorous and silicon but not zinc or nickel.

Copper Nickels: Copper alloys with nickel as the principal alloying metal.

Copper-nickel-zinc-alloys: Copper alloys containing nickel and zinc as the principal and secondary elements; commonly known as nickel silver.

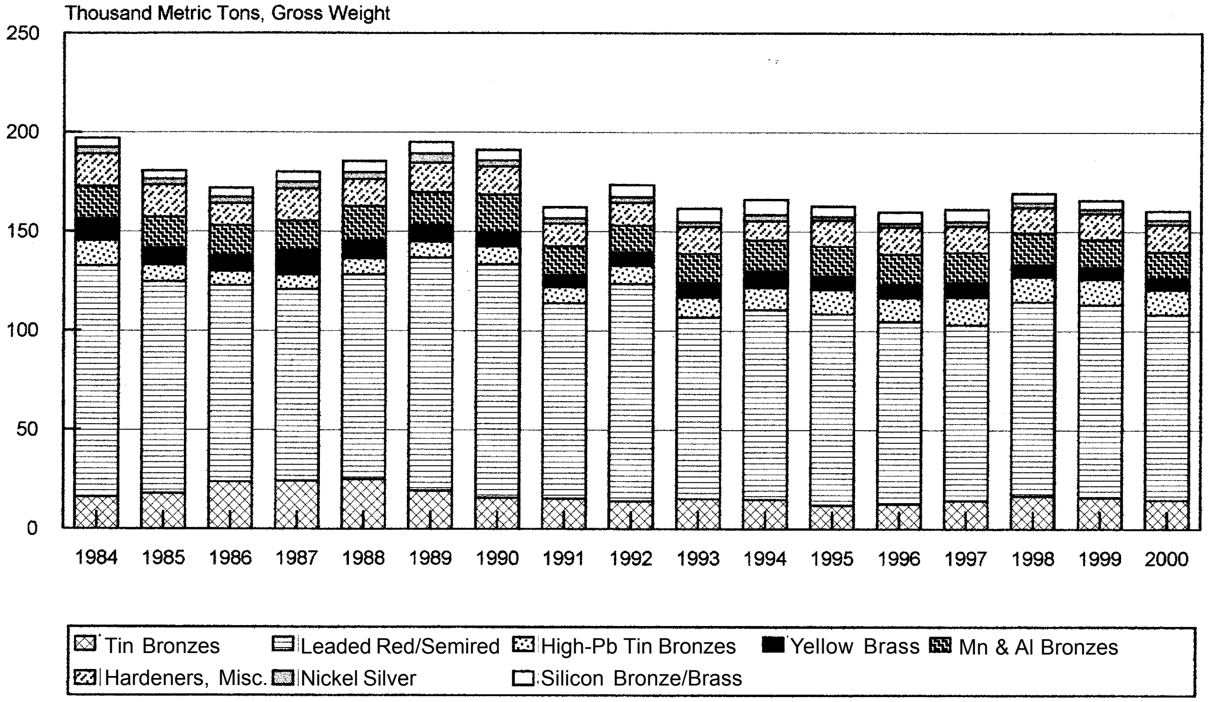
Leaded coppers: Cast copper alloys containing 20% or more lead, usually a small amount of silver but no zinc or tin.

Special alloys: Copper alloys with compositions not covered by the above descriptions

Master alloys and hardeners are also produced by a select group of ingotmakers for use by others in performing certain functions in their melt. Master alloys usually contain 10-15% of the desired metal, and the remainder is copper. They perform the function of making the addition of potentially difficult metals easier to melt. Master alloys are produced in shot or ingot form and are used as a melt addition to deoxidize, harden, improve fluidity or control composition in many base alloys. For example, phosphor copper master alloy is used as a deoxidizing additive in making copper tube.

Refined Copper. According to data collected by the U. S. Geological Survey, 150,000 tons of refined copper was produced from scrap in 2001, down significantly from 460,000 tons produced in 1993. Refined products formed include cathode, ingots, billets, shot (small metallic pellets), wirebar and continuous cast rod. In addition, about 7,500 tons of copper powder was also produced from scrap. **Table 12** shows the manner in which copper is extracted from scrap and the form of recovery from 1992 through 2000. **Table 7.** shows the historical production of refined secondary copper in the United States for the years 1966 through 2001. The decreased recovery of secondary copper, from 27% to 8% since 1987, is obvious in the data trends shown in **Table 7** and is a reflection of the loss of U.S. secondary refinery and smelter capacity over this period.

Figure 7. U.S. Copper Alloy Ingot Production, by Ingot Group, 1984-2000



Source: U.S. Bureau of Mines and Geological Survey Mineral Yearbooks.

Black copper. Black copper is an intermediate product produced in a blast furnace from low-grade scrap. Black copper still contains some iron and zinc along with most of the tin, lead and nickel of the charge. A typical composition is 75% to 88% copper, 1.5% tin, 1.5% lead, 0.1% to 1.7% antimony, 3% to 7% iron, and 4% to 7% zinc. Traditionally, this material can be refined in a scrap converter with the addition of liberal coke to the charge, which adds extra heat and provides a mildly reducing condition, thus facilitating the removal of zinc, tin and lead. Copper anode is then poured for further refining in an electrolytic tank house. Slag, produced as a by-product, may contain 1.5% copper, or more, and can be granulated and sold as aggregate or reprocessed when the copper content is high enough.

Copper Chemicals and Powders. Most copper chemicals made in the United States today, such as the copper oxides and hydroxides and copper sulfate, are derived from processing copper scrap or from the process waste liquors associated with refining copper. Generally, the purer, less contaminated forms of scrap are preferred for making chemicals to avoid inclusion of deleterious metals. Even so, some hydrometallurgical processes permit the use of some types of mixed scrap, such as copper-plated steel and printed circuit boards. Copper powders are also made from refined metal derived from scrap. Copper powder and copper sulfate production in the United States is shown on **Table 10**. Copper sulfate production reached 55,500 tons in 2000, up significantly from 33,200 tons in 1989, according to the U.S. Geological Survey statistics. Copper powder production has ranged between 7.4 to 11.7 thousand tons in recent years.

According to Queneau and Gruber (1997), about 13,320 metric tons of contained copper per year is extracted from copper-base scrap as chemicals. This copper is produced as copper oxides and hydroxides, copper sulfates and other copper chemicals and is extracted hydrometallurgically from a variety of copper-bearing scrap. In addition, a small amount of low-grade cathode is produced from electrowinning pickle liquors and sludges.

Secondary Copper By-products. In the process of ingotmaking, fire-refining and casting of copper and its alloys, some low-copper or mixed scrap materials are generated, such as: scalper and other dusts, grindings, mill scale, drosses, skimmings, ashes, slags and other residues. Most of these residues are marketable, or can be used and recycled at the plant of generation. Scalper scrap and dusts generated in the process of cleaning billet and other pure copper forms may be entirely copper. Copper skimmings and drosses from melting furnaces can run 20% to 65% copper and contain notable amounts of other metals such as nickel and zinc. Grindings may be as much as 100% metal and contain 10% to 76% copper. Many of these residues contain valuable by-products other than copper, such as precious metals, tin, antimony, lead, nickel or zinc, for example, which can be recovered and upgraded.

Copper slags resulting from fire-refining can run up to 65% copper, making them highly desirable and marketable products. This is especially true of slags resulting from fire-refining No. 1 scrap, where there are few, if any, associated deleterious metals. However, more metals may result in the slag than is desirable from cleaning up less pure scrap. These slags may require further metallurgical treatment to recover the valuable by-product metals. High silica slags have been used for many nonmetallurgical purposes when they are free of deleterious elements. Among other uses, slags have been used for the production of light-weight aggregate and rock wool.

In making some master alloys, special types of residues are generated. In the case of making phosphor copper master alloy, the dominant residue contains phosphoric acid. Most of the phosphoric acid by-product thus formed is collected and sold to fertilizer manufacturers for use in making fertilizers.

Some brass mills process their own pickling solutions to recover copper by electrolytic processes. In recent years, there have been several hydrometallurgical plants that have thrived on processing other companies' sludges and residuals for copper, zinc, selenium, tellurium and other metals. Waste treatment plant sludges may contain 15% copper and a 1% to 2% zinc content. Nickel dross from copper-nickel alloys may run as high 40% copper and 6% nickel, making it a valuable market material. Copper and brass drosses may run as high as 55% copper and contain notable amounts of other metals such as antimony, zinc, tin and nickel. Scalper dusts generated by scalpers that remove copper oxide from mill products may also contain enough copper to be recoverable and are often recycled within the plant of origin.

Baghouse Dusts. Baghouse dusts are usually sold for their zinc, copper and tin content. About 30% of U.S. zinc consumption (James Jolly, 1993) is derived from all secondary materials, including flue dust collected during copper alloy processing. Nearly three-quarters of U.S. recycled zinc in 1997 (Palachy, 1997) was derived from the new scrap generated mainly in galvanizing and diecasting plants and at brass mills. Recycled zinc was used for the production of zinc metal and alloys and zinc oxide. The Zinc Corporation of America's plant in Monaca, Penn., is the largest processor of secondary zinc. Clean, new brass scrap and clippings usually require only remelting. Most of the zinc from flue dust is recovered through various pyrometallurgical methods.

Bag house dusts collected from the typical blast furnace or cupola used in melting low-grade copper scrap generally contain (Spendlove, 1961) 58 – 61% zinc, 2 – 8% lead, 5% – 15% tin, 0.5% copper, 0.1% antimony, 0.1 – 0.5% chlorine, and some unburned carbon. When high in zinc (about 65%) and low in lead (less than 3%), these materials can be used for animal feed and for making fertilizer components. Most of the zinc oxide is shipped either in large (2,000 lb.) plastic bags (Supersaks) or in metal drums. Some of the zinc oxide collected, however, may be lower in zinc (20% to 40%) and higher in some of the less desirable elements. In this case, when they are sent to another plant for treatment, they may be shipped as hazardous materials.

Other Metal Recovery. In the process of making copper-base alloys from scrap, notable amounts of other metals, such as tin, antimony, lead, zinc, nickel and aluminum are also recovered. The U.S. Geological Survey in its annual Minerals Yearbook reports the average composition of secondary copper-alloy production. According to the 2000 USGS report, brass and bronze ingot production from scrap resulted in the recovery of 136,000 tons of copper, 5,240 tons of tin, 8,430 tons of lead, 14,400 tons of zinc, 252 tons of nickel and 14 tons of aluminum. Secondary metals that were recovered in making brass mill products were estimated to be 844,000 tons of copper, 1,650 tons of tin, 7,450 tons of lead, 199,000 tons of zinc and smaller amounts of other metals. In addition to 42,200 tons of copper at U.S. foundries, 633 tons of tin, 837 tons of lead, 1,700 tons of zinc and smaller amounts of other metals also were recovered from secondary sources.

Items that Go to the Landfill. While most low-grade residues have traditionally found markets for further processing or use, it sometimes becomes economically impracticable to further process a material or, for economic reasons, to find a buyer for the materials. In these cases, these materials are sent to a landfill. The kind of landfill selected is determined by the tests the materials must pass. At a minimum, all production by-products sent to a land fill must pass the USEPA TCLP test before a dumping permit is granted. Even so, the landfilled material can serve at times a useful purpose at the landfill. For example, some brass mill slags and the black glass residue from a slag cleaning process can play an important part in the operation of the local dump as a suitable substitute for sand, which is usually purchased and used to cover a landfill at the end of the day. Spent refractory and furnace brick are also used in a similar way at some localities.

Some materials, such as the mildly acid water resulting from making phosphor copper shot, are treated to make an inert calcium phosphate sludge before being landfilled. Spent sulfuric acid (pickling solutions) that has already had metals removed from it may be shipped as a hazardous material to another plant for treatment and disposal as gypsum in a landfill. Some firms specialize in treating spent sulfuric acid for disposal.

The most commonly landfilled materials associated with metal making are the spent metallurgical brick and ceramic materials used for lining the furnaces, when these are not high enough in metal value to attempt recovery. These materials also must pass the TCLP tests prior to dumping. Most brass mills, foundries and ingot makers ship some spent furnace brick to the landfill, although some have indicated that the material may be used also as road material, purchased by a scrap dealer for further distribution in the market, used in making concrete, or may be sold for its metal content. Some firms have indicated that spent furnace brick containing significant cadmium or lead will be shipped as a hazardous material.

Description of the U.S. Secondary Industry. The main consumers of copper and copper-base alloy scrap are smelters, refineries, ingot manufacturers, and the brass and bronze mills. Brass and bronze ingot makers and mills make cast and wrought alloys mainly from brass and bronze scrap. Copper alloy scrap may be supplemented by other materials such as No. 1 copper scrap, small amounts of refined copper, and alloying additives such as tin and zinc and master alloys. According to data collected by the USGS, ingot makers accounted for 9.7% of total copper recovered from U.S. copper-base scrap consumption in 2000, 75% of which was from *old* scrap.

Brass mills make wrought alloys poured in shapes, such as billet and slab, that are then fabricated to finished mill products, such as sheet, tube, rod, and pipe. Brass, copper tube, and wire-rod mills accounted for 68% of the copper recovered from copper-base scrap in 2000, only 2.6% of which was from old scrap. Brass mills use purchased copper alloy scrap and No. 1 copper scrap along with significant quantities of home-generated scrap, refined copper, and alloying additives such as slab zinc, lead, tin and nickel. No. 2 and lower grades of copper scrap are usually refined before use by the mills. Copper tube mills utilize a higher percentage of *old* scrap than brass mills, but demand a high quality No. 1 copper scrap from dealers and scrap preparers when a refinery is not associated.

Refiners use both low-grade and high-grade scrap as raw material. Low-grade scrap is treated by a series of pyrometallurgical operations followed by electrolytic refining. The electrolytic cathodes are then melted and cast into various shapes by the mills. Higher grades of scrap can be introduced in the later stages of processing. For example, No. 2 copper is generally introduced before the anode melting step that is required before electrolytic refining in a tank house. No. 1 copper may be either fire-refined or introduced at the cathode-melting step, as a substitute for cathode. Refiners and smelters accounted for 16.8% of copper recovered from copper-base scrap in 2000, 81% of which was from *old* scrap.

The U.S. copper industry has undergone significant changes since the early 1980s. Most U.S. reverberatory furnaces closed in the early 1980s in response to environmental pressures to clean up the air, as well as to cope with the strong dollar and a deteriorating competitive position. These useful workhorse furnaces were replaced in the primary copper industry with flash furnaces that depend upon a high sulfur content in their feed for efficient operation. This action not only cut the need for copper scrap by the primary smelters, but it also trimmed the potential capacity available for processing low-sulfur, low-copper ashes and residues. The reverberatory furnaces also began to disappear in the secondary industry for similar reasons. The large secondary smelter at Carteret, New Jersey, closed during this period owing to environmental requirements and poor markets of the time. Air quality standards forbid the burning of associated materials to obtain old scrapped metal, such as plastics and circuit boards associated with electronic and electrical scrapped items, making it nearly impossible to process these materials by smelter. Although replaced in part by rotary and submerged arc furnaces and improved air-particle capture systems, capacity has nearly ceased in the United States for processing low-grade copper scrap and residues.

The Nassau metals facility in Gaston, South Carolina, which was based on the need to process-scrapped wire from AT&T operations, was purchased in the early

1990s by Southwire. For several years, Southwire operated both its Carrollton, Georgia, and Gaston, South Carolina, secondary smelters and refineries. However, in 1995, Southwire closed the Gaston plant to concentrate its recycling efforts at Carrollton. In 1999, Southwire announced its intention to sell its Carrollton plant and, by 2000, had closed both its smelter and electrolytic refinery associated with its wire-rod plant in Carrolton, Georgia.

Only five years ago, there were 7 primary and 4 secondary smelters, 8 electrolytic and 6 fire refineries, and 14 primary electrowinning plants operating in the United States. Two of the electrolytic refineries were dedicated to two of the secondary smelters, processing anode made from scrap. Several of the primary smelters and refineries also processed some scrap and secondary anode. The U.S. fire refiners processed only scrap. In addition, about 23 ingot makers, 53 brass mills, 15 wire-rod plants and about 600 foundries, chemical plants and other manufacturers consumed copper scrap in the United States. In September 1996, the Franklin Smelting and Refining Co. in Philadelphia, a relatively small secondary smelter with capacity to produce about 15,000 tons per year of blister copper, closed as a result of the high cost of environmental compliance.

Cerro Copper Products and Chemetco in Illinois and Southwire in Georgia once operated secondary smelters. Chemetco produced anode for sale to others for electrolytic refining. Cerro had a completely internal process dedicated for use in its associated copper tube plants and Southwire produced copper for use in its wire-rod mill. In April 1998, Cerro Copper suspended operations at its 40,000 ton-per-year electrolytic refinery and associated secondary smelter but still retained use of its 30,000 ton-per-year fire refinery.

In 2001, the smelter at Chemetco closed. Difficult times had come for the secondary smelters, stemming from the low copper price, high cost of environmental compliance and the cost-squeeze that these two had created. Chemetco also had been under suit for potential water contamination associated with its operations. Although in 2000, there were still six secondary fire refiners, the last of the secondary electrolytic refineries at Southwire closed in 1999.

In addition to continued retraction of the secondary industry in 1999, three of seven U.S. primary smelters also closed in response to lower copper prices and market surpluses and remained closed through 2002. According to the USGS, U.S. copper smelter and refinery production fell in 2000 by 42% and 26%, respectively, compared with 1998. The loss of capacity and the effect of lower prices on scrap availability also impacted secondary output. There continued to be generally a shortage of scrap for fire refining in 2001. Although the fire refinery at Warrenton, Missouri, closed in 1999, it reopened again in 2000 under new ownership. There would appear to be still a large number of foundries, but only the strongest of the ingot makers have done well under the difficult market conditions of the past few years.

Most high-grade U.S. copper base scrap is consumed at brass and tube mills. One wire-rod mill has a direct cast operation in conjunction with fire refining its own wire-mill-generated scrap. Although it is estimated that there currently are about 53 primary brass and tube mills, it is difficult to count the actual number, since these have tended to change ownership as well as to expand the number of plants under the same company name. It is sometimes also difficult to separate downstream mills, such as rolling mills, from those that process metal to make semifabricates. Only plants that melt raw material to make primary forms are considered *primary* brass or tube mills. Reroll and redraw mills, or mills that operate with imported basic shapes, are not included in the primary mill lists.

Brass Mills. U.S. primary brass mills (a generic term that includes copper tube and sheet mills) have been concentrated in the middle and northeastern United States. The largest brass mills are located in Missouri and Ohio. The following is the number of brass mills operating in the United States, by State:

Alabama (1)
Arkansas (1)
California (1)
Connecticut (5)
Indiana (2)
Iowa (1)
Illinois (4)
Kentucky (2)
Louisiana (1)
Massachusetts (1)
Michigan (3)
Mississippi (2)
Missouri (1)
New Jersey (3)
New York (2)
North Carolina (3)
Ohio (5)
Oklahoma (1)
Pennsylvania (8)
Rhode Island (1)
Tennessee (2)
Virginia (2)
Wisconsin (2)

It should be noted that reroll, or redraw mills are not included in the above list.

Foundries. Foundries are mostly small, family-owned operations located near major industrial centers, such as those in Illinois, Alabama, Indiana and Wisconsin. Foundries, as a rule, do not produce alloy ingot for making their products. Even so, there are a few large foundries that have an associated ingot making facility. Virtually all foundries remelt the gate scrap and the sprues, risers and rejected castings scrap generated during production. According to the U. S. Geological Survey, about 58,100 tons of purchased copper and copper alloy scrap was processed by the foundry industry in 1998. However, most foundries do not have the capability to perform smelting, refining, and chemical analysis of purchased scrap. Therefore, large quantities of scrap cannot be used, and the purchase of ingot with a known chemistry is relied upon. Some foundries, however, do prefer some types of scrap, such as No. 1 chopped wire because of its small size and easy melting. In effect, foundries are remelters and producers of engineering shapes. Although 100% ingot charges may be used, charges comprised of combined ingot, returns, and scrap are not uncommon. Experience, the quantity of shop returns, and the cost of available raw materials will dictate the exact proportions.

Ingot Makers. These plants produce a wide variety of copper and copper alloy and master alloy ingot for foundry, brass mill and other industry consumption. In addition to purchasing a large proportion of the *old* copper and copper alloy scrap collected each year, ingot makers also purchase significant quantities of skimmings, grindings, high-grade drosses and other by-products for their metal content. There are about 23 currently operating ingot makers, down from the 28 counted in 1991. These are concentrated near the industrial centers of Chicago, Los Angeles and the eastern United States (**Table 14**). Ingot makers are consumers of a wide variety of copper and copper alloy materials and other metals. Most U.S. ingot makers are independent, largely family-owned and operated businesses.

Secondary Smelters and Refiners. From the total of 5 plants in 1991, there currently is no secondary smelting plant operating in the United States that is capable of processing the lower grades of copper scrap. The last operating plant in Illinois closed in 2001. There are no operating secondary electrolytic refineries. One fire-refining plant, located in Warrenton, Missouri, produces refined copper ingot and wire bar from scrap. This plant closed in early 1999 but reopened again in 2000 under new management. Two fire-refining furnaces are associated with tube and wire-rod plants, making a total of 3 fire refineries remaining in the United States in 2001.

Hydrometallurgical Plants. A number of plants in the United States have created thriving businesses based on hydrometallurgical processing of secondary by-products produced by other metal production and metal finishing companies. Some of these companies are listed in **Table 14**. Using circuit board scrap, bimetallics , No. 2 and No. 1 scrap, most of these companies produce products such as cupric oxide, copper sulfate and copper carbonate. A few companies produce low-grade copper cathode and other metal products from wastes, sludges and pickling liquors.

Classic secondary copper feed for hydrometallurgical processing includes:

- Wire choppings, mill scale, mud from wire drawing, tubing, turnings and grindings, clips and leaded cable.
- Scrapped brass and bronze such as plumbing fixtures
- Auto radiators
- Shredder pickings from automobiles
- Spent etchant and pickling solutions
- Circuit boards
- Spent catalyst, including metallic copper
- Waste water and other sludges (F006 wastes)

Metal Finishing Facilities. Although beyond the scope of this paper, a brief mention should be made of the metal finishing industry and its contribution to the flow of secondary copper by-products. There are over 31,000 metal finishing facilities in the United States, a modest proportion of which use copper products. They vary in size, age and type of operation. Typical wastes generated include industrial wastewater and treatment residues (sludges), spent copper plating and process baths, spent cleaners and waste solvents and oil. The metal-laden sludges (F006 wastes) generated at these plants provide a source of copper and other metal raw material for some hydrometallurgical recovery plants.

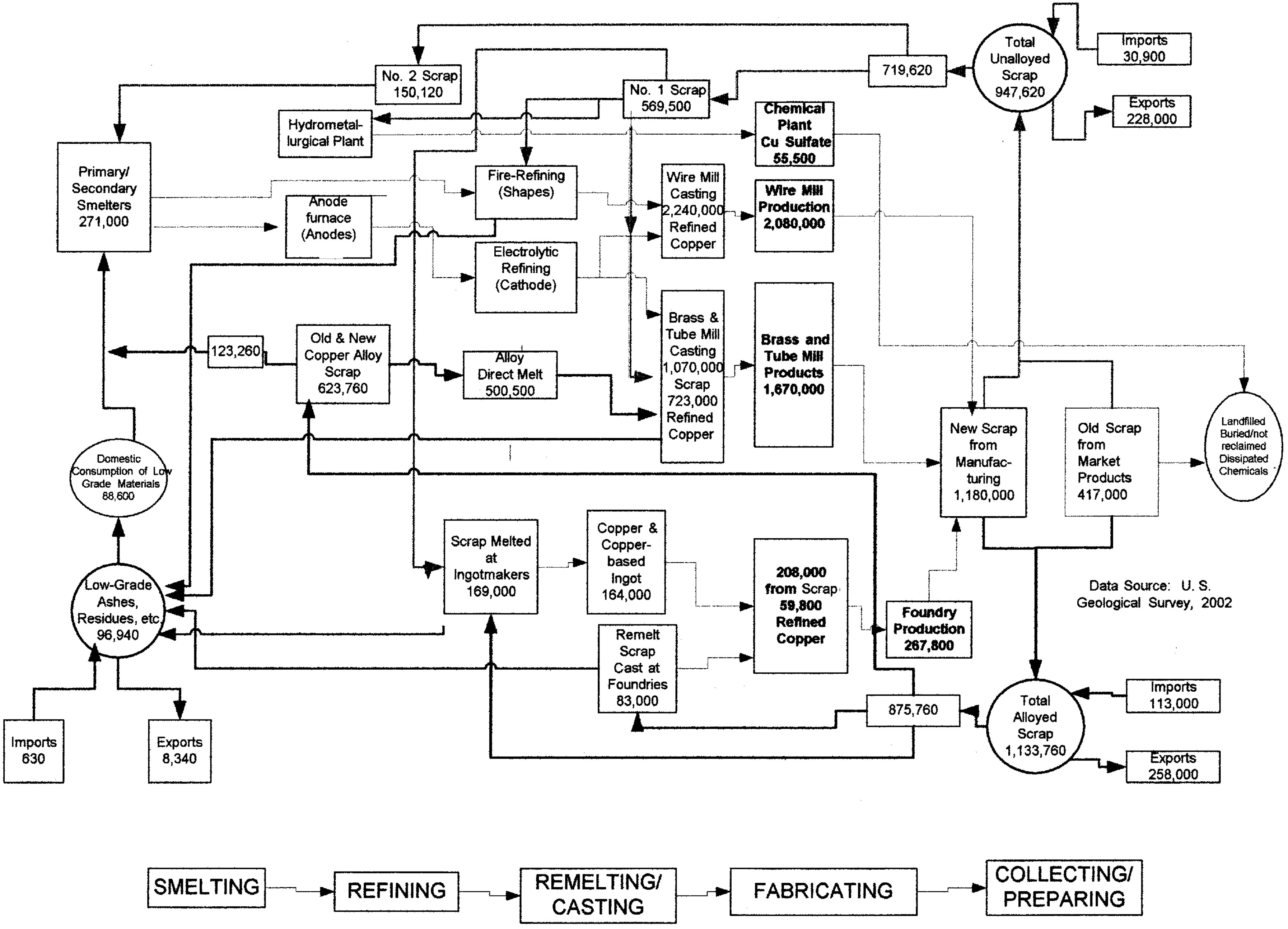
Flow of Materials.

Summary of Scrap Flow. The chart in **Figure 8** shows the flow of purchased secondary copper-base materials from the various sources to the final manufacturing destination. The chart traces the scrap flow from old and new, unalloyed and alloyed, and low-grade copper scrap types as they are processed from sources through secondary smelters, refineries, ingot makers, brass mills, and foundries to final products. The domestic sources for low-grade ashes and residues are the processing facilities (ingot makers, secondary smelters and refineries, brass and wire mills) themselves. Some low-grade ashes and residues are also imported and exported. Not shown on this chart, but also important, is the significant amount of runaround, or home scrap that is used by the industry. At tube mills, this in-house scrap can amount to as much as 30% of the material first poured to make billet and then processed to tube. Since this material generated within the plant can be easily remelted, or fire refined, much of the home scrap generated is not sold to the open market. Although about 28% of the skimmings and slag and other by-products generated are processed in house, most enter the purchased scrap market. The home scrap environment is similar at a brass mill that is fully integrated. The clean copper alloy scrap generated from milling and edge trimming operations is recycled to the brass mill casting shop, were it is remelted and cast into cakes and other forms for further use.

A current trend in response to the disappearing secondary smelting industry has been the effort by some ingot makers and brass mills to process their own by-product skimmings, slag and other residues. It has been estimated that as much as 28% of the slag and skimmings generated are reprocessed in house. Home scrap data will not appear in the published data on purchased scrap, since it never leaves the plant and is not purchased or sold. It forms an essential part of the production process, however, and is commonly known as runaround, since this is what essentially happens. This particular scrap source goes around and around and is not considered a *new* source of copper supply. As a useful reference, the purchased scrap data collected by the U.S. Geological Survey for 2000 are shown at the major points to indicate the gross weight quantity of scrap processed. Most of the numbers used in this flow sheet can be found in the tables included with this report. Others are published in various U.S. Geological Survey reports.

Figure 8. U.S. Copper and Copper Alloy Purchased Scrap Flow Chart for 2000

(metric tonnes, gross weight)



Total U.S. Scrap Consumed:
1,593,000 Tons

CHAPTER 2 – OVERVIEW OF SCRAP SOURCES AND TYPES

Scrap Sources and Types

The Institute of Scrap Recycling Industries, Inc. (ISRI) recognizes about 53 classes of copper and copper alloy scrap. The organization publishes a scrap specification circular that details guidelines for nonferrous scrap. Although there are several grades within each, the major unalloyed scrap categories are No. 1 copper (common names – Barley, Berry, Candy and Clove), which contains greater than 99% copper and often is simply remelted, and No. 2 copper (common names – Birch, Cliff and Cobra), which usually must be re-refined. No. 2 copper consists of unalloyed copper having a nominal 96% copper content (minimum 94%) as determined by assay. Light copper scrap (Dream) contains between 88% and 92% copper. All grades are clear of excessively leaded, tinned or soldered copper scrap and bronzes and brasses, etc. Refinery Brass has a minimum of 61.3% copper and maximum of 5% iron and consists of brass and bronze solids and turnings, and alloyed and contaminated copper scrap. Copper alloy scrap of various types may be classified by alloy type, or by end-use derivation, since certain alloys are consistently used for the same machine part or other useful item. For example, composition or red brass scrap derived from valves, machinery bearings and other machinery parts is used again for making similar cast items. Red brass scrap should be free of semi-red brass castings (78% to 81% copper), railroad car boxes and other similar high-lead alloys. **Table 15** shows a list of generalized chemical compositions for various scrap types.

Several alloy scrap type groups, such as mixed unsweated auto radiators (Ocean), provide sizeable amounts of copper scrap each year, as shown below. Other important sources of scrap, by volume, include cartridge cases (70/30 brass) from the military and other yellow brass castings, rod turnings and rod ends. Significant amounts of unalloyed copper are derived from discarded wire, busbars, clippings and tube. A relatively new scrap type, aluminum/copper radiators, also is finding use among scrap remelters. As shown in **Table 16**, copper from aluminum-base scrap has been increasing, from 8,000 tons in 1950 to 73,000 tons in 2000. Copper from all scrap sources over the same period increased from 886,000 tons to over 1.4 million tons in 1997, but in 2000 was down to a little over 1.3 million tons.

In addition to the many copper and copper alloy scrap types, there are many special types, such as skimmings, ashes, refining slags and residues, which contain 10% to 65% copper. Copper may also be recovered from other mixed scrap of lower copper content, such as electronic scrap, printed circuit and other clad materials, and metal-laden waste liquors. The markets for these products are different from those for the purer grades of copper-base scrap, because they must be reprocessed, smelted or electrowon to obtain the valuable metals contained in them. In the market, products of less than 65% but higher than 10% copper, including refinery brass and low-grade copper containing materials, have been traditionally processed by copper smelters and refiners or ingot makers.

Several terms have been applied to copper-containing materials with less than 65% copper but more than 10% copper. The Department of Commerce trade classifications describe this material as "metal-bearing materials used for extraction of metal, with chief weight of copper" (prior to 1989), and "copper materials containing over 10% copper" (since 1989) but not listed under primary ores and concentrates. These materials are commonly called copper-containing ashes and residues as a general group, but they contain a wide variety of products that are generated as by-products of copper and copper alloy metal manufacture. In examining the trade lists, it is impossible to distinguish between skimmings, residues or slags containing copper. It becomes even more difficult in the international trade arena with the earlier SITC codes used by the United Nations, which contain other products lumped together with the copper items.

EPA Secondary Product Definitions

The U.S. Environmental Protection Agency (EPA) plays such a big role in how the secondary industry carries out its business, it is worth reviewing that agency's definitions for secondary products**.** According to the EPA (40 CFR Chapter 1 (7/1/98 Ed.) (261.2)), a material such as process slags and residues is reclaimed if it is processed to recover a usable product, or if it is regenerated. A material is *used or reused* if it is either:

(1) Used as an ingredient (including as an intermediate) in an industrial process to make a product. However, a material will not satisfy this condition if distinct components of the material are recovered as separate end products. For example, this is the case when metals are recovered from secondary materials.

(2) Used in a function of application as a substitute for a commercial product such as sludge conditioner in wastewater treatment. *Scrap metal* is defined as bits and pieces of metal parts. This includes turning, bar, rod, sheet, wire or metal pieces that may be combined together with bolts or soldering (car radiators *etc.*) that can be recycled.

A material is a *by-product* if it is not one of the primary products of a production process and is not solely, or separately, produced by the production process. Examples are process residues such as slags. The term does not include a co-product that is produced for the general public's use and is ordinarily used in the form produced by the process. A *spent material* is any material that has been used, and as a result of contamination, can no longer serve the purpose for which it was produced without further processing.

A material is *recycled* if it is used, reused or reclaimed. A material is *accumulated speculatively* if it is accumulated before being recycled. It is not speculative, if it can be shown that there is a feasible means available for recycling it. There is a 75% turnover requirement for recycling The amount of material that is recycled or transferred to a different site for recycling must equal at least 75% by weight or volume of the amount accumulated starting on January 1 of the period. The 75% requirement is applied to each material of the same type that is recycled in the same way. Materials are no longer in this category once they are removed from accumulation for recycling.

Excluded scrap metal is processed scrap metal, unprocessed home scrap metal, and unprocessed prompt scrap metal. *Processed scrap metal* is that which has been manually or physically altered either to separate it into distinct materials to enhance economic value or to improve the handling of said materials. *Processed scrap metal* includes, but is not limited to, scrap metal that has been baled, shredded, sheared, chopped, crushed, flattened, cut, melted or separated and sorted by metal type. It also includes fines, drosses and related materials that have been agglomerated. Shredded circuit boards being sent for recycling are not considered processed scrap metal. They are covered under the exclusion from the definition of solid waste for shredded circuit boards being recycled. (261.4(a)(I3))

In a document issued March 1, 1990, EPA clarified the reclamation of unused, off-specification printed circuit boards. When reclaimed, unused printed circuit boards (30% copper, 68% fiberglass, 2% tin and lead) are considered as commercial chemical products; used circuit boards are spent materials; and circuit board trimmings are by-products. The unused circuit boards are secondary materials. Under 40 CFR 261.2, the Agency designates those secondary materials that are RCRA Subtitle C solid wastes when recycled. According to Section 262.2 (c) (3), unused off-specification commercial chemical products listed in 40 CFR 261.33 are not considered solid wastes when sent for reclamation. They are considered to be non-listed commercial chemical products and, thus, not solid wastes when reclaimed. The printed circuit board trimmings meet the definition of by-product, rather than scrap metal, and are not solid wastes when reclaimed under Section 2161.2 (c)(3). Although the trimmings are physically similar to scrap metal, to meet the definition of scrap metal, the material must have significant metal content; *i.e.,* greater than 50% metal.

Home scrap metal is scrap metal as generated by mills, foundries and refineries, such as turnings, cuttings, punchings and borings. *Prompt scrap metal* is metal as generated by metal working and fabrication industries. It includes scrap such as turnings, cuttings, punchings and borings. *Prompt scrap* is also known as *industrial* or *new scrap metal*. (See FR 83119, May 19, 1990, and amendments through May 12, 1997 (FR 26018).

By not distinguishing adequately between home scrap, runaround scrap and purchased scrap, EPA has not recognized the market potential of all scrap generated. When a scrap or by-product of any type leaves the plant for a market, it becomes purchased scrap. Purchased scrap of all types is traded at all levels of the industry. Home scrap, or runaround scrap is completely contained and never leaves the plant.

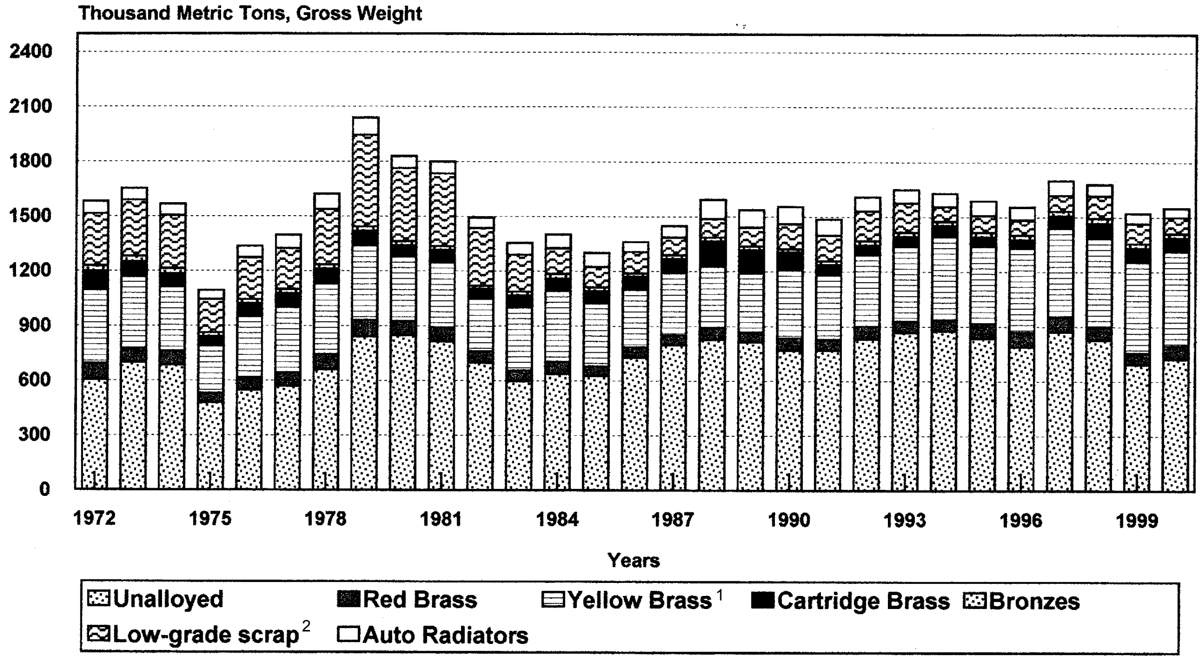
Consumption by Scrap Type.

According to the U. S. Geological Survey, the major copper-base scrap types consumed in the United States during 2000 were: No. 1 copper, (35.8%); No. 2 copper (9.4%); leaded yellow brass (26%); yellow and low brass (6.5%); automobile radiators (3.2%); red brass (4.7%); cartridge cases (4.6%); and low-grade ashes and residues (5.6%). A wide variety of other alloy scraps makes up the remaining 4%. Brass and copper tube mills processed 80% of the No. 1 copper and most of the cartridge cases and yellow brass, while the secondary smelters and ingot makers processed 87% of the No.2 scrap and most of the auto radiators and red brass scrap. About 30% of the scrap consumed each year is lead bearing and includes auto radiators using lead solder and leaded-yellow and leaded-red brasses.

The consumption of No. 2 scrap is expected to decrease at U.S. plants, since all smelters and electrolytic refiners have closed. Some primary smelters have been accepting limited tonnage of No. 2 scrap. However, exports are anticipated to make up for the loss of U.S. capacity, as discussed in the previous section on international trade. It is difficult to quantify the total volume of No. 2 scrap recycled each year, since the only statistics reported for the United States are consumption-based. Scrap traders are not surveyed. Adding exports to the No. 2 scrap consumption statistics also is not a certain solution, since these materials are not specifically defined as to type in those statistics. One might use a percentage calculation applied to the unalloyed copper scrap exports based on the ratio of No.1 to No.2 consumption for years before the demise of the smelter industry. In 1988, the ratio of No. 1 to No. 2 scrap consumed by the U.S. industry was about 1:1, but it has been deteriorating since that time (**Table 17**). In 1990, No. 2 was 45% of total unalloyed scrap consumed. Using 45% applied to 2001 exports of unalloyed scrap yields 98,000 tons of No. 2 scrap, plus another 154,000 tons that was consumed by U.S. industry. This results in about 13,500 tons of No. 2 scrap recovered per month, compared with an estimate of 32,000 tons per month that was common some 10 years ago. Some part of the decrease in total No. 2 scrap generated may also be related to the increase in better wire and cable recovery by scrap processors. More is converted to No. 1 scrap quality than has ever before been possible.

A few trends in consumption rates, shown in **Table 17** and in **Figure 9**, for certain types of scrap are worth mentioning. The amount of auto radiators (does not include aluminum/copper radiators) consumed by the U.S. industry has ranged between 48,000 tons and 104,000 tons per year since 1970, with the peak occurring in 1988. The amount has been steadily decreasing since 1988 to the current rate of around 51,000 tons. Yellow (including leaded-yellow) and low-brass scrap consumption has been steadily increasing, especially since the early 1990s. These categories were lumped together in **Table 17** to allow for possible definition changes over the period of statistical collection between types of yellow brass scrap. The amount of bronze scrap consumed has ranged between 18,000 tons and 32,000 tons per year since 1970. Although aluminum bronze scrap has

Figure 9. U.S. Copper and Copper Alloy Scrap Consumption, by General Alloy Group



[1] Includes yellow brass, leaded yellow brass and low brass.

[2] 20% – 65% copper. Refinery brass is excluded.

Source: U.S. Bureau of Mines, U.S. Geological Survey Mineral Yearbooks and Mineral Industry Surveys.

remained at a more or less constant rate of consumption, the number of plants using it have diminished, resulting in the number being withheld by the government statistical collectors since 1991. Cartridge brass consumption reached 131,000 tons during the last three years of the Vietnam conflict (1970–1973). Since that time, cartridge brass consumption has remained in the range of 46,000 tons to 90,000 tons, with exception of the 1988-1990 period, when consumption reached as high as 140,000 tons during a time of temporary military buildup for Desert Storm.

The amount of marketed low-grade scrap processed in U.S. plants has been decreasing since 1985, as indicated by data collected from the industry by the U.S. Geological Survey and U.S. Bureau of Mines (**Table 17** and **Figure 9**). While the amount of low-grade, copper- bearing materials consumed in 1998 and 1999 was marginally higher than the previous 4 years, it still was only one-third that of the 1970s and early 1980s. Low-grade scrap and residues consumed in 2000 was only 88,600 tons.

Scrap consumption was lowest during the recession years of the middle 1970s and early 1980s. Some of the underlying causes for these trends are discussed in **Chapter 1** and in **Appendix A**. In particular, the lack of adequate processing capacity for domestic copper-bearing scrap has been responsible for much of the observed trend.

Volumes of Scrap Generated

Since 1906, at a rate ranging between 10,000 tons and 1.6 million tons per year, the calculated U.S. cumulative consumption of copper from old and new scrap amounted to 75.5 million tons by 2001. Of this amount, 46% was from old recycled scrap. More will be discussed about these statistical relationships in the next section on life cycles and the scrap reservoir.

In 2001, recycled copper was derived 74% from purchased *new scrap* generated in the process of manufacture and only 26% from *old scrap* derived from used products. Copper from scrap recovery exceeded 1 million tons per year in 1965 and has continued to be above this level through 2001, dropping below to 800,000 tons in only one year (1975) (**Table 6**).

According to the U.S. Geological Survey (Minerals Yearbook, 2000), a total 1.3 million tons of copper was recovered from copper base and non-copper base scrap in 2000. P*urchased new scrap* derived from fabricating operations yielded about 906,000 tons of contained copper, 91% of which was recovered at brass mills. A manufacturer may generate more than 60% scrap in the form of slippings, trimmings, stampings, borings and turnings during the processing of copper and copper-base products into finished articles. This new, or *mill-return*, scrap is readily used by brass and copper tube mills to generate new semifabricates. Secondary materials that require minimal processing commonly are called *direct-melt scrap*. In the United States, direct-melt scrap provided over 1 million tons (**Table 2C**), or about 87% of copper from all secondary materials in 2000. New scrap made up about 28% of U.S. apparent consumption of copper from all sources (primary and recycled) in 2000. Copper in old and new scrap together comprised about 38% of U.S. apparent total copper consumption in 2000 (**Table 6**).

The U.S. Government (U.S. Bureau of Mines and the U.S. Geological Survey) has long collected data from plants consuming purchased low-grade scrap and residues.

By current definition, this material is comprised of copper-bearing ashes, residues, drosses, skimmings and other materials of less than 65% copper. Long-term trends (**Table 17**) for this statistic, however, are complicated by the fact that the definition has changed subtly several times. Material that might more appropriately be classified as refinery brass or a higher-grade copper material, but less than 65% copper, may also be included in the reported numbers from time to time. In addition, some slags and residues from primary copper processing may have also been included in some of the historical data. It should be emphasized that this number only reflects the marketed component of this material, it does not count the same material as it is generated and reused as home scrap. It also does not include exported materials.

The entire purchased scrap market for domestically shipped, low-grade copper ashes and residues may be estimated by using a formula that adds exports to the amount reported as consumed and then, subtracts imports to eliminate the foreign component. Using this procedure, the domestic industry market shipments are estimated to have ranged between 57,000 tons and 169,000 tons gross weight per year over the last 11 years (**Table 9**). Copper content of this material ranged between 19,000 tons and 59,000 tons per year. This is the approximate size of the *purchased scrap* market within this category, and these statistics do not include any of the materials that are processed in-house as runaround scrap. Both exports and domestic consumption reported for low-grade residues have diminished in recent years. This may be a reflection of a current trend toward plants recycling more and more of this type of material internally. It may also be partially the result of new production methods instituted to cut down on the volumes of residues created. The goal is generally that only the most innocuous and uneconomic material will leave the plant for a landfill or purpose other than metal recovery.

The data in **Table 17** show a distinct reduction in U.S. consumption of low-grade material as a purchased scrap beginning in the early 1980s. This coincides with cutbacks in the domestic smelter industry, the decrease in use of the reverberatory furnaces by the primary copper industry, and the closure of secondary smelters. The increased use of flash furnace technology by the primary industry, which relies on a high sulfur content of the ores processed to maintain a high heat, has lessened the use of low-grade scrap by the primary industry. Previous primary smelters, such as the AMAX smelter at Carteret, New Jersey, were significant consumers of low-grade scrap and residues prior to the 1980s. Low-grade scrap, residues and slags are currently exported or consumed by only one remaining domestic secondary smelter and the several ingot makers who may have cupolas, reverberatory or other furnaces adequate to handle these materials. In the 1970s, the U.S. smelting and ingot-maker industries were consuming 300,000 – 500,000 tons of low-grade scrap and residues. This compares with a rate of about 80,000 – 100,000 tons in the 1990s.

Special surveys were made by the Copper Development Association in 1994, and again in 1999, for by-product information. The combined response rate for the two surveys was about 72% for the brass mills, 62% for the ingot-makers, and about 15% for the foundries, based on the total production for each group. The data were aggregated by industry group and matched with similarly aggregated production data provided by the U. S. Geological Survey. The result was statistically adjusted to derive a full industry estimate for 1998. While most fire refiners were included in this survey, two of the secondary smelters were not. It might be presumed that most of the low-grade residues produced by these firms are recycled in-house.

It is interesting that the total production of these products, as shown in **Table 18**, is similar to the total low-grade, purchased ashes and residues scrap data tracked by the U.S. Geological Survey. This observation lends credence to the reliability of both sets of data. The total by-product production shown in **Table 18** is larger than the purchased scrap data of the USGS, owing to the fact that some home or runaround scrap is included in **Table 18**, but not in the USGS data. It is estimated that at least 28% of the skimmings and slags are recycled in-house, as indicated by the reports.

Not surprisingly, the brass mill group (including tube mills, wire-rod mills and their associated refineries) was the source for most of the by-products surveyed. Next in size, and commensurate with its share of scrap consumed and types of processing, was the ingot maker group. Though their numbers are many, the total amount of by-products generated by copper-base foundries is small compared with the rest of the secondary processing industry.

A wide variety of by-product materials were reported, not all of which could be classified into uniform product groups. Reported drosses included a variety of copper, nickel and brass drosses. Other products included in *other residues* of **Table 18** are copper residues from refinery and pickling processes, water pit and other sludges, anode recovery solids, machine shop turnings, cupola flue cleanout, afterburner dusts, scalper dusts, other reclamation dusts, metal skimmings, mill scale, and copper cathode recovered from pickling solutions. Of all the products reported, very few were indicated as being sent directly to a landfill; most firms were able to find some market or other processor that could accept it as useful material. Most were sold to ingot makers, secondary U.S. and foreign smelters, hydrometallurgical plants, concrete makers and zinc smelters, or they were shipped for direct use as agricultural products and animal feed.

The zinc oxide dust reported was shipped to zinc processing and smelting firms such as Zinc Corporation of America, Big River Zinc, M & M Metals, Phillip Environmental Services, American Micro Trace and the Horsehead Resources Development Co. The zinc oxide was most often shipped in 55-gallon steel drums by truck. However, some companies prefer to ship zinc oxide in 2,000-pound plastic bags (Supersaks). Most zinc oxide is sold; very few reported the occasion to dump it.

Secondary smelters such as Chemetco, and Franklin Smelting and Refining (both of which are now closed) were significant purchasers of furnace slag and skimmings shipped. Some of this material also was exported to Noranda in Canada. The furnace slag and skimmings ranged between 8% and 65% copper, up to 6% tin, up to 25% zinc, and less than 5% lead. Spent furnace brick is often sent to the landfill, but it generally contains less than 1% of all elements (Cu, Sn, Zn, Pb, Cd) analyzed and, thus, does not require special permits for handling. The only products shipped as hazardous included some low-grade metal oxide dust, baghouse dust and some furnace and refractory bricks. Elements such as cadmium and lead usually caused the product to be classified as hazardous, when these were present in significant amounts.

The average product yield from certain melts were the subject of a 1961 U.S. Bureau of Mines research report (Spendlove, 1961). According to this study, the following products may be expected from processing 190,000 tons of brass and copper scrap in a tilting, cylindrical reverberatory furnace. The melt had the following average composition: 84.5% Cu, 4.4% Sn, 5.25% Pb, 5.4% Zn, 0.15% Fe, 0.22% Sb (from babbitt in tin scrap), and trace Al and Si. Also added were 2000 pounds of zinc, tin and lead metal, and 4,000 pounds of flux. From this mixture, about 178,000 pounds of brass ingot resulted with a 93% metal recovery rate. In addition to the ingot, about 10,000 pounds of slag was produced as a by-product. The slag had an average composition of 20% zinc oxide, 20% iron oxides, 35% silicon dioxide, 20% copper prills, 5-8% copper oxide and small amounts of cadmium oxide, magnesium oxide, and aluminum oxide. Estimated losses, gases, dust and other residues amounted to 1,600 pounds.

Spendlove (1961) also reported that in producing 85-5-5-5 red brass ingot from a 50 ton-per-day rotary furnace, the following charge is typical: 50.3% red brass solids, 18.5% red brass borings, 13.7% radiators, 7.6% light copper, 3.9% hard brass borings, 3.7% spatters, 0.5% scrap lead, 0.1% phoscopper and 1.7% nonmetallic. The following can be expected to be produced from this charge: 89.8% red brass ingot, 7.2% slag, 1.8% splatters and 1.2% losses (gases, dusts, *etc.*).

Use of Home Scrap

At Brass and Wire Mills. All copper and brass mills use home scrap derived in the process of making wrought products. Considerable home scrap can be derived from the process of making brass or tube mill products. Whether or not the scrap is used for direct melt back into the melting furnace depends upon its character at the time of collection. Dirty or contaminated scrap cannot be used directly, but good, clean scrap of known composition can be, and is used. Most home scrap generated within the brass mill or copper tube plant is reused in house and also is called runaround scrap. As much as 30% of the material poured for making tube ends up as home scrap generated in the process of making tube. This material is reprocessed in a fire refinery at the plant when one is available. When pure enough, such as scalper residues from cleaning billets and tube ends, it can be put back into the production process directly. It is otherwise sold as No. 1 or No. 2 scrap for processing and use outside the plant of origin. Wire mills must be more particular with in-house-generated scrap, requiring a fire-refining step before reintroduction to an Asarco shaft furnace for recasting. Items such as flue dusts, drosses and other minor materials generated are not usually runaround, since these items may be shipped to other companies for reprocessing. Home scrap ceases to be runaround scrap when it is sold to another plant for further processing. The scrap is then referred to as *new purchased* scrap, entering the secondary materials market for trade. The marketed drosses, skimmings and other residues are new purchased scrap.

At Secondary Smelters and Refiners. The by-product scrap generated at smelters and refiners, such as slags, flue dusts and spilled metal, can be partially or wholly reprocessed in-plant. Some, such as the flue dusts generated, must be sold or shipped to other facilities for treatment and disposal. Slag is often sold into a direct use market, but may also be reprocessed in the home plant or locally landfilled. Some slag resulting from fire refining of scrap can contain as much as 65% copper and, thus, is a very desirable and marketable product.

At Foundries. Every foundry generates scrap returns from gating systems, risers, and occasional scrapped castings. A shop with its own machining and stamping operation will also produce considerable quantities of turnings and borings. It is common practice to absorb these materials in the melting operation as a portion of the charge makeup, rather than to use a 100% return charge. However, gates and risers from sand castings may not be completely clean of mold materials and other contaminants; turnings may be covered with cutting fluids; residual deoxidizers or impurities may be building up in the return materials. Each of these can contribute to casting defects and are not normally used without preparation. With successive remeltings, there will be a decided trend toward the gradual loss of volatile elements, such as zinc, as well as an accumulation of contaminants, such as iron. Depending upon melting and subsequent deoxidization practices, the level of residual phosphorous in the melt may rise to undesirable levels. Thus, a consistent monitoring of internal scrap composition should be made before reuse. A particularly serious contaminant in the case of copper-tin-lead-zinc alloys is aluminum. Unfortunately, aluminum beverage cans and foil wrappers may accidentally find their way into the charge material. When this happens, not only are serious problems generated in the melt, but also such metals must be discarded and resold to a smelter, since their reuse could cause the same problems over and over. Many foundries restrict the use of these materials to confined areas.

Use of Purchased Scrap

When purchased scrap is used, a complete analysis of each melt is necessary to assure freedom from contamination. Some forms of purchased scrap are relatively reliable, such as heavy copper wire, or bus bar, or automotive radiators. Obsolete *old* scrap from certain sources and applications also may be reasonably reliable. However, in some cases, it will not have been properly sorted and therefore, if used directly, could result in contaminated heats. The increased use by the U.S. consumer of imported faucets, tube and other products made from foreign-made alloys has increased the need for constant vigilance of the scrap purchased. Most ingot makers and mills must have sophisticated procedures for analyzing purchased scrap, adding to the cost of using this material. Purchased customer-returned scrap to brass mills can usually be presumed reliable for *direct melt*, but even these must be closely monitored. Product specifications call for a very low content of certain elements, such as aluminum and silicon. In the red brass series, for example, the maximum acceptable levels of aluminum and silicon are 0.005% and 0.003%, respectively. Meeting these specifications is achieved by controlling the composition of the scrap charged to the furnace. Impurities such as iron, sulfur, cadmium, bismuth, phosphorus and manganese can be removed by various techniques involving oxidation and the use of slags.

Life Cycles and the Theoretical Resource for Scrap

The availability of secondary copper is linked with the quantity of copper consumed and product life cycles. Many estimates for life cycles have been made for individual products. Product life cycles may even vary from country to country according to construction methods and concepts. However, copper in electrical plants and machinery has been estimated to average 30 years; in nonelectrical machinery, 15 years; in housing, 45 years; and, in transportation, 10 years. The average useful life for copper products is said to be about 25 years before being scrapped and entering the market as old scrap.

Keeping these longevity measures in mind, it is not hard to visualize that copper is being recovered today from scrapped items that were produced for use about 25 years ago. New (manufacturing) scrap, on the other hand, has a short life of about 30 days, and domestic manufacturing rates and efficiencies limit its recovery. This wide difference in turnaround and availability, in addition to the growing manufacturing base from which generates it, has resulted in a gradual increase of new scrap versus old scrap collected in the United States since the 1930s. (**Table 6**). The rate of copper consumption in the United States and the world has more than doubled since the 1960s. Scrap (old and new) has made up more than 40% of annual U.S. copper consumption over most of this period, only dropping below 40% since 1993.

Though copper is one of the most recycled of metals, some still enters solid waste disposal sites. Copper that is not recovered from end-use products may be placed in one of three categories: (1) still in use or buried and unaccountable, (2) solid waste disposal, (3) dissipated and lost. Recovery of copper from the first two categories is always possible with adequate incentives and technology. Copper has few applications that are dissipative in nature, such as in chemicals, paints and some powders. It has been estimated (Carrillo, 1974) that in 1970 only 0.5% of total copper consumed was lost and not retrievable. Most copper is used in some metal form, easily recognizable and easily recoverable. Some household products such as toasters, motors, TVs, electronic equipment, *etc.,* may have been dumped into landfills in the past, rather than collected or sold for their metal content. However, with the current emphasis on the selection of household and municipal-dump items for recycling, the amount of copper actually placed in a landfill is probably diminishing.

The variances in estimates for the amounts recycled are directly related to a lack of reliable data as well as to the procedures used for making the estimations. Because time is always a factor, it has been difficult to quantify how long a product has been in use and how much of it was recovered over what time period. Some have estimated copper not recovered to be as high as 50% of all products reaching the end of a useful life. However, other estimates have suggested that the recovery rate may be in excess of 70% for copper products no longer in use. Because, generally, it has been cost effective to collect, prepare and sell copper-base scrap over the years, a much higher percentage of copper may be recovered from outcast products than may have been previously estimated. It is widely known that it may not be cost effective at all times to recover some buried cable and pipe, and thus, it may remain buried for years. Even so, the metal is not destroyed or dissipated and may eventually be reclaimed, if the cost and incentives are right.

The estimated resource calculations made below indicate that more than 65% of total primary copper consumed in the United States has been returned and reused as new and old scrap over time. The scrap recovery rate was as high as 67% between 1989 and 1996, but has dropped to around 65% currently. This change undoubtedly is related to the drop in U.S. old scrap consumption, as reported. The rate of old scrap recovery from the end-use resource has been decreasing since a peak of 54% that was reached in 1993. The recent loss of U.S. smelter and refinery capacity is directly related to the drop in old scrap consumption by U.S. industry.

The rate of old scrap recovery is limited not only by copper's long life and its essential uses, but also by the sensitivity of scrap collection to market prices. When copper prices are depressed, old scrap tends to be less available and is directly related to the cost to recover and process it. The distinct decrease that is observed in the old-scrap to new-scrap recovery ratio since 1990 has more than a price relationship attached to it. Since the closing of all secondary and primary copper reverberatory smelters occurred over this time period, one can only assume that the sharp drop off in consumption of old scrap over the same period is related to the lack of adequate processing facilities in the United States. Once sought out for its metal content, this material is either being exported, or it is not being collected for consumption. U.S. scrap exports have increased significantly in recent years and might logically be presumed to be mostly old scrap. At the same time, new scrap recovery has been increasing at a rapid pace in tandem with the higher rate of copper consumption and manufacturing.

Resource Theory and Calculations. All of the copper ever generated from the earth can be represented by primary copper consumption or production statistics collected and published over time. Scrap, old or new, is excluded as a primary constituent of the theoretical resource base, since no new (primary) copper can be generated from it. Therefore, primary copper forms the only contribution to the theoretical accumulating resource base.

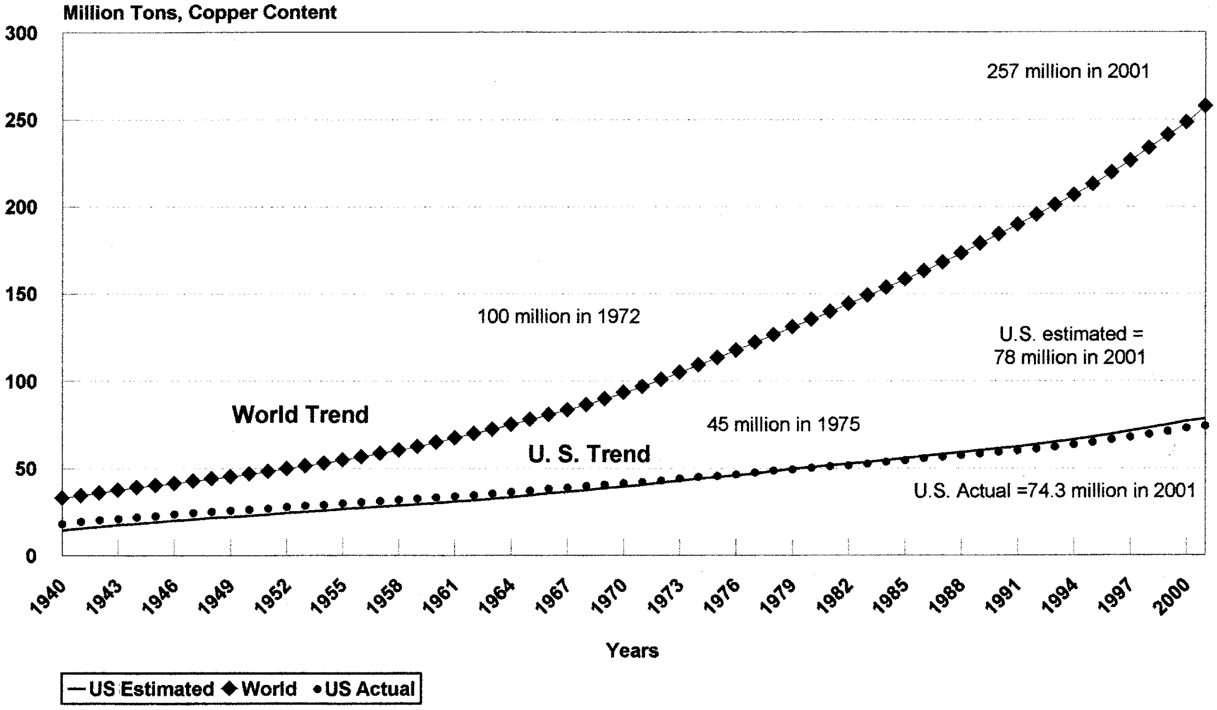
According to McMahon (1965), a large reserve of secondary copper, in the form of recoverable end-use products, has been accumulating in the United States and the world. This end use resource is continually being augmented because of copper's consumption patterns and indestructibility. Each year, this reservoir produces copper in the form of old scrap in the United States, which in 2001 comprised only 12%, but in 1960 comprised about 25% of annual consumption. McMahon also attributed an equivalent amount (about 25%) to new scrap generated in 1960 from fabricating and manufacturing semifinished and finished products. McMahon recognized that new scrap copper does not form a reservoir supply to supplement production of primary copper. New scrap such as defective castings, clippings, punchings, turnings, *etc.,* represents a circulating quantity of copper previously accounted for as a supply of primary copper and returned to the fabricating process without reaching the product stage. It is, in effect, 100% recycled. Even so, data on the movement of new scrap have significance as indicators of business activity in fabricating and scrap reclamation industries

The resource estimation procedure adopted by McMahon deduct an estimate of 25% annually from the cumulative series of primary copper consumed. McMahon (1965, Table 10, p. 77) also purposely does not include old scrap in his reservoir calculations. Although he does not specifically identify the 25% deducted for unused primary copper as new scrap, it is here presumed to be the case based on his detailed description of scrap relationships. In other words, he presumes that only 75% of the primary copper consumed each year goes to the end-use market, and 25% of it does not. This copper has not dissipated, but has been recirculated and recycled in small amounts every year.

McMahon's calculation procedure provides a resource base of end-use copper from which to retrieve old scrapped items. Using the above estimation method, the U.S. industry's contribution to the secondary materials reservoir of items in use, or abandoned in place, has increased from about 14.5 million tons in 1940 to around 78.5 million tons in 2001. According to McMahon (**Table 10**, p.75), about 52% of the end-use reservoir so calculated had been returned and reused as old scrap by 1960.

McMahon's method for estimating the world resource involved a simple ratio equation based on the assumption that the rest of the world consumes copper in much the same manner as the United States. Using this formula with cumulative world copper consumption, as McMahon suggests, yields some 314 million tons of copper for the current resource base. This estimation is a little too

Figure 10. U.S. and World Scrap Resource
Poll of Copper Materials in Use



Sources: JJolly, July 2002. McMahon, 1965
World Resource= Copper mine production increase less 40% deducted for: recirculating scrap (25%) and process losses (15%)
U.S. Estimated Resource= Primary copper consumption increase less 25% for annual recirculating copper.
U.S. Actual Resource= Primary copper consumption increase less annual reported new scrap generated (1864-2001).

high, however, because the world consumption statistics include copper from scrap.

Since imports and exports between countries are not an issue, it is not necessary to use consumption statistics to estimate the old-scrap resource base for the world. We can use, instead, statistics for either world primary refined, or mine production. Mine and smelter production are used for this paper because these are the longest, most reliable historical statistics available. This world *old scrap* end-use reservoir also does not include the pool of new scrap that is recycled and reused every year. An estimated 40% is deducted annually from the world production of primary mined copper to account for (1) processing losses and (2) for recirculating scrap. Because *New* and *Home* scrap are, by definition, almost 100% recycled and recovered, 25% is deducted for recirculating scrap that, in theory, never reaches the product reservoir in the year that it is generated. Another 15% are deducted from world mine and smelter production for the process losses incurred in conversion to refined copper.

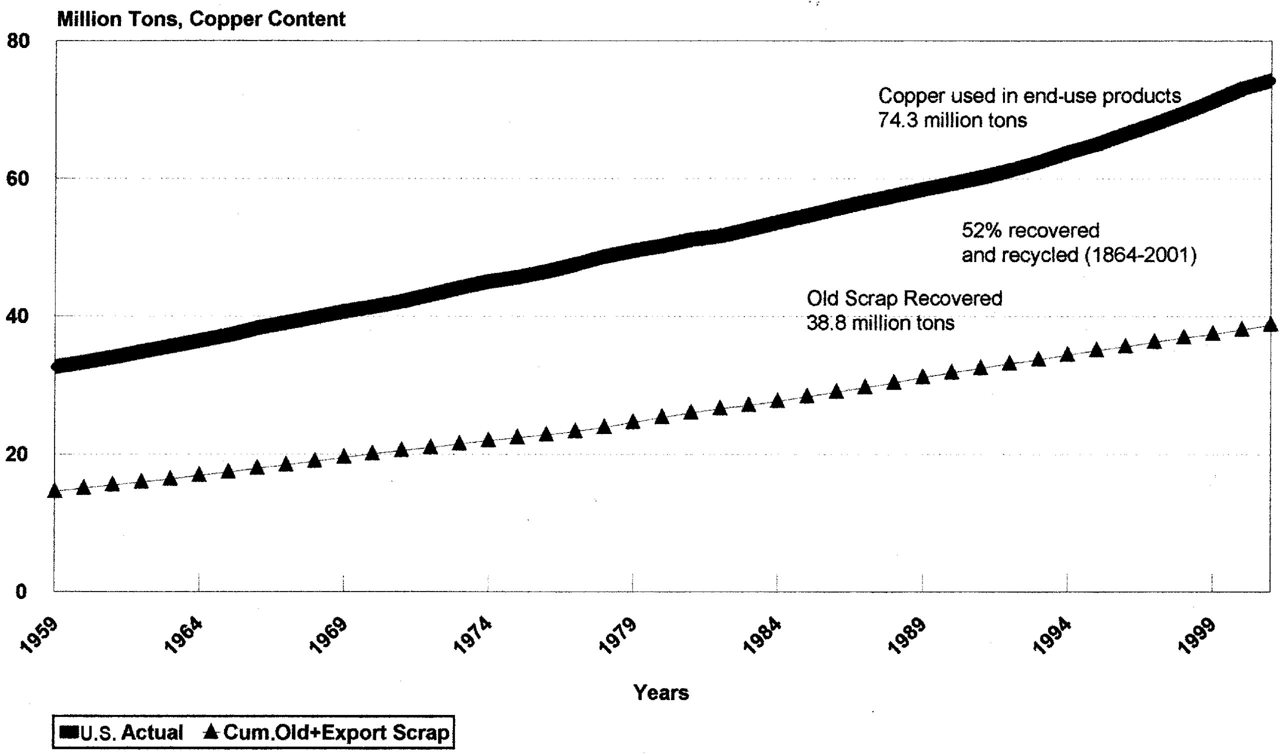
Using world mine production, the world resource of copper in use, in place or buried, was calculated to have grown to about 258 million tons of copper (**Figure 10**) by 2001. An alternative procedure would be to use primary refined copper production as a basis for the series. In this case, only 25% for new scrap generated would need to be deducted from the cumulative series. The same would apply to the world refined consumption series. Deducting 25% each year, the cumulative world refined consumption (including scrap) would amount to 366.9 million tons from 1889 through 2001.

The resource of available copper in end-use products for the United States may also be estimated by using actual primary copper and scrap-consumption statistics reported each year, instead of an estimate for new scrap (**Table 6A**.) A certain amount of new scrap that is generated as home and mill-return scrap in the United States is sold to other companies to use in their semifabricating processes. In 2001, the United States derived about 27% of its total copper (primary plus scrap) consumption from new purchased scrap (**Table 6**).

By comparing cumulative copper consumption statistics, the relationships of the scrap components to the total primary copper consumed over time can be quantified and compared as equivalent statistics. These relationships are shown in the flow diagram of **Figure 13** for the cumulative (1864 through 2001) resource data. Even though the available primary copper is augmented each year by the return of copper from old scrapped manufactured items, primary copper is the only contribution to the resource base. Scrap is, in essence, derived from the total copper originally mined and can not be added as a duplicative constituent to an end-use resource base.

Figure 11. U.S. Copper Resource for Old Scrap

Poll of Copper Materials in Use, 1959-2001



Source: JJolly, July 2002.

U.S. Actual = Cumulative primary copper consumption increase less annual new scrap generated (1864-2001).
Old Scrap Cumulative = Cumulative recovery of copper in old scrap returned from end use sector and reused, plus copper in net exports of scrap.

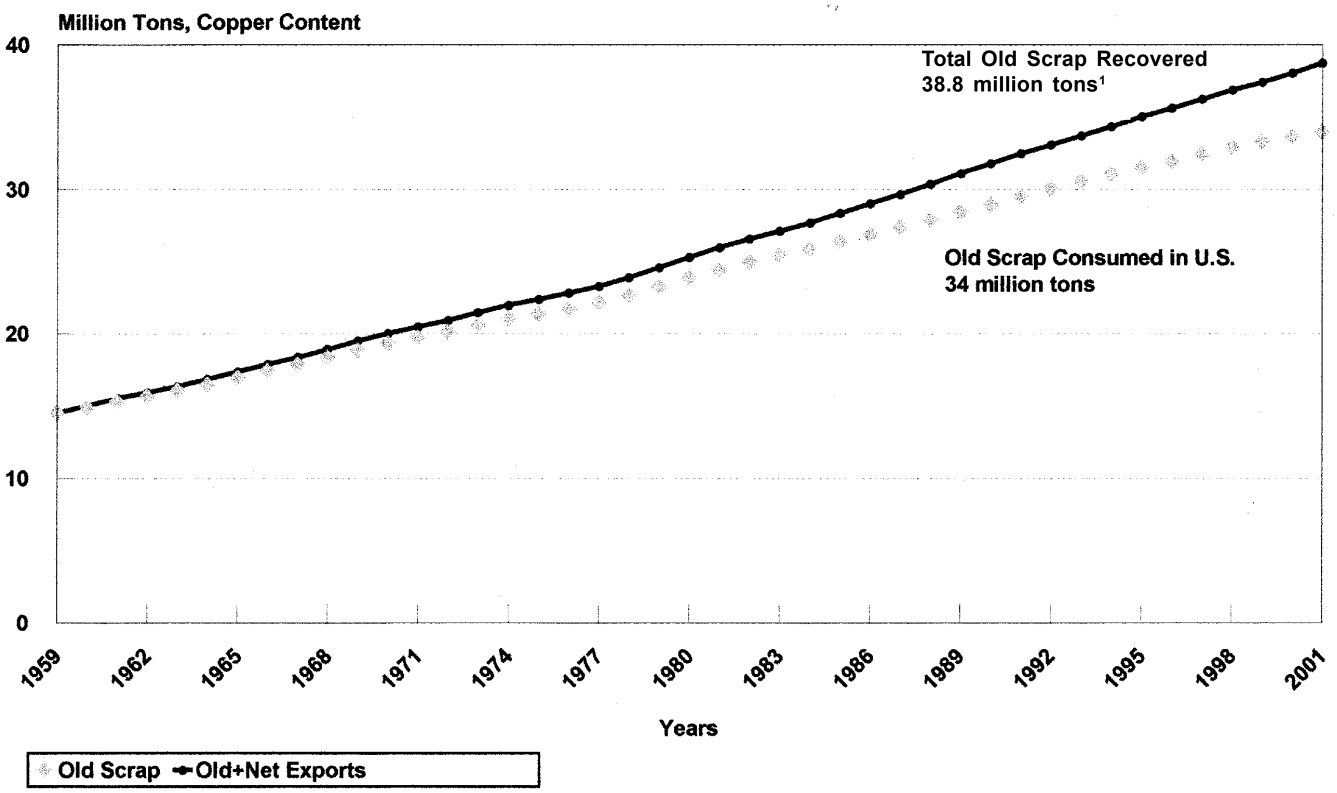
Based on reported U.S. annual data, the cumulative primary refined copper consumed in the United States since 1864 amounted to 115.8 million tons by 2001. From this initial mined source, a cumulative 75.5 million tons (65%) of copper from old and new scrap had been returned for consumption by the industry through 2001. New scrap was recycled at rates ranging between 4,000 and 970,000 tons per year between 1906 and 2001, comprising 36% of the total, primary consumed over the period. At the same time, old scrap from obsolete end uses was recovered at a rate ranging between 6,000 tons and 620,000 tons per year, 1906 through 2001. This resulted in a cumulative 34 million tons (51% of the end-use resource) of old scrap being returned for consumption by 2001

In the United States, old scrap copper consumed by industry in 2001 was only 309,000 tons. However, by adding net copper in scrap exports (presumed to be all old scrap) to the copper in old scrap consumed by U.S. industry, about 690,800 tons may have been recovered as old scrap in the United States in 2001. Thus, it would appear that more than half of the old scrap recovered in 2001 was exported. As illustrated in **Figure 12**, an increasing amount of old scrap collected in the United States has been exported since the mid-1970s. This can partially explain the consistent decrease over this period in U.S. old scrap consumption.

The deduction of all items scrapped (old and new) each year from cumulative total primary copper consumed (1864-2001) results in only 35.5 million tons (48% of the primary end-use resource) of copper remaining in manufactured goods that have never been recycled and are still in use or abandoned in the U.S. reservoir of end-use products. It should be noted here that these calculations do not take into account the growing amount of copper in end-use products that enter this country as manufactured goods. The contribution of these finished-goods imports to the scrapped products reported and to the U.S. resource of unused products is not easily quantifiable or available.

Old scrap derived from finished products has commonly been considered a new resource of copper in the year of reuse, as it re-enters the manufacturing stream. It is a useful augmentation to available primary copper. New scrap, on the other hand, is derived from manufacturing and processing, has a short shelf life and, in theory, recirculates before ever reaching the end-use market. As McMahon (1965) points out, new scrap does not form a reservoir supply to supplement new copper. To include recirculating new scrap in consumption estimates each year by adding it to new mined copper (primary), would present a double-counting problem as the same (primary) copper goes through the processing chain over and over, never reaching

Figure 12. Cumulative Old Scrap Copper
In the United States, 1959-2001

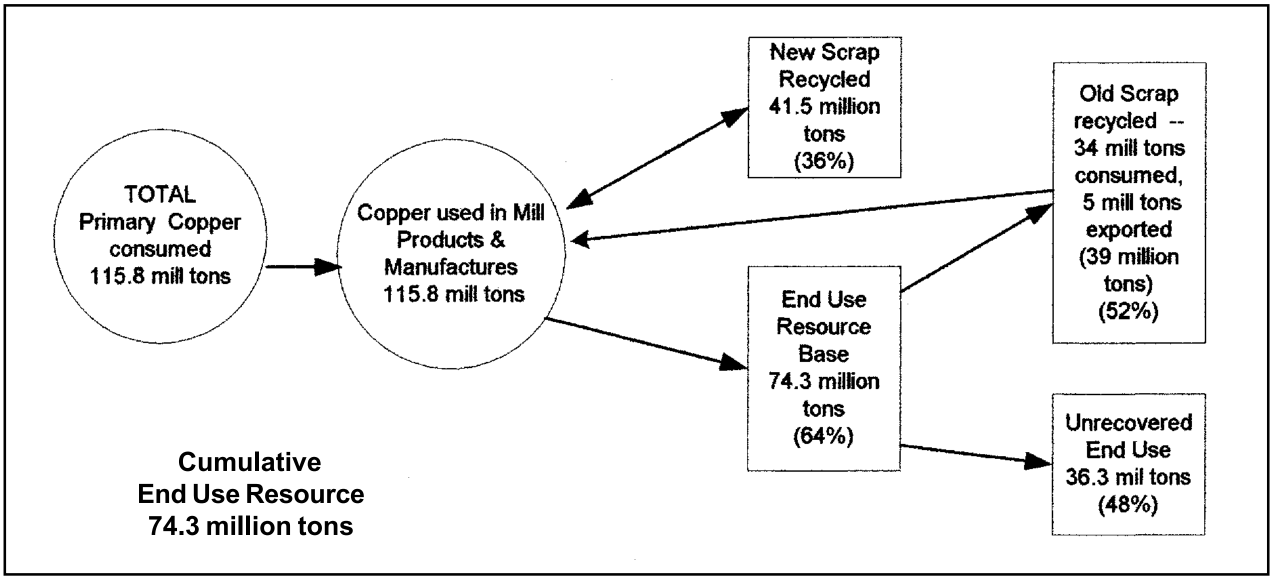


Source: JJolly, July 2002.

[1] Copper in net scrap exports are added to old scrap consumption.

Figure 13. Relationships of Primary Copper and Old and New Scrap to U.S. Cumulative Copper Resource Calculations, 1864 Through 2001

(metric tons, copper)



NOTE: Each year, the available primary copper is augmented by return of copper in old scrap, which is consumed in making refinery and mill products. However, primary copper is the only contribution to the resource base over time. Scrap, old or new, should not be added in duplication to the primary copper of the end-use resource.

the end-use market. Because of this phenomenon, new scrap is excluded from primary copper use annually in order to calculate an estimated primary end-use resource without scrap. This primary end-use resource is the total pool of copper from which to estimate the percentage return of old scrap, which is derived from the copper used in final products.

These calculations yield an estimated 74.3 million tons of copper accumulated over the period 1864 through 2001 as the U.S. resource of copper in manufactured products in use (**Figure 11**). Interestingly, about 52% of this adjusted, theoretical end-use resource has been recovered and reused as old scrap copper (including exports) through 2001 (**Table 6A**. and **Figure 14**). Net exports of copper scrap were added to old scrap copper consumed by U.S. industry to achieve a total old scrap yield.

The rate of old scrap recovery from the copper end-use resource increased rapidly prior to 1945, when the rate increased in excess of 1% per year, between 1906 and 1938. The recovery of cumulative old scrap from the total resource was only about 9% by 1914 but had reached 37% by 1938. The rate of copper in old scrap recovery has been increasing by a little less than 1% per year since 1945 and has hovered around 50% to 54% of the cumulative resource since 1980. The annual U.S. contribution to the copper reservoir of items in use has been increasing at a rate of 1 – 2 million tons of copper per year since 1963.

Calculations related to the cumulative primary copper consumed also yield an estimate of about 48% for products never recycled by 2001. This is contrived by deducting the old scrap portion of the resource from the total**.** (**Figure 13**). This estimate includes items that are still in use, buried or, to lessor extent, possibly dissipated.

The available copper in the end-use resource may seem large but, as discussed above, the potential rate for retrieval in a uniform and reliable way is limited by many factors. Of particular significance is copper's long life in many of its end uses. With a recovery life of 25 – 45 years, copper items produced in the 1960s and 1970s may only be in the recovery process today. In 2001, only 1.9 million tons of recovered world copper might be considered from *old* scrap sources compared with a total 6 million tons of copper derived from all scrap sources (**Tables 2C** and **2D**).

CHAPTER 3 – OVERVIEW OF SCRAP PREPARATION, MELTING AND PROCESSING

Scrap Preparation

All scrap used must be prepared and analyzed prior to processing to alter its shape and size and/or its purity. This can some times add significant cost to its use. Scrap preparation may be done by manual, mechanical, pyrometallurgical or hydrometallurgical methods. Manual separation and cutting of large pieces of scrapped items is very necessary, as is an accurate analysis of the material. Large, solid items are reduced in size by diamond saws, shearing machines, pneumatic cutters, or manually by a sledgehammer. Mechanical methods include sorting, stripping, shredding, and magnetic and air separation. Because scrap is a bulky material, the customary practice is to bale light scrap and cut heavy scrap to size so that it can be handled. The scrap may be further compressed by hydraulic press into briquettes, bales, bundles or hockey pucks. Brittle, springy turnings are crushed in hammer mills or ball mills to reduce bulk for easier handling. Slags, drosses, skimmings, foundry ashes, spills, and sweepings may be ground to liberate prills or other metallics from the nonmetallics so that metallic fraction can be recovered by gravity separation or other physical means. They may also be set aside in special areas to be drained of oil before further processing. Pyrometallurgical preparation may include sweating, burning insulation from copper wire (not recommended, and may be banned) and kiln drying to volatilize oil and other organic compounds. Cartridge shell scrap may also be heated in a furnace to pop the live shells.

An important copper recycling material is cable scrap. At one time, burning of cable to remove the plastic parts was acceptable practice, but this is no longer always possible or desirable. Thus, mechanical dismantling of the cables is common practice through cutting, granulating and use of various metal separation techniques to separate the plastics and fluff from the metal. Most wire is chopped into pieces smaller than 0.5 inch to assure liberation of wire from insulation so that air tabling can then make a separation. Another mechanical device strips insulation from long lengths of cable. Over time, wire choppers have been able to upgrade insulated wire to No. 1 grade instead of No. 2, which was generated by burning.

Some have noted, however, that lower grades of wire increasingly have been headed overseas for processing (*Recycling Today,* Feb. 2002). In developing countries, plastics are disposed of not only through landfilling but also by open burning of the coated wire. While copper and aluminum have resale value to smelters, the plastic coating is often disposed, or burned away. *Recycling Today* estimates that some 700 controlled-atmosphere furnaces have been sold worldwide to scrap recyclers who use them to burn off plastic coating. Scrubbers are used with these furnaces to remove the hydrochloric acid generated when burning PVC. Open burning offers no such protection.

Flotation may be used to concentrate and recover copper when the slag treated contains more than 10% copper. The slag is ground and combined with water and flotation chemicals. The additives help the copper to float for removal and concentration and to prepare it for further processing.

In 1974, H. Fukubayashi (USBM RI 7880, 1974) estimated that flue dust collected from secondary brass furnaces averaged about 2 tons per day per operating brass furnace. The material is ordinarily too light and fluffy for easy handling, and thus is shipped in containers, such as barrels, to the zinc smelters for metal recovery. Pelletization of the zinc dusts reduces the volume for shipping and facilitates handling. Some companies ship up to 2,000 pounds of zinc dusts in large plastic bags (Supersaks).

When circuit boards used by the printed wire board industry are manufactured, the bonded copper foil that is applied to the fiberglass sheets is trimmed by shearing off the rough edges. This copper clad trim is shipped to some hydrometallurgical firms for processing to produce copper chemicals. During the production of printed wire circuit boards, a cupric ammonium chloride etchant is used for removal of copper metal from the unprotected parts of the boards. Copper increases in the etching solution as the process proceeds. The spent etchant is shipped to a hydrometallurgical processor for removal of the copper and regeneration of the etchant. Another etchant is cupric chloride. Spent cupric chloride etchant contains about 1.2 pounds of copper per gallon. This metal is also recovered, but the etchant is converted to ammonia chloride, which is returned to the circuit board industry.

Some large U.S. companies have shredders that can process electronic materials to allow for metal recovery. Canada is a large export market for circuit boards that can be handled by shredder and smelter. According to *Recycling Today* (Feb. 2002), a midwestern recycler dismantles computers and other electronic products by hand and sends the circuit boards to smelters (presumably in Canada), which have associated shredders. Because the company charges a per-pound fee to recycle electronics, the dismantling is financially viable. Many of the computers handled are reused instead of dismantled. There is a strong demand for the reuse of Pentium 133s, but anything less is likely being purchased by dealers who send the computers to third world nations, such as China. Beryllium copper clips gleaned from these electronics are sorted and sent back to beryllium copper producers in Ohio and Pennsylvania. Handling these materials must be done carefully since any hazardous materials from landfilled electronics can leach into the soil and, when burned, toxins can be released into the air.

Some companies recycle copper by hydrometallurgical processing of weak or spent copper plating solutions and sludge generated by wastewater treatment of copper plating operations. The product is sent to a smelter for further processing.

Laboratory Testing

Several standard methods of testing scrap materials, ingots and other alloy products are used. Methods such as chemical analysis, optical emission spectroscopy, x-ray fluorescence, atomic absorption analysis, inductively coupled plasma-emission spectrometry analysis and various types of mechanical testing are used. Details for conducting wet chemical analysis on copper-based alloys are given in several ASTM standards (E 478, E 54, E 75, E 88). The wet chemical methods are slow and make it difficult to obtain results for production heats until well after the metal has been cast, limiting their value as a process control tool. More commonly, chemical methods are used for analyzing the composition of raw materials (ingot and scrap) before being melted. The mechanical tests usually associated with copper-based foundry alloys are those for hardness, tensile and impact-strength properties, following various ASTM standards. Radiographic inspection of metallic objects is a means of observing internal defects nondestructively by using either x-rays or gamma rays.

Occasionally, a radioactive check must be made on materials received for processing. Copper scrap from atomic power plants is particularly suspect. While the radioactive elements can be separated from the copper metal produced, the slags may become contaminated and radioactive.

Energy Use

Recycling provides benefits such as energy savings. Of the commonly used metals, copper has one of the lowest energy intensities for production. The energy intensity for recycling of copper varies by the purity of the scrap. Clean scrap, which requires only remelting, requires only about 1 MWh/t. Scrap that requires electrolytic refining requires about 6 MWh/t, and that which must be purified by re-smelting requires about 14 MWh/t.

Because many applications for copper, particularly alloys, use scrap rather than virgin metal, the energy intensity of that metal is a function of how much scrap is used. For example, in a copper and brass automotive radiator, which typically uses 40% scrap, mainly for brass in tubes and header plates, the energy intensity is 20 MWh/t, not the 30 MWh/t of newly produced copper.

For Scrap Preparation. Chopping of copper wire requires about 1.75 million Btu (USBM, IC 8781, 1978) per ton of prepared scrap; 1.05 million Btu of which represents process energy, 0.40 million Btu represents pollution control energy, and 0.3 million Btu is for space heating. By comparison, incineration of the covered wire requires 1.67 million Btu, most of which is consumed in the afterburner. If the insulation contains PVC, a serious air pollution problem arises, requiring the use of wet scrubbers and the treatment of the effluent. The electric energy required for compressing low-density scrap into balers is less than 0.05 million Btu per ton. For briquetting, the electric energy requirement is on the order of 0.10 million Btu per ton.

Melting Scrap. Reverb melting of No. 1 copper scrap requires about 3.81 million Btu per ton of refined copper shapes poured, such as billets and cakes. Of this, about 95% is process energy; the remainder represents pollution control and space heating energy. Recycling of No. 2 scrap requires process energy of 15.71 million Btu per ton of poured copper wirebar. Air pollution control energy accounts for 0.21 million Btu per ton of wirebar, and space heating accounts for an additional 1.35 million Btu per ton. The total of these components amounts to 17.27 million Btu per ton of copper wirebar produced from No. 2 scrap.

Process energy required for recycling brass and bronze scrap to ingot (85:5:5:5 red brass) is about 5.86 million Btu per ton of alloy produced. Air pollution control energy accounts for 0.91 million Btu, and space heating accounts for 0.32 million Btu, making a total energy requirement of 7.09 million Btu per ton of red brass alloy produced. The energy analyses for other alloys are not significantly different.

Process energy for processing low-grade, copper-bearing scrap (25% to 35% copper) in a reverberatory or cupola requires 39.70 million Btu per ton of product. Total energy required is 42.42 million Btu per ton of product, including 1.37 million Btu for pollution control energy and 1.35 million Btu for space heating (USBM, 1978).

Scrap Melting and Processing

Most purchased new scrap is simply melted at ingot makers and brass mills. Direct melt scrap comprised 88% of total U.S. scrap consumed in 2001 (**Tables 2C and 2D**). The scrap remainder is reprocessed by either smelting or refining or by leaching and electrowinning to form a pure copper product. Fire refining in a reverberatory or other furnace may be sufficient for the better grades.

The fire-refining process uses oxidation, fluxing and reduction to produce refined ingot, wire bar, slab or billet. For higher grades of refined cathode, however, the poorer grades of scrap must be first smelted with various fluxes, poled to remove oxygen, and then cast into anode form for further processing to cathode in an electrolytic refinery. By-products, such as tin and precious metals, may be retrieved during the preliminary procedures of smelting or, during refining, from tank house sludges. Other impurities, such as iron, lead, arsenic and antimony may be removed from the slag by fluxing. Reverberatory or electric rotary melting furnaces are used for casting various copper forms, such as slabs, cakes, billets or ingots. Asarco shaft furnaces may be used with holding furnaces, in conjunction with continuous casting systems.

Processing complex copper-containing materials, such as drosses, flue dust, catalysts, collector dust, slimes from electroplating wastewater, and metal-rich slags from converter and furnace processes requires versatile production processes. Low-grade, copper-bearing scrap, such as copper-containing skimmings, grindings, ashes, iron-containing brasses and copper residues are usually smelted in a cupola or blast furnace to produce black copper. Black copper is then converted to blister copper in a converter and, then, is fire-refined or electrorefined, much as in the primary copper industry.

Most metal processing plants have built-in water recirculation systems and pickling solutions in which some of the metal content is recaptured and reused. Many of these wastes also must be treated for metal recovery. In general, a combination of various hydrometallurgical techniques such as precipitation, cementation, ion exchange, solvent extraction, reverse osmosis, gaseous reduction and electrolysis are used. Cementation has been successfully employed to recover copper from waste effluents. Solvent extraction and ion exchange are highly selective methods for separation of copper from other common metals in solution. Mechanical and thermal dismantling, and more recently, leaching and solvent extraction and electrowinning procedures have proved effective in treatment of certain types of electronic scrap and copper-coated steel wire. Electrowinning recovery is also used for waste processing fluids and sludges that contain copper and other metals. A low-grade copper cathode, as well as copper chemicals such as copper sulfates, oxides and hydroxides, copper precipitates and by-product metals can be produced through this method.

Melt Control. The term *melt control* refers to the control for furnace and atmosphere conditions during processing of molten metal. Variables affecting melt quality include the following: (1) Furnace selection; (2) Fluidity (Higher pouring temperatures make chemistry and gas control more difficult.); (3) Mold materials (All materials can produce gas, and mold gas coupled with gas derived from melting can result in "gassy castings"); (4) Gating (Improper gating can result in gas pickup and porous castings.); (5) Solidification and shrinkage; and, (6) Mechanical properties (Input materials are commercial-purity raw materials, scrap, secondary ingot, returns, and late additions. How much of each is used is dependent upon availability, cost and the casting quality required). Some companies use a computerized system to determine the heat characteristics, cost and most efficient method of mixing the melt, including the detailed procedure to be followed in forming it. This helps to simplify the procedure to be followed for a particular alloy. Often, three or more scrap types are required for a given melt.

Commercial-purity raw materials are seldom justified on cost, except possibly for new alloy development. Other pure metal scrap, such as zinc strip, may also be used for adding metal to the melt. Some elements, such as silicon in the silicon bronzes and iron in the aluminum bronzes, do not readily go into solution in copper and, so, are often purchased as already alloyed ingot. These additive alloys are called master alloys. Master alloys contain 10% to 15% of the desired metal required. Most foundries to do not compound their own alloys from raw materials. The practice of using an all-scrap charge creates the risk of possible pickup of detrimental elements. On the other hand, scrap, such as pure copper bus bar, wire or piping, provides an excellent charge of known characteristics. Another example of scrap use is the melting of soldered brass automotive radiator cores for plumbing alloy castings, because of the known lead content.

Drosses and Dross Formation. The most common causes of melt losses are dross formation due to reaction with the atmosphere, refractory material, or ladle material, and losses owing to vaporization of low-boiling point elements. Even if secondary ingot charges are well within a chemical specification range, melt losses may result in scrap castings. Much of the dross in copper-base alloy melts (*Casting Copper-Base Alloys,* 1984) is due to reaction between the metal and the atmosphere, since it is usually not possible to exclude the atmosphere. Several techniques may be used to minimize dross formation. These include the use of lower temperatures, shorter furnace time, crucibles or refractories that are inert to the melt, and melt covers or fluxes. Lower temperatures result in less dross through lower chemical reaction rates. Clay graphite crucibles provide carbon in the crucible that will react with the atmosphere, resulting in less dross. Melt covers, such as charcoal, carbon and fluxes, show mixed results but also can be effective in reducing the amount of dross formed. One company reported an 80% reduction in dross and ash formation through the use of synthetic graphite instead of charcoal as a melt cover.

Melt Covers (Fluxes). Fluxing is an essential part of both melting and refining. The basic functions of fluxes are essentially the same, used in reverberatory, rotary or crucible furnaces. Two general types of fluxes used for melting and refining scrap copper are: (1) Nonmetallic fluxes and (2) Fluxing alloys. Nonmetallic fluxes may be solid, liquid, gaseous or mixtures of these. Some are used for protecting the surface of a melt from the atmosphere, while others refine by mechanical or chemical reaction.

Nonmetallic fluxes include materials such as sodium chloride, charcoal, borax, anhydrous rasorite, slacklime, glass, nitrogen, oxygen and various combinations of these. Sodium chloride may be used as a cover and as a fluid medium for separating metallic and nonmetallic materials in heterogeneous melts. Charcoal covers are used to add heat to the surface and provide a reducing atmosphere. Borax, slacklime and glass are added in various combinations to protect the metal surface and reduce volatilization of the melt. Anhydrous rasorite is a sodium borate flux used in the secondary copper industry. This flux has a great affinity for metal oxides and siliceous materials and is used primarily to scavenge oxides and to provide a protective cover for molten scrap brass and bronze. Borax is also used to aid the release of ingots from their molds. Caustic soda has been used for the removal or iron and aluminum from some alloys. Gaseous fluxes are usually introduced into the melt through a pipe inserted below the surface. Small bubbles of inert gas adhere to particles providing buoyancy, which raises them to the surface where they can be removed with the slag.

Metallic fluxes are either pure metals or alloys that can be introduced to the melt to produce a refining action. A metal fluxing agent used for copper-base alloys would also be alloyed with copper as a base metal. Fluxing alloys are usually classified according to their functions. They are known variously as deoxidizers, degasifiers, densifiers, stabilizers and fluidizers. Many provide two or more of these functions simultaneously. Some melters may use the fluxing alloys as master alloys to produce others that are not commercially available. Phosphor-copper, for example, contains 10% to 15% phosphorus alloy and is used for deoxidizing. In some cases, the flux alloy is added so that the excess phosphorus will alloy with the melt as one of the desired constituents. In this case, the alloy is used as a deoxidizer and a hardener. There are many other fluxing alloys such as the binaries of silicon, manganese, magnesium, lithium and cadmium.

Oxidizing melt covers (copper oxide, silicate-borate mixtures) can be used to remove hydrogen, or maintain it at low levels, and to consolidate drosses and oxides for ease of removal. Neutral melt covers (glass, dry silica sand) form a mechanical barrier between the melt and the furnace atmosphere. This can reduce exposure to hydrogen sources, but may also prevent oxygen absorption; it is generally not reliable for gas control, but is advantageous for dross removal and reduction of vaporization losses.

Reducing melt covers (charcoal, graphite) prevent excessive oxidation losses but may be a source of hydrogen, if they contain moisture or hydrocarbon additives. If used in excess, they may prohibit oxygen absorption from the melt atmosphere, thereby allowing hydrogen pickup. Reducing melt covers are useful in retaining a low oxygen level in the metal after deoxidization and prior to pouring.

Fluxes or slag covers are generally unnecessary when melting copper and beryllium copper alloys. A layer of dry charcoal or granular graphite may be used to cover molten copper. In melting chromium copper, a flux cover of lead-free glass or liquid salt is recommended to minimize oxidation of chromium.

Fluxing materials used in a typical blast furnace include limestone, millscale, and metallic iron. The resulting slag from a 60 – 70 ton-per-day blast furnace (Spendlove, 1961) with charge materials containing 10 – 11% coke, will have the following approximate composition: FeO (29%), CaO (19%), SiO_2 (39%), Zn (10%), Cu (0.8%) and Sn (0.7%).

Use of Deoxidizers. *Phosphor copper* is often used in deoxidization of copper and copper alloy melts such as in making copper tube and copper-tin-lead-zinc alloys (red brasses and tin bronzes). The principal cause of high residual phosphorus is over deoxidization. This usually occurs for one of two reasons: (1) porosity problems are misjudged to be the result of insufficient deoxidization (3) Extra phosphorus is added to impart greater fluidity to the metal to avoid misruns in thin castings, or when pouring cold metal. Over-deoxidization will result in gassy castings and will negate efforts to maintain low hydrogen levels during melting. Because beryllium and chromium are strong deoxidizers, no deoxidization treatment is required for melting these alloys. However, deoxidization is required for melting pure copper. In forming *high-conductivity copper,* a high oxygen content is induced to the melt to limit the amount of hydrogen and to oxidize impurities that may be deleterious to conductivity. The melt is then deoxidized using calcium boride or one of the various deoxidants available commercially.

Cut cathode squares (an alternative primary raw material) contain no oxygen; hence, they may contain considerable hydrogen and strong oxidation will be needed to remove it. In-process scrap should contain neither oxygen nor hydrogen but may contain residual deoxidants.

Vapor Losses. The same techniques used for dross minimization will also reduce vapor losses. The most notable element loss in molten copper (brass) alloys takes place with zinc, which is usually replaced in the melt just prior to pouring. Elements such as lead and beryllium may also be associated in the processing of some copper alloys.

Particulate Matter and Fugitive Emissions. Secondary smelting and melting processes release some particulate matter into the air stream used to oxidize undesirable elements in scrap. Since scrap does not contain considerable sulfur, arsenic or other volatile elemental combinations found in natural ore minerals, these are not of great concern here. The principal materials of concern are those derived from burning plastic coating materials and electronic boards, when a smelting technique is used for these materials. New hydrometallurgical procedures have been developed, however, that have been shown to be efficient in removing the precious metals, copper and other metals from these materials. No fugitive air emissions are involved. Another group of elements of concern is those more volatile metals found in some copper alloys that are partially released during melting. These include zinc, mercury, lead and cadmium. Numerous mechanisms have been developed to keep these emissions to a minimum as well as to capture most of the emitted metals through the use of emissions scrubbing systems. Both wet scrubbing and electrostatic precipitators are in use. Particulate emissions associated with metal processing can be collected in mechanisms called *baghouses*. Products recovered from baghouse dusts are generally valuable materials that can be sold for further processing or for direct use in certain applications. However, because these materials sometimes contain certain metals currently classified as hazardous air pollutants (HAPs), as defined in Title III of the 1990 Clean Air Act Amendments, they are shipped and sold as hazardous materials.

The current trend has been to eliminate the burning of covered, insulated wire and to use mechanical means to prepare the copper wire for further processing. Wire burning generates large amounts of particulate matter, primarily composed of partially combusted organic compounds. Direct-flame incinerators, called afterburners, can effectively control these emissions. An efficiency of 90% or more can be achieved if the afterburner combustion temperatures are maintained above 1000 C (1800 F). If the insulation contains chlorinated organics, such as polyvinyl chloride, hydrogen chloride gas will be generated. Hydrogen chloride is not controlled by the afterburner and is emitted to the atmosphere. In eliminating the burning of insulated wire, however, a by-product called *fluff* is generated. The industry has been working in conjunction with firms such as Goodyear Rubber to find new uses for this material. Generally, however, it is baled and sent to a hazardous materials dump because of its lead content, which was used in plastics to prevent exposure breakdown while in use.

The EPA reported emission factor averages and ranges for 6 different types of furnaces, shown in **Table 19**, the data for which was derived from unpublished documents of the New Jersey Department of Environmental Protection, New York Department of Air Resources, Wayne County, Michigan, Department of Health, the State of Ohio EPA, the City of Chicago Department of Environmental Control, the City of Cleveland Department of Public Health and Welfare, and the South Coast Air Quality Management District in Los Angeles, California.

Furnaces

The kind of raw material that can be used depends upon the furnace in use at a plant. Fire refining and smelting require large furnaces or cupolas that are distinctly different from that used for direct melt of scrap. Few ingot makers or brass mills and no foundries maintain furnaces that are sufficient for large-scale fire refining or smelting. These types of furnaces generally are left to those firms that specialize in secondary smelting and refining. The stationary reverberatory is the most practicable furnace for large tonnage, but the rotary furnace is more flexible. Tilting and stationary crucible furnaces, either gas or electric, are used for making small melts of special alloys. Electric induction furnaces are more popular at ingot plants and foundries where special alloys are made.

No. 1 and No. 2 scrap can be melted in a reverb or rotary furnace for fire refining, similar to the process used in the anode furnace of primary copper production. Scrap is melted and partially fire refined. After the melt is oxidized to saturation, a poling step is carried out until the oxygen content is around 0.2%. The molten copper is then cast on a molding wheel, either into anodes for further electrolytic refining or into wire bar or ingot for use by foundries and brass mills. When anodes are refined, the tank house sludges are sources of valuable by-products such as precious metals.

To process low-grade copper scrap, secondary smelters commonly use a combination of cupola, blast, reverberatory or rotary furnaces that are either gas or electrically fired. A flux is commonly added to retrieve impurities in the earlier stages of the process, and a slag product is also produced in addition to the high-copper melt. The upgraded copper melt is charged to a converter where the product is oxidized to remove unwanted gases and the purity is increased to around 90% and then to a fire-refining furnace where the product is further upgraded to around 99% copper and is poled with either gas or wood to remove the residual oxygen.

Arc Furnaces. Once popular, *arc furnaces* are not used as much in copper-alloy ingotmakers and foundries today. Whether direct-arc, indirect-arc or submerged-arc, these furnaces melt within a closed chamber. The material is heated either directly by an electric arc between an electrode and the work or, indirectly, by an arc between two electrodes adjacent to the material (*ASM Metals Handbook*). The intense heat of the arc causes combustion of the graphite electrodes to occur by reaction with any oxygen present in the furnace atmosphere. The remaining atmosphere is nitrogen, carbon monoxide and any residual moisture from incoming air. Suppressing hydrogen absorption by excess air has the disadvantage of greatly increasing the rate of electrode consumption. Sealing off the tap hole with refractory cement also minimizes the flow of air into the furnace, but depends upon keeping atmospheric moisture out. Flushing the heat with dry nitrogen or an inert gas can reduce hydrogen absorption, if necessary. The submerged-electric-arc furnace is used for extracting metal components from reduced scrap pellets by Inmetco, according to its Web site, where it claims to be the only secondary submerged-arc smelting furnace in North America dedicated to the high-temperature metal recovery of nickel, chromium and iron.

ASARCO Furnaces. Named after the American Smelting and Refining Company, these furnaces are commonly used for melting pure copper cathodes and clean scrap. The product is tough-pitch copper, which is normally fed to wire-rod casting machines. They were first operated in the late 1950s and have since been built in a range of sizes. They are shaft furnaces shaped internally like an inverted cone, about one-half as wide at the bottom as at the top. By adjusting the fuel-to-air mixture, the atmosphere is kept slightly reducing. Fuels include natural gas, propane, butane and naphtha. Energy consumption is 1 million Kcal per ton of cathode.

Crucible Furnaces. A fairly large tonnage of secondary copper products is produced in crucible furnaces. These furnaces are fuel-fired with natural gas, fuel oil, propane or combinations of these. These fuels are all hydrocarbons. As a result, their combustion causes the formation of large quantities of water vapor. The water vaporizes if part of the visible flame comes into contact with the molten metal before it is exhausted from the furnace. Crucible furnaces are used for melting clean, well-segregated scrap – mostly in foundries. Nonmetallic fluxes are used for a protective covering, but alloy fluxes may be added as a refining agent and as a means of introducing some constituents into the melt.

The most common cause of porous copper-alloy castings is the reaction of the water vapor with the molten metal allowing dangerously high amounts of hydrogen to be formed and dissolved by the melt. Use of a cover material on the surface of the molten bath has been used to avoid or prevent hydrogen contamination in fuel-fired furnaces. The use of glassy, slag-like covers can be relatively effective in protecting the melt, but there are disadvantages. Such covers can prevent oxygen in the furnace from reacting with the bath. The British, reportedly, have been known to add oxidizing materials, such as cuprous oxide, to the slag cover to overcome this disadvantage. At best, however, covers can be a potential source of inclusions in castings, and their use shortens the life of furnace refractories and reduces the thermal efficiency during melting.

Scrap is usually melted in crucibles by the puddling method – melting enough scrap to make a liquid puddle, then forcing new scrap below the surface to become part of the molten body. Crucible furnaces may be either stationary or tilting, the latter being the most preferred. A ceramic-type of material (dry-vibration, low-moisture castable lining) is usually used to line the furnace in a manner not unlike molding cement.

Blast Furnace, Cupola. The function of a blast furnace is the reduction of copper compounds and the formation of copper matte and slag. The blast furnace is used in secondary smelters for smelting low-grade copper and brass scraps, refinery slags, drosses and skimmings. When used primarily for melting scrap, with little or no reduction of oxidized materials, it is called a *cupola*. The typical secondary blast furnace is a top-charged, bottom-tapped shaft furnace that is heated by coke burning in a blast of air introduced through tuyeres placed symmetrically around the bottom of the shaft. The upper section of the shaft is cylindrical, but the lower section (the bosh) is an inverted, truncated, tapering cone. A crucible is placed below the bosh to collect molten metal and slag produced in the smelting zone above. Refractories used in the furnace are usually fire-clay brick from top to bottom. The crucible is lined with magnesite or chrome brick.

The scrap is heated as it descends through hot rising gases, becoming liquid when it reaches the smelting zone. Brass and copper may actually melt above the normal smelting zone. Limestone, silica and iron oxide fuse in the smelting zone and form a molten slag, which mixes with the metals in the gas turbulence. The gases rising through the shaft are composed of CO, CO_2 and nitrogen. The amount of carbon dioxide increases at higher elevations in the shaft; the coke-to-air ratio is adjusted to provide a reducing atmosphere. Oxides of the base metals either dissolve in the slag or fume off; many are reduced and dissolved in the copper. The black-copper product of the blast furnace may contain zinc, lead, tin, bismuth, antimony, iron, silver, nickel or other metals contained in the scrap. Many of these are later fumed off and recovered as baghouse dust.

Both slag and metal are usually tapped through a launder into a reverberatory where they are held in a quiescent state to allow more complete separation of metal and slag. The metal product produced in the blast furnace will vary widely depending upon the materials charged. The range of composition will be 75% to 88% copper, 1.5% tin, 1.5% lead, 0.1% to 0.7% antimony, 0.5% to 1.5% iron, 4% to 10% zinc, and 0.5% to 1.25% sulfur. The calcium-iron-silica slag may also contain up to 1.5% copper.

Reverberatory Furnaces. A reverberatory furnace is a box-like, refractory-lined structure designed to heat the charge by both conduction and radiation. The furnace is usually lined with magnesite, or chrome-magnesite bricks, fused magnesite bottoms, and suspended magnesite brick roofs. Secondary smelter reverberatories may be as large as 100 tons per day or more. Charge materials must contain a minimum of 40% copper in order to prevent excess slag accumulation, which reacts with the refractories and shortens the furnace lining life. Scrap is charged at regular intervals until the furnace is filled. Melting is more efficient, if light scrap is densified by bailing or briquetting. Oxidation and volatilization losses are usually kept to a minimum by rapid melting in a slightly oxidizing atmosphere with a fairly fluid slag cover. A few of these furnaces are still in operation as fire-refining operations associated with copper tube mills in the United States. The reverberatory furnace used for processing primary copper and scrap at primary copper operations has disappeared. Primary copper producers currently use flash-furnace technology for smelting ores and concentrates. Flash furnaces, operating with the exothermic heat of sulfur oxidation, do not require much scrap except for cooling the melt. This has resulted in a significant reduction of low-grade copper scrap consumption by the primary producers.

Converters. Scrap may also be added to a primary copper converter as a convenient way to keep the melt from exceeding the proper temperature. These vessels are used for converting primary copper matte, an impure mixture of iron and copper sulfides, into blister copper by oxidizing the sulfides. The sulfur dioxide gas is expelled with other furnace gases, and the iron oxide combines with a siliceous flux to form an iron-silicate slag, which is poured off. A converting vessel is also used for making blister from black copper derived from scrap materials, as described above.

Rotary Furnaces. Top-blown, rotary converters are sometimes used to smelt and refine copper-bearing materials. These furnaces are more flexible than reverbs, but the capacities are limited in size to about 50 short tons per day of nonferrous metals. They can be operated in batch or semicontinuous modes. The barrel rotation ensures good mixing of flux and scrap. The thermal efficiency is good owing to direct heating of the barrel walls by the burners, followed by direct conduction of the hot refractory wall to the charge as it rotates. Some believe that it has an advantage over stationary furnaces for melting loose or bailed light scrap. The rotary furnace is a cylindrical steel shell with insulating material placed inside next to the shell. Magnesite or chrome-magnesite brick is used for lining. A cushion of grain magnesite usually backs the brick lining. Linings may last 100 or more heats, and the capacity of the furnace may increase owing to the erosion of the lining by abrasion and reaction with the slag. Heat losses also increase proportionately. Flux comprises equal amounts of anhydrous soda ash and anhydrous borax forming about 1-1/3% of the charge in melting 85-5-5-5 ingot (Spendlove, 1961). After melting of the charge, the metal and dross are tapped off separately.

Low-frequency Induction Furnaces. Brass mills may use low-frequency induction furnaces to melt copper, copper-alloy scrap, runaround (home) scrap, and significant amounts of primary copper and alloying elements such as slab zinc. Melting rates with induction furnaces can be high, but capacity is typically limited to a maximum of 5 metric tons. Energy costs for melting are usually higher due to the use of electrical power, but this may be compensated by the fact that no combustion gases are generated and no gas handling system may be needed. The heating equipment is more complex than standard gas burners. Induction furnaces produce little metal oxidation and have high metal recovery rates. However, they require relatively clean scrap, since contaminants tend to be entrained or entrapped in the recirculating molten metal pool.

Sweating

Scrap as journal bearings, lead-sheathed cable, radiators and mixed auto shreddings can be sweated to remove babbitt, lead and solder as valuable by-products, which would otherwise contaminate a melt. Both reverberatory and muffle furnaces are used for this purpose. The simplest furnace for sweating is the conventional sloping-hearth-fired furnace (Spendlove, IC 8002, 1961). The charge materials are placed at the highest point on the hearth. Low-melting constituents liquefy and flow to the low end of the hearth and out of the furnace into a collecting pot. The sweated babbitt, lead or solder may be used to make white-metal alloys. Small-sized scrap can be sweated efficiently in a rotary kiln with scrap charged continuously at the elevated end of the kiln.

Because some soldered items are difficult to sweat when the solder remains in folds and seams, even when melted, other furnaces have been developed to counteract this problem. One is a reverberatory furnace with a shaking grate of steel rails about the size of the furnace floor. The scrap is shaken to remove the liquid solders from the scrap. The molten solder falls to the floor of the furnace, where it flows to a low corner and is collected. Some melters have used tunnel furnaces where the scrap is carried on trays or racks through a heated tunnel by an endless conveyor. Some of the solder melts and falls from the scrap while inside the furnace tunnel.

CHAPTER 4—ENVIRONMENTAL OVERVIEW

Since the passage of the Clean Air Act of 1970, numerous laws and regulations relating to improving human health and the environment have been promulgated by Congress and the federal and state agencies that enforce them. This review is not meant to be a comprehensive review of all of them but, rather, a sampling of some of the more significant ones as to how they currently affect the way the secondary industry does business.

With a view to protect the environment by preventing the production of waste and by organizing its disposal or recycling, administrations and legislators worldwide have decided to take charge of all aspects of waste management — whether hazardous or not — including the management of recyclable raw materials that the industry recycles, processes and sells. Regulators tend not to distinguish between recyclable raw materials and waste and, in the process, create enormous obstacles for the entire reclamation and recycling industry. Metals should not be viewed as wastes but rather as renewable resources that can be used again and again in new products, conserving scarce resources, saving energy and preventing pollution. Recycling should be given priority over disposal. The failure to look at the interplay of markets, commodities and regulations before putting into effect new recycling regulations has ended up being a very costly storage and disposal program.

Basel Convention

One of the most contentious international agreements to surface has been the Basel Convention. In 1989, the Basel Convention on the Control of Transboundary Movements of Hazardous Wastes and Their Disposal came into force. It has since been ratified by more than 100 countries, including the United States, although the United States has not passed legislation necessary to implement its participation in the Convention. In 1997, the Convention's Technical Working Group completed recommendations for assigning materials to the "A list," wastes characterized as hazardous, and the "B list," wastes not inherently hazardous. Copper scrap, slags and oxide mill scale were placed in the B list. The B list of materials is not covered by the Basel Convention as hazardous and, thus, not subject to any export ban.

Annex VII defines the countries of the Convention that can trade in hazardous wastes (which include valuable metal containing ashes, drosses and residues, etc.) The criteria for defining countries in Annex VII is of concern: the current impasse that restricts these countries to those predominantly from the northern industrialized hemisphere does not reflect the sources for the hazardous wastes nor the necessity to treat these materials in countries other than where they are generated (*BIR Newsletter,* 2002).

In 2001, the Basel Convention Conference of Parties (COP5), a Protocol on Liability and Compensation, was adopted for damage resulting from transboundary movements of hazardous wastes and their disposal. *(www.basel.int/meetings/cop/cop5/docs/prot-e.pdf)* A declaration was also made reaffirming the Convention and supporting sustainable development. Areas targeted for further study included waste minimization, cleaner technologies, recovery and disposal of wastes as well as waste prevention. The meeting for COP 6 will take place in Geneva in May 2002.

OECD Rulings. On June 14, 2001, the OECD Council adopted the final decision on the Control of Transboundary Movements of Wastes Destined for Recovery Operations. This decision streamlines the OECD control system, is more economically efficient and environmentally safe, and enhances harmonization with the Basel Convention. Three OECD lists are replaced with two Annexes of the Basel Convention, applying OECD *green* controls to Annex IX wastes and OECD *amber* controls to Annex VIII wastes. The OECD review mechanism is eliminated, while retaining the option of different controls in exceptional cases. Examples of exceptions for *green* and *amber* wastes, respectively, are: electronic scrap and drained motor vehicle wrecks; and, flammable magnesium scrap and vanadium residues. OECD membership is comprised of 30 countries including the EU and United States. The major points of "benefit" to the recycling industry include the following: (1) A new definition for a mixture of wastes, specifying this as a waste that results from a mixing of two or more different wastes. A single shipment consisting of two or more wastes, where each waste is separated, is not a mixture of wastes. (2) *Green*, as a control procedure, shall be applied to mixtures of *green* wastes for which no individual entry exists. On the other hand, where *green* waste is mixed with more than a minimal amount of *amber* waste, or a mixture of amber wastes, it will be subjected to the *amber* control procedure.

CERCLA Overview

The Comprehensive Environmental Response, Compensation, and Liability Act (CERCLA), commonly known as Superfund, was enacted by Congress on December 11, 1980, and amended by the Superfund Amendments and Reauthorization Act (SARA) on October 17, 1986. SARA provided the framework for the environmental taxes that establish the Hazardous Substance Superfund and the Leaking Underground Storage Tank Trust Fund. A trust fund of $8.5 billion was authorized over 5 years. This law created a tax on the chemical and petroleum industries and provided broad federal authority to respond directly to releases, or threatened releases, of hazardous substances that may endanger public health or the environment

CERCLA established prohibitions and requirements concerning closed and abandoned hazardous waste sites; provided for liability of persons responsible for releases of hazardous waste at these sites; and, established a trust fund to provide for cleanup when no responsible party can be identified. The law allows for both short- and long-term response actions. Long-term remedial actions permanently reduce the dangers associated with releases of hazardous substances. These actions can be conducted only at sites listed on EPA's National Priorities List (NPL). A National Contingency Plan (NCP) provides guidelines and procedures for the release of hazardous materials.

CERCLA, Section 107, designates those that can be held liable for contamination and cleanup. When EPA is investigating contamination at a site, any person potentially covered by Section 107(a) can be designated as a Potentially Responsible Party (PRP). PRPs include the current owner and operator of the site, any person who at the time of disposal of hazardous substances owned or operated the property, or any person who arranged for disposal or transportation of hazardous substances at a property where a "release" has occurred. Section 107(b) provides three possible defenses to liability: an act of God, an act of war, or action by a third party under certain circumstances.

To identify PRPs responsible for site contamination, EPA reconstructs the history of operations that occurred at the site, by conducting an extensive search through site, state agency and EPA files. Once EPA has enough information to identify parties as potentially liable for contamination of a site, EPA issues a general notice letter to each PRP, notifying them of their potential liability.

The Superfund cleanup process starts with site discovery by various parties including citizens, state agencies and EPA regional offices. Once discovered, the site is listed on the Comprehensive Environmental Response, Compensation, and Liability Information System (CERCLIS). This is EPA's inventory of potential hazardous-substance release sites. EPA evaluates these sites through the following steps:

- Preliminary Assessment/Site Inspection (PA/SI) — site condition investigations
- Hazard Ranking System (HRS) Scoring — sites are screened to be placed on the NPL
- Remedial Investigation/Feasibility Study (RI/FS) — the nature and extent of contamination is determined.
- Record of Decision (ROD) — Cleanup alternatives are described for the NPL sites.
- Remedial Design/Remedial Action (RD/RA) — Plans are prepared and implemented for site remedy.
- Construction Completion — The completion is described.
- Operation and Maintenance (O&M) — Ensures that all actions are effective and operating properly.
- NPL Site Deletions — Removal of sites from the NPL.

A Superfund liability exemption for scrap recyclers was signed into law on November 29, 1999. Called the "Superfund Recycling Equity Act of 1999," the exemption law applies to processors of scrap materials, as well as to mills and other facilities that are involved in reclaiming recycled materials. The EPA estimated the cost to remaining liable parties at current Superfund sites would range between $156 million and $175 million. According to an ISRI list, 16 Superfund sites would be affected by the new legislation. Two of the sites are former brass foundries, and another two are former scrap metal reprocessing sites.

Included in the 1999 Superfund liability amendment were scrap paper, plastic, glass, textiles, rubber, metal, and spent lead-acid, nickel cadmium and other batteries, as well as minor amounts of material incident to, or adhering to, the scrap material as a result of its normal use. Shipping containers with 30 liters to 3,000 liters capacity that had hazardous materials associated were not included.

Transactions involving scrap metal must demonstrate that the person making the transaction was in compliance with all regulations or standards for storage, transport, management or other activities associated with metal recycling and that the person did not melt the scrap metal prior to the transaction. Melting, according to this definition, does not include sweating to thermally separate metals. Scrap metal is defined as bits and pieces of metal parts or metal pieces held together with bolts or soldering.

Hazard Ranking System (HRS). First promulgated July 16, 1982 (47 FR 51532), as Appendix A of the NCP, it was revised December 14, 1990, in response to CERCLA Section 105(c). The HRS is the principal mechanism that EPA uses to place uncontrolled waste sites on the NPL. It is a numerically based screening system derived from the preliminary assessment and the site inspection. The sites with the highest scores do not necessarily get the first attention. EPA relies on more detailed studies in the remedial investigation/feasibility study that typically follows listing. Factors are grouped into three categories: the likelihood that the site poses a hazardous substance release into the environment; the characteristics of the toxicity and waste quantity; and the people or sensitive environments affected by the release expected. Four pathways are scored: ground water migration; surface water migration; soil exposure (population affected); and, air migration (population and sensitive environments affected). The site score can be high, even if only one pathway score is high. Sites are placed on the NPL using the HRS. The second mechanism for placing sites on the NPL allows states or territories to designate one top-priority site, regardless of score. A third mechanism allows listing the site if it meets all three of the following requirements:

(1) The Agency for Toxic Substances and Disease Registry (ATSDR) of the U.S. Public Health Service has issued a health advisory that recommends removing people from the site;
(2) EPA determines that the site poses a significant threat to public health; and,
(3) EPA anticipates it will be more cost-effective to use its remedial authority (available only at NPL sites) than to use its emergency removal authority to respond to the site.

Resource Conservation and Recovery Act (RCRA)

RCRA was passed into law in 1976. The goals of the law are to conserve energy and natural resources, reduce the amount of waste generated and ensure that wastes are managed to protect human health and the environment. RCRA gives EPA power to make and enforce regulations for managing many kinds of wastes. RCRA regulations apply to 3 kinds of waste management: municipal, solid waste landfills; hazardous waste generators and transporters, and treatment, storage and disposal facilities; and underground tanks that store hazardous materials.

Generally, sites that may be cleaned up under RCRA or certain other laws will not be put on the NPL. By "deferring" the cleanup authority to another program like RCRA prior to placement on the NPL, EPA can reserve CERCLA response activity funding for sites that are not eligible to be addressed under other federal authorities. If a site on the NPL falls under RCRA authority, it usually will undergo RCRA corrective action before Superfund remedial activity. In some cases, the EPA may delete the site from the NPL. For more information on the interface between RCRA and CERCLA, see the September 24, 1996, EPA memorandum entitled "Coordination between RCRA Corrective Action and Closure and CERCLA Site Activities."

Toxicity Characteristic Leaching Procedure (TCLP)

Section 1004 (5) of the RCRA defines hazardous waste as solid waste that may "pose a substantial present or potential threat to human health and the environment when improperly treated, stored, transported or otherwise managed." RCRA Section 3001 charged EPA with the responsibility of defining which specific solid wastes would be considered hazardous waste, either by identifying the characteristics of the waste or listing particular hazardous wastes. In response, the EPA identified 4 characteristics of hazardous waste: 1) toxicity, 2) corrosivity, 3) reactivity, and 4)ignitability. The EPA also developed standardized procedures and criteria for determining whether a waste exhibited any of these characteristics. Testing procedures are detailed in EPA's report, *Test Methods for Evaluating Solid Waste,* SW-846 (1995).

The Extraction Procedure (EP) was the original test developed by EPA to determine whether a waste exhibits toxicity characteristics. A set of assumptions was developed under a mismanagement scenario that simulated a "plausible worst case" of mismanagement. Under this worst-case scenario, it was assumed that hazardous wastes would be co-disposed with municipal solid waste (MSW) in a landfill with actively decomposing material overlying an aquifer. EPA felt this was justified given its mandate to protect human health and the environment. The toxicity of a waste was defined by measuring the potential for toxic constituents present in the waste to leach out and contaminate groundwater and surface water at levels of health or environmental concern. Specifically, the EP required analyzing a liquid waste or liquid waste extract to determine whether it contained unacceptably high concentrations of any of 14 toxic constituents identified in the National Interim Drink Water Standards (NIPDWS). To account for the likely dilution and attenuation of the toxic constituents that would occur as they traveled from the landfill to a drinking water source, the EPA multiplied the NIPDWS by a "dilution and attenuation factor" (DAF) of 100. The DAF of 100 was not derived from any model or empirical data, but was an estimated factor.

In the 1984 Hazardous and Solid Waste Amendments (HSWA), Congress directed EPA to expand the toxicity characteristic (TC) and reevaluate its use of the EP to determine the toxic characteristics of a waste. In response, the EPA developed a new test in 1986 — the Toxicity Characteristic Leaching Procedure (TCLP). Two objectives were satisfied: (1) a test to generate replicable results for organics, and (2) a test that could yield the same results for inorganics as the original EP test. The TLCP began with the same assumptions that waste would be co-disposed with actively decomposing municipal solid waste in a landfill. Thus, the test is designed to determine the mobility of toxic constituents in wastes when exposed to organic acids. The adequacy of DAFs of 100 was confirmed for all of the listed toxic constituents.

After particle size reduction, a liquid extract is obtained by exposing the waste to a leaching medium (also called extraction fluid). In contrast to the EP, which specified only one leaching medium, the TCLP allows the use of two media. The medium used is determined by the solid waste alkalinity. The extract is analyzed for any of 39 listed toxic constituents. Details concerning TCLP procedures may be found in 40 CFR part 261, Appendix II, or in EPA's publication SW-846. The primary difference between EP and TCLP is that TCLP covers a broader range of constituents and more accurately addresses the leaching potential of wastes containing organic constituents.

Two difficulties with the TCLP are: (1) it does not account for the many parameters that affect leaching; and, (2) the TCLP has been applied in situations where it is not appropriate. The latter is important because a test designed to predict leaching in MSW landfills may over- or under predict leaching potential in other scenarios. Ideally, testing procedures should bear a rational relationship to actual conditions under which waste is managed and consider the many parameters that affect the leaching behavior of contaminants from the waste.

Suggested Improvements for the Toxic Characteristics Leaching Procedure (TCLP). In February 1999, the Science Advisory Board's Environmental Engineering Committee (EEC) prepared a commentary to call attention to the need for a review and improvement of EPA's current waste leachability testing procedure. The Committee's single most important recommendation is that EPA must improve leach test procedures, validate them in the field and then implement them. They recognized that the TCLP might require the development of multiple leaching tests. The result may be a more flexible, case-specific, tiered testing scheme or a suite of related tests incorporating the most important parameters affecting leaching. Applying the improved procedures to the worst-case scenario could ameliorate many problems associated with current procedures. Although the Committee recognized that these modifications might be cumbersome to implement, they felt this protocol might better predict leachability.

The TCLP model assumes 5% industrial solid waste and 95% municipal solid waste in a sanitary landfill. The TCLP specifies a procedure for liquid wastes, which are those with less than 0.5% dry solid material and for wastes greater than or equal to 0.5% dry solid waste. Liquid waste is filtered through a fine glass fiber filter to form the TCLP extract, which is stored for later analysis. The solid phase may then undergo the size reduction. The EP required particle size reduction through a 9.5-mm sieve and that this requirement be retained by the TCLP. In the TCLP, the waste must be ground or milled until it passes a 9.5-mm sieve. Two extraction fluids are used: One is a pH 2.9 acetic acid solution for moderately to highly alkaline wastes and the other is a pH 4.9 acetate buffer solution that is used for all other wastes. Although defined as a test of toxicity characteristics of contaminants in a waste, TCLP has found a variety of other applications. For example, TCLP has been used in administrative delisting procedures as an end point test for clean-up standards and as a source term for risk assessments/site closure modeling.

Kinetics: The TCLP is based on an arbitrarily chosen extraction time of 18 hours. Timing of the leaching process is difficult. Some solid matrices display a long period of slow release that may be more relevant to the protection of health and the environment that the early, fast release. For some constituents, the TCLP may not measure this slow release.

Liquid/Solid Ratio: The TCLP uses a 20:1 liquid-to-solid ratio, chosen for analytical and administrative procedural purposes. Liquid-to-solid ratios can vary depending upon field conditions. Degree of saturation, weather, climate and infiltration rates as well as hydrological impacts of engineered systems can result in substantial deviations in this ratio.

pH: The TCLP assumes that, in the MSW landfill scenario, the disposal venue (not the waste) governs the leaching fluid chemistry. The two current TCLP leaching fluids cannot account for the diversity of wastes and waste management conditions. Many contaminants do not leach from waste matrices. Higher pH values than that assumed cause the higher than predicted concentrations of regulated metals that form oxoanions (*e.g.* Sb, As, Mo, Se and V) in the MSW leachate. Similarly, aggressive simulated MSW leachate (TCLP fluids) may significantly over predict the availability and mobility of contaminants in natural settings.

Colloid Formation: Colloids may be formed during the end-over-end agitation required in the TCLP testing. The aggressive agitation can dislodge or otherwise create colloidal particles, which may pass through the filtering process and subsequently be analyzed as part of the extract. An over prediction of the aqueous phase as a constituent may result from hydrophobic organics and metals that preferentially bind to these colloidal particles.

Particle Size Reduction: TCLP particle size reduction requirements may not represent field conditions. Monolithic wastes have a lower leaching potential caused by physical stabilization and the resulting increase in length of diffusion pathway from waste into the leachate. Additionally, some processes also provide for chemical stabilization by binding heavy metals in insoluble hydroxide and other complexes. Reductions caused from solidification/stabilization of monolithic wastes are ignored.

Leachability Phenomena: Reduction in particle size affects testing of volatile compounds. The EPA concluded that the advantages of particle size reduction outweighed the potential problems. However, the ECC recommends that EPA reconsider the issues of volatile loss and/or increases in constituent solubility.

Aging: At present, wastes are tested at the time of generation. A lapse of considerable time between generation and dumping may allow chemical or physical transformations to take place.

Volatile Losses: Volatile losses may occur during the leaching procedure and analysis. When addressing volatile compounds, the most important pathway for release to the environment may not be leachability. In these cases, the mass release of volatiles should be considered.

Interaction with other wastes: The TCLP assumes municipal solid waste leachate governs leachate chemistry and rate of release. In the presence of co-solvents, solubility of the organic phase, rather than the aqueous phase, may control the leachate concentration. Surfactants may also mobilize hydrophobic contaminants.

Field Validation of the Tests: The 1991 EEC commentary, "Leachability Phenomena," suggested that field tests were needed to validate the tests before broad application. **The TCLP was not intended to be representative of insitu field conditions, but rather of a generic MSW landfill worst-case scenario.** There should be a means for reconciling any leach test results with expected or observed field leachate concentrations. A model should be developed.

Multiple Extraction Procedure (MEP). The MEP is designed to simulate the leaching that a waste will undergo from repetitive precipitation of acid rain on a landfill to reveal the highest concentration of each constituent that is likely to leach. This test is currently used in EPA's delisting program and has been designated method 1320 in the SW-846 manual. The MEP is intended to simulate 1,000 years of freeze-and-thaw cycles and prolonged exposure to a leaching medium. Reportedly, one advantage of the MEP over the TCLP is that the MEP gradually removes excess alkalinity in the waste. Thus, the leaching behavior of metal contaminants can be evaluated as a function of decreasing pH, which increases the solubility of most metals.

Hazardous Wastes

Under 40 CFR Chapter 1 (7-1-98 edition) solid wastes that are subject to regulation as hazardous wastes are identified under parts 261 through 265, 268 and parts 270, 272 and 124. Subpart A of the Chapter defines the terms "solid waste" and "hazardous waste". It also identifies those wastes that are subject to regulation under parts 262 through 266, 268 and 270, and establishes special management requirements for hazardous waste produced by conditionally exempt small-quantity generators and hazardous waste that is recycled. Subpart B sets forth the criteria used by EPA to identify characteristics of hazardous waste and to list particular hazardous wastes. Subpart C identifies characteristics of hazardous wastes. Subpart D lists particular hazardous wastes.

In February 1999, EPA proposed a rule to promote metal recovery from the hazardous waste water treatment sludge (FOO6, as regulated under RCRA). It was proposed to encourage the legitimate recovery of metals from F006 waste that would otherwise be land-disposed. The F006 wastes generated from electroplating processes in the metal finishing industry generally contain recoverable amounts of metals. Although some of this sludge is recycled for metals recovery, a large percentage (according to EPA) is land-disposed. By minimizing economic barriers to recycling of F006 waste through metals recovery, this route will be more commonly sought. EPA proposed to allow generators of F006 waste up to 270 days to accumulate the waste on site without requiring a hazardous permit, provided certain safeguard conditions are met. Currently, only 90 days are allowed. The EPA feels that the increased time will allow larger shipments of F006 waste to be shipped, reduce transportation costs and provide additional incentive to recover metals rather than dumping the material. According to some industry sources, however, this rule falls short of providing the necessary incentive required for increased recovery of metals from FOO6 sludges. Because these materials are classified as hazardous wastes, they are subject to all the shipping, handling and licensing requirements of hazardous materials. EPA has allowed a variance to at least one company in Phoenix, Ariz., in an effort to promote recycling and to recognize that when used for metal recovery, these materials are analogous to virgin raw materials used by primary smelters.

Toxic Release Inventory (TRI) System and Other Databases

The Toxic Release Inventory (TRI) system is a database of more than 300 designated toxic chemicals released to the environment by manufacturers or businesses in the United States. The inventory is updated yearly and provides a means for interested persons to access information on toxic chemicals being released, stored or transferred to their communities. This data has been made available under the Emergency Planning and Community Right-to-Know Act (EPRA) of 1986. Under the Act, manufacturers and businesses are required to report locations and quantities of toxic chemicals if the facility produces substantial amounts (more than 25,000 pounds). This reporting became more comprehensive following the Pollution Prevention Act (PPA) of 1990. The strategy focuses less on tracking and managing the waste and more on avoiding them. Facilities are now required to indicate amounts of chemicals that are recycled, used for energy recovery, and treated on site. Source reduction activities are also noted. TRI is available on the Internet (www.epa.gov/tri) and in various types of publications. In addition, the Agency for Toxic Substances and Disease Registry (ATSDR) maintains the *Hazardous Substance Release/Health Effects Database (HAZDAT).* Chemicals on the Toxic Release Inventory include antimony, arsenic, barium, beryllium, cadmium, chromium, cobalt, copper, lead, manganese, mercury, nickel, selenium, silver, thallium and zinc compounds, in addition to a long list of organic chemicals, acids and gases.

The National Risk Management Research Laboratory has developed and is continuing to expand a database on the effectiveness of proven treatment technologies in the removal/destruction of chemicals in water, wastewater, soil, debris, sludge and sediment. This database gives performance data on numerous technologies and is called the Treatability Database (TDB). TDB is available from NRMRL in Cincinnati, Ohio.

Lead in the Workplace Directives (OSHA)

The Office of Safety and Health Administration (OHSA) promulgates workplace and safety rules for U.S. industries. On November 14, 1978, OSHA defined the lead standard (29 CFR 1910.1025) (43FR 52952). This standard required that employers achieve a lead exposure limit (PEL) of 50 $\mu g/m^3$ based on an 8-hour time-weighted average (TWA)(29CFR 1910.1025(c)). Both industry and labor challenged the standard. The court found that OSHA had failed to establish feasibility of meeting the PEL for 38 of the industries covered and remanded OSHA to reconsider the ruling.

In December 1981, OSHA published its new findings for all but nine of the industries. The nine industries included brass and bronze ingot manufacturing/production, collection and processing of scrap, nonferrous foundries and secondary copper smelting. In March 1987, the court asked OSHA to reconsider the application of the ruling for these remaining nine industries. On July 11, 1989, OSHA filed with the court additional reasons that compliance with the PEL solely by means of engineering and work practice controls was feasible for eight of the remaining nine industries. OSHA felt that the ninth industry, nonferrous foundries, could comply with the PEL by means of engineering and work practice controls, but it was not economically feasible for small nonferrous foundries to comply with paragraph (e) (1) of the ruling (54 FR 29142). Later, OSHA published on January 30, 1990, a determination that the small nonferrous foundries could comply and achieve an 8-hour TWA airborne concentration of lead of 75 µg/m^3 (55 FR 3146). Six of the nine industries challenged OSHA's findings including brass and bronze ingot manufacturing, collecting and processing scrap, the nonferrous foundries and copper smelting.

On March 8, 1990, the court lifted the stay on paragraph (e) (1) for all remanded industries (39 industries), except the six that challenged the feasibility findings. The 39 industries were given two and one-half years to comply with the PEL. Eventually, on July 19, 1991, the court reaffirmed OSHA's feasibility findings for five of the six contested industries, and lifted the stay. These industries included the nonferrous foundries (large and small), secondary copper smelting, and collection and processing of scrap. Employers in these three industries were given until July 16, 1996, to comply.

With regard to the brass and bronze ingot manufacturing, however, the court concluded that, while OSHA had shown that it was technologically feasible to comply, it had not shown that it was economically feasible to do so. The court remanded that portion of the record to OSHA for additional consideration and continued the stay of paragraph (e) (1) for the brass and bronze ingot industry.

OSHA concluded that an 8-hour TWA airborne lead concentration of 75 µg/m^3 was the lowest economically feasible level that could be achieved by means of engineering and work practice controls in the brass and bronze ingot industry as a whole (60 FR 52856). Then on June 27, 1995, the Brass and Bronze Ingot Manufacturing association and the Institute of Scrap Recycling Industries entered into an agreement with OSHA acknowledging that this level was economically feasible for the industry as a whole. Based on the record, OSHA also recognized that most employers could not achieve the 50 µg/m^3 PEL without supplemental use of respiratory protection, and that it was not economically feasible to achieve even an 8-hour TWA of 75 µg/m^3 in the briquetting and baghouse maintenance operations. Therefore, OSHA assumed the burden for proving economic feasibility in any enforcement proceeding under paragraph (e) (1) of the Lead Standard concerning these operations. OSHA is allowing employers 6 years from the date the court lifts the stay to comply. Follow-up instructions listing the new compliance date will be issued at that time.

On February 27, 1997, the Directorate of Compliance Programs published directive number CPL 2-2.67 to change compliance requirements and compliance dates for enforcement of the engineering and work practice controls provisions of the Lead Standard (29 CFR 1910.1025 (e) (1). The stay on enforcement of paragraph (e) (1) of the Lead Standard as it applies to the brass and bronze ingot manufacturing industry has not yet been lifted by the court. Until the stay is lifted, employers in this industry must continue to control lead exposures to 200 µg/m^3 solely by engineering and work practice controls, and to 50 µg/m^3 by some combination of engineering and work practice controls and respiratory protection. Six years after the judicial stay of the Lead Standard is lifted by the court, the Compliance and Safety and Health Officer (CSHO) shall determine whether the employer in the brass and bronze ingot manufacturing industry is in compliance with all provisions of the Lead Standard.

Clean Air Act Ruling.

The Clean Air Act is the comprehensive federal law that regulates air emissions from area, stationary and mobile sources. This law authorizes the U.S. EPA to establish national Ambient Air Quality Standards (NAAQS) to protect public health and the environment. The Act was amended in 1977 to set new goals and dates for achieving NAAQS deadlines. The 1990 amendments were intended to meet insufficiently addressed problems such as acid rain, ground-level ozone, stratospheric ozone depletion and air toxics. On February 28, 2001, the U.S. Supreme Court ruled unanimously that federal law doesn't allow the EPA to consider expense to industry when it sets clean-air standards and permissible pollution levels. The Court agreed with the fundamental principle that the Clean Air Act was designed to protect people's health without regard to cost. However, the ozone standards can't be implemented until the case goes back to the U.S. Court of Appeals for the D.C. Circuit to assure that EPA reaches a lawful and reasonable interpretation of ozone standards and enforcement policies. Beyond the cost factor, the Court ruled that Congress did not unconstitutionally delegate its power to EPA. The rules affect airborne soot and smoke from trucks and power plants, as well as smog or ground-level ozone from chemical plants and other sources. The 1997 standards limit ozone to 0.08 parts per million, instead of 0.12 parts per million under the old requirement.

CHAPTER 5—PROBLEMS AND SOLUTIONS

The Problems

The responsibilities placed on the secondary copper and copper alloy industry by the steadily increasing application of environmental laws have been enormous, ranging from increased paperwork and reporting requirements to the need for installing expensive equipment. The paperwork, reporting requirements and mandatory cleanup procedures, which the federal agencies use to control the way the industry does business, are not only expensive, but also counter productive. The result , in many cases, has been the shut down of useful, necessary businesses. One has to look only at the demise of the secondary smelter industry in the United States to see what has happened and what will continue to happen.

The last operating secondary smelter was under suit for allegedly dumping undesired water and closed in 2001. This kind of threat and action has become a way of life for this segment of the metals industry. The expense of extensive litigation, permitting procedures and requirements for new equipment has resulted in the eventual shut down of most of these plants and their removal from a very important role in the U.S. recycling industry. Even so, some other parts of the secondary industry, with more firm financial backing, are attempting to meet similar problems head on and have enthusiastically embraced new technology and improved techniques as a better way of doing business.

The shutdown of secondary smelter and ingot-making capacity has presented the remainder of the industry with several problems. Aside from the problem of finding new markets for the sale of their lower grades of scrap and copper processing by-products, which were previously processed by these companies, there is a growing problem for others in securing the relatively inexpensive raw material that these businesses could provide in return. The current economic uncertainty of the international copper markets, with its continuing over capacity and lower prices, has added extra penalties to the secondary market. Collection of old scrap, in particular, has suffered in recent years. The supply is not as available as it could be.

Problems confronting the foundry industry include (Regan and Contos, 1990):

- Market pressure from foreign competitors, limiting selling price of domestic products
- Loss of production lines and management positions associated with plant closings
- Diminishing approved landfill space accompanied by increased tipping fees
- Continuing pressure from state regulatory officials to comply with more strict environmental and labor regulations, and
- Lack of capital at small-scale operations for retrofitting and/or modifying basic pollution control processes.

Problems for most of the secondary industry also emanate from the potential responsible party (PRP) aspects of the Superfund law. The potential here is to be named liable for expensive cleanup solely because you may have sold raw material to a firm that is currently on the CERCLIS and listed on the NPL. This has happened to a number of firms that did business with the Jacks Creek/Sitkin Smelter and Refinery, for example. This kind of approach to solving Superfund finances is sure to have far-reaching repercussions in the metal processing industry as they think twice about shipping materials to certain firms.

Liability concerns have been enormous barriers to development, redevelopment and cleanup technologies. Because financial institutions can be liable for cleanup costs when they acquire the properties through default, they are unwilling to provide loans for development.

A whole set of new problems will arise should the by-products of metal processing become controlled substances under RCRA. Shipment of these materials to others would become an expensive proposition. In short, the markets for these materials would change drastically. Most producers would have to pay for their disposal, rather than receive money for their valuable metal content. Processing facilities also would be reluctant to take these materials, owing to their new hazardous classification.

Electronics recycling has become a significant concern in recent years. Computers, in particular, are becoming obsolete more quickly than ever (the typical computer now has a life span of 2 – 3 years, down from 5 years in 1997 (*Recycling Today,* Feb. 2002). Some recyclers have been shipping components overseas for dismantling by hand. Because labor is less expensive in China, and hand dismantling results in less waste than shredding, much of this material had been headed there. This traffic may not continue at the same pace in the future, owing to a new environmental awareness in China and new tariffs against the import of scrapped electronic parts. China threatened to crack down on illegal imports of junked computers and other electronic scrap. In Guiyu, China, stacks of broken computers and electronic parts filled unused rice paddies, and circuit boards were being melted over open fires. A substantial tariff was levied in May 2002 on what China called “Class 7” copper scrap and blocked containers of copper scrap from entering the country. Some U.S. brokers considered the measure severe and likely to affect U.S. copper exports to China.

Industry Solutions

In talking to industry representatives, one finds enthusiasm for the various methods and equipment they have developed for coping with heightened environmental awareness. Most of the surviving industry has managed to solve many of the pollution problems in their particular part of the industry and are proud to be a part of the solution. In addition to solving the environmental and labor health problems posed by EPA and OSHA, many in the industry also are striving to achieve ISO 9000 and ISO 14000 quality standards to maintain high-quality goals in their production processes.

Some companies have made strategic investments in their businesses during the slower economic times of the past several years. Melting and fabricating processes have been rethought and retooled to run with fewer people. Many of these new fabricating methods and machines have been in-house inventions and are unique to the user plant. Simple measures such as using a different melting additive has cut down copper loss in skimmings and drosses. A new baler installed saves about $50,000 per year in electrical costs. The current market downturn has provided an opportunity for some firms to reevaluate current operations to ensure maximum efficiency and recovery rates.

Some secondary metal processors have instituted their own slag and residue cleanup and recovery systems, preferring to retain all benefits to their own company. For some, this has been a rewarding effort, but this is not possible at all sites. In addition to the significant financing and risk required, there are problems of adequate space and permits. Although exports to other nearby countries, such as Canada and Mexico, are alternatives, this has not been pursued as broadly as one might have expected. Exports of lower-graded (and less valuable) scrap have been lower than expected owing to the low price of copper and the strong dollar over the past several years. Of course, the high-grade slags (up to 65% copper) generated from fire refining have found, and will continue to find, ready export markets.

Unfortunately, one industry solution to the weakening availability of old copper-base scrap has been to put up for sale or shut down operating smelters and associated refineries. This could spell trouble for the recycling industry, since the recourse of last resort may be dumping in landfills those materials that previously had been usable and valuable residues. This is also potential trouble from a national security point of view. Secondary smelters are essential during wartime buildup and scarcity of primary raw materials.

In 1999, the National Electrical Manufacturers Association (NEMA) petitioned the EPA to delist copper from its Toxic Release Inventory (TRI) because it felt that recycling prevents most copper from entering the environment. There also was growing evidence that copper was not detrimental to the environment as previously theorized. Public access to information on the TRI list could cause undue public concern and stigmatize some of its members. In 1997, the TRI report indicated that 34,500 tons of copper had been released to the environment. A similar petition to delist copper in 1996 was rejected (*American Metal Market,* 1999).

Process Recovery Corp. The need for improved, cost-effective technologies and management strategies for maximizing the use and disposal of foundry industrial by-products prompted a group of foundries in Pennsylvania to establish the Process Recovery Corporation, Inc. (PRC). The PRC is headquartered in Reading, Penn., and represents about 33 foundries in that area. The general goal of the PRC is to establish a centralized facility for the collective management of residual (non-hazardous) solid wastes (RSW) from its members. The PRC provides options for reclamation of foundry sand for reuse, finding alternative uses for other foundry wastes and, lastly, managing ultimate residuals by landfilling. Researchers from Pennsylvania State University have assisted the PRC in several aspects of the project dealing with engineering and the environment. The individual foundry members contributed technical and operating data to the PRC, as well as funding for its efforts. (Regan and Contos, 1990).

Management Systems and ISO Standards. Management systems differ from the traditional kinds of functional standards enforced by OSHA and EPA. Management systems standards define the processes and documentation that an organization or company should implement, rather than defining the limits or quantitative objectives of performance. Two international management systems currently exist: the ISO 9000 quality management system standards and the ISO 14000 environmental management systems standards.

The ISO 9000 series is published internationally under the auspices of the 90-country membership of the ISO (International Organization for Standardization). According to ISO procedures, all ISO standards must be reviewed and revised or reaffirmed at least every 5 years. These standards were derived from the 1987 British Standards Institute after they were revised to include service providers as well as manufacturing companies. In 1994, ISO 9000 was again revised and published internationally. In particular, the sections covering Process Control, Corrective Actions and Servicing were strengthened and clarified. Today, the ISO 9000 Standards Series has all but replaced other, more parochial standards for doing business and guaranteeing quality. In only a few short years, the term ISO 9000 has become synonymous with quality in almost every language used to conduct trade and commerce. These standards require strict methods of procedure and labor training. The results have been better, more streamlined operations and improved markets for their products.

The American National Standards Institute (ANSI) and the Registrar Accreditation Board (RAB) established an accreditation system in response to the need to accredit registration bodies as required by ISO 14001, 14010 and 14011. The ANSI-RAB National Accreditation Program Criteria (NAP), published September 13, 1996, specifies requirements for a registration body. Audit teams from the registration body go out to organizations seeking registration and compliance with ISO 14001 standards. ISO 14001 requires an organization to have an environmental policy statement that includes: a commitment to prevention of pollution, a commitment to continual improvement, and a commitment to compliance with relevant legislation and regulations. Top management is to define the organization's environmental policy and ensure that it includes a commitment to comply with relevant environmental legislation and regulations.

In September 1996, ISO determined that there was insufficient support to proceed in developing international voluntary consensus standards on occupational health and safety management systems (OHSMS). One of the reasons stated was that national or regional standards are different, owing to different socioeconomic conditions and cultural differences. There is little to harmonize, and, therefore, an ISO OHSMS standard would not facilitate international trade. In addition, companies have not had sufficient experience in evaluating the benefits and effectiveness of ISO 9000 quality management systems and ISO 14000 environmental management systems standards. The costs associated with implementing an OHSMS standard would outweigh the potential benefits.

Although handling electronic scrap has been a growing problem in the United States, new companies are being formed to address it Some U.S. and Canada scrap preparers use shredders on electronic scrap, but some also hand dismantle these materials, charging a fee to make the process economically viable.

When considering electronics, there are environmental concerns with the disposal of these items, as they contain potential hazards. Some organizations take older computers and parts for reconstruction, redistribution and resale. Some parts of Europe and Mexico, reportedly, have found use for computers that might be considered outdated by U.S. standards. However, reuse is not possible for all of the discarded electronics. Most recyclers test for reusable components before completely dismantling the items. What cannot be reused can be processed, usually by hand dismantling, or by shredding, to retrieve metals such as copper, steel, aluminum and the precious metals.

Government Solutions

Because liability concerns have been a problem, interest in *brownfield* redevelopment has surged over the past decade, owing to a combination of federal, state and local programs aimed at reducing regulatory burdens and mitigating liability. Congress also has recently been taking an interest. A *brownfield* is a site, or portion thereof, that has actual or perceived contamination and an active potential for redevelopment or reuse. CERCLA establishes the liability regime that affects brownfield sites as well as Superfund sites. While brownfield cleanups typically cost much less, the contamination extent is usually unknown. Several state environmental agencies, the USEPA and other governmental agencies have been working to develop procedures to ameliorate and develop brownfield sites. The USEPA's Brownfields Initiative strategies include funding pilot programs and other research efforts, clarifying liability issues, entering into partnerships, conducting outreach activities, developing job training programs, and addressing environmental justice concerns. The USEPA has been working with states and municipalities to develop guidance that will provide some assurance that, under specified circumstances, prospective purchasers, lenders and property owners do not need to be concerned with Superfund liability.

In 1977, Congress enacted the Community Reinvestment Act (CRA) to require banks, thrifts and other lenders to make capital available in low- and moderate-income urban neighborhoods. Environmental concern and financial liability for cleaning up these sites has made potential investors reluctant to undertake this development. Rather than reuse former urban industrial sites, businesses have instead moved to suburban or rural "Greenfield" areas, which carry fewer risks to development.

On September 30, 1996, as part of the Omnibus Appropriations Bill the "Asset Conservation, Lender Liability, and Deposit Insurance Protection Act of 1996" was passed. The Act includes lender and fiduciary liability amendments to CERCLA, amendments to the secured creditor exemption set forth in Subtitle I to RCRA, and validation of the portion of the CERCLA Lender Liability rules. In addition to specific guidance, the EPA is exploring other ways to address the fear that affected parties may have concerning Superfund liability at previously used properties.

On August 5, 1997, the Taxpayer Relief Act was passed and included a new tax incentive to spur the cleanup and redevelopment of brownfields in distressed urban and rural areas. In 1997, several bills also were introduced in Congress to establish a process and funding for states to work with the EPA and industry in voluntary cleanup programs. The bills are currently stalled, while debate over retroactive liability continues. To date, 36 states reportedly have implemented, or are in the process of implementing, voluntary cleanup programs. A state's brownfield cleanup program can provide relief only from action under state law, and the possibility of federal action cannot be eliminated. In 1996, EPA had signed State Memoranda of Agreements (SMOAs) with 11 states to help them develop cleanup programs, giving the states a lead role in addressing sites not on the Superfund National Priority List, and delineating clearly the roles of states and the EPA.

In November 1999, Congress passed the Superfund Recycling Equity Act of 1999, which exempted a broad scope of scrapped material from liability to "promote the reuse and recycling of scrap material in furtherance of the goals of waste minimization and natural resource conservation, while protecting human health and the environment" (S.1528). While including a wide variety of scrapped economically viable materials, this bill fell short of also including those valuable recyclable secondary by-products of copper and copper alloy scrap processing that also have markets.

A new EPA rule, which will clarify RCRA, is to be proposed in 2002. The new rule will likely ease restrictions that have caused many cities and recyclers to shy away from recycling cathode ray tubes (CRTs), which is one of the largest sources of lead in solid waste dumps, and cabling and older casings, which contain polyvinyl chloride (PVC). Other nations are taking a look at how to handle electronics in their recycling and waste streams, and manufacturers are also involved.

The Organization for Economic Cooperation and Development (OECD) began examining this issue about two years ago. The OECD Working Group on Waste Prevention and Recycling is developing a program to give greater assurance of proper management of recyclables being exported and to take a close look at management of electronics recycling. Guidelines are expected for members who rely on third party auditing to ensure that hazardous materials are handled in a safe manner. The Basel Action Network is also working toward developing guidelines to stop the export of hazardous wastes. The European Union has proposed a Waste Electrical and Electronic Equipment (WEEE) Directive that will give manufacturers responsibility for recycling their products when they are discarded. In the United States, some manufacturers and retailers have helped states and municipalities sponsor electronics recycling programs. Some states have also enacted legislation to place restrictions on the disposal of products containing hazardous material to encourage manufacturers to reduce the use of certain materials (*Recycling Today,* Feb. 2002).

New technical guidelines are also being developed with the Basel Convention to address concerns that some developing countries lack facilities to cope with piles of plastic wastes of all kinds. The recycling of wire and cable is getting special attention from the group. It is unclear how vigorously developing nations would enforce any burning ban, or whether it would cause more recycled wire to remain in the United States. Some researchers claim the burning of PVC plastics produces persistent organic pollutants that circulate globally. The Basel delegates has adopted a set of technical guidelines for burning of certain types of plastic, according to the Environmental News Service (ENS).

New European rules on recycling old cars will force Britain's scrap yards and dismantling companies to invest around $750 million on new tooling and equipment. Under the directive on so-called "end of life vehicles," scrap operators will need to remove all fluids, glass and reusable metal and plastic parts from old cars before they are dismantled. The British Metals Recycling Association has warned that the investment costs will be passed on to vehicle owners. Some two million vehicles per year are scrapped or dismantled in Britain. Some companies recycle copper by the hydrometallurgical processing of weak or spent copper plating solutions and sludge generated by wastewater treatment of copper plating operations. The product may be sent to a smelter for further processing.

Table 1. LME, COMEX and U.S. Refined, Scrap and Ingot Prices[1]

(U.S. currency)

				U.S. Buying Prices		
PERIOD	**LME Grade A, Cash cents/lb**	**COMEX HG, 1st Pos. cents/lb**	**U.S. Producer Price cents/lb**	**Refiners #2 Scrap cents/lb**	**Brass Mill #1 Scrap cents/lb**	**Red Brass Turnings cents/lb**
1980	99	97	101	75	88	61
1981	79	79	84	64	75	57
1982	67	66	73	41	59	46
1983	72	72	77	58	68	46
1984	62	61	67	49	58	43
1985	64	61	67	48	57	40
1986	62	62	66	49	58	38
1987	81	78	82	63	73	55
1988	118	115	121	87	101	76
1989	129	127	131	100	116	59
1990	121	119	123	97	112	63
1991	106	106	109	89	102	61
1992	104	103	107	88	99	57
1993	87	85	92	70	81	45
1994	105	107	110	85	101	47
1995	133	135	138	104	123	63
1996	104	106	109	84	102	52
1997	103	104	107	82	100	51
1998	75	75	79	60	74	40
1999	71	72	76	58	71	38
2000	82	84	88	65	80	39
2001	72	73	77	59	70	41

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[1] Source: Metals Week, American Metal Market, ICSG Copper Bulletin, U.S. Geological Survey Mineral Industry Survey and Compendium.

Table 2A. World Copper Recovery from All Sources[1]

(thousand metric tons)

Year	Western Europe	Africa	Middle East and Asia	America	Oceania	Total World	Percent Scrap
1966	1,987	726	773	3,654	149	7,787	38
1967	2,071	804	888	3,053	130	7,483	38
1968	2,240	791	1,022	3,421	140	8,193	37
1969	2,271	860	1,152	3,844	162	8,904	38
1970	2,173	670	1,252	3,861	162	8,845	37
1971	2,173	803	1,237	3,653	202	8,876	36
1972	2,242	894	1,359	4,047	208	9,676	34
1973	2,488	930	1,574	4,007	204	10,210	35
1974	2,400	1,025	1,695	4,029	220	10,438	34
1975	2,196	941	1,464	3,462	214	9,430	30
1976	2,385	1,001	1,638	3,827	213	10,252	32
1977	2,358	987	1,735	3,969	218	10,523	31
1978	2,316	933	1,811	4,225	213	10,833	33
1979	2,300	897	1,909	4,686	214	11,361	36
1980	2,456	952	2,058	4,375	209	11,457	36
1981	2,462	918	2,259	4,590	240	11,856	35
1982	2,432	969	2,258	4,029	224	11,328	34
1983	2,477	1,040	2,419	3,969	245	11,631	34
1984	2,504	1,023	2,421	4,141	245	11,953	34
1985	2,564	976	2,530	4,122	235	12,108	35
1986	2,661	963	2,718	4,163	223	12,657	33
1987	2,647	921	2,837	4,419	258	13,053	35
1988	2,651	908	3,028	4,803	263	13,541	35
1989	2,691	892	3,054	5,021	296	13,868	35
1990	2,665	809	3,112	5,223	314	13,863	36
1991	2,653	713	3,227	5,220	313	13,721	36
1992	2,842	707	3,860	5,522	328	14,743	38
1993	2,869	635	4,096	5,674	343	15,045	38
1994	2,983	568	4,432	5,804	365	15,561	40
1995	3,135	539	5,023	6,122	291	16,551	41
1996	3,317	545	5,194	6,535	333	17,408	39
1997	3,523	519	5,025	7,208	292	18,171	37
1998	3,440	467	5,264	7,682	308	18,785	36
1999	3,404	464	5,606	7,647	442	19,329	36
2000	3,550	412	6,146	7,392	510	19,893	36
2001	3,400	485	5,722	7,523	588	19,661	31

[1] Includes primary and secondary copper production in refined and direct melt scrap.

Data sources: International Copper Study Group, USGS, USBM.

Table 2B. World Production of Refined Copper by Source
(thousand metric tons and percent of total)

Year	Primary Refined	Secondary Refined	SX-EW Refined	Total Refined	Percent Secondary Refined
1966	4,858	1,052	0	5,910	18
1967	4,613	1,073	0	5,686	19
1968	5,116	1,126	10	6,252	18
1969	5,518	1,212	22	6,752	18
1970	5,522	1,290	33	6,844	19
1971	5,665	1,126	33	6,824	17
1972	6,335	1,153	28	7,517	15
1973	6,568	1,220	37	7,826	16
1974	6,838	1,310	31	8,179	16
1975	6,550	1,032	36	7,619	14
1976	6,930	1,147	78	8,155	14
1977	7,150	1,205	112	8,468	14
1978	7,142	1,335	124	8,600	16
1979	7,065	1,474	263	8,802	17
1980	7,033	1,506	286	8,825	17
1981	7,394	1,473	334	9,201	16
1982	7,133	1,475	318	8,927	17
1983	7,402	1,506	300	9,208	16
1984	7,591	1,381	317	9,289	15
1985	7,651	1,582	213	9,446	17
1986	8,165	1,458	279	9,903	15
1987	8,171	1,631	332	10,135	16
1988	8,323	1,756	431	10,510	17
1989	8,443	1,926	543	10,911	18
1990	8,188	1,945	660	10,792	18
1991	8,055	1,930	689	10,675	18
1992	8,340	1,946	754	11,041	18
1993	8,617	1,880	763	11,260	17
1994	8,472	1,808	830	11,110	16
1995	8,675	2,101	1,069	11,846	18
1996	9,226	1,980	1,463	12,669	16
1997	9,642	2,090	1,759	13,491	15
1998	10,011	2,038	2,018	14,067	14
1999	10,083	2,098	2,324	14,505	14
2000	10,288	2,151	2,345	14,784	15
2001	10,954	1,864	2,621	15,438	12

Data Source: International Copper Study Group.

Table 2C. World Consumption of Copper in Direct Melt Scrap[1]

(thousand metric tons, copper content)

Years	Europe	Africa	Asia	America	Oceania	World Total	United States [2]	
							1,000 tons	% of World
1966	789	10	226	817	35	1,878	749	40
1967	748	10	278	728	33	1,797	669	37
1968	799	10	332	763	37	1,941	713	37
1969	914	10	352	834	42	2,152	778	36
1970	840	12	371	740	37	2,001	668	33
1971	835	15	362	800	40	2,052	725	35
1972	856	16	374	879	34	2,159	796	37
1973	1,037	23	432	848	45	2,384	769	32
1974	869	25	456	863	46	2,259	769	34
1975	748	22	371	634	36	1,811	569	31
1976	891	20	380	770	37	2,098	699	33
1977	819	16	378	808	35	2,056	736	36
1978	895	18	386	899	34	2,232	827	37
1979	940	22	423	1,134	40	2,559	1,054	41
1980	1,055	31	491	1,010	44	2,632	922	35
1981	1,006	32	578	991	49	2,656	925	35
1982	941	32	579	803	46	2,402	720	30
1983	960	31	643	746	42	2,423	682	28
1984	1,012	41	675	889	48	2,664	813	31
1985	1,035	43	704	840	41	2,662	767	29
1986	1,102	37	785	792	38	2,754	721	26
1987	1,132	38	825	874	50	2,918	799	27
1988	1,033	39	986	933	40	3,031	860	28
1989	1,051	41	898	925	41	2,957	828	28
1990	1,016	38	992	985	40	3,071	870	28
1991	1,097	36	984	895	34	3,046	783	26
1992	1,256	35	1,410	976	25	3,702	844	23
1993	1,225	37	1,517	980	25	3,785	832	22
1994	1,375	37	1,917	1,097	25	4,451	936	21
1995	1,487	43	2,077	1,074	25	4,706	965	20
1996	1,454	26	2,118	1,119	22	4,739	975	21
1997	1,591	28	1,832	1,206	22	4,680	1,068	23
1998	1,565	24	1,852	1,254	22	4,718	1,073	23
1999	1,577	66	1,928	1,230	23	4,824	1,088	23
2000	1,690	65	2,015	1,316	23	5,109	1,095	21
2001	1,526	65	1,435	1,169	28	4,223	1,054	25

[1] Reported for some countries, such as the United States, but estimated for others based on semis production.

[2] Revised to include copper from other than copper-base scrap.

Data sources: International Copper Study Group, U.S. Bureau of Mines, U.S. Geological Survey.

Table 2D. World Recovery of Copper from Copper-base Scrap, by Country and Area
(thousand metric tons, copper content)

Year	Copper From Direct Melt and Refined Scrap						Percent of World Copper Scrap			
	Western Europe	N. & S. America	Mid East and Asia	China	Japan	World	Western Europe	N. & S. America	Asia	China
1965	1,186	1,161	332	5	326	2,853	42	41	12	0
1966	1,184	1,264	327	5	318	2,929	40	43	11	0
1967	1,241	1,102	360	5	339	2,870	43	38	13	0
1968	1,341	1,147	412	5	386	3,067	44	37	13	0
1969	1,414	1,293	469	5	444	3,364	42	38	14	0
1970	1,405	1,211	482	5	457	3,290	43	37	15	0
1971	1,302	1,171	476	5	449	3,178	41	37	15	0
1972	1,300	1,285	490	5	463	3,313	39	39	15	0
1973	1,481	1,299	584	10	549	3,605	41	36	16	0
1974	1,366	1,339	603	10	570	3,569	38	38	17	0
1975	1,153	970	475	10	433	2,844	41	34	17	0
1976	1,319	1,140	527	20	459	3,244	41	35	16	1
1977	1,263	1,194	522	20	448	3,261	39	37	16	1
1978	1,311	1,361	589	64	475	3,567	37	38	17	2
1979	1,362	1,685	663	78	536	4,034	34	42	16	2
1980	1,512	1,582	723	105	527	4,138	37	38	17	3
1981	1,436	1,517	835	137	563	4,128	35	37	20	3
1982	1,382	1,303	837	130	603	3,877	36	34	22	3
1983	1,436	1,202	922	123	665	3,929	37	31	23	3
1984	1,485	1,248	932	129	674	4,045	37	31	23	3
1985	1,611	1,282	981	127	654	4,245	38	30	23	3
1986	1,524	1,251	1,048	130	630	4,212	36	30	25	3
1987	1,685	1,357	1,099	207	594	4,550	37	30	24	5
1988	1,631	1,458	1,329	236	704	4,787	34	30	28	5
1989	1,693	1,480	1,308	245	676	4,882	35	30	27	5
1990	1,717	1,519	1,414	233	700	5,015	34	30	28	5
1991	1,831	1,409	1,382	217	723	4,977	37	28	28	4
1992	1,961	1,546	1,859	435	849	5,648	35	27	33	8
1993	1,985	1,513	1,910	520	746	5,665	35	27	34	9
1994	2,085	1,581	2,342	687	861	6,259	33	25	37	11
1995	2,265	1,572	2,720	972	902	6,807	33	23	40	14
1996	2,218	1,585	2,703	938	1,014	6,718	33	24	40	14
1997	2,445	1,737	2,363	799	953	6,770	36	26	35	12
1998	2,388	1,726	2,389	751	871	6,756	35	26	35	11
1999	2,428	1,593	2,447	888	813	6,922	35	23	35	13
2000	2,546	1,637	2,568	678	986	7,260	35	23	35	9
2001	2,267	1,413	1,893	454	789	6,086	37	23	31	7

Data Sources: ICSG, USBM, U.S. Geological Survey.

Table 3. World Copper and Copper Alloy Scrap Exports

(thousand metric tons, gross weight)

Countries	1994	1995	1996	1997	1998	1999	2000	2001[e]
Australia	24	37	29	33	32	27	35	32
Austria	21	18	27	23	24	18	20	17
Belgium	56	56	60	96	72	99	153	137
Canada	111	120	113	126	101	65	73	72
Chile	3	2	2	3	3	0	0	0
China	16	19	8	12	10	11	10	10
Czech Rep.	26	29	27	27	28	32	37	33
Denmark	33	54	33	31	32	35	39	40
Finland	16	23	29	38	21	17	14	14
France	159	142	126	133	122	200	203	190
Germany	200	264	258	342	327	300	290	261
Greece	7	8	6	11	5	3	6	4
Hong Kong	78	101	93	72	212	55	148	130
Hungary	23	22	13	13	14	14	21	20
Ireland	10	10	9	11	10	9	12	9
Israel	11	15	10	12	11	10	10	0
Italy	34	44	47	58	51	54	66	56
Japan	40	52	60	80	76	84	110	157
Malaysia	51	51	37	54	121	91	31	20
Mexico	48	67	57	96	58	145	72	71
Netherlands	111	127	105	106	74	104	132	80
New Zealand	2	2	2	2	2	2	3	2
Norway	9	13	11	13	9	13	17	17
Oman	80	96	104	59	39	34	2	0
Peru	2	3	3	4	3	2	2	2
Philippines	10	16	22	33	26	57	28	22
Poland	2	1	1	3	9	10	26	22
Portugal	11	10	9	10	10	12	20	14
Rep. of Korea	8	14	13	28	25	16	34	30
Russian Fed.	150	210	214	355	357	201	19	9
Singapore	48	59	66	65	71	58	60	29
Slovakia	5	3	1	3	5	8	8	5
South Africa	18	36	12	0	0	76	58	31
Spain	33	37	41	44	31	49	54	52
Sweden	20	18	18	19	14	19	31	29
Switzerland	38	43	44	53	43	51	62	58
Taiwan	28	30	22	33	27	42	75	50
United Kingdom	146	110	114	112	109	106	173	156
United States	360	457	393	380	308	315	486	534
Venezuela	12	14	13	9	7	10	11	10
Other Countries	152	195	154	149	200	241	366	296
World	2,209	2,628	2,403	2,747	2,697	2,695	3,016	2,719

Source: International Copper Study Group, April 2002.

[e] Estimated on partial-year data.

Table 4. World Copper and Copper Alloy Scrap Imports

(thousand metric tons, gross weight)

Countries	1995	1996	1997	1998	1999	2000	2001[e]
Australia	6	3	4	4	7	5	3
Austria	67	56	91	85	89	82	59
Belgium	196	183	200	207	224	265	244
Brazil	21	5	2	1	1	4	3
Canada	167	153	174	113	67	92	101
China	1,189	710	797	957	1,701	2,501	3,333
Czech Rep.	7	2	3	3	2	3	3
Denmark	11	10	7	15	8	8	15
Finland	20	29	34	15	11	8	3
France	91	90	88	101	93	87	71
Germany	442	435	571	618	523	491	391
Greece	1	2	4	1	3	8	2
Hong Kong	341	356	332	189	113	107	93
Hungary	7	5	7	8	6	9	5
India	111	132	145	193	162	32	50
Indonesia	2	1	3	1	2	4	3
Ireland	1	0	1	1	0	1	1
Italy	206	228	260	254	195	179	169
Japan	153	146	194	163	174	190	143
Malaysia	10	10	19	33	14	16	12
Mexico	0	16	29	62	30	29	7
Netherlands	103	96	101	93	77	78	51
New Zealand	4	3	2	4	5	3	2
Norway	5	6	6	5	6	6	8
Poland	1	1	2	1	3	6	4
Portugal	0	1	1	3	2	1	1
Rep. of Korea	151	112	120	89	185	204	177
Singapore	22	27	28	27	19	22	9
Slovakia	4	8	8	6	0	4	1
South Africa	6	5	5	5	6	5	4
Spain	57	60	68	77	67	81	79
Sweden	34	29	38	41	36	35	32
Switzerland	13	14	19	24	20	17	14
Taiwan	26	35	38	39	50	44	61
Turkey	8	23	17	7	15	22	6
United Kingdom	38	48	58	53	36	23	21
United States	183	212	212	166	136	146	115
Other countries	49	34	37	19	20	28	8
World	3,755	3,285	3,720	3,682	4,108	4,844	5,298

[e] Estimated on partial year data.

Source: International Copper Study Group, Jan. 2001, and U.S. Geological Survey.

Table 5. World Production of Copper and Copper Alloy Ingots[1]

(thousand metric tons)

Country	1994	1995	1996	1997	1998	1999	2000
Austria	1.7	1.7	2.7	3.6	3.5	3.2	3.3
Brazil	2.2	0.0	N/A	N/A	N/A	N/A	N/A
Finland	1.3	1.7	1.7	2.4	2.4	2.3	1.9
France	10.4	10.3	9.1	11.7	11.7	12.4	13.8
Germany	57.5	58.0	53.9	60.2	58.5	56.1	62.6
Italy	93.1	112.0	99.5	114.8	117.1	116.4	116.1
Japan	84.1	84.2	87.8	92.9	82.2	83.9	86.4
Netherlands	0.7	1.1	2.5	2.5	2.6	2.6	2.6
Poland	18.2	18.0	18.9				
Portugal	0.7	1.4	1.5	1.5	1.8	1.9	1.5
Spain	12.5	13.5	14.6	14.5	12.3	12.5	14
Switzerland	6.2	6.2	5.7	6.6	6.5	5.6	1.7
Sweden	10.9	9.6	8.0	9.2	9.2	9.2	9.8
United Kingdom	38.2	38.9	37.3	35.5	42.1	38.1	34
United States	157.4	150.7	146.3	148.6	157.8	144.9	140.2
Other Europe[2]	0.6	1.1	3.3	3.6	3.3	N/A	N/A
World[e]	495.6	506.5	492.7	506.4	510.9	489	347.6

Data Source: International Copper Study Group and U. S. Geological Survey.

N/A = Not available at time of printing.

[1] Master alloys and hardeners are not included. Nickel-silver alloys also excluded in European nations.

[2] Countries include Greece, Ireland, Norway and Belgium.

[e] Estimated on partial-year data.

Table 6. U.S. and World Refined Copper Consumption and U.S. Copper from Scrap
(metric tons, copper)

		U.S. Copper Consumption and Copper-base Scrap Statistics								
Year	World Refined Copper Consumption	U.S. Refined (Reported) Consumption	Percent Scrap in U.S. Refined Consumption	Copper in Old U.S. Scrap	Percent Old in All Scrap	Percent New in All Scrap	Cu in Total U.S. Scrap[1]	Apparent Total Consumption including all scrap	Percent All Scrap in Consumption	Percent New Scrap in U.S. Consumption
1918	1,411,300	876,671	9	160,272	50	50	320,062	1,068,637	30	15
1919	981,792	666,186	11	138,436	53	47	260,677	694,486	38	18
1920	1,084,264	374,948	23	153,278	54	46	283,810	767,101	37	17
1921	690,185	269,411	51	119,739	61	39	197,301	480,501	41	16
1922	1,000,113	513,809	20	183,977	60	40	304,515	736,176	41	16
1923	1,217,512	878,480	15	245,756	66	34	372,928	981,615	38	13
1924	1,371,864	740,046	17	241,493	69	31	352,407	995,312	35	11
1925	1,518,628	782,278	21	264,000	69	31	381,211	1,041,316	37	11
1926	1,566,708	968,027	19	305,994	70	30	435,229	1,167,748	37	11
1927	1,594,831	854,316	21	307,899	69	31	444,628	1,116,661	40	12
1928	1,822,535	970,672	21	331,576	68	32	486,430	1,248,403	39	12
1929	1,891,481	1,113,502	24	366,866	65	35	568,301	1,411,837	40	14
1930	1,544,915	829,923	27	310,439	73	27	423,629	1,031,513	41	11
1931	1,282,760	606,710	28	237,047	75	25	314,593	750,447	42	10
1932	988,832	375,729	34	164,110	73	27	225,042	473,297	48	13
1933	1,129,445	490,061	36	236,140	77	23	306,820	621,799	49	11
1934	1,361,685	501,525	40	282,044	82	18	342,372	466,666	73	13
1935	1,644,726	658,254	37	328,129	81	19	407,235	826,823	49	10
1936	1,894,202	845,422	28	347,180	79	21	439,622	1,089,577	40	8
1937	2,184,501	903,404	29	370,948	77	23	482,713	1,113,823	43	10
1938	1,972,220	557,092	31	242,491	74	26	326,405	724,796	45	12
1939	2,284,000	807,314	17	260,271	57	43	453,320	1,146,197	40	17
1940	2,598,000	1,088,866	14	302,899	63	37	482,664	1,432,065	34	13
1941	2,634,465	1,615,487	7	374,394	57	43	658,976	2,246,440	29	13
1942	2,766,000	1,622,954	6	387,479	46	54	841,645	2,215,083	38	21
1943	2,756,000	1,590,733	8	387,841	39	61	985,246	2,354,212	42	25
1944	2,585,000	1,568,179	6	414,321	48	52	862,680	2,181,230	40	21
1945	2,211,717	1,251,255	7	450,957	49	51	913,096	2,104,915	43	22
1946	2,113,741	1,029,835	10	368,728	51	49	728,965	2,074,492	35	17
1947	2,575,498	1,327,478	19	456,655	52	48	872,477	2,029,686	43	20
1948	2,577,313	1,288,732	18	458,549	52	48	882,499	2,028,404	44	21
1949	2,335,094	1,024,834	20	347,949	54	46	646,953	1,632,216	40	18
1950	2,700,690	1,292,225	15	440,176	50	50	886,537	1,783,590	50	25
1951	2,887,570	1,285,359	11	415,603	49	51	845,752	1,972,350	43	22
1952	2,963,773	1,342,391	10	376,151	46	54	819,367	2,058,959	40	22
1953	2,902,992	1,355,529	14	389,534	45	55	869,504	2,043,751	43	23
1954	3,170,612	1,138,271	16	369,284	48	52	761,951	1,715,501	44	23
1955	3,586,102	1,362,596	16	466,823	52	48	897,210	2,076,394	43	21
1956	3,680,450	1,380,181	17	425,006	50	50	844,284	2,010,632	42	21
1957	3,691,336	1,226,627	18	403,237	53	47	763,747	1,812,288	42	20
1958	3,762,096	1,134,595	17	373,186	52	48	723,378	1,655,279	44	21
1959	4,099,569	1,327,240	17	427,291	51	49	844,199	1,963,605	43	21
1960	4,458,814	1,224,605	22	389,514	49	51	790,510	1,853,104	43	22

(table continued on next page)

[1] Includes copper from other than copper-base scrap.

Data Source: U.S. Bureau of Mines and U.S. Geological Survey Minerals Yearbooks.
World consumption series from International Copper Study Group.

Table 6. *(continued)* **U.S. and World Refined Copper Consumption and U.S. Copper from Scrap**
(metric tons, copper)

		U.S. Copper Consumption and Copper-base Scrap Statistics								
Year	**World Refined Copper Consumption**	**U.S. Refined (Reported) Consumption**	**Percent Scrap in U.S. Refined Consumption**	**Copper in Old U.S. Scrap**	**Percent Old in All Scrap**	**Percent New in All Scrap**	**Cu in Total U.S. Scrap[1]**	**Apparent Total Consumption including all scrap**	**Percent All Scrap in Consumption**	**Percent New Scrap in U.S. Consumption**
1961	4,629,365	1,327,057	19	372,953	48	52	770,145	1,914,387	40	21
1962	4,645,694	1,451,202	18	377,093	45	55	836,269	2,099,229	40	22
1963	4,981,353	1,582,378	23	382,690	43	57	883,985	2,213,412	40	23
1964	5,513,000	1,655,868	19	429,571	43	57	991,572	2,338,878	42	24
1965	5,709,000	1,818,564	22	465,781	41	59	1,136,930	2,652,724	43	25
1966	6,007,000	2,140,915	21	485,217	40	60	1,210,411	2,941,428	41	25
1967	5,762,000	1,755,940	21	437,861	42	58	1,052,250	2,449,960	43	25
1968	6,130,000	1,705,780	22	472,436	43	57	1,105,260	2,542,002	43	25
1969	6,678,000	1,943,388	23	521,531	42	58	1,247,827	2,785,198	45	26
1970	6,769,000	1,853,654	25	457,286	40	60	1,131,806	2,493,241	45	27
1971	6,700,000	1,832,066	20	403,812	37	63	1,088,731	2,569,568	42	27
1972	7,322,000	2,031,067	19	415,667	35	65	1,180,223	2,904,989	41	26
1973	8,106,000	2,210,853	19	441,086	35	65	1,249,336	3,031,528	41	27
1974	7,702,000	1,990,516	23	438,562	36	64	1,219,547	2,916,312	42	27
1975	6,780,000	1,392,083	22	334,908	38	62	881,752	2,019,655	44	27
1976	7,939,000	1,807,008	19	380,225	37	63	1,038,975	2,582,858	40	26
1977	8,495,000	1,982,162	18	409,928	38	62	1,085,425	2,759,205	39	24
1978	8,913,000	2,189,301	19	501,650	40	60	1,247,235	3,123,572	40	24
1979	9,250,000	2,158,442	23	604,301	39	61	1,552,525	3,382,365	46	28
1980	9,045,000	1,862,096	28	613,458	43	57	1,437,427	3,003,074	48	27
1981	9,153,000	2,025,169	24	591,805	42	58	1,407,397	3,086,642	46	26
1982	8,534,000	1,658,142	28	517,726	44	56	1,187,466	2,432,125	49	28
1983	8,699,000	1,803,929	22	449,478	41	59	1,083,579	2,671,594	41	24
1984	9,578,000	2,122,734	14	460,695	41	59	1,119,914	2,771,277	40	24
1985	9,353,000	1,976,101	19	503,407	44	56	1,139,084	2,780,111	41	23
1986	9,794,000	2,097,351	19	477,469	42	58	1,126,528	2,785,041	40	23
1987	10,053,000	2,127,178	19	497,937	41	59	1,214,059	2,913,002	42	25
1988	10,521,000	2,210,424	20	518,179	40	60	1,306,891	3,003,881	44	26
1989	10,988,000	2,203,116	22	547,561	42	58	1,308,455	2,945,257	44	26
1990	10,849,000	2,150,426	20	535,656	41	59	1,309,529	2,942,053	45	26
1991	10,757,000	2,057,824	20	518,000	43	57	1,200,690	2,765,237	43	25
1992	11,164,000	2,178,191	20	555,000	43	57	1,277,077	3,027,320	42	24
1993	10,987,200	2,367,930	19	543,000	42	58	1,285,695	3,256,313	39	23
1994	11,552,900	2,680,200	15	500,000	38	62	1,327,897	3,512,297	38	24
1995	12,052,200	2,534,371	14	442,509	34	66	1,316,795	3,411,795	39	26
1996	12,549,600	2,613,472	13	428,362	32	68	1,319,152	3,718,252	35	24
1997	13,083,600	2,790,350	14	497,670	34	66	1,464,596	3,904,996	38	25
1998	13,451,900	2,888,600	12	465,894	33	67	1,422,223	3,941,423	36	24
1999	14,253,500	2,987,677	8	380,936	29	71	1,331,409	3,998,209	33	24
2000	15,222,900	3,030,000	7	363,000	28	72	1,310,000	4,088,900	32	23
2001	14,751,700	2,620,000	6	309,000	27	73	1,144,040	3,137,540	36	27

[1] Includes copper from other than copper-base scrap.

Data Source: U.S. Bureau of Mines and U.S. Geological Survey Minerals Yearbooks.
World consumption series from International Copper Study Group.

Table 6A. U.S. Cumulative Copper Calculations, 1945–2001
(metric tons, copper content)

Year	Annual Statistics[1]			Resource Calculations[4]		Cumulative U.S. Statistics		
	U.S. Apparent Consumption[2]	Copper in Old Scrap	Primary Copper Consumed[3]	Cumulative Primary Consumption	Cum. Resource (less Annual New Scrap)	Cumulative U.S. Consumption of Old and New scrap, 1906-1990	Cumulative U.S. Consumption of Cu in Old Scrap plus Net Exports	Percent Old Scrap Recovery in Cum. Resource
1945	1,642,776	450,957	1,191,819	28,388,764	22,832,853	14,364,159	8,808,047	38.6
1946	1,714,255	368,728	1,345,527	29,734,291	23,818,143	15,093,124	9,176,775	38.5
1947	1,613,864	456,655	1,157,209	30,891,500	24,559,530	15,965,601	9,633,430	39.2
1948	1,604,454	458,549	1,145,905	32,037,405	25,281,485	16,848,100	10,091,979	39.9
1949	1,333,212	347,949	985,263	33,022,668	25,967,744	17,495,053	10,439,928	40.2
1950	1,337,229	440,176	897,053	33,919,721	26,418,436	18,381,590	10,880,104	41.2
1951	1,542,201	415,603	1,126,598	35,046,319	27,114,885	19,227,342	11,295,707	41.7
1952	1,615,743	376,151	1,239,592	36,285,911	27,911,261	20,046,709	11,671,858	41.8
1953	1,563,781	389,534	1,174,247	37,460,158	28,605,538	20,916,213	12,061,392	42.2
1954	1,322,834	369,284	953,550	38,413,708	29,166,421	21,678,164	12,430,676	42.6
1955	1,626,799	466,823	1,159,976	39,573,684	29,915,218	22,575,374	12,897,499	43.1
1956	1,641,023	425,006	1,216,017	40,789,701	30,662,288	23,419,658	13,322,505	43.4
1957	1,451,195	403,237	1,047,958	41,837,659	31,350,319	24,183,405	13,725,742	43.8
1958	1,304,939	373,186	931,753	42,769,412	31,932,028	24,906,783	14,098,928	44.2
1959	1,547,231	427,291	1,119,940	43,889,352	32,634,526	25,750,982	14,526,219	44.5
1960	1,452,182	389,514	1,062,668	44,952,020	33,296,124	26,541,492	15,041,122	45.2
1961	1,517,154	372,953	1,144,201	46,096,221	34,043,174	27,311,637	15,528,785	45.6
1962	1,639,881	377,093	1,262,788	47,359,009	34,846,958	28,147,906	15,938,552	45.7
1963	1,712,345	382,690	1,329,655	48,688,664	35,675,090	29,031,891	16,355,766	45.8
1964	1,776,341	429,571	1,346,770	50,035,434	36,460,395	30,023,463	16,872,279	46.3
1965	1,981,932	465,781	1,516,151	51,551,585	37,305,040	31,160,393	17,388,022	46.6
1966	2,216,369	485,217	1,731,152	53,282,737	38,310,863	32,370,804	17,894,957	46.7
1967	1,835,788	437,861	1,397,927	54,680,664	39,094,184	33,423,054	18,378,479	47.0
1968	1,909,069	472,436	1,436,633	56,117,297	39,898,102	34,528,314	18,931,537	47.4
1969	2,058,319	521,531	1,536,788	57,654,085	40,709,177	35,776,141	19,509,294	47.9
1970	1,818,866	457,286	1,361,580	59,015,665	41,396,092	36,907,947	20,043,030	48.4
1971	1,886,418	403,812	1,482,606	60,498,271	42,192,010	37,996,678	20,496,343	48.6
1972	2,142,445	415,667	1,726,778	62,225,049	43,152,220	39,176,901	20,950,635	48.6
1973	2,223,351	441,086	1,782,265	64,007,314	44,126,162	40,426,237	21,470,476	48.7
1974	2,144,892	438,562	1,706,330	65,713,644	45,041,942	41,645,784	21,978,496	48.8
1975	1,473,444	334,908	1,138,536	66,852,180	45,633,001	42,527,536	22,394,379	49.1
1976	1,923,872	380,225	1,543,647	68,395,827	46,518,134	43,566,511	22,827,177	49.1
1977	2,069,701	409,928	1,659,773	70,055,600	47,516,417	44,651,936	23,293,894	49.0
1978	2,369,537	501,650	1,867,887	71,923,487	48,647,169	45,899,171	23,885,326	49.1
1979	2,434,234	604,301	1,829,933	73,753,420	49,528,785	47,451,696	24,590,717	49.6
1980	2,178,849	613,458	1,565,391	75,318,811	50,270,463	48,889,123	25,319,992	50.4
1981	2,271,416	591,805	1,679,611	76,998,422	51,134,116	50,296,520	25,989,194	50.8
1982	1,762,385	517,726	1,244,659	78,243,081	51,709,035	51,483,986	26,585,582	51.4
1983	2,012,739	449,478	1,563,261	79,806,342	52,662,949	52,567,565	27,101,892	51.5
1984	2,116,058	460,695	1,655,363	81,461,705	53,655,093	53,687,479	27,679,845	51.6
1985	2,144,436	503,407	1,641,029	83,102,734	54,660,443	54,826,563	28,350,784	51.9
1986	2,138,223	477,469	1,660,754	84,763,488	55,669,897	55,953,091	29,004,126	52.1
1987	2,196,540	497,937	1,698,603	86,462,091	56,652,718	57,167,150	29,665,031	52.4
1988	2,213,768	518,179	1,695,589	88,157,680	57,560,996	58,474,041	30,359,678	52.7
1989	2,184,534	547,561	1,636,973	89,794,653	58,436,904	59,782,496	31,111,624	53.2
1990	2,168,179	535,656	1,632,523	91,427,176	59,295,555	61,092,025	31,800,027	53.6
1991	2,090,000	518,000	1,572,000	92,999,176	60,177,412	62,292,715	32,473,337	54.0
1992	2,300,000	555,000	1,745,000	94,744,176	61,205,578	63,569,792	33,098,069	54.1
1993	2,510,000	543,000	1,967,000	96,711,176	62,433,501	64,855,487	33,703,793	54.0
1994	2,690,000	500,000	2,190,000	98,901,176	63,790,004	66,183,384	34,358,907	53.9
1995	2,540,000	442,509	2,097,491	100,998,667	65,010,718	67,500,179	35,034,133	53.9
1996	2,830,000	428,362	2,401,638	103,400,305	66,519,028	68,819,331	35,608,661	53.5
1997	2,950,000	497,670	2,452,330	105,852,635	67,992,502	70,283,927	36,246,330	53.3
1998	3,020,000	465,894	2,554,106	108,406,741	69,555,373	71,706,150	36,831,273	53.0
1999	3,120,000	380,936	2,739,064	111,145,805	71,271,700	73,036,150	37,366,937	52.4
2000	3,110,000	363,000	2,747,000	113,892,805	73,103,600	74,350,150	38,031,137	52.0
2001	2,280,000	309,000	1,971,000	115,863,805	74,262,060	75,494,190	38,706,909	52.1

[1] Annual Statistics from U.S. Bureau of Mines, U.S. Geological Survey.
[2] Consumption = primary refined production + old scrap + net imports + stock change
[3] Primary copper = consumption less old scrap.
[4] Series based on 1864-2001 data.

Table 7. U.S. Production of Refined Copper, by Source, 1966-2001

(thousand metric tons)

Year	Primary Refined	Secondary Refined	SX-EW Refined	Total Refined	Percent Secondary Refined
1966	1,552	446	0	1,998	22
1967	1,028	369	0	1,397	26
1968	1,304	378	10	1,692	22
1969	1,581	453	22	2,056	22
1970	1,568	464	33	2,065	22
1971	1,411	363	33	1,808	20
1972	1,671	384	28	2,083	18
1973	1,658	422	37	2,117	20
1974	1,470	451	31	1,952	23
1975	1,268	313	36	1,617	19
1976	1,318	340	78	1,737	20
1977	1,254	350	104	1,707	20
1978	1,354	420	95	1,869	22
1979	1,419	498	97	2,015	25
1980	1,099	515	116	1,730	30
1981	1,385	483	159	2,027	24
1982	1,096	468	130	1,694	28
1983	1,080	402	102	1,584	25
1984	1,074	307	100	1,481	21
1985	967	372	90	1,429	26
1986	949	406	125	1,480	27
1987	968	415	159	1,542	27
1988	1,178	446	228	1,853	24
1989	1,165	480	312	1,957	25
1990	1,183	441	394	2,017	22
1991	1,136	418	441	1,995	21
1992	1,209	433	502	2,144	20
1993	1,302	460	491	2,253	20
1994	1,346	392	493	2,230	18
1995	1,390	352	539	2,282	15
1996	1,434	333	574	2,341	14
1997	1,484	380	587	2,451	16
1998	1,531	349	609	2,489	14
1999	1,303	243	586	2,132	11
2000	1,028	209	557	1,794	12
2001	1,013	150	641	1,805	8

Data Source: U.S. Bureau of Mines and U.S. Geological Survey.

Table 8. U.S. Exports and Imports of Copper and Copper Alloy Scrap, 1973-2001.
(metric tons)

Year	Unalloy Scrap Imports	Copper Alloy Scrap Imports Gross Weight	Copper Alloy Scrap Imports Copper Cont.	Total Copper Scrap Imports Gross Wt.	Total Copper in Scrap Imports	Copper Alloy Scrap Export Gross Wt.	Copper Alloy Scrap Export Copper Cont.	Unalloy Scrap Exports	Total Copper Scrap Export Gross Wt.	Total Copper in Scrap Exports
1973	13,353	15,962	11,326	29,315	24,679	100,112	65,073	38,361	138,473	103,434
1974	22,884	20,524	14,859	43,408	37,743	107,227	69,698	37,505	144,732	107,203
1975	13,063	11,628	8,084	24,691	21,147	90,004	58,503	40,825	130,829	99,328
1976	14,241	17,956	12,413	32,197	26,654	76,706	45,232	33,995	110,701	79,227
1977	12,097	19,723	14,081	31,820	26,178	82,023	48,367	34,375	116,398	82,742
1978	15,436	19,018	13,199	34,454	28,635	106,717	69,366	49,076	155,793	118,442
1979	14,652	21,624	14,983	36,276	29,635	116,992	76,645	54,080	171,072	130,725
1980	16,053	19,162	13,704	35,215	29,757	129,767	84,349	61,225	190,992	145,574
1981	17,639	24,100	17,539	41,739	35,178	96,149	62,497	50,078	146,227	112,575
1982	16,459	25,449	18,844	41,908	35,303	91,592	59,535	54,419	146,011	113,954
1983	23,086	42,005	31,832	65,091	54,918	80,262	52,681	47,986	128,248	100,667
1984	23,005	42,369	32,016	65,374	55,021	108,833	70,415	80,810	189,643	151,225
1985	23,014	32,208	23,517	55,222	46,531	145,859	91,161	134,300	280,159	225,461
1986	27,216	39,017	28,844	66,233	56,060	152,971	98,867	136,422	289,393	235,289
1987	33,123	44,183	32,874	77,306	65,997	185,279	120,430	108,535	293,814	228,965
1988	37,152	50,028	36,122	87,180	73,274	200,682	129,969	119,773	320,455	249,742
1989	31,579	79,320	57,110	110,899	88,689	212,522	138,139	154,935	367,457	293,074
1990	35,904	96,710	71,071	132,614	106,975	184,766	120,098	139,624	324,390	259,722
1991	28,751	97,177	69,967	125,928	98,718	175,275	122,710	131,318	306,593	254,028
1992	52,398	116,352	83,773	168,750	136,171	145,441	104,708	101,195	246,636	205,903
1993	45,772	154,075	110,934	199,847	156,706	152,349	109,677	109,753	262,102	219,430
1994	102,000	58,400	42,000	160,400	144,000	217,567	156,822	142,292	359,859	299,114
1995	95,100	88,100	63,400	183,200	158,500	233,000	168,065	223,152	456,152	391,217
1996	90,300	121,824	87,700	212,124	178,000	195,324	126,750	197,416	392,740	324,166
1997	91,400	120,000	86,700	211,400	178,100	174,400	113,100	205,200	379,600	318,300
1998	54,400	111,000	80,100	165,400	134,500	193,400	139,248	114,100	307,500	253,348
1999	34,400	101,800	73,296	136,200	107,696	186,700	134,424	128,000	314,700	262,424
2000	30,900	112,800	81,216	143,700	112,116	257,800	185,616	227,700	485,500	413,316
2001	30,300	84,400	60,768	114,700	91,068	272,000	195,840	262,000	534,000	457,840

Sources: U.S. Dept. of Commerce, U.S. Bureau of Mines and U.S. Geological Survey.

Table 9. U.S. Trade and Consumption of Copper Ash and Residues[1] and Zinc Products from Scrap.

(thousand metric tons)

Product	1990	1991	1992	1993	1994	1995	1996	1997	1998	1999	2000	2001
Exports												
Copper Ash and Residues (Gross Wt)	25.45	9.89	12.50	12.27	23.36	28.11	21.15	25.87	11.42	14.00	12.99	8.34
Zinc dross and skimmings (262019)												
Zinc content of dross, etc.	19.79	22.34	24.34	12.10	18.21	17.77	14.02	11.33	8.70	4.56	14.15	16.59
Imports:												
Copper Ash and Residues[2]	0.17	1.82	1.74	1.55	1.06	1.74	1.68	0.49	1.20	0.66	0.76	0.63
Zinc content of product:												
Zinc dross & skimmings (26201930)	5.99	7.86	14.33	13.62	13.91	13.29	15.99	18.66	23.83	22.66	17.59	13.69
Zinc ash and residues(26201960)	1.14	0.24	0.44	1.25	1.70	0.79	1.74	1.08	0.46	0.31	0.16	0.02
Total Zinc in Dross etc.	7.13	8.10	14.77	14.87	15.60	14.08	17.73	19.74	24.30	22.97	17.75	13.71
Zinc Recovered from Scrap:												
Zinc recovered as Pb-free zinc oxide	34.73	34.73	NA	36.00	36.80	33.60	47.10	47.90	64.20	35.90	23.10	23.10
Zinc recovered from all scrap	341.40	353.70	NA	355.00	361.00	353.00	379.00	374.00	434.00	399.00	435.36	435.36
Zinc recovered in Copper Alloys[3]	155.99	124.39	149.76	153.76	172.68	169.63	179.63	193.97	201.00	206.70	211.00	211.00
Purchased Copper-base Scrap:												
Low-grade copper ash, residues, etc.												
Gross weight scrap	136.40	141.25	161.79	161.31	81.40	92.60	83.10	87.10	124.00	111.00	88.60	50.10
Copper Content[4]	47.74	49.44	56.62	56.46	28.49	32.41	29.09	30.49	43.40	38.85	31.01	17.54
Low-grade Copper-base Shipments[5]												
Copper content of shipments	56.48	51.08	59.26	59.21	35.61	40.50	34.81	39.05	46.20	43.09	34.80	19.82
Gross Weight of shipments[4]	161.36	145.93	169.31	169.16	101.73	115.72	99.46	111.56	131.99	123.11	99.42	56.64

Data sources: USGS, USBM Minerals Yearbooks and Mineral Industry Surveys, Bureau of Census Trade Data.

[1] Skimmings, drosses, ashes and residues containing 20-65% copper

[2] Reported in copper content of material shipped.

[3] Composition of secondary copper alloy production; 96% from scrap, 4% from other

[4] Assumption of 35% copper. USGS published series is gross weight.

[5] Calculated shipments of low-grade ashes and residues from domestic producers. (Consumption plus total exports minus imports of low grade ash and residues.)

Table 10. Ingots, Foundry Castings, Brass- and Wire-Mill Semis and Copper Sulfate Production in the United States (thousand metric tons)

Type of Product	1989	1990	1991	1992	1993	1994	1995	1996	1997	1998	1999	2000
Alloy Ingots:												
Leaded & Semi-red Brass	117.5	117.7	98.7	109.6	91.4	95.7	96.5	92.0	88.6	88.6	97.3	93.5
Yellow Brass	8.2	7.0	6.3	6.8	7.4	8.3	6.7	6.8	7.4	6.2	6.0	5.7
Tin & High Leaded Tin Bronze	27.4	24.6	23.2	23.2	25.3	26.1	24.3	24.5	28.4	29.4	28.8	27.3
Nickel Silver	4.7	3.0	2.7	2.7	2.2	3.1	1.8	1.9	2.3	2.4	2.1	2.3
Aluminum & Manganese Bronze	16.6	19.2	14.5	13.5	14.7	15.6	15.1	15.3	15.0	15.9	13.9	13.3
Other Alloy Ingots	9.8	9.1	9.8	9.6	12.5	8.7	5.3	5.6	7.3	6.0	4.7	8.2
Hardeners and Master Alloys	10.8	10.4	7.1	8.1	7.9	9.7	13.1	13.7	13.4	12.9	13.2	13.8
Total Ingots	195.0	191.0	162.2	173.4	161.5	167.1	163.8	160.0	162.4	170.7	166.0	164.0
Foundry Castings	251.0	185.9	214.3	220.4	214.5	230.7	225.3	229.8	237.2	224.2	258.1	267.8
Copper Sulfate (Gross Weight)	33.2	35.3	40.2	46.8	46.4	48.4	52.0	43.6	48.4	44.0	52.7	55.5
Copper Powder	8.6	8.5	7.8	10.8	9.2	10.6	11.7	10.1	9.9	7.6	7.4	7.5
Copper Semis	2,095.6	2,047.1	1,963.0	2,053.3	2,258.6	2,488.2	2,500.8	2,768.5	2,977.5	3,036.7	3,156.8	3,178.1
Copper Alloy Semis	680.8	660.5	660.0	729.8	740.3	846.4	796.4	815.6	875.4	874.1	902.8	904.0
Total Semifabricates	2,776.4	2,707.6	2,623.0	2,783.1	2,998.9	3,334.6	3,297.2	3,584.1	3,852.9	3,910.8	4,059.6	4,082.1

Data Sources: U.S. Geological Survey, U.S. Bureau of Mines, International Copper Study Group.

Table 11. Standard Designations for Cast Copper Alloys

Alloy Class	UNS Range	Percent (range) of principal metals in cast alloys						
		Copper	Tin	Lead	Zinc	Aluminum	Nickel[1]	Other
High copper alloys[2]	81300-82800	94.2-98.5	0.1	0.02	0.1	.10-.15	.10-3.0	.6-2.75
Red brasses & leaded red brasses	83100-83800	82.0-94.0	.2-6.5	.10-7.0	1.0-9.5	0.005	.05-2.0	.005-.50
Semired brasses & leaded semired brasses	84200-84800	75.0-82.0	2.0-6.0	2.0-9.0	7.0-17.0	.005-.01	.8-1.0	.02-.40
Yellow brasses & leaded yellow brasses	84200-85800	57.0-75.0	.7-3.0	.8-5.0	20.0-41.0	.005-.8	.2-1.0	.005-.8
Manganese & leaded manganese bronzes	86100-86800	53.5-68.0	.2-1.5	.2-1.5	22.0-42.0	.5-7.5	1.0-4.0	.4-5.0
Low & high silicon bronzes & brasses	87200-87900	63.0-94.0	0.25	.15-1.0	.25-36.0	.15-.8	.20-.50	.01-5.5
Tin bronzes	90200-91700	79.0-94.0	6.0-20.0	.20-.50	.05-5.0	0.005	.10-2.0	.005-1.2
Leaded tin bronzes	92200-92900	78.0-90.0	5.5-17.0	.3-6.0	.25-5.0	0.005	.20-4.0	.005-.50
High leaded tin bronzes	93100-94500	68.5-86.0	1.5-14.0	2.0-34.0	.50-4.0	0.005	.25-1.0	.005-1.5
Nickel tin bronzes	94700-94900	79.0-90.0	4.0-6.0	.10-6.0	1.0-6.0	0.005	4.0-6.0	.005-.30
Aluminum bronzes	95200-95900	71.0-88.0	.1-1.0	.03-.10	.3-.5	6.0-13.5	.25-5.5	.05-14.0
Copper nickels	96200-96800	65.0-69.0		.005-.03			9.0-33.0	.05-1.8
Nickel- & leaded-nickel silver & nickel bronze	97300-97800	53.0-67.0	1.5-5.5	1.0-11.0	1.0-25.0	0.005	11.0-27.0	.05-1.0
Leaded coppers	98200-98840	42.0-79.0	.25-5.0	21.0-58.0	0.1			.02-5.5
Special alloys[3]	99300-99750	54.0-61.0	.05-2.5	.02-2.0	.5-25.0	.25-11.5	.20-16.5	.02-45.0
Phosphor copper	ASTM B52	86.0-90.0						10.0-14.0

[1] May include columbium.

[2] Includes beryllium copper and chromium copper.

[3] Special alloys include Incramet 8009, Incramute 1, while tombasil etc.

Data Source: Copper Development Association Inc.

Table 12. Copper Recovered from Scrap in the United States and Form of Recovery

(metric tons, copper)

Form of Recovery	1992	1993	1994	1995	1996	1997	1998	1999	2000
Electrolytic Refined	331,057	337,221	269,000	215,000	193,000	233,000	201,556	156,196	128,000
Fire-Refined	102,127	122,567	122,000	137,000	152,000	163,000	147,463	73,723	80,000
Copper Powder	8,826	9,182	10,600	10,600	10,100	9,880	7,598	7,415	7,510
Copper Castings	493	631	697	699	706	739	707	647	839
Total unalloyed	442,503	469,601	403,000	364,000	355,000	407,000	357,324	237,981	217,000
In Brass and Bronze	776,981	753,968	861,000	887,000	892,000	981,000	987,432	1,000,462	1,010,000
In Alloy Iron and Steel	1,495	654	745	756	739	743	664	599	549
In Aluminum Alloys	55,607	61,049	62,800	64,600	70,700	75,000	76,590	78,200	74,900
In Other Alloys	199	206	115	114	110	113	132	125	125
In Chemical Compounds[1]	292	217	219	183	305	252	83	11,775	11,700
Total	1,277,077	1,285,695	1,327,879	1,316,653	1,318,854	1,464,108	1,422,225	1,329,142	1,314,274

[1] 1999 & 2000 reflect addition of copper sulfate and other copper chemical producers, not reflected in previous data.

Source: USGS Minerals Yearbook, Copper Chapter.

Table 13. List of U.S. Brass and Tube Mills

COMPANY NAME	CITY	STATE
1. Ampco Metal Inc.	Chicago	Illinois
2. Ampco Metal Inc.	Milwaukee	Wisconsin
3. Anchor Bronze & Metals	Bay Village	Ohio
4. Ansonia Copper & Brass	Ansonia	Connecticut
5. Ansonia Copper & Brass Inc.	Waterbury	Connecticut
6. Brush Wellman Inc.	Elmore	Ohio
7. Brush Wellman Inc.	Reading	Pennsylvania
8. Cambridge Lee Industries	Reading	Pennsylvania
9. Cerro Copper Tube Co.	Sauget	Illinois
10. Cerro Copper Tube Co.	Shelbina	Missouri
11. Cerro Copper Tube (Heatcraft)	Bossier City	Louisiana
12. Cerro Metal Products	Bellefonte	Pennsylvania
13. Cerro Metal Products	Paramount	California
14. Chase Copper & Brass	Montpelier	Ohio
15. Chicago Extruded Metals	Cicero	Illinois
16. Concast Metal Products	Mars	Pennsylvania
17. Concast Metal Products	Birmingham	Ohio
18. Copperweld Bimetallics Division of Copperweld	Fayetteville	Tennessee
19. Drawn Metal Tube Co.	Tomaston	Connecticut
20. The Electric Materials Co.	Northeast	Pennsylvania
21. Extruded Metals	Belding	Michigan
22. Halstead Industries	Greensboro	North Carolina
23. Heyco Metals	Reading	Pennsylvania
24. Howell Metal Company	New Market	Virginia
25. Hussey Copper Ltd.	Leetsdale	Pennsylvania
26. Hussey Copper Ltd.	Eminence	Kentucky
27. Kobe Copper Products	Pine Hall	North Carolina
28. MAC Metals Inc.	Kearny	New Jersey
29. The Miller Co.	Meriden	Connecticut
30. Mueller Brass	Port Huron	Michigan
31. Mueller Copper Tube Co.	Fulton	Mississippi
32. Mueller Copper Tube Products Co.	Wynne	Arkansas
33. National Copper Products	Dowagiac	Michigan
34. NGK Metals Corp.	Reading	Pennsylvania
35. NGK Metals Corp	Sweetwater	Tennessee
36. NIBCO Inc.	Stuarts Draft	Virginia
37. Nippert Co.	Delaware	Ohio
38. Olin Corp.	E. Alton	Illinois
39. Olin Corp	Indianapolis	Indiana
40. Outokumpu American Brass Inc	Buffalo	New York
41. Outokumpu Copper Franklin, Inc.	Franklin	Kentucky
42. Phelps Dodge Specialty Copper	Elizabeth	New Jersey
43. PMX Industries Inc.	Cedar Rapids	Iowa
44. Revere Copper Products	Rome	New York
45. Revere Copper Products	New Bedford	Massachusetts
46. Scott Brass Inc.	Cranston	Rhode Island
47. Scott Brass, Inc.	Mishawaka	Indiana
48. Ullrich Copper Inc. (Div. Of Hussey Copper)	Kenilworth	New Jersey
49. Valleycast Inc.	Appleton	Wisconsin
50. Waterbury Rolling Mills	Waterbury	Connecticut
51. Wolverine Tube Inc. (Hdqs Huntsville, Ala)	Decatur	Alabama
52. Wolverine Tube Inc.	Shawnee	Oklahoma
53. Wolverine Tube Inc.	Roxboro	North Carolina
54. Wolverine Tube Inc.	Boonville	Mississippi

Table 14. List of U.S. Ingotmakers, Secondary Smelters and Refiners, and Secondary Hydrometallurgical Plants

Company Name	City	State	Remarks	Status
Admetco Inc.	Fort Wayne	Indiana	Phos copper, copper anodes	Operating
American Nickel Alloy Mfg. Corp	New York	New York		Operating
Atlas Pacific	Altadena	California	Was Fed. Weiner Metals, 1992	Operating
Belmont Smltg & Refg. Works, Inc	Brooklyn	New York		Operating
Brush Wellman Inc.	Cleveland	Ohio	Beryllium Master Alloy	Operating
California Metal - X	Los Angeles	California		Operating
Colonial Metals Co.	Columbia	Pennyslvania		Operating
Federal Metal Co.	Bedford	Ohio		Operating
H. Kramer & Co.	Chicago	Illinois		Operating
Handy & Harman	Attleboro	Maine		Operating
I Schumann & Co.	Bedford	Ohio	OGDEN Alloys Inc.	Operating
Kearny Smelting & Refining Corp.	Kearny	New Jersey		Operating
Lee Brass (Amcast Industrial)	Anniston	Alabama	Foundry & ingotmaker	Operating
Metallurgical Products Co.	West Chester	Pennsylvania	Master alloys, Plating Anode	Operating
Milward Alloys, Inc.	Lockport	New York		Operating
Monett Metals Inc.	Chicago	Illinois	New name, 5/92	Operating
National Metals Inc.	Leeds	Alabama		Operating
R. Lavin & Sons, Inc.	North Chicago	Illinois	N. Chicago Ref. & Smelters	Operating
River Smelting & Refining Co.	Cleveland	Ohio		Operating
SIPI Metals Corp.	Chicago	Illinois		Operating
South Bend Sm & Rfg Co.	South Bend	Indiana		Operating
Specialloy Inc	Chicago	Illinois		Operating
The G.A. Avril Co.	Cincinnati	Ohio	Avril G.A. Brass & Bronze	Operating
W.J. Bullock	Fairfield	Alabama		Operating
Secondary Smelters and Refiners:				
American Iron and Metal	Warrenton	Missouri	Fire Refinery, ingot, wirebar	Operating
Amrod Corp	Newark	New Jersey	Fire Refinery, wire mill	Operating
Cambridge-Lee Industries	Reading	Pennsylvania	Fire Refinery, billet casting	Operating
Cerro Copper Products	E. St Louis	Illinois	Fire Refinery, billet casting	Operating
Cerro Copper Products	Mexico	Missouri	Fire Refinery, billet casting	Operating
Cerro Copper Products	E. St Louis	Illinois	Electrolytic refinery/smelter	Closed, 1998
Chemetco (Concorde Metals)	Alton	Illinois	Secondary smelter, anode	Closed, 2001
Essex Wire	Ft Wayne	Indiana	Fire Refinery, wire rod	Operating
Franklin Smelting & Refining Co.	Philadelphia	Pennsylvania	Secondary smelter	Closed, 1996
Gaston Copper Co. (Nassau)	Gaston	South Carolina	Secondary smelter, refinery	Closed, 1994
Southwire	Carrolton	Georgia	Secondary smelter, fire refinery	Closed, 2000
Textin Corp.	Texas City	Texas	Fire Refinery	Closed, 1990
Secondary Hydrometallurgical Recovery Plants				
American Chemet	Helena	Montana	Copper Chemicals	Operating
Encyle Texas (Div. Of Asarco)	Corpus Christi	Texas	Processes cu-bearing waste	Operating
Griffin Corp.(several plants)		Georgia	Copper Chemicals	Operating
Heritage Environmental Services	Indianapolis	Indiana	Copper Chemicals	Operating
Hickson	Conley	Georgia	Copper Chemicals	Operating
Hydromet Environmental Inc.	Newman	Illinois	Electrowon metals	Operating
MacDermid	Waterbury	Connecticut	Copper Chemicals	Operating
Peninsula Copper Inc.	Hubbell	Michigan	Copper Chemicals	Operating
Phibro-Tech (5 Plants)	Santa Fe Springs	California	Copper Chemicals	Operating
SCM Metals (OMG Americas)	Raleigh-Durham	North Carolina	Copper Chemicals	Operating
U.S. Filter Recovery Service	Minneapolis	Minnesota	Copper Chemicals	Operating

Table 15. Copper and Copper Alloy Scrap Types, Showing General Range in Compositions (in percent metal content)

Scrap Type	Copper		Tin		Lead		Zinc		Aluminum		Nickel/Cobalt		Manganese		Other	
	Low	High	Low	High	Low	High	Low	High	Low	High	Low	High	Low	High	Low	High
Unalloyed Copper Scrap																
No. 1 Copper	99.00	99.90														
No. 2 Copper, mixed, light	94.50	99.00														
Other	94.00	99.00														
Copper-base Alloy Scrap																
Red Brass	87.00	98.00	0.20	0.35	0.10	3.00	2.00	12.00	0.00	0.01	0.05	1.00			0.03	0.08
Leaded red & semired brass	75.00	86.00	2.00	6.00	3.50	7.00	4.00	17.00	0.01		0.30	2.00			0.10	0.40
Yellow, leaded and heavy brass	57.00	75.00	0.70	2.00	0.20	5.00	20.00	41.00	0.01	8.00	0.20	1.00	0.20	0.50	0.01	0.80
Yellow & low brass, and other copper-zinc brasses	65.00	82.43			0.02	0.30	17.50	31.50							0.05	0.10
Copper/nickel/zinc alloys	42.00	73.50	1.50	5.50	0.03	11.00	1.00	25.00	0.00	0.01	4.00	27.00	0.50	2.50	0.15	1.50
Copper/nickel alloys	62.27	97.90			0.01	0.03	0.00	1.00			2.00	33.00	0.05	2.50	0.05	1.20
High leaded tin bronzes	45.50	91.50	1.50	14.00	7.00	34.00	0.00	4.00	0.00	0.01	0.00	1.00			0.00	1.50
Tin brasses	57.00	88.00	0.25	4.00	0.05	2.50	3.75	42.70	0.00	0.10	0.00	0.50	0.00	0.15	0.00	1.00
Tin bronze/phosphor bronze	71.19	93.00	6.00	20.00	0.25	0.50	0.25	5.00	0.01	0.01	0.50	2.00	0.00	0.10	0.00	1.20
High coppers[1]	93.88	99.98	0.00	0.10	0.00	0.02	0.00	0.10	0.00	0.15	0.00	3.00			0.02	2.75
Manganese bronze	35.60	68.00	0.50	1.50	0.20	0.40	22.00	42.00	0.50	7.50	0.00	4.00	0.10	5.00	0.40	4.00
Aluminum bronze[2]	71.00	88.00			0.00	0.05			6.00	13.50	0.00	5.50	0.00	14.00	0.05	5.00
Silicon bronze & brass	63.00	94.00	0.00	0.25	0.15	1.00	0.25	36.00	0.00	0.80	0.00	0.20	0.00	1.50	0.00	0.20
Common Scrap Groups																
Water meters	62.00	65.00			0.80	1.50	33.00	36.40	0.00						0.15	0.15
Auto radiators (Ocean)	68.00	70.00	3.00	5.00	7.00	12.00	10.00	15.00								
Cocks & faucets[3] (Grape)	65.00	77.00	0.00	2.00	2.00	6.00	15.00	33.00			x				x	
Cartridge cases and brass	68.50	71.50			0.07	0.07	28.40	31.40								
Refinery brass[4] (drink)	61.30															39.00
Aluminum/copper radiators		45.60				0.02				54.00		0.50				0.20
Copper-bearing material	20.00	60.00													40.00	80.00

[1] Be, Cd, Cr coppers

[2] Al, Fe, Ni alloys

[3] Mixed red and yellow brass plumbing fixtures, including nickel/chrome-plated. Free of zinc die-cast and aluminum parts.

[4] Limit 5% iron, includes copper, brass and bronze alloyed metal.

Sources: Copper Development Association Inc. and ISRI, 1989, U.S. Bureau of Mines.

Table 16. Principal U.S. Scrap Source Materials for Copper
(thousand metric tons, copper)

Copper from Type of Scrap	1950	1960	1970	1980	1990	1994	1995	1996	1997	1998	1999	2000
New Scrap:												
Copper-base	440	396	664	804	751	792	837	853	923	913.8	902.7	906
Aluminum-base	6	5	10	20	23	35	37	38	44	42.4	46.2	45.5
Nickel-base	0.2	0.1	0.1	0.2	0.04	0.09	0.09	0.09	0.09	0.103	0.094	0.018
Zinc & tin-base	<.01	0.03	0.01	0.02	nil	nil	nil	nil	nil	nil	nil	nil
Total	446	401	674	824	774	827	874	891	967	956.3	950.5	952
Old Scrap:												
Copper Base	437	387	453	596	502	472	415	394	466	431.8	349.5	334
Aluminum-base	2	2	4	15	34	28	28	33	30	34	31.2	28.4
Nickel-base	1.00	0.50	0.70	0.10	0.08	0.01	0.03	0.05	0.03	0.05	0.04	0.17
Zinc- & tin-base	0.09	0.08	0.04	0.1	0.03	0.02	0.02	0.02	0.02	0.04	0.03	0.032
Total	440	390	458	611	536	500	443	427	497	465.9	380.9	363
Total Copper in Scrap	886	791	1,132	1,435	1,310	1,327	1,317	1,318	1,464	1,422	1,331	1,310

Source: U.S. Bureau of Mines and U.S. Geological Survey, Minerals Yearbooks, var. issues.

Table 17A. U.S. Copper Scrap and Copper Alloy Consumption, 1971–1985[1]

(metric tons)

Scrap Consumption by:	1971	1972	1973	1974	1975	1976	1977	1978	1979	1980	1981	1982	1983	1984	1985
Plant type:															
Brass Mill	593,426	677,453	704,623	644,908	470,252	600,968	615,205	637,942	703,138	608,205	633,879	508,478	624,466	675,472	621,023
Secondary Smelters & Refiners	852,352	873,448	912,585	895,536	611,539	709,941	745,980	918,238	1,281,257	1,168,398	1,115,275	946,480	693,678	689,375	736,034
Foundries and Misc. Plants	59,831	65,044	72,994	72,104	54,520	62,516	67,238	86,799	88,831	74,302	76,413	59,889	63,472	68,610	54,722
Total, Gross Weight:	1,505,609	1,615,945	1,690,202	1,612,548	1,136,311	1,373,425	1,428,423	1,642,979	2,073,226	1,850,905	1,825,567	1,514,847	1,381,616	1,433,457	1,411,779
Source: [1]															
Old Scrap	601,412	613,159	625,009	620,300	441,156	518,504	555,140	664,289	830,335	791,080	776,984	659,574	574,376	572,311	570,923
New Scrap	904,197	1,002,786	1,065,194	992,248	695,155	854,921	873,283	978,690	1,242,891	1,059,825	1,048,583	855,273	807,240	861,146	840,856
Ratio Old/New	0.67	0.61	0.59	0.63	0.63	0.61	0.64	0.68	0.67	0.75	0.74	0.77	0.71	0.66	0.68
Type of Scrap:															
Unalloyed copper:															
No. 1 Scrap	270,116	300,705	382,442	373,164	259,407	302,214	304,928	331,910	392,112	380,386	346,295	279,877	271,990	270,228	348,087
No. 2 Scrap, Mixed	272,039	301,617	314,218	311,240	220,005	244,891	262,413	326,112	447,267	466,951	466,174	417,004	324,665	367,436	278,047
Total Unalloyed:	542,155	602,322	696,660	684,404	479,412	547,105	567,341	658,022	839,379	847,337	812,469	696,881	596,655	637,664	626,134
Red Brass[2]	85,467	87,545	76,831	74,204	48,959	62,868	73,452	84,052	89,427	75,799	77,170	61,264	57,277	64,496	56,196
Cartridge Brass	130,586	102,225	80,788	70,261	50,859	70,963	74,601	82,852	80,520	61,354	67,948	54,057	66,534	70,781	67,221
Yellow and low Brass[3]	327,992	405,424	394,438	353,487	259,533	338,956	359,569	385,836	408,392	355,194	355,772	288,327	345,638	387,165	347,074
Automobile Radiators	58,872	66,714	62,364	62,791	48,372	61,762	73,051	83,453	94,123	65,546	65,058	58,942	64,814	75,440	77,230
Bronze	28,400	29,168	31,366	29,173	21,876	22,441	24,413	23,299	24,574	22,461	21,708	18,195	20,949	24,593	19,994
Nickel Silver/Cupronickel	25,547	29,575	29,842	36,415	38,127	33,528	28,247	18,894	28,449	17,265	22,756	17,564	22,912	21,811	15,819
Aluminum Bronze	1,068	1,253	1,781	1,358	909	1,244	1,043	941	1,605	1,551	1,705	1,396	1,136	972	969
Low-grade Scrap and Residue[4]	299,820	286,160	307,581	291,290	183,123	230,722	223,403	303,337	500,872	400,271	397,935	315,294	202,094	140,318	111,243
Refinery Brass and Other Scrap	5,620	5,558	8,551	9,165	5,141	3,837	3,302	2,293	5,885	4,127	3,046	2,927	3,607	10,217	89,899
Total Alloyed Scrap	963,454	1,013,623	993,542	928,144	656,899	826,320	861,082	984,957	1,233,847	1,003,568	1,013,098	817,966	784,961	795,793	785,645
Copper Recovered from Scrap:															
Refined from Scrap	363,475	383,960	421,953	450,787	312,513	340,335	349,646	420,103	498,459	515,083	482,837	467,549	401,668	306,537	371,787
Unalloyed Powder & Castings	25,794	21,923	17,690	14,878	10,002	14,128	15,075	17,017	17,812	19,473	20,966	14,016	17,186	31,652	15,882
Total Unalloyed Products	389,269	405,883	439,643	465,665	322,515	354,463	364,721	437,120	516,271	534,556	503,803	481,565	418,854	338,189	387,669
Brass and Bronze	669,334	739,529	710,688	714,062	518,902	635,795	670,712	755,978	976,402	850,188	850,546	660,152	625,349	735,154	716,833
In Aluminum Alloys	24,033	29,344	34,093	34,739	35,909	42,653	44,218	48,153	53,608	47,306	47,728	41,930	36,704	43,511	29,423
From Other Alloys & Chemicals[5]	6,095	5,468	6,080	5,081	4,426	6,064	5,774	5,984	6,244	5,377	5,320	3,819	2,672	3,060	5,159
Total Copper from Scrap:	1,088,731	1,180,223	1,190,503	1,219,547	881,752	1,038,975	1,085,425	1,247,235	1,552,525	1,437,427	1,407,397	1,187,466	1,083,579	1,119,914	1,139,084

Source: U.S.G.S. and U.S.B.M. Minerals Yearbooks and Mineral Industry Surveys.
W= Withheld, data in other scrap.

[1] Gross Weight.
[2] Includes Railroad car boxes.
[3] Includes leaded-yellow brass.
[4] Includes low-grade scrap and residues at primary and secondary smelters and refiners.
[5] 1999 Includes copper sulfate and other chemicals.

Table 17B. U.S. Copper Scrap and Copper Alloy Consumption, 1986–2000
(metric tons)

Scrap Consumption by:	1986	1987	1988	1989	1990	1991	1992	1993	1994	1995	1996	1997	1998	1999	2000
Plant type:															
Brass Mill	627,628	683,431	757,047	725,586	754,386	695,200	854,771	744,000	862,000	886,000	909,000	1,010,000	1,020,000	1,046,800	1,070,000
Secondary Smelters & Refiners	804,344	823,032	797,682	828,905	777,833	802,139	748,953	892,000	779,000	695,000	655,000	693,000	644,000	501,000	440,000
Foundries and Misc. Plants	63,037	72,173	64,507	66,097	75,654	55,680	64,800	60,700	67,000	71,500	61,300	62,700	58,700	79,900	83,000
Total, Gross Weight:	1,495,009	1,578,636	1,619,236	1,620,588	1,607,873	1,553,019	1,668,524	1,696,700	1,708,000	1,652,500	1,625,300	1,765,700	1,722,700	1,627,700	1,593,000
Source: [1]															
Old Scrap	612,896	675,088	644,314	673,258	696,125	696,125	731,596	741,817	669,000	621,000	583,000	594,000	574,000	464,000	417,000
New Scrap	882,113	903,548	974,916	943,501	856,892	856,892	936,928	954,883	1,040,000	1,030,000	1,040,000	1,170,000	1,150,000	1,164,000	1,180,000
Ratio Old/New	0.69	0.75	0.66	0.71	0.81	0.81	0.78	0.78	0.64	0.60	0.56	0.51	0.50	0.40	0.35
Type of Scrap:															
Unalloyed copper:															
No. 1 Scrap	389,198	410,636	416,655	418,893	424,128	430,790	448,285	480,600	513,900	572,000	533,500	597,800	583,900	538,000	569,500
No. 2 Scrap, Mixed	338,031	383,862	409,332	392,755	342,658	335,456	380,284	385,690	361,350	262,090	254,480	271,670	240,500	154,000	150,120
Total Unalloyed:	727,229	794,498	825,987	811,648	766,786	766,246	828,569	866,290	875,250	834,090	787,980	869,470	824,400	692,000	719,620
Red Brass[2]	54,592	61,222	53,638	68,448	74,954	62,126	70,151	61,400	62,340	81,910	81,090	79,650	71,700	62,800	74,430
Cartridge Brass	71,549	78,461	139,074	126,224	97,726	56,068	51,619	54,300	61,100	49,900	46,100	66,800	82,600	78,400	72,600
Yellow and low Brass[3]	314,405	341,347	338,949	326,167	371,656	351,351	393,268	409,560	454,850	424,220	459,930	488,630	486,200	497,200	519,180
Automobile Radiators	55,555	62,260	104,364	96,395	94,947	88,621	77,129	71,800	70,970	79,910	70,400	79,870	61,610	55,200	51,050
Bronze	20,030	21,050	21,296	21,092	18,608	20,683	25,001	23,600	23,200	25,000	25,900	27,400	27,500	23,670	22,900
Nickel Silver/Cupronickel	13,229	9,617	14,968	23,619	21,303	17,952	14,708	14,800	21,900	20,500	23,300	17,800	17,400	22,300	28,100
Aluminum Bronze	970	965	1,005	2,696	2,246	W	W	W	W	W	W	W	W	W	W
Low-grade Scrap and Residue[4]	115,937	95,266	101,223	102,448	136,395	141,250	161,785	161,000	81,400	92,600	83,100	87,100	124,000	111,000	88,600
Refinery Brass and Other Scrap	125,555	113,950	18,732	41,806	31,102	48,721	46,516	33,710	57,180	45,840	48,180	45,070	27,000	19,060	18,900
Total Alloyed Scrap	767,780	784,138	793,249	808,940	841,087	786,773	839,955	830,410	832,750	818,410	837,320	896,230	898,010	841,000	875,760
Copper Recovered from Scrap:															
Refined from Scrap	406,000	415,000	446,000	480,000	440,757	417,757	433,223	459,788	391,000	352,000	345,000	396,000	349,000	229,919	208,000
Unalloyed Powder & Castings	8,446	8,757	10,478	9,282	9,143	8,330	9,316	9,182	11,297	11,299	10,806	10,619	8,305	8,062	8,349
Total Unalloyed Products	414,446	423,757	456,478	489,282	449,901	426,087	442,539	469,601	403,000	364,000	355,000	407,000	357,000	237,981	216,349
Brass and Bronze	662,242	736,725	800,221	774,770	800,772	727,618	776,295	753,968	861,000	887,000	892,000	981,000	987,432	1,000,462	1,010,000
In Aluminum Alloys	45,171	47,932	45,632	41,719	56,489	44,277	55,607	61,049	62,800	64,600	70,700	75,000	76,600	78,200	74,900
From Other Alloys & Chemicals[5]	4,669	4,672	3,797	2,684	3,412	2,708	1,986	1,077	334	307	415	365	215	11,925	11,825
Total Copper from Scrap:	1,126,528	1,214,059	1,306,891	1,308,455	1,309,529	1,200,690	1,276,426	1,285,695	1,330,000	1,320,000	1,320,000	1,460,000	1,422,000	1,328,568	1,313,074

Source: U.S.G.S. and U.S.B.M. Minerals Yearbooks and Mineral Industry Surveys.
W= Withheld, data in other scrap.

[1] Gross Weight.
[2] Includes Railroad car boxes.
[3] Includes leaded-yellow brass.
[4] Includes low-grade scrap and residues at primary and secondary smelters and refiners.
[5] 1999 Includes copper sulfate and other chemicals.

Table 18. Estimated Secondary By-products for 1998, by Plant-Type Sector

(metric tons)

Plant type	Zinc Oxide	Other Residues				Slag and Skimmings[3]	Furnace Linings and Bricks	Total All By-Products
		Grindings	Drosses	Dusts, Fines, Sludges etc.	Total: Other Residues[2]			
Brass, Tube & Wire Rod Mills[1]	4,440	1,375	3,472	9,079	13,926	28,476	9,700	56,542
Foundries	428	2,327	425	6,978	9,730	25,453	3,137	38,748
Ingotmakers[1]	9,479	203	50	1,199	1,452	39,142	1,678	51,751
Grand Totals	14,347	3,905	3,947	17,256	25,108	93,071	14,515	147,041

[1] Includes fire refineries and cupolas at these facilities.

[2] Other residues includes grindings, Ni and Cu drosses, dusts, fines, waste water sludges, pickle liquor products, turnings and other products.

[3] It is estimated that about 28% of slag and skimmings are reprocessed in-house.

Data derived from 1994 and 1998 Copper Development Association surveys. The combined data represents responses by more than 70% of the copper and brass mill and ingot-maker production. The response rate for foundries was somewhat lower. All data was rationalized to represent each entire 1998 industry sector, using comparative production data from the U. S. Geological Survey.

Table 19. Particulate Emission Factors for Furnaces Used in Secondary Copper Smelting and Alloying Process[1] (units in kilograms of materials processed)

Furnace and Charge Type	Type of Emissions Control	Total Particulate	Emission Factor Rating	PM-10[2]	Emission Factor Rating	Lead	Emission Factor Rating
Cupola							
Insulated Copper Wire	ESP	5	B	ND	E	ND	NA
Insulated Copper Wire	None	120	B	105.6	E	ND	NA
Scrap Copper and Brass	ESP	1.2	B	ND	NA	ND	NA
Scrap Copper and Brass	None	35	B	32.1	E	ND	NA
Reverberatory furnace							
Copper	Baghouse	0.2	B	ND	NA	ND	NA
Red/yellow Brass	None	ND	NA	ND	NA	6.6	B
Other Alloy (7%)	None	ND	NA	ND	NA	2.5	B
High Lead Alloy (58%)	None	ND	NA	ND	NA	25	B
Brass and Bronze	Baghouse	1.3	B	ND	NA	ND	NA
Rotary furnace							
Brass and Bronze	ESP	7	B	ND	NA	ND	NA
Brass and Bronze	None	150	B	88.3	E	ND	NA
Crucible, pot furnace							
Brass and Bronze	ESP	0.5	B	ND	NA	ND	NA
Brass and Bronze	None	11	B	6.2	E	ND	NA
Electric arc furnace							
Copper	Baghouse	0.5	B	ND	NA	ND	NA
Brass and Bronze	Baghouse	3	B	ND	NA	ND	NA
Electric induction furnace							
Copper	Baghouse	0.25	B	ND	NA	ND	NA
Brass and Bronze	Baghouse	0.35	B	ND	NA	ND	NA
Fugitive emissions[2]							
Cupola	None	ND	NA	1.1	E	ND	NA
Reverberatory	None	ND	NA	1.5	E	ND	NA
Rotary	None	ND	NA	1.3	E	ND	NA
Crucible	None	ND	NA	0.14	E	ND	NA
Electric induction	None	ND	NA	0.04	E	ND	NA

ESP = Electrostatic Precipitator. NA= Not Available. ND = Not Detected.

[1] Sources unpublished data, U.S. EPA. URL: http://www.epa.gov:80/ttnchie1/ap42pdf/c12s09.pdf
EPA document 450/4-90-003

[2] PM-10 and fugitive emissions listed in Air Facility Subsystem Source Classification Codes and Emission Factor Listing for Criteria Air Pollutants, U.S. EPA 450/4-90-003, March 1990.

APPENDIX A

Historical Review of U.S. Export Controls on Copper-base Scrap:

Copper and copper-base scrap becomes particularly valuable during periods of military conflict and economic expansion. The following summary of events prompting export and other controls on copper during the 1941-1970 period is extracted from the copper chapters of the Bureau of Mines Minerals Yearbooks over that period.

Because supplies of copper in the United States were inadequate to fill requirements over much of the period between the end of World War II and 1970, copper raw materials, including scrap, were subject to export controls. This was particularly true during the period of the Korean Conflict (1949-1953) and the Vietnam War (1964-1973). During the World War II period, controls were exercised on all copper materials under authority of the War Production Board, the National Defense Advisory Commission and the Office of Production Management to insure the most efficient use and allocation.

When it became evident that copper was rapidly becoming scarce, the first measures for increasing imports were passed and mandatory priorities were issued. Among the first steps taken to conserve and increase copper supply was the placement of copper on the list of materials requiring license for export. Since such a large proportion of raw materials was comprised of scrap, this portion of supply was controlled by a number of orders including Supplementary Order M-9-b of September 30, 1941, which was issued to assure that scrap generated would be returned to mills. According to orders issued Dec. 31, 1941, copper-base scrap could be purchased by consumers only. Unalloyed copper scrap was allocated to replace refined copper wherever possible, and fabricator segregation of brass scrap was made mandatory so that the scrap could be remelted at brass mills for reuse in wrought products. Although refining of copper from yellow-brass scrap was subsidized to some extent by the government, beginning in April 1942, by amendments to the scrap price schedule, total production of secondary refined copper was less than in 1941.

Many of the supply and price restrictions remained in place throughout the WWII period. Trading of copper on the Commodity Exchange was suspended July 23, 1941, through July 15, 1947. Some restrictions on transactions in copper and brass scrap, which had remained in effect after the wartime price ceilings were lifted on November 10, 1946, were removed at the end of the first quarter of 1947, including a regulation that provided for allocation of cartridge brass from military sources. There were substantial increases in the prices of nonferrous metals following the removal of price ceilings.

Under the Defense Production Act of 1950, defense measures included ceiling prices for all copper and copper alloy materials as well as strict export controls. On Sept. 12, 1950, the National Production Authority (NPA) was organized, and it immediately issued its first regulation, which limited inventories of all materials, including scrap, to a reasonable working quantity. Despite all efforts to increase supplies, the copper available during 1951 fell below that of 1950. A labor strike at midyear compounded the shortage. Some 55,000 tons of copper were released from the National Stockpile.

The world shortage of copper in 1951 led to placing copper under international allocation among the Market Economy Countries. The controls that had been inaugurated under the Defense Production Act of 1950 were extended. On July 13, 1951, the National Production Authority (NPA), which reinstituted the Controlled Materials Plan (used effectively in World War II for copper), announced that copper raw materials would be placed under complete allocation control, effective August 1. Quotas were established by the International Materials Conference for the 4th quarter of 1951. The member countries voluntarily accepted restrictions upon quantities to be consumed. While price controls were in effect in the United States, international copper prices soared and were higher than any year since 1918.

Trading in copper on the Commodity Exchange of New York was temporarily suspended between January 29, 1951, to June 1, 1953. Orders issued by NPA in 1950 that affected copper were: *Regulation 1*, which prohibited accumulation of excessive inventories by limiting the quantities of materials that could be ordered, received or delivered; *Order M-12*, which reduced civilian use of copper by 15% in January and February, and 20% in March 1951; *Order M-11*, which set rules for placing, accepting and scheduling rated orders for copper and copper-base alloys; and *Order M-16*, which aimed at maintaining the flow of copper and copper-base alloy scrap through normal channels and limited toll agreements, except as authorized.

Copper supply continued to be inadequate in 1952, with less copper available in 1952 than in 1951. A further release of 22,000 tons of copper was authorized from the National Stockpile, to meet the temporary emergency. Following the Office of Price Stabilization permission to raise prices for foreign copper and to pass on to consumers most of the costs, the situation improved, so that copper was nearly in balance by yearend. Probably the most outstanding feature of the year, and the most controversial, was the multiple prices for copper (foreign vs. domestic) as domestic prices were controlled by the General Ceiling Price Regulation that had been in force since January 1951. The price for copper in foreign markets in late 1952 was lower than it was in the USA, in contrast with the earlier situation in which foreign prices sharply exceeded those in the United States. Exports of copper continued to be subject to export control in 1952; exports of refined copper rose 31%, nonetheless.

Early in 1953, the situation had eased to the point where price controls and national and international allocations of copper were abandoned, although military and Atomic Energy Commission needs were still to receive preferential treatment. An inadequate supply condition was prevalent from 1954 to 1956. Due to the continuing shortage of copper, quantity export controls were maintained on refined copper through the third quarter of 1956 and on copper scrap through the 3rd quarter of 1957. In 1956 new production highs were established. The record output resulted from high prices and mine production that was uninterrupted by labor strikes for the first time since 1952. By the end of the year, the supply situation changed to one in which copper was in surplus of requirements. In 1956, most of the copper exported from the United States was refined or as advanced manufacture forms. Refined and unrefined copper of foreign origin, except that produced from Canadian origin copper scrap, continued under open-end licensing. Refined copper of domestic origin and that produced from Canadian-origin scrap generally was not approved for export. As the copper supply situation eased during the year, the export quotas were changed. On June 22, 1956, the Bureau of Foreign Commerce (BFC) announced increases in the quotas for new and old copper-base scrap containing 40% or more copper, copper-base alloy ingots and other crude forms.

Copper production declined in early 1958, owing largely to voluntary restrictions in output following the surpluses of 1957. Effective Nov. 10, 1958, copper items, including copper scrap and copper-base scrap were removed from the Dept. of Commerce positive list of items requiring export licenses and placed on the general list for export to all destinations, except Hong Kong, Macao and the Sino-Soviet bloc. At the same time, after a seven-year suspension, the excise tax on copper imports was reimposed on July 1. The effective rate was 1.7 cents per pound. On June 11, 1958, the President signed a bill to continue suspension of duties on metal scrap to June 30, 1959. In 1959, the United States was affected by the longest copper mine labor strike to date, lasting 6 months. As a result, mine output fell 16% from the previous year, and the substantial loss in production created the need for a larger quantity of imports. On Feb 20, 1959, the Dept. of Commerce reimposed controls on all copper exports; shippers were required to declare destinations of all shipments except those to Canada.

In 1960, imports and exports were almost equal, and in 1961, the United States had again become a net exporter of copper materials. The priorities provided for under the Defense Materials System (DMS), which was basically similar to the Controlled Materials Plan (CMP) administered during both World War II and the Korean conflict, were in place in 1962, despite a relatively easy supply situation. Nevertheless, exports of scrap in 1960 expanded sixfold. Stocks of copper scrap at mills dropped 15% during 1960, as a result of heavy buying from foreign buyers in Japan and Western Europe. West Germany received about one-third of the total.

By 1960, the Government National Stockpile of copper contained more than 1 million tons of copper. With the onset of escalation of the Vietnam War, however, much of this copper would be released. Sale of 590,000 tons of copper from the strategic stockpile was authorized by legislation in 1965 and 1966, reducing the stockpile to about 228,000 tons by 1968. The remainder was released in 1974. Only 20,000 tons of refined copper remained in the National Stockpile until 1993, when it was all sold.

The copper industry established new records, as demand began to accelerate late in 1963 and continued strong through 1964. Exports of copper scrap during 1964 increased more than threefold, and exports of copper-base scrap almost doubled. Japan received 44% of the copper scrap and 77% of the copper-base scrap exported. Copper continued in tight supply through 1965, despite an increase of 4% in free world mine production. The record production was attained in spite of strikes in Chile, losing an estimated 100,000 tons of potential production. Substantial quantities of copper also were released from the Government National Stockpile. Yet supply was inadequate to meet record demand for metal caused by unprecedented prosperity in the free world and by military action in Vietnam. On Nov. 17, 1965, the Government announced a 4-point program to reduce inflationary pressures on the price of copper that might impair the defense effort in Vietnam. The program called for: (1) release of 200,000 tons of copper from the National stockpile; (2) control of exports of copper and copper scrap for an indefinite period to conserve domestic supply; (3) legislation to suspend the 1.7 cent-per-pound import duty on copper, to encourage a greater inflow of metal, and (4) imposition of higher margin requirements on copper trading by directors of the COMEX to lessen speculation in the metal. Copper scrap export limits were put at 30,000 tons in 1966 to all countries except Canada. The scrap limit applied to the scrap content containing more than 40% copper and was based on a company's recent trade volume. Copper exports other than scrap were not limited.

Labor strikes in 1967 reduced U.S. mine capacity by 80% and lasted for nine months. Before the end of December, shortages and the increasing cost of copper had forced some manufacturers to stop production. There were also supply restraints from Central Africa, Chile and Peru, largely owing to labor disputes. Some 176,000 tons of refined copper was distributed from the National Stockpile during the first nine months of 1967, but it was insufficient to immediately stem the shortages. Even so, during the first six months of 1967, U.S. export controls permitted the exportation of 16,500 tons of copper scrap, 25,000 tons of refined copper and 10,000 tons of copper contained in copper-base alloy and copper semifabricated products and masteralloys. A virtual embargo had been in place on exports of domestic origin copper since Jan. 20, 1966. The strikes, which began on July 15, 1967, rapidly disrupted normal relations between the mines and smelters and refineries. The mines began to stockpile concentrate to the point that production was threatened. To relieve this situation, export regulations for mine and smelter products were amended to permit licensing for export. The licensing arrangement was later modified to permit the exportation of scrap that could not be processed in the United States for technical or economic reasons or because of the strike. Scrap exports were concentrated in the last five months of 1967, making the annual amount near that for 1966. A 50% increase in exports of copper-base alloy scrap accounted for most of the 1967 increase in alloy exports.

At the beginning of 1968, more than 90% of the domestic copper industry was closed by continuation of the labor strike that started in July 1967. A further 13,800 was withdrawn from the National Stockpile, leaving only 201,300 tons in the stockpile at yearend. On resumption of operations after settlement of the copper industry strike, export controls, administered by the Office of Export Control, and producer set-asides, administered by the Business and Defense Services Administration (BDSA), both in the U.S. Department of Commerce, again became effective. Export licensing quotas for the second half were 25,000 tons of copper-base scrap, in addition to quotas for refined copper, semifabricated productions and other copper materials. Owing to the large increase in exports of copper scrap to Canada during the year, Canada was added to the quota list near yearend and allotted 2,400 tons for 1969. Despite the export controls, exports of unalloyed copper scrap were 34,000 tons, an increase of almost 100% from those of 1967; and exports of copper alloy scrap were 86,000 tons, up 32% from 1967 levels. Export controls on copper products continued through 1969. The quota on refined copper from domestic primary sources was 50,000 tons, and on scrap it was 60,000 tons of contained copper.

In 1970, the domestic copper industry experienced record high production, reduced consumption and an increase in copper stocks. Considerable expansion in world copper production capacity, coupled with reduced demand in the United States, resulted in a dramatic reversal in copper markets, from one of short supply to one of surplus supply. This reversal was reflected in a price increase in April followed by price reductions in October and December. The improved supply situation led to removal in September 1970 of export controls imposed in 1965. A total of 260,467 short tons of copper remained in the stockpile.

The world supply of copper generally has been in oversupply since 1975, with the exception of a few years in the late 1980s and mid- 1990s, when all of the excess world stocks accumulated over the 1970s had finally been worked down. New World industrial demand was underway in the mid-1990s, and the new mine capacity under construction since the early 1990s had not yet been put in place. All concern for potential shortages of scrap and of copper disappeared and the remainder of the U.S. copper stockpile was sold off in 1993.

APPENDIX B

Superfund Sites

The following secondary copper-base processing plants have been found on EPA's computerized CERCLIS.

Listed on the National Priorities List (NPL):

(1) ***Jacks Creek/Sitkin Smelting and Refinery***, Lewistown, Penn. ROD date: 9//30/97 (EPA/541/R-97/087

Contaminants listed: Sb, Cd, Cu, Pb, Se, Ag, Zn, dioxins and polychlorinated biphenyls (PCBs). Sitkin Smelting was an active ingot maker at the site from 1958 through 1977, when it declared bankruptcy. A number of related facilities also have been named responsible parties (PRPs) owing to shipments of materials to this firm for treatment.

Major remedies for the site include: excavation of soils with treatment off site; excavation and onsite consolidation of waste pile materials and soils; vacuum dredging and consolidation of Jacks Creek sediments; covering and capping of soils, sediments and waste piles; covering and revegetation of all excavated areas and demolition of unsound buildings. Groundwater and surface waters will undergo long-term monitoring.

(2) American Brass, Headland, Alabama**.,** Discovery 7/25/96. Final listing on NPL 5/10/99. This was an active ingotmaker until 1996, when the plant closed.

(3) Kearsarge Metallurgical Corp., Conway, N.H. Discovery 11/1/82. ROD 9/28/90. Currently on the Final NPL. Kearsarge was a nonferrous foundry. High on the contamination list is chromium, HF acid, organic compounds, ceramics and flammable liquids. The nine-acre site is located within the 100-yr floodplain of the Saco River. The ground water in the upper aquifer under the site was determined to be contaminated.

(4) Metal Banks, Philadelphia, Penn. Discovery 6/1/77. On the Final NPL, ROD date: 12/31/97,EPA/541/R-98/012. Contaminants include metals as well as acids, dioxins and PCBs. Starting in 1962, the site was used for scrap metal storage, then from 1968-1973, it was used for transformer salvage. Copper wire was burned to remove insulation 1968-1972. In the southern area, scrap metals were recovered and scrap storage continued until 1985, and transformer salvage operations stopped in 1973.

(5) Tex-Tin Corp. (Gulf Chemical & Metallurgical) . Texas City, Texas Currently on the Final NPL. Discovery 11/1979. Record of decision 9/29/2000. Consent decree 10/2000. Was a copper scrap fire refinery.

Not listed on the NPL:

(6) Franklin Smelting and Refining, Philadelphia, Penn. Not on the NPL. Franklin was an active secondary smelter for years at this site. The plant closed in 1998. Also includes *Franklin Slag Pile*. Removal assessment 10/6/2000.

(7) Talco Metals, Philadelphia, Penn. No action listed.

(8) ***Shenango, Inc***, Sharpsville, Penn. Discovery 3/29/1985. Site inspection 10/17/89.

(9) ***Eastern Smelting and Refining***, Los Angeles, Calif. Discovery 2/15/96. Prelim. Assessment 6/30/98. Not on the NPL.

(10) ***Anaconda Industries Brass***, Detroit, Mich. Discovery 7/29/92, Prelim. Assessment 9/26/96. Not on the NPL.

(11) ***H.Kramer & Co.,*** El Segundo, Calf. PRP removal 11/07/90. Not on the NPL. Abandoned foundry.

(12) ***Ansonia Copper & Brass***, Waterbury, Conn. Discovery 1/1/81. Preliminary assessment 8/30/86. Not on the NPL.

(13) ***Anaconda American Brass.*** Ansonia, Conn. Not on the NPL. Discovery 1/81. Site inspection 10/91.

(14) ***Revere Copper & Brass Inc.,*** Clinton, Ill. Discovery 9/1/80. Site inspection 10/24/90. Not on the NPL.

(15) ***Vulcan-Louisville Smelting Co. (Lavin & Sons),(North Chicago Refiners & Smelters),*** North Chicago, Ill. Discovery 8/29/90. Expanded site inspection 8/1/95. Not on the NPL. PPA assessment 5/19/2000. Unilateral admin. order 9/21/2000. The site is associated with an active ingot maker.

(16) ***Southwire Co. Copper Division.,*** Carrolton, Ga. Discovery 8/01/80. Preliminary assessment 6/17/85. Not on the NPL.

(17) ***Prier Brass Mfg. Co.,*** Kansas City, Mo. Discovery 12/18/86. Negotiation 4/17/97. Consent agreement 5/8/97. Not on the NPL.

(18) ***Bridgeport Brass,*** Norwalk, Conn. Discovery 1/1/87. Site inspection 6/7/93. Not on the NPL.

(19) ***Seymour Brass Turning,*** Seymour, Conn. Discovery 12/13/88. Site inspection 4/23/93. Not on the NPL.

(20) ***Seymour Specialty Wire,*** Seymour, Conn. Discovery 5/16/89. Site inspection 11/07/94. Not on the NPL.

(21) ***Chase Brass and Copper,*** Waterbury, Conn. Discovery 1/1/81. Site inspection 6/25/85. Not on the NPL.

(22) ***Phelps Dodge Refining Corp.*** Maspeth, N.Y. Not on the NPL. Discovery 5/79. Site inspection 8/83. Closed copper refinery.

(23) ***Nassau Recycle Corp.*** Staten Island, N.Y. Not on the NPL. Discovery 1/80. Proposal to NPL 2/92. Processed copper wire scrap.

(24) ***National Smelting & Refining Co*.** Atlanta, Georgia. Not on the NPL. Discovery 8/80. Admin order on consent 6/89. Vol. Cost recovery 3/92.

(25) ***Chemetco***. Hartford, Illinois. Not on the NPL. Discovery, 12/07/1999.

(26) ***CMX***., Los Angeles, California. Not on the NPL. Preliminary assessment start 8/15/2000, completed 6/29/2001.

(27) ***Federal Metals***. Los Angeles, California. Not on the NPL. Discovery 1/1/1987. Site inspection 9/24/1991. Site reassessment completed 6/7/2000.

(28) ***Kocide Chemical***. Casa Grande, Arizona. Not on the NPL. Deferred to RCRA.

(29) ***Anchor Metals***. Anniston, Ala. Not on the NPL. Assessment complete. Decision needed.

(30) ***Lee Brothers Brass Foundry***. Anniston, Alabama. Not on the NPL. Discovery 5/1/2000, Preliminary assessment 9/30/2000, Site inspection 10/18/2001.

Archived Sites: Archive status indicates that, to the best of EPA's knowledge, Superfund has completed its assessment and has determined no further steps will be taken to list that site on the NPL.

(1) ***Lee Brass Company***. Anniston, Alabama. Deferred to RCRA. Archive site 12/23/1996.

(2) ***Monarch Foundary***. Plano, Illinois. Not on the NPL. ESI ongoing. Discovery 8/03/1991, Site inspection 9/19/1994.

(3) ***United Refining & Smelting Co***. Franklin Park. Illinois. Discovery 8/01/1980. Archive Site 10/19/1990.

(4) ***Olin Corp Main PLT***. East Alton, Illinois. Discovery 4/01/1979. Archive site 7/09/1987.

(5) ***Olin Corp***. Zone 17 Plant. East Alton, Illinois. Deferred to RCRA. Archive site 12/08/1995.

(6) ***Brush Wellman, Inc***. Elmore, Ohio. Discovery 10/01/1980. Archive site 3/28/1990.

(7) ***Ohio Brass Company***. Barberton, Ohio. Discovery 6/28/1984. Archive site 9/26/1995.

(8) ***Federated Fry***. San Francisco, California. Discovery 6/01/1988. Archive site 11/21/1988.

(9) ***Cerro Metal Prod***. Calfifornia Works. Newark, California. Discovery 12/01/1979. Archive site 7/20/1990.

(10) ***H***. Kramer & Co. El Segundo, California. Unilateral Admin. Order 7/7/1988. PRP Removal 11//7/1990. Admin. Records 3/26/1992. Archive site 7/24/2000.

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