2013 Technical Report

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

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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 historical and current background on the U.S. copper and copper alloy secondary processing industry. It is felt that policy and decision-makers can use a ready reference on an industry that is generally so little understood. The industry has undergone many changes over the past few decades and has been in decline over much of the last ten years. While the coverage is not comprehensive, a brief mention is made of the many problems impacting the health of the industry. 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 past decade has been particularly difficult, given the restrictions within which they have operated, the potential for new restrictions, and the variable copper markets.

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, the Late Alan Silberof RECAP, who was of tremendous help in outlining the original report. Daniel Edelstein, Copper Specialist with the U.S. Geological Survey, also provided substantial help and advice. The International Copper Study Group, was, and continues to be of great assistance in providing world copper industry statistics. The research for this report was supported by the Copper Development Association. This thirteenth edition presents updated data tables and observations made since the first report was written in 1999. It is hoped that the historical perspective presented will help in understanding future events and making new decisions.

ABOUT THE AUTHOR

Janice L.W. Jolly has had more than 35 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. Following this, she served 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 for more than 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 (ICSG) as its first Chief Statistician and was instrumental in establishing the ICSG 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. Currently a copper industry consultant, she resides in Dayton, Maryland.

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EXECUTIVE SUMMARY

The worldwide industrial recession, which began suddenly in 2008, continued through late 2009. The economy was somewhat improved through much of 2010 and 2011. By mid-year 2012, however, traders were expecting the market to trend down because of a number of factors outside of North America. Concern over the shaky European market worried many recyclers. Economic concerns that started in Greece spread to Spain, Italy and France. In addition, the Chinese economy continued to slow, adding to the short term negative outlook for nonferrous scrap markets. While metal prices and the stock market recovered gradually from late 2009 onward, U.S. industrial activity generally lagged over much of the period.

Meanwhile, China's higher consumption in 2009 and 2010 was largely supported by government policy. Metal intensive products were also helped by policy measures. In 2009, substantial parts of China's stimulus package were targeted at infrastructure. The end result was that China's demand picked up much of the "slack" for reduced demand in most of the rest of the world. Even so, the Chinese government showed signs of concern about an overheated economy when it raised interest rates at mid-year 2010. Toward yearend 2010 and in 2011, China's demand was slower as indicated by lower imports, rising stockpiles, falling premiums, rising treatment fees and higher scrap supply. Higher copper prices over much of the 2009-2011 periods prompted worries about "demand destruction" in an overheated Chinese economy. By 2010, China tightened monetary policy in an attempt to dampen excessive stockpiling and other speculative activities.

Even so, copper scrap concluded 2012 on a somewhat positive note. After slumping during the middle half of the year, interest in copper scrap increased at the end of 2012. specially from buyers for Chinese consumers. These buyers were interested in adding to their inventories, contributing to the movement and price of copper throughout Western Europe. According to a Recycling Today report (Jan 2013), the German copper producer and copper scrap recycler Aurubis reported an increase in sales for 2012 and was expressing a more bullish outlook for 2013. Regarding copper scrap, the company noted that its availability had improved through 2012, leading to higher utilization rates for the group's recycling capacities. In general, Aurubis noted that the copper scrap market was good during its 2011/2012 fiscal year.

Looking back historically, world copper was in short supply through most of the period, 2005 through 2008. Shortages persisted despite efforts by the major copper producers to bring mines back on stream, or start new mines, to increase production. Labor strikes, lower ore grades and other production problems seemed to plague the industry. The supply/demand deficit for 2005 was 73,000 tons according to the International Copper Study Group (ICSG). At the end of December 2006, total world copper inventories, were 1.1 million tons and were about 23% less than that required to supply the world for one month. Owing to the release of unknown, but apparently significant, quantities of copper from the Chinese strategic stockpile, world copper supplies were partially ameliorated during the latter part of 2006, and prices began to soften. By yearend 2007, visible world copper stocks were estimated by the ICSG to be around 970,000 tons, down by about 105,000 tons from that of yearend 2006 (ICSG, Nov. 2011). These inventories represented about 1.5 weeks of average world copper consumption, and well below the four-week level (1.4 million tons) for world consumption that by many is considered to be "normal", or in balance. Inventories increased during early 2008 to around 1.26 million tons. A delicate balance between supply and demand persisted. By October 2012, the ICSG reported refined stocks at 1.1 million tons, well below one month's average consumption of 1,683 million tons per month.

Copper prices were extremely volatile and variable over the periods 2007 through 2011. By January 2009, the LME price had retreated from the lofty highs of 2007 and early 2008 to a low of $1.46 per pound. As a result of the continued pressure on available supplies through 2010, the average LME price for refined copper was in the mid-$3 range through most of the year, reaching $4.45 per pound by yearend. The weaker dollar and the speculative pressure of Chinese buying were largely responsible for the rise in prices. However, it also was revealed late in 2010 that a brokerage firm, J.P. Morgan, had purchased nearly 90% of the copper inventories on the LME, ostensibly to establish a new copper exchanged-traded-fund (ETF). Several other firms were considering similar moves. By mid-year 2012, however, the mood of the market began to change. The average LME refined copper price for 2012 was $3.61 per pound.

In August, and September of 2008, despite a series of financial "rescue" packages by the U.S. government, the credit crises abruptly stifled industry throughout the world. On the major stock exchanges, the share values for the copper mining companies had also plummeted by up to 80%, within a few short weeks. Even though basic industrial growth continued to languish, the U.S. stock exchange prices began to gradually improve from 2009 through 2010, even as inventories were seen as rising over the period, World inventories, while historically low, continued to rise through 2011. Inventories had increased from 970,000 tons in 2007 to about 1.161 million tons at yearend 2008 (ICSG, October 2010). Total world inventories at yearend 2009 were 1.35 million tons. However, at the end of October, 2012, total inventories held by the exchanges, producers and consumers were marginally lower at 1.1 million tons. These levels were well below one month's world consumption. To put this into perspective, this level compares with the 1.69 million tons of refined copper that the ICSG estimated to be consumed by the world in October 2012.

Looking back to the effects of the supply buildup between 1998 and 2003, U.S. secondary copper-base scrap collection and processing capacity were severely impacted by a number of problems. In addition to lower scrap prices caused by surplus world copper production, higher environmental compliance costs and escalating scrap exports to competing nations affected the entire industry. Higher recovery costs combined with lower prices from 1998 through 2003 to create a cost squeeze that would result in the closing of all U.S. secondary smelters and associated electrolytic refineries. Of the four secondary smelting and two electrolytic refining firms operating in 1996, none remained after 2001. Fire refining, which requires a better grade of scrap, held its own through much of the period, but was also affected by occasional cutbacks and closings. Plant closings also occurred in the ingot-making and foundry sectors of the industry. Without a basic domestic secondary-processing infrastructure, more valuable metals likely 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 might be traded domestically, could become less marketable.

The significant competition by foreign nations for quality domestic scrap since 1999 negatively impacted U.S. scrap dealers, scrap processors and users alike. A temporary drop in U.S. scrap exports in 2005 probably was partially owing to the threat from a short supply petition made to the U.S. Government in early 2004 as well as a move by the Chinese Government to tighten control on certain metal imports. Although the U.S. Government turned down the industry petition for control and monitoring of scrap exports, the U.S. scrap availability situation had improved by year's end 2004 for a short period. Some U.S. wire choppers reported significant pickup in activity and a return to profitability. However, U.S. scrap exports continued at a high pace through 2007 and most of 2008, and were more than double the export rate of 1999. A record of about 1.2 million tons of copper and copper alloy scrap was estimated exported from the United States in 2011.

U.S. scrap processors and their U.S. customers (brass mills, ingot makers and foundries) remained at a critical point through 2012. Scrap supplies for domestic users since 1999 remained tight and some qualities (such as auto radiators) were difficult to obtain. Price spreads varied, but owing to higher processing costs (labor, environmental, energy and taxes), and high competitive scrap exports, domestic markets remained difficult. Tight scrap supplies were driving prices over much of the past 12 years. China, South Korea and India continued to be large importers of U.S. and European scrap.

For a pictorial illustration of U.S. refined copper consumption over time, one has only to take a look at the historical trends for the United States shown in **Figure 14**, in **Appendix A** of this report. The figure shows a graphic illustration of copper consumption from 1927 through 2012 During the U.S. industrial recovery of the 1988 to 1999 period, refined copper consumption in the United States increased to nearly 3 million tons. Copper industrial consumption increased by about 10.4% between 1994 and 2000. . By 2003, U.S. refined consumption decreased to around 2.3 million tons, recovering modestly to around 2.4 million tons in 2004. By 2007, copper consumption was down again to nearly 2.1 million tons, and by 2010 was only 1.76 million tons. It is also worth noting that in 2006, the United States imported record amounts of refined copper, reaching nearly 1.1 million tons. These record imports were a continuing sign of a growing and higher U.S. import reliance. The U.S. import reliance reached nearly 40% in 2006, compared with only 2% in 1993.

The decrease in domestic copper consumption was the result of a struggling U.S. brass and wire mill industry. Semi fabricate (tube, sheet, strip, rod etc) production suffered as facilities closed. U.S. production of semi fabricates at brass and tube mills decreased from 3.9 million tons in 1999 to around 2.9 million tons in 2007. Two main factors contributed to tubing company demise: increasing use of plastic pipes for construction applications and increased imports of copper and aluminum tubing from China, Mexico and other countries. Further evidence of the industry contraction is illustrated by the fact that an estimated 16 brass mill plants and facilities closed in the United States over this period. This contraction occurred despite the fact that the United States (2001-2007) was undergoing a tremendous housing boom and supporting a foreign war, both large consuming activities for copper products. Between 2000 – 2009, a total of 695,000 manufacturing jobs were lost from the primary metals and fabricated metal products sectors (Bureau of Labor Statistics, 2009).

While the United States copper industry was shrinking, world refined copper consumption increased to more than 20.5 million tons by 2012 owing to increased growth in other countries. Despite higher secondary (scrap) exports and lower copper consumption, the United States remained a leading consumer of copper from copper-based scrap with 9% of the world's total refined copper usage in 2012. In 2012, the United States consumed about 1.793 million tons of copper from scrap and primary sources, including about 735,000 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 was as high as 613,000 tons in 1980, but was only 150,000 tons in 2012. However, if net scrap exports 944,890 tons are classified as old scrap and are included in an estimate for all *old* scrap recovered, the potential amount of copper in old scrap collected in 2011 was about 1.1 million tons (old scrap plus net exports). This much higher value implies that the rate of old scrap copper recovered from the U. S. end-use reservoir has not really diminished, as otherwise might be indicated by reported domestic U.S. scrap consumption data.

World trade (imports) in copper-base scrap nearly tripled between 1989 and 2009, largely in response to the increased industrial growth in the Far East and Europe. Asia and Middle Eastern countries received about 71% of world copper scrap imports in 2010. The United States continued to be the largest exporter of copper scrap in the world, exporting 22% of the world's total copper-base scrap exports in 2011. U.S. exports of scrap were estimated to be in excess of 1.2 million tons in 2011. The Middle East and Asia region used an estimated 64% of world copper recovered from scrap in 2011. (Table 2D) China has become the largest copper scrap-consuming nation in the world.

In response to environmental concerns, China implemented import controls for scrapped electronics and the lower grades of copper scrap in 2002. Even so, China reduced its import duty on copper scrap in 2006 to promote the development of the metal recycling industry and to help shortages in the nonferrous metals sector, in general. China, a member of the World Trade Organization (WTO), has been accused by the European scrap processors of assisting its domestic companies through tax subsidies, credit facilities and other protectionist benefits that cause harm to the European scrap metal recycling industry.

Trade restraints on scrap, such as import quotas, export licenses, price controls and other mechanisms have been used many times over the past 30 to 40 years in the United States and other countries. These have been applied mainly during times of national emergency and supply shortage. The entire U.S. secondary copper processing industry was treated as a critical and strategic industry during these tight supply periods, such as during WWII and the Vietnam War. However, the United States has had no trade restrictions on copper-base scrap since 1970. All of the remaining copper in the National Defense Stockpile was sold in 1993. In April 7, 2004, the U.S. copper consuming industries filed a short supply petition under the Export Administration Act, requesting imposition of monitors and controls on the export of copper-based scrap. The U.S. Government turned down the petition later in the year.

The U.S. secondary copper processing industry currently consists of 5 fire-refiners, 23 ingot makers, 44 primary brass mills, 12 wire-rod mills and about 500 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. Many copper chemicals, such as cupric oxide, copper sulfate and others are produced from scrap in the United States. Some chemicals are also produced from the fluid streams of primary copper refiners. While one chemical plant closed in Texas during 2005, another opened in Arizona, associated with a primary producer. Two ingot makers have closed since 2003, as have an estimated 16 brass and tube mills. One wire rod mill closed in 2008.

The EU-15 as a group of countries is the largest ingot-producing entity in the world. However, the United States (30%), followed by Italy, Japan, and Germany, is the world's leading ingot-making country. The United States ingot makers provide the domestic foundry and brass mill industries with special alloys for casting and milling. Ingot-making, in particular, is a very scrap intensive industry, using mostly scrap as its raw material. Even so, the brass mill industry (78% in 2010 copper-base scrap consumption) consumes most of the copper-base scrap recycled in the United States. Some 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 secondary smelting and refining facilities have closed, owing to a poor economic environment for processing scrap and, at times (as in the late 1990s), the easy availability of low-priced primary refined copper.

In 2011, recycled copper consumed in the United States was derived 83% from purchased new scrap generated in the process of manufacture and 17% from old scrap derived from used products. According to the U.S. Geological Survey, purchased new copper-base scrap yielded about 649,000 tons of contained copper in 2011, 78% of which was consumed at primary brass, tube, and wire rod mills. A manufacturer may generate up to 60% scrap in the form of clippings, 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 semi fabricated 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-base 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, only 23,000 tons of low-grade ashes and residues was purchased and consumed domestically for its metal content in 2010. 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 ingot makers.

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 as a result of decreased U.S. processing capacity.

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 for direct use as animal feed and agricultural products, most is sent to zinc smelters and processors for treatment and zinc recovery. Only the poorest grades are landfilled.

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 end 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 leach ability 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 (the Resource Conservation and Recovery Act), 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 have increased. 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.

Problems on the horizon include the safe collection and processing of junked electronics equipment and the potential for renewed recycling of radioactive metal from dismantled U.S. nuclear plants. U.S. scrap handlers and processors have been adapting rapidly to handle the increased recycling of electronics scrap. At the same time, however, adequate provision for facilities to handle the relatively small amount of radioactive copper scrap expected from dismantled nuclear facilities remains a problem to be solved in the future. More recently, additional charges to be levied through the carbon capture program associated with the so-called Global Warming efforts by the U.S. Government could deal a severe blow to the industry.

How much copper has been recovered for reuse in the United States over time? Recent calculations indicate that since 1864, more than 64% of all primary copper consumed in the United States has been returned and reused as scrap. Since 1864, based on reported U.S. data, cumulative primary refined copper consumed in the United States amounted to 132 million tons by 2011. From this source, a cumulative 46.4 million tons (55.4%) of copper from old end-use scrap has been returned for consumption by the industry through 2011. This leaves an estimated 44% remaining in use or recirculating as new manufacturing scrap. The latter percentage includes a very small amount known to have been dissipated through use as copper chemicals. It is not known how much may have been irretrievably dispensed with or thrown away, but it is suspected that this is small and may be only about 5% and no more than 15% of the total measured consumption.

The domestic copper scrap industry continues to face difficult times in the near future. Not only can a continuing difficult economic environment be expected as a result of a potentially prolonged recession, but the underlying negative factors impacting the industry’s competitiveness also will continue. The sharp drop in copper demand that occurred after September 2008 continued through mid-2009. While copper prices and Chinese demand have recovered, domestic copper demand has been slower to respond. As a result of the lower price since early 2009 and the slowing industrial economy, scrap supplies have also been lower. Though lower energy costs may exist temporarily, higher taxes, labor costs, unfair trade rules and new environmental costs can be expected to be onerous. The new health care rules are also expected to impact ease of doing business. Under the misguided notion of changing the planet’s climate, the U.S. government, through either the Clean Air Act, or new legislation, has the potential to levy onerous regulations on the industry for the control of carbon and carbon gas emissions. This might be viewed as the “nail” in the coffin. Without a considerable change in Government attitude toward industry and the economic environment, the outlook will continue to be poor. Foreign competition for the scarce scrap supplies also can be expected to continue.

CHAPTER 1: Industry Perspectives

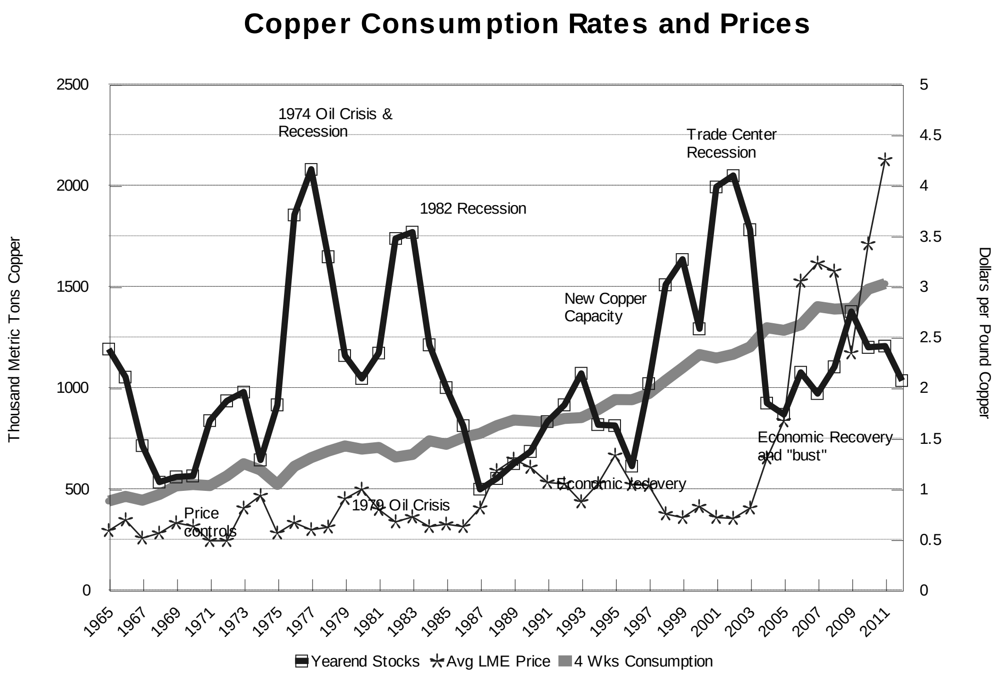
Global Industry Perspective

World Copper Consumption and Production. Copper ranks third in the world consumption of metals, after iron and aluminum. Refined copper consumption is estimated at 20.5 million metric tons for 2012, compared with 16.7 million tons achieved in 2005. According to the International Copper Study Group (ICSG), for the first ten months of 2012, world apparent usage of copper grew by 4.2% compared with that in the same period of 2011, principally owing to the strong growth in Chinese consumption. Based on a 40% increase in net imports of refined copper, China's consumption grew by 15.5% in the first ten months, compared with the same 2011 period. There was anecdotal evidence that some of the high Chinese import level during early 2012 was supported by an increase in inventories held in bonded warehouses. Usage in other leading World consuming regions, the EU, Japan and the United States, declined by 7.5% and 1.5% or remained unchanged. World refined production increased by 1.7% during the first ten months of 2012 compared with the same 2011 period. The main contributors were China (+9%), Japan (+15%) and the Democratic Republic of Congo (DRC) (+29%). Refined production declined by 3% in the United States owing to s series of smelter maintenance shutdowns, and by 67% in the Philippines owing to a fire at its sold smelter.
World mine production increased by 3.9% in 2012 from Chile (3.8%), China (28%), Dem. Republic of Congo (DRC) (20%), Mexico (18%) and Peru (6%). Mining declined in Australia (-4.6%) and Indonesia (-35%). Regionally, production rose by 6% in Africa, 4.3% in the Americas, 4.9% in Asia and 3.5% in Europe, but declined by 4.3% in Oceania.

Over the past several years, the increased Chinese growth in industrial copper was reportedly owing to stockpiling as well as to new domestic growth, export policies and largely supported by government policy. By 2009, substantial parts of China's stimulus package were targeted at infrastructure. Metal intensive products were also helped by policy measures. The end result was that China's demand since 2008 has helped to pick up the "slack" for reduced demand in most of the rest of the world. By late 2010, however, a tightening monetary policy in China reportedly tended to dampen excessive stockpiling and other speculative practices.

According to the ICSG, China's refined production was 5.79 million tons in 2011 up from 3.8 million tons of copper produced in 2008. China maintained a position of leading refined copper producer, exceeding that of Chile (3.1 million tons in 2011)). However, about 35% of China's refined production is from scrap, whereas all of Chile's refined production is from primary sources. China continued to be the leading world importer of copper concentrates and scrap. About one-third of China's domestic scrap consumption is derived domestically, the rest is imported.

Figure 1. World Copper Inventory Trends

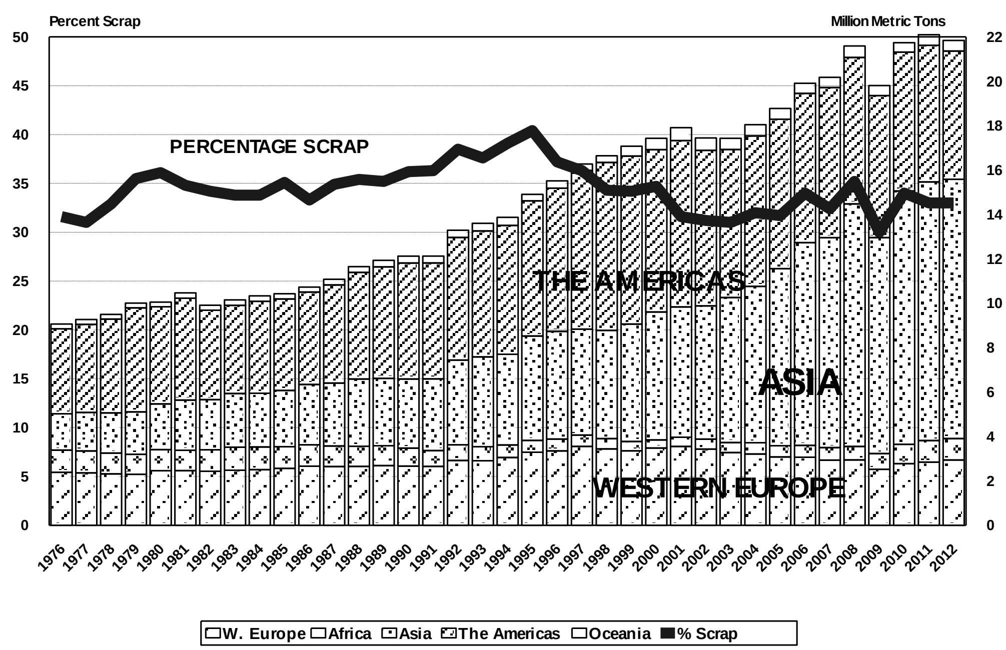


In this report, 2012 production and trade estimates on the data tables were made for the convenience of the interested reader. These current year estimates, for the most part, were based on 8 to 10 months of reported data. The previous (2011) year's estimates are revised to a provisional status based on published data now available by the reporting agencies. In recent years, mineral and secondary industries data from the critical Minerals Information group of the U.S. Geological Survey has been severely impacted by a lack of government funding and contraction of available staff. As a consequence, public data delivery has continued to suffer. Not many in the public realize that this organization (previously part of the Bureau of Mines) is the backbone to U.S. scrap data collection, which it has been collecting for over 100 years. The minerals information community would otherwise be much more concerned. The 2011 scrap data reported is the data found in the USGS 2011 Minerals Yearbook

Following several years of soft demand and high inventories on the LME , Comex and SHME, copper inventories reached new lows by late 2004 (see trends on Figure 1). At the end of 2005, world inventories, according to the ICSG were only 867,000 tons and about 32% less than that required for one month's world consumption. Despite efforts by the major copper producers to bring mines back on stream during 2005 and to increase production, shortages persisted through much of 2006-2008. Copper prices exhibited marked increases during this period. Labor strikes, lower ore grades and other production problems also seemed to plague the industry. Production and consumption appeared to be more in balance by year-end 2006, and inventories decreased slightly through mid- 2008. Except for the last 4 months of 2008, prices remained mostly above $3 per pound, averaging $3.15 for the year. While copper hit its LME price bottom in December 2008, it steadily gained from February 2009 to average $ 2.34 per pound for 2009. Copper prices were significantly higher during the period 2010-2012., exceeding $4 per pound for brief episodes, and averaging about $3.42 per pound for 2010 about $4 per pound in 2011 and $3.62 over 2012 (See **Table 1**).

Looking back at inventory changes, by January 2009, the LME price had retreated to a low of $1.46 per pound. Inventories had increased to a world total of about 1.161 million tons on the exchanges at yearend 2008 (ICSG, Oct. 2010).
By October 2012, total inventories held by the exchanges, producers and consumers had increased to about 1.25 million tons, but was down from 1.34 million tons in October 2011. To put this in perspective, this inventory level is less than the 1.7 million tons that is estimated to represent one month's copper consumption for the world. As a result of the continued pressure on supplies, the average LME price for refined copper continued to be in the mid-$3 range through most of 2012. Prices continued to be high through 2011 and 2012, when pressure from Chinese purchases diminished and the world's

Figure 2: World Copper Recovery from All Sources 1/
And Percent Copper from Scrap, 1976-2012



1/ Includes copper in primary and secondary refined production and estimates for direct melt scrap consumption.
Data Sources: ICSG and USGS reports. See Table 2A, this report.

economies were affected by continued financial problems. Even so, the average LME copper price was around $3.62 for 2012 (See **Table 1**).

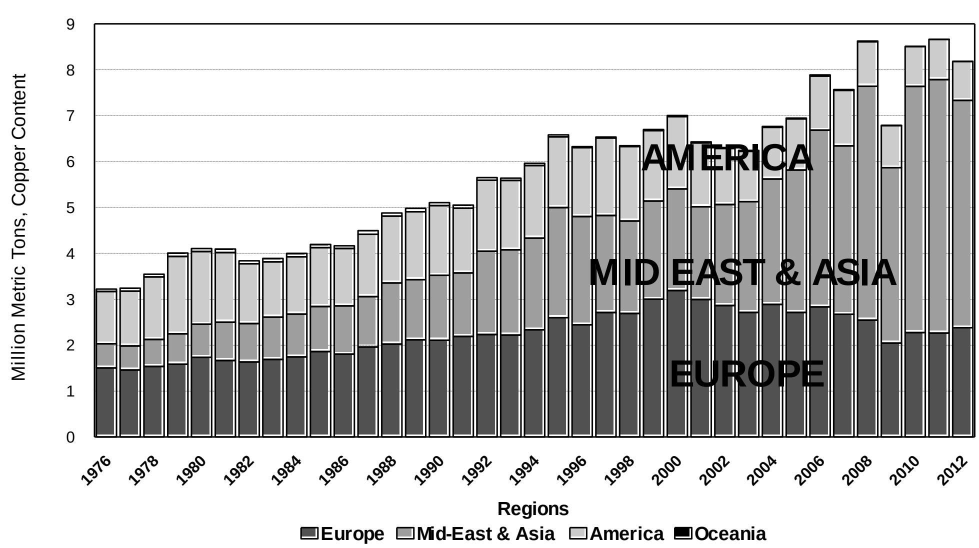
In addition, the China Nonferrous Metals Industry Association reported China's declared inventories at 2 million metric tons at the end of 2010 and they had increased significantly by the end of 2011.

The driving force in China was and is the export market, which is responsible for about 40% of the country's GDP. The drop in global demand because of the recession, as well as increased protectionism, based not only on duties but more frequently on quality standards, certificates, sanitary and ecological requirements, does not favor an optimistic prognosis for future Chinese exports. Exports generate primary capital, including wages. Without a strong export market to drive China's economy, the country's economy could fall into a recession. The growth of raw material stocks is explained as a method of diversifying China's financial assets from its reliance on U.S. bonds and treasury bills.

Scrap collection and use tends to be very price dependent. World copper prices steadily decreased 1997 through 2003, as a result of the more than adequate world supply of copper (see **Table 1**). During this period, copper prices reached low levels not seen since the recession years of the early 1980's. Since lower prices tend to prompt a decrease in the supply of copper scrap, the use of copper scrap as a component of world refined copper also decreased from 16% in 1996 to about 12% in 2003. World production of refined copper from scrap increased along with the higher prices that dominated the period 2004-2008. According to the ICSG, refined copper from scrap comprised about 15% of total world refined copper production 2004 through 2008, reaching 18% in 2009 through-2011.

A reasonable spread in price also 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 or higher in coincidence to the decreasing or increasing refined copper price in recent years**.** For example, the price spread (between COMEX High Grade, first position and Refiners buying price for number 2 scrap) in the United States was as high as 31 cents in 1995, but ranged between 11 and 22 cents per pound over the 1996-2004 period. The price spread for these years was lower than the 12-17 cent spread experienced during the recession years of 1983-1987. The price spreads increased again between 2004 to 2007 in tandem with the higher copper price. 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 drastic cost squeeze during the poor pricing period (1998-2002) prompted U.S. secondary processors to rethink business methods and in fact, some opted to get out of the business. It is encouraging to note that the

Figure 3: World Consumption of Copper from Direct Melt and Refined Scrap, by Region, 1976-2012



Note: Europe includes Eastern Europe and Russia. America represents both North and South America countries.
Sources: International Copper Study Group and USGS. See Table 2D, this report.

estimated average price spreads were 21 cents in 2004 , more than 31 cents in 2005, 48 cents in 2006, and as high as 34 cents in 2008.

When the producers price is used in calculating the spreads, it adds an extra 4 cents to 5 cents per pound for shipping and insurance. This is the delivered price. If the COMEX price is used for the comparisons, the spreads are more narrow. Refer to the scrap and refined prices shown in **Table 1** for a complete series and comparisons. During 2009, variability in scrap prices were generally credited to Chinese buying and lower U.S. scrap generation, and not to increased domestic demand.

World copper recovered from all forms of scrap (refined and direct melt, **Table 2D**) decreased slightly to about 6.7 million tons in 2009, but was up to an estimated 8.1 million in 2011. In a word of caution, the actual amount of copper from direct melt scrap may be underestimated, since these data (with only a few exceptions) are based largely on known (and estimated) semi fabricate production in a particular country. No amount of scrap that might be properly classified as "home scrap", or that is lost in the production process, is added to the direct melt scrap presumed to be part of the end product. The general formula is comprised of total semi fabricate production less amount of refined copper consumed. The copper content of direct melt scrap is based on percentages ranging between 75% and 90% of the total, dependent upon type of products produced (i.e., brass mill or copper rod mill etc). The average copper content is about 80% of total gross weight direct melt scrap estimated. The United States reports actual numbers for types of scrap consumed, but is unusual among nations reporting scrap data.

In 2010, the ICSG published its first edition of Global Recyclables Survey. The data covered by this report extends through 2008. The survey indicated a decrease in global copper scrap use in 2008, owing to a decrease in use of direct melt scrap. The fall off in direct melt usage in 2008 reflected, in part, falling overall semis production in the major semis producing countries, including the United States, Japan, Germany, Italy, Taiwan, the Korea Republic, France and others. (ICSG, 2010 Annual Global Recyclables Survey, 9 p.)

Copper recovered from all scrap, as a percent of total world copper produced, has ranged between the low of 30% in 2009 to as high as 40% during 1995, as shown on **Table 2A** and in **Figure 2**. The current rate of recovery (2010 and 2011) is estimated to be about 35%. The percentage of scrap used by the world, relative to primary copper, was noticeably lower after 1996. This trend shows a striking parallel to a downward trend in prices between 1996 and 2003 (see **Table 1**). This was also a period of surplus primary copper production. Periods of low scrap recovery, such as those in 1975-1978, 1983-1984, and again in 2001-2003, coincide with low copper prices and surplus copper supplies. Scrap supplies also slowed in late 2008 when copper prices dropped precipitously.

Scrap consumption in Asia has seen a remarkable increase since the early 1980's. As a group, the Middle East and Asian countries account for about 64% of world copper recovered from scrap in 2011 (see **Table 2D**). Consumption of copper from scrap in Asia grew from about 723,000 tons in 1980 to 2.4 million tons in 1995-1996. Following a short industrial contraction in 1997-1998, the region experienced an 8% drop to about 2 million tons of copper in scrap. However, by 2008, Asia and the Middle East scrap consumption had recovered to 5 million tons of copper per year, largely through the continued insatiable growth of Mainland China. China, with an estimated 47% of world copper recovered from all scrap in 2011, has become the largest copper scrap-consuming nation in the world.

The Chinese Government in its 11th Five-Year Plan (2006-2010) was encouraging the greater use of scrap metals to help alleviate a shortfall in supplies. The target consumption of secondary copper was 35% of the total national copper consumption, an increase of about 14% (Peoples Daily Online, 2007). China's 12th Five-Year Plan, beginning in 2013 was to target an increased electrical grid, calling for more scrap copper. China looked to recycle 70 percent of the Nation's waste streams by 2015 (Resource Recycling, p. 6, December 2011). China has steadily increased copper in scrap consumed from around 100,000 tons in 1980 to over 3 million tons per year every year since 2008. Chinese copper scrap imports (gross weight) reached 5.6 million tons in 2008 (see Table 4), but has dropped down to about 4 .6 million tons per year since 2009. However, in the second half of 2011, scrap import levels at several Chinese ports were curtailed because of an August 2011 law proposing to treat scrap as waste. More paperwork is involved and the scrap may be returned to the shipper for violations. Scrap shipments were reportedly backlogged at several Chinese ports. Other major copper scrap consuming nations for 2011 in the Middle East and Asian country group (as a percent of total world scrap) include Japan (61.8%), South Korea (3.4%)and India (2%). The Western European countries account for 22% and the countries of North and South America accounted for 11% of world copper recovered from all scrap in 2011. Germany, Italy, France and the United Kingdom are the leading consumers of copper scrap in Western Europe. The United States (15% of world total) is the major copper scrap consuming country of the America group shown in **Table 2D** and **Figure 3**. The Americas (11%) are the third largest copper scrap-consuming region, after Western Europe and Asia. The Oceania and Africa countries are minor scrap consumers.

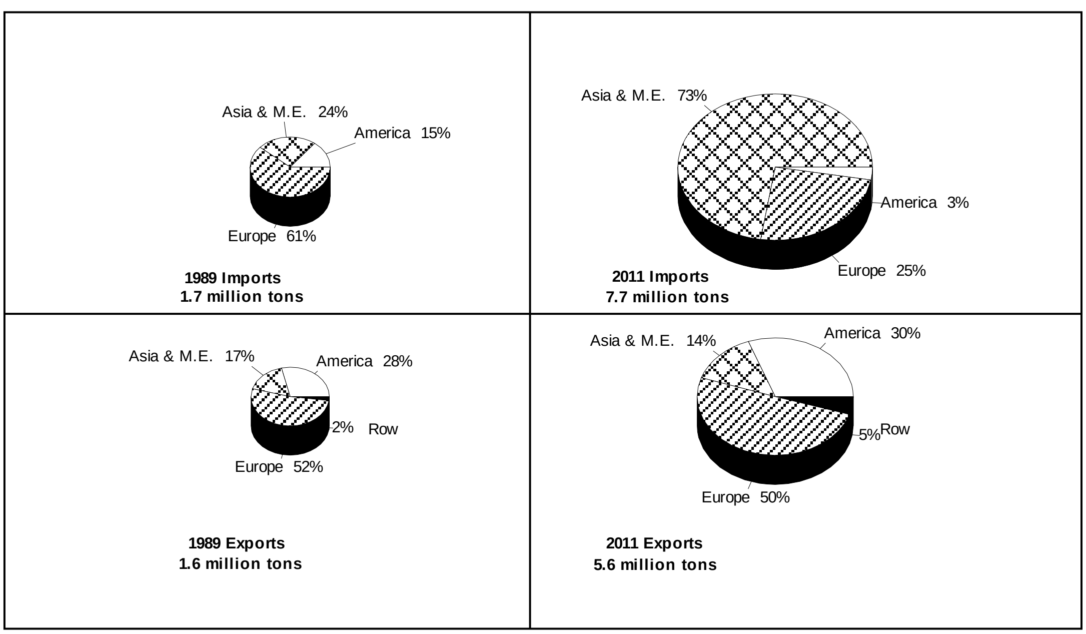
As peak growth years of China's production of wire, cable and the copper products seem to have ended. Challenges for scrap importers remained through differences in customs between European (70 types of scrap material listed on manifests) and China (20 types of scrap approved to enter country). Globally e-scrap was the fastest growing with 20-50 million tons generated worldwide annually.

World Trade in Copper Scrap. The United States (22% of world copper-base scrap exports in 2011) is the largest exporter of copper scrap in the world. U.S. exports of scrap have increased by 132% since 2001. Access to raw materials such as scrap remains critically important for all U.S. manufacturing industries. Since 1999, export trade barriers have increased around the world and have been enacted by countries such as China, Russia, Ukraine and India. These include export bans, export taxes and quotas, export licensing restrictions and currency valuations. Many of these trade barriers are in violation to World Trade Organization agreements, and all of them adversely impact U.S. manufacturers as well as the general global economy (2008, Wiley Rein LLP, Wash. D. C.). In a move contrary to U.S. government efforts in recent years, the U.S. International Trade Commission (ITC) voted unanimously that the U.S. steel industry had been materially injured or threatened with injury by imports of certain tubular (steel pipe) goods from China (Recycling Today, 12/30/2009). Some in other similarly impacted industries viewed this action as hope for a change in US government attitude.

Export duties caused Russia's export of copper scrap to slow to a trickle after 1999. Since that time, Russia restricted the export of raw materials from its territory by maintaining onerous export duties and an unpredictable customs service. Such barriers serve to protect Russia's manufacturers by artificially inflating supply and depressing domestic prices for raw materials and other inputs. Russia's exports of copper base scrap increased 3-fold between 1993 and 1998 to around 357,000 tons, but since 1999 have dropped sharply to less than 1,000 tons during 2011. Germany (10%), United Kingdom (9%), France (5.4%), Japan (4.7%), Netherlands (5.5%) and Canada (3%) are also major exporters of copper-base scrap, as shown in **Table 3 for 2011**. Since 1999, exports of copper-based scrap increased significantly from Japan, from around 84,000 tons in 1999 to about 425,000 tons for 2007, but have decreased since then to 288,000 tons in 2011. World imports of copper-base scrap, as shown in **Figure 4**, increased 6 fold between the years 1989-2011 in response to the significant industrial growth of the Far East and Europe. The Asia & Middle East region is the largest recipient for both the United States and World scrap exports. This region received some 73% of total world imports in

Figure 4. Trade in Copper and Copper Alloy Scrap

by World Region, 1989 and 2011



Source: International Copper Study Group

2011. In 1989, Asia accounted for only a 24% share. Europe (61%), had a higher share of the world's imports of scrap in 1989. In 2011, as shown in **Figure 4**, Europe (West and East Europe) accounted for only 25% of global scrap imports. The countries in the Americas (North and South America) have seen their share of world scrap imports diminish from 15% (1989) to around 3% (2011) over this period.

Of all countries, China has had the most significant growth in scrap imports over the period 2001 through 2012, 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 by 1998. By 2001, China's imports of copper-based scrap was 4-times that of 1996. By 2007, Chinese imports were 67% higher than that of 2001. South Korea, Taiwan, Hong Kong, Japan and India also have been significant importers of copper base scrap in recent years.

Looking back, by early 2001, the availability of copper scrap was reported as especially tight in the United States, owing to low prices and the higher exports to the Far East. Birch/cliff and berry/candy grades were in particular demand. This difficult situation coincided with the closure of the last secondary copper smelter in the United States in 2001. Since that time, China has emerged as the major outlet for U. S. exports of No. 2 scrap and mixed grades of alloyed scrap, in particular. Supplies of scrap in 2009 and 2010 continued to be very tight in the United States as a result of lower prices in 2009 and a drop-off in manufacturing-based new return scrap.. With the precipitous drop in copper prices in 2008-2009, a cutback of copper demand from China and equally abrupt cancellation of several contracts, U.S. copper scrap exports slowed to a trickle through early 2009. Supplies to U.S. metal traders essentially dried up while the prices were trying to stabilize. In late 2008 and early 2009, some dealers were stuck suddenly with supplies for which they had paid much higher prices than the current buying market. By yearend 2009, however, owing to higher prices, dealers reported that orders had picked up, but there still wasn't much excess material available, but China was again active in the market.. Along with a shortage of scrap generation during 2009, container availability also was a problem for some overseas shippers. By the spring of 2010, higher prices prompted more scrap to come out of the system. Copper rose to about $3.50 in April. Domestic brass and bronze ingot makers were buying on a more limited basis from regular suppliers. Even so, mid-2010 saw another slowdown as Europe entered its slow season and margins were being squeezed with difficult pricing.

In Europe, exports of copper scrap to the Far East also increased dramatically between 1999 and 2008. This occurred at a time of lower local scrap availability in the European Union (EU), creating problems for European refiners. Some in Europe, as well as in the United States, felt that unfair customs regulations, and lower labor and environmental costs had enabled the Asian countries to pay higher prices for scrap over this period. The European economy was only slowly recovering during 2012. High debt saddled much of Western Europe, contributing to a fairly dim outlook for 2013. The continuing fiscal problems, specially throughout southern Europe was creating a sizable drag over much of the economy. Demand for nonferrous metals was expected to be somewhat muted through the first half of 2013, though pricing may be finding a floor (Recycling Today Global, Jan 2013)

Owing to decreased manufacturing levels and other problems, scrap exports from Europe dropped off during 2009. The brass and copper industry in Italy was reported as operating at 60% of capacity (Recycling Today, Dec. 2009). Italy, normally a large importer of copper scrap, had decreased imports to around 148,00 tons in 2011. (see **Table 4**). By September 2010, half the brass industry in Italy had been closed and half were sitting idly by (Recycling Today, Sept/Oct 2010). Some recovery was indicated by the increased Italian scrap imports during 2010 and 2011 (see **Table 4**).

In recent years, the United States has increased its domestic collection and processing of electronic scrap, but U.S. export of low-grade copper scrap derived from electronic products such as computers remained an issue of concern. A report issued in 2011 by the Institute of Scrap Recycling Industries (ISRI) indicated, from a survey of 182 U.S. organizations, that most end-of-life electronics were now being processed in the United States and not dumped overseas.

Even though China was tightening its rules for importing electronics scrap, other poor countries may still be willing to accept these materials. According to some reports (Recycling Today, Feb. 2002), Pakistan had become a bigger market for electronic scrap and used computers. China reportedly applied import restrictions on electronic scrap and in May 2002 instituted a substantial tariff on class 7 scrap. This class includes lower grades of copper scrap such as unprocessed wire and die cast alloyed parts. The tariff may have also been enacted to force the domestic smelting industry to use higher grades of scrap as a pollution reduction measure. China continued to tighten regulations and began in November 2004 to ban all used television sets and other electronic scrap imports in a bid to clean up its environment.

China reportedly reduced the import duty on copper scrap in 2006 and 2007 to promote growth in the metal recycling industry and assist the nonferrous metal sector in its need for raw materials. China reduced the import tariff for copper scrap from 1.5% to 0% in mid-July 2007 (ISRI Friday Report, July 20, 2007). In late 2007, China announced that it would remove import duties on refined copper. The 3% import tax for refined copper was cut on Jan. 1, 2008 (12/28/07, www.recycleinme.com). In mid-November 2005, China also signed the first East Asian trade agreement with Chile (a major source of primary copper) as an important bilateral trading partner.

To maintain adequate supply for the home market, the Chinese Government applied strict controls on the export of copper-based products. In November 2006, the export tax rebate on copper products was cut to 5% from 13% and the export tariff on copper concentrates increased to 10%. Meanwhile, export tariffs on copper scrap, blister copper and electrolytic (refined) copper were also raised. The Chinese Government levied an export tax on nonferrous scrap at 10% from June 1, 2007 (Recycling Today, May, 2007). In September 2007, a huge back up of containers filled with scrap was reported, caused by a crackdown on importers trying to avoid complying with the new duties for scrap. Two months previously, Chinese customs officers launched a major offensive against importers, who had been trying to avoid complying with new duties. There also had been a widespread practice among many Chinese importers of mixing lower content scrap with higher purity material to avoid paying higher taxes. Duties are applied to the copper content, so a reduced copper content means lower duty. Another problem area is “mixed” loads of scrap where the high value copper is loaded in front of the container and lower grade scrap is loaded in back.

In mid-summer, 2009, a slowdown in customs clearance in Guangzhou, China was reported as having a big effect on domestic importers of copper scrap. A large number of containers were stranded at the ports. The number of containers were reported as exceeding 2,000 at each port (Recycling Today, Aug. 2009). The government was introducing new procedures to standardize and improve imports of metal scrap. Inspection was intensified to prevent violations of price deception, lower bidding and omission of proper reporting. In October, 2010, China for the first time in 3 years raised interest rates, reducing loan volume by an estimated 22%. China felt its strong economy was becoming inflationary. This caused a slight correction in metal prices, but the upward trend was still intact and continued through much of 2011.

In 2010, China published Notice 32, which required separate packaging of different materials. In addition, China’s General Administration of Quality Supervision, Inspection and Quarantine (AQSIQ) registration process was defined for overseas suppliers on July 1, 2010. Certification to ISO 9001, Recycling Industry Operating Standard (RIOS) or an equivalent quality assurance standard would be required for first time applicants for an AQSIQ license. (Recycling Today 7/30/2010).

Export controls on scrap (such as those imposed in China, Russia and Ukraine) have been commonly applied in the world during periods of scarce supply. Historically, copper base scrap has been a highly prized raw material, especially in those nations with scarce natural raw material sources for copper. European scrap export controls during the 1980’s were seen as affecting the U.S. copper industry unfairly. As a result, the U.S. Copper and Brass Fabricators Council (CBFC), representing domestic brass mills submitted a 301 petition concerning the trade of copper and zinc scrap to the U.S. Trade Representative on Nov. 14, 1988. The application was not successful in developing U.S. controls. Domestic semifabricators asserted that European (EEC) and Brazilian brass mills had been able to maintain materials cost and product price advantages since the middle 1970’s, largely through export controls on the flow of copper and zinc scrap. However, in 1992, the EC terminated the export controls on copper and copper alloy scrap. Several Asian nations and Russia 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.

In April 7, 2004, the CBFC and Non-Ferrous Founders Society filed a short supply petition under the Export Administration Act, requesting imposition of monitors and controls on the export of copper-based scrap. ISRI and its members were opposed to the petition as they did not want exports restricted. The Commerce Department issued its decision in August 2004 citing no need for controls or monitoring of copper-based scrap exports. See Appendix A for a more complete discussion.

The voluminous paperwork requirement the Chinese government implemented for the importation of scrap also was viewed as an impediment in early 2004. Some scrap recyclers and brokers labored to comply with export regulations being put in place by the Chinese Government’s Administration of Quality Supervision Inspection and Quarantine (ASQIQ) (Recycling Today, August 2004). The significant load of paperwork required had an initial deadline set at

July 1, 2004 in order to be registered or permitted to ship scrap to China. Not only the information requirement was tedious, but some information such as floor plans and other operational details of the exporting company, required to qualify for the CCC mark system, was objectionable. The suspicion existed that the Chinese importers were determined to help themselves to efficient production facility know - how through this information.

Another problem with copper scrap exports to China revolved around China's handling of its VAT (Value-added Tax). The VAT tax on copper waste and scrap was 17% in 1999 (www.chinavista.com). The same tax applied to refined copper imports. Chinese copper scrap importers and Chinese customs officials were accused of manipulating the VAT to the detriment of U.S. industries. Chinese importers received a rebate on VAT and then further manipulated import documents to gain greater VAT refunds. These actions caused global copper scrap prices to rise because Chinese importers could pay more for scrap, but still make a profit. U.S. manufacturers that use scrap were faced with higher prices for raw materials, thus increasing their production costs. Finished products from China were subsequently undersold in U.S. markets (US Info.State.Gov. 10/7/2003).

In December, 2008 (Recycling Today, Dec.2008), China's Nonferrous Metal Industry Association (CNMIA) announced that the government was considering canceling the 17% VAT tax on scrap imports. The CNMIA hoped the move would help companies cut costs as the economy slowed.

Pegging the yuan to the dollar was also reported as a deliberate strategy to support Chinese industry and boost exports. China's undervalued currency was acting as an additional trade barrier to U.S. exports and an unfair subsidy for all Chinese exports (Congressional-Executive Commission on China, Sept 24, 2003).

Some observers have used problems in Chinese trade regulations to explain the tremendous differences between reported world statistics for copper scrap imports and exports. (See **Tables 3 and 4** in this report for differences.) Among importing countries, the import statistics for China seem to be the most suspect. Copper scrap imports are over reported because some other industrial recycle material has been claimed at customs as copper or copper alloy scrap. Some believe this may be the result of the lower copper scrap import duty relative to other industrial wastes. Some traders may be trying to avoid the higher import duty by importing non-copper industrial waste as copper scrap. Imports of scrapped electrical domestic and office goods also may have been imported as copper scrap, since these have been prohibited since Aug. 15, 2002.

Ukraine's parliament gave approval to a bill in late 2006 that would lift the ban on exports of scrap nonferrous metals. An export duty of 30 Euros per metric ton would apply the first year the bill is in effect and would be gradually reduced to 15 Euros per metric ton over the next 5 years. The duties would start when Ukraine joined the World Trade Organization. (Recycling Today, 11/30/06). Export taxes are not the only trade barrier that Ukraine maintains. Ukraine does not allow the export of scrap metal products unless exporters are properly registered with the Ministry of Economy and are issued an export license. Export registration fees also obstruct trade in scrap metals. Until recently, the fee for export licenses for ferrous and non-ferrous scrap was five times higher than the ordinary customs clearance fee of 0.1 percent of the value of the export contract. Despite Ukraine's pledge to reduce its high export taxes in 2006, political divisions leading up to the 2010 presidential election, coupled with the substantial influence of industry leaders, have slowed progress towards trade liberalization and deregulation. In the face of its commitments to eliminate or reduce export and import bans and tariffs across a wide variety of industries, and just days after Ukraine became a working member of the WTO, the Ukrainian parliament passed a major bill containing export and import duties that were in direct violation of WTO agreements (Wiley Rein, 2008).

In late 2009, the Bureau of International Recycling (BIR) was reported (Recycling Today, Aug. 2009) as pressing India to make changes to its requirements for the import of recyclables. Imports were being impeded by the requirement of pre-shipment inspection certificates. The new Indian rules restricted imports to end users and thereby excluded traders. This was a major issue for trading companies and their business associates, who were seeking amended rules.

World Production and Trade in Copper Alloy Ingot. 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 nonferrous foundries, brass mills, steel mills and other parts of the world's manufacturing industry are dependent on the special alloys produced by these essential-processing plants. Because the ingot makers and associated foundries of the world are heavily reliant on scrap, especially old scrap from returned manufactured and used products, it is important to put this industry in world perspective.

The United States is a world leading producer of copper and copper alloy ingots and foundry products from scrap (see **Tables 5A, B and C** and **Table 10**). The United States produced 254,000 tons (23%) of world nonferrous foundry products in 2002 , but only 194,000 tons in 2010, about 12% of world total. In 2009, Italy (4.2%), Japan 5.3%) and Germany (5.4%) are also significant producers of nonferrous foundry products. China (42%) has increased foundry production significantly since 1999, producing more than 600,000 tons per year since 2008.

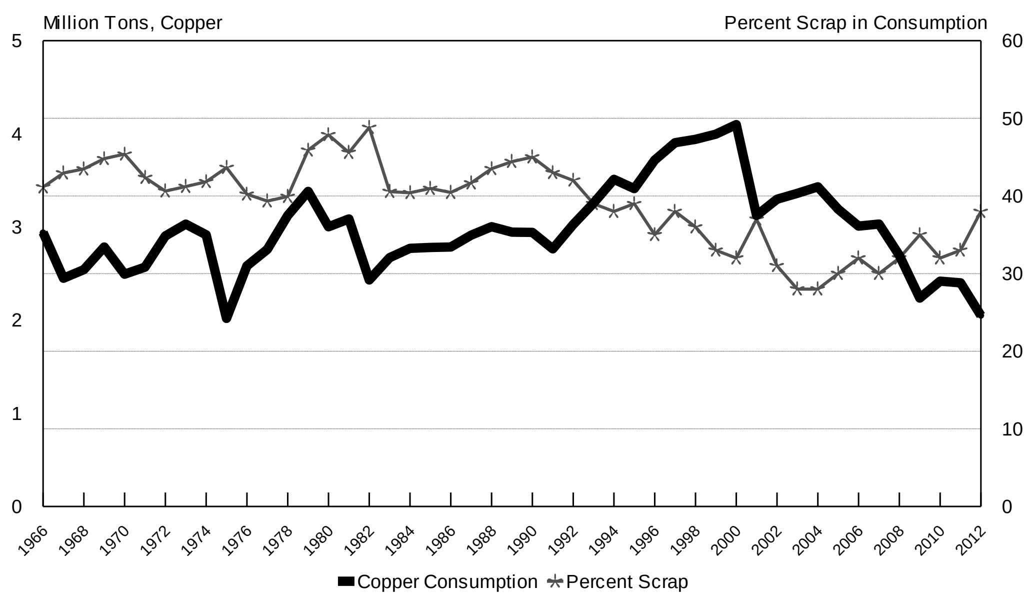
The United States produced 27% of the total world ingot production of 438,000 tons in 2008 (See **Table 5)**. Nearly 80% (349,000tons) of the world's alloy ingot production, of around 438,000 tons per year in 2008, was exported (see **Table 5C**) The ICSG Copper Bulletin reported world ingot imports at 248,000 tons and exports were 310,000 tons in 2010. During 2011, China (15%), Germany (13%), Italy (6%), Taiwan (4.3%), Canada (1.8%), and France (3.4%) were the largest importers of ingot. Since 1999, China has decreased its imports of ingots from around 63,600 tons in 2005 to around 39,600 tons in 2010..

The leading exporters of ingot in 2010 were the United States (35,700 tons), Japan (21,800 tons), Germany (12,300 tons), the United Kingdom (16,900 tons), South Korea (21,200 tons), and Spain (16,000 tons). Over the past 8 years, U.S. ingot exports were between 29,000 tons and 40,000 tons, reaching a peak in 2007. U.S. ingot imports decreased markedly from about 23,000 tons per year in 1999 to around 4,000 tons per year in 2003, but increased to around 10,000 tons in 2006, and 12,100 tons in 2010. Ingot imports have decreased generally in every region of the world with exception of the Middle East and Asia, which has tripled the amount of alloy ingot imports since 1999. China, in particular, increased ingot imports from 28,000 tons in 2001 to 39,800 tons in 2010 (See **Table 5B**).

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 most end use sectors of the economy. According to the Copper Development Association (CDA),4,977 million pounds (1.195 million metric tons) of copper and copper alloy mill products were shipped for domestic 2011 end-use markets. The products were distributed in sectors as follows (electrical is distributed through all end-use markets): Building Construction (44%), Electrical and Electronic Products (20.4%) Industrial Machinery and Equipment (7.4%), Transportation Equipment (16.4%) and Consumer and General Products (11.8%). In 2011, copper wire mill production of 2,721 million pounds was much below the high point of 4,580 million pounds for 1999. Though smaller in total tonnage than the electrical and electronics uses of copper, the copper powder and chemical industries also provide important products.

Figure 5. U. S. Total Copper Consumption 1/
Including All Scrap, 1966 to 2012



Source: U.S. Bureau of Mines and U.S. Geol. Survey.
1/ Total Copper Consumption = Primary refined, secondary refined + copper in direct melt scrap.

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 anti-fouling 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. See **Tables 10, 10A and 10B** in this report for production and trade in some of these products.

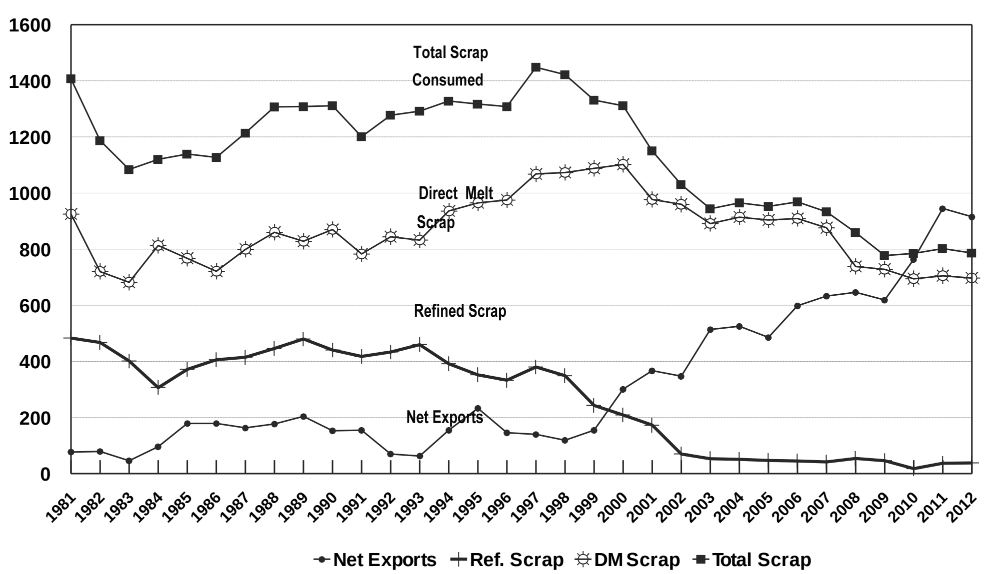
U.S. Consumption of Copper. In the United States, copper derived from both primary (mined) and secondary (recycled) sources is consumed at industrial production plants. U.S. industry import reliance for copper in the last 14 years has increased from less than 1% of domestic consumption in 1991 to over 48%, and 32% in 2003 and 2008, respectively. In 2006, a record level of refined copper, around 1.1 million tons, was imported into the United States. In excess of 600,000 tons of refined copper has been imported by the United States each year 2008- 2010. This compares with only 343,000 tons of refined imports as recently as 1993. Copper derived from domestic mines and as well as from domestic scrap sources has steadily decreased in recent years as imports of refined copper have increased. As copper consumption at U.S. plants dropped further in 2008, however, the rate of refined imports also declined. US refined imports for 2011 were only 297,300 tons. U.S. refined copper consumption for 2012 was estimated to be 1.79 million tons. (See **Table 6**)

Recycled copper used to make semi fabricated products may be derived from (1) scrap that is first refined before use (*refined scrap*), or (2) from copper and copper alloy scrap that can be directly melted at the time of use (*direct melt scrap*). Total refined copper, from both primary and secondary sources, consumed by the U.S. industrial sector in 2011 was a about 1.76 million tons, according to the U.S. Geological Survey (see **Table 6**), and considerably lower than the high point of 3 million tons in 2000. Of the total refined copper consumed in 2010 only 143,000 tons (or 2%) was derived from scrap processed at a refinery (see **Table 7**). This is down considerably from 480,000 tons (25% of refined consumption) of copper from refined scrap in 1989. In addition, the United States industrial sector consumed about 705,000 tons of copper in 2011 derived from direct melt, copper-based scrap (See **Table 2C**). Total copper from scrap (refined plus direct melt copper base scrap and from other than copper-base scrap) amounted to about 742,000 tons in 2010. The range in annual average copper content for direct melt copper-based scrap in the United States has been 83% to 85% of the gross weight over the past 10 years, according to an analysis of data provided by the U.S. Geological Survey.

Traditionally, scrap used in refining and smelting has been made up mostly of "*old*" scrap, while the

Figure 6. Trends in U.S. Net Exports and Consumption

of Copper in Scrap[1/], 1981 - 2012



Source: US Geological Survey .
1/ Revised to include copper from copper- base and other-base scrap.

purchased direct melt scrap used by brass mills is mostly "*new*", customer-returned scrap. The rate of recovery for "*old*" scrap copper in the United States is related to the variability in the copper price, the domestic industry demand for this type of raw material, competition from exporters, and the availability of primary copper. The small amount of U.S. secondary refined copper in 2009 was 55% derived from old scrap sources and 45% from new scrap sources, according to the U.S. Geological survey (2009 MYB, Table 7). The amount of secondary copper in U.S. refinery production in 2009 was only 46,400 tons out of a total 1.08 million tons refined copper, and only 18,000 tons (revised down) of a total 1.054 tons produced in 2010 This was down considerably from around 480,000 tons of refined copper derived from scrap in 1989. The significant decrease observed since 2000 was the result of the gradual and complete closure of all of the secondary smelters in the United States. Refer also to **Figure 8** for complete statistical details on smelter capacity changes over this period.

Ingot making also uses large quantities of copper from "*old*" scrap (84% derived from old scrap in 2009). Copper from old scrap only made up 16.4% of total copper recovered from copper-base scrap in 2009. (USGS, 2009MYB, Table 7). Some copper tube mills may use a higher proportion of old scrap when purchased from dealers as good clean, No. 1 copper scrap. It is many times impossible for a mill to determine whether the scrap is "*old*" or "*new*" in its origin after it has been chopped and processed by an intermediary.

U.S. scrap statistics shown in **Table 6,** represent consumption, or copper scrap usage, as reported at industrial plants, and thus, do not reflect the total amount of material collected at scrap dealers and traders. An increasing amount of U.S. scrap collected has been exported in recent years. Using an assumption that most internationally-traded copper scrap may be derived from used materials, the addition of U.S. scrap exports to *old scrap* reported as consumed by the industry will provide an estimate of total old scrap recovered in a particular year. This also assumes, of course, that most *new* scrap is returned to the domestic mill of material origin and is not also sold abroad.

Old scrap recycling and its contribution to U.S. total copper derived from scrap has fallen from 43% in 1992 to 18% in 2010 (see Table 6). U.S. recovery and consumption of "*old*" scrap was highest during WWII, the 1950's and 1960's, which were years of high copper demand and good prices. Old scrap recovery was also high during the Great Depression years, when mine production was severely curtailed. As a percent of total copper consumed, (see **Figure 5 and Table 6**) copper from scrap has declined from 49% since the early 1980's to around 30% in 2007. Despite the robust U.S economy over much of the period 1994-2007, domestic use of copper from old scrap and refined from scrap, in particular, experienced a significant decline (See **Tables 6 and 7**). For example, copper from old scrap recovery was as high as 613,000 tons in 1980, but was only about 143,000 tons in 2010. Exacerbating the decline in collection, processing and consumption of old and low-grade scrap in the United States has been the closure of essential U.S. smelting and refining plant capacity. All U.S. copper scrap smelting plants, most scrap refining plants and some ingot makers have closed owing to the higher costs associated with tight environmental regulations, increased worker safety standards, and the competitive pressures from increased export of scrap.

Scrap is a necessary raw material 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 during the process of new manufacture. Customer-returned new scrap tends to be recirculated to the plant of domestic origin. In 2009, about 98% of copper-based scrap consumed at brass and wire rod mills was new scrap, according to the U.S. Geological Survey (2009 MYB Table 11). The purchased scrap market gradually increased in the United States through 1997, as shown in **Table 6** and in **Figure 6.** This increase has been presumed to reflect the steadily increasing industrial base, from which more customer return scrap is generated. It was also the result of the gradual decrease in processing capacity for old scrap. Since 1997, however, total scrap use has declined, coincidental to the significant increase in U.S. scrap exports (**Table 3** and **Table 8**). Lower copper prices (see **Table 1),** associated with an increase in primary copper supplies until 2003, also contributed to decreased use of scrap Though higher copper prices generally have been the case since 2004, significant foreign competition for scarce domestic supplies continued to impact copper availability for domestic firms through 2010. A general decline in copper-base manufacturing plants has also impacted domestic return scrap from this source since 2001.

Even while the brass and wire mill sectors of the U.S. secondary-based industry were expanding capacity, mill consumption of scrap copper relative to primary copper was decreasing. 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 1980's, the contribution of copper from scrap to domestic copper usage gradually has been decreasing to around 30% in 2007 (see **Table 6**). Copper prices have escalated since 2003, but a coincidental increase in US industrial scrap consumption did not accompany the higher prices. Instead, U.S. scrap exports steadily increased over the period.

Copper consumption from scrap, as shown on **Table 6**, does not include the significant amount of *run-a-round* or *home scrap* that is generated at every plant. Between 15% and 40% of raw material consumed remains in the production cycle of brass and wire 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 forms an essential part of the semis production cycle. Unfortunately, few statistics are available to quantify run-a-round material.

U.S. Trade in copper and copper alloy scrap.
Copper and copper alloy scrap of all types has significant intrinsic value for the manufacturing industries of both the United States and the World. 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. As a consequence, recycled materials form a significant part of the U.S. copper exports and imports. This has been particularly significant in recent years since the manufacturing bases of the Asian countries have been growing and demanding more raw materials. The domestic market for scrap is still as large as exports though exports have been growing at a fast rate. U.S. industry consumption of scrap has decreased from around 1.77 million tons in 1997 to about 930,000 tons in 2010(see T**able 17**). Net exports of copper scrap for 2011 were slightly higher at 944,890 tons.

The United States is a significant exporter of copper and copper alloy scrap as shown on **Tables 3** and **8**, and has been the world's largest exporter of copper-based scrap since 1999. U.S. net exports of scrap in 2011 were estimated at 944,890 tons, up from a net export of around 62,700 tons in 1993, and 140,000 in 1997. The most significant U.S. scrap export destinations are in Western Europe and Asia. Although the amounts have been declining since 1997, the United States also imports around 100,000 tons per year of scrap. The most important U.S. import sources of copper and copper alloy scrap in 2008 continued to be Canada (40%) and Mexico (35%). Scrap exports generally have been increasing since the early 1970's. Exports suddenly doubled between 1999 and 2000 (see Table 8), and have remained well over 500,000 tons annually since that time. Lower scrap imports and exports in 1996 through 1999, were the result of the worldwide depressed copper prices, the strong U.S. dollar and a temporary setback in Chinese imports during the early part of this period. The lower scrap price and stronger dollar also combined to make U.S. scrap scarce for domestic buyers, as well as expensive for foreign buyers over that short (1996-1999) period of time. Since 1999, however, foreign buyers (principally China) have managed to outstrip local mills in competition for scarce purchased scrap.

U. S. copper and copper alloy scrap exports set another record in 2011 reported by the USITC (data webb, Nov 2012)at 1.239 million tons (see **Table 8A**). Since 2005, U.S. trade statistics have tracked the type of scrap in its export statistics, as shown on **Table 8A**. While unalloyed scrap exports remained around 350,000 tons per year until 2011, alloyed and mixed scrap exports have escalated from around 300,000 tons in 2005 to 738,730 tons in 2010. The bulk (80%) of this mixed copper and copper alloy scrap has been destined for China (USGS, Dec 2008 MIS, Table 17). In 2012, unalloyed scrap exports reached an estimated 484,000 tons.

In lieu of scrap, primary copper at bargain prices between 1998 and 2003 provided a ready substitute in the United States for those who could utilize it. However, owing to the types of furnaces used, size of charge needed, and chemical requirements for certain alloys, this was not possible for all secondary metal users, and the market became difficult for these industries. Those mills and ingot makers that were dependent upon direct melt alloy scrap were highly affected by the increased U.S. exports.

The trend in U.S. net scrap exports appears as a mirror image to the trend of copper recovered from refined 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 1980's 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 nomenclature, 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 on **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 1980's to reach 28,110 tons in 1995, but then decreased to as low as 2,950 tons in 2002. Since 2004, copper ash and residue exports again began to increase and, in 2007, and 2011 were 62,150 tons and 38,300 tons, respectively. Imports of copper-containing ashes and residues have been decreasing; from 5,400 tons of copper content in 1988 to less than 700 tons in 2002 (see **Table 9**.). Imports of ashes and residues increased slightly since 2003, reaching 8,700 tons in 2007, but were lower at less than 1,000 tons for 2009 through 2011 (**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 (HTS 26201960), exports reached a peak in 1992, but declined through 1999 to 4,500 tons. Exports of zinc ash and residues increased significantly since that time to reach 25,000 tons in 2002, and 13,200 tons in 2004. Zinc residues exports were 9.350 tons in 2010 and 15, 460 tons in 2011, according to ITC reports. Zinc ash and residues imports steadily increased to around 24,300 tons, as measured in contained zinc through 1998, but then decreased to a range of between 14,000 and 17,000 tons until 2005. Zinc ash and dross imports were again higher at 33,750 tons in 2006 but have been lower for the past several years at less than 1,000 tons annually (See **Table 9**)

U.S. Export Controls on Scrap. During periods of high military activity and/or difficult economic conditions, copper and copper-base scrap has been in such tight demand and scarce supply that U.S. export controls and other restrictions have been placed on its use. Tight supply periods occurred in the 1960's and early 1970's, occasioned not only by requirements of the Vietnam War, but also by the effects of long copper mine labor strikes during the late 1960's. To compensate for the severe shortages, more than 1 million tons of copper from the National Defense Stockpile were released. In addition, during the early 1970's, price controls were briefly implemented. A review of the historical events surrounding the use of export and price controls relative to the copper market and the need for copper scrap may be found in **Appendix A.** 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 from Scrap

Wrought copper and copper alloys. The making of brass and bronze wrought metal alloys by 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 fabricated into products such as sheets, tubes, rods and pipes. Wire rod mills produce continuous cast, pure copper rod for making wire that is 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 2011, the combined semi fabricate production of brass and wire mills amounted to 2.2 million tons of copper and copper alloy products. (**Table 10**). This was somewhat lower compared with 3.4 million tons of semi fabricate products produced in 2004 (**Table 10**), and considerably lower than the peak of 3.9 million tons reached in 1999-2000. The current lower production rate is the result of continued U.S. industrial retraction that has been experienced since 2000. About 16 brass and tube mills have closed in the United States since 2000 (see **Table 13A**). Two main factors contributed to tubing company demise: (1)increasing use of plastic pipes for construction applications and (2) increased imports of copper and aluminum tubing from China, Canada, Mexico and other countries. More recently, a large wire rod mill closed in Illinois.

U.S. copper consumption statistics, as shown in **Table 6**, are reported from brass and wire mill activity. These statistics do not represent the entire U.S. population's consumption of copper in finished products. The statistics for the domestic population would include copper contained in finished and semi fabricate imported goods. To determine a complete U.S. societal copper consumption estimate, copper in imported finished goods also should be considered, such as copper in imported cars, refrigerators and other goods. These statistics are difficult to estimate, and is beyond the scope of this paper. Judging by the volumes of products scrapped, however, it is suspected that the U.S. society remains the largest consumer of copper in the world, regardless of where the product originated or how it was used.

Brass and Bronze Ingots. Ingot making was a critical U.S. industry during World War II, comprising a basic support for the essential brass mill and foundry production needed for the war effort. This was so much the case, the Defense Production Act required that, among all other Government copper surveys, only the ingot maker, 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 were dependent upon domestic production from ingot makers and foundries.

Ingot production ranged from 300,000 tons to 380,000 tons of ingot in the 1960's and 1970's. However, ingot production has been less than 200,000 tons in the United States since the 1980's. According to the U.S. Geological Survey, ingot production (including master alloys) in the United States was 125,000 tons (see **Table 10**) in 2008, but was down to 108,000 tons in 2011. U.S. ingot exports have increased significantly in recent years to around 28,000 tons in 2008 and 35,700 tons in 2011 (see **Table 5C**). U.S. ingot imports also increased to around 9,000 tons in 2008, and reached an estimated 15,400 tons in 2012.

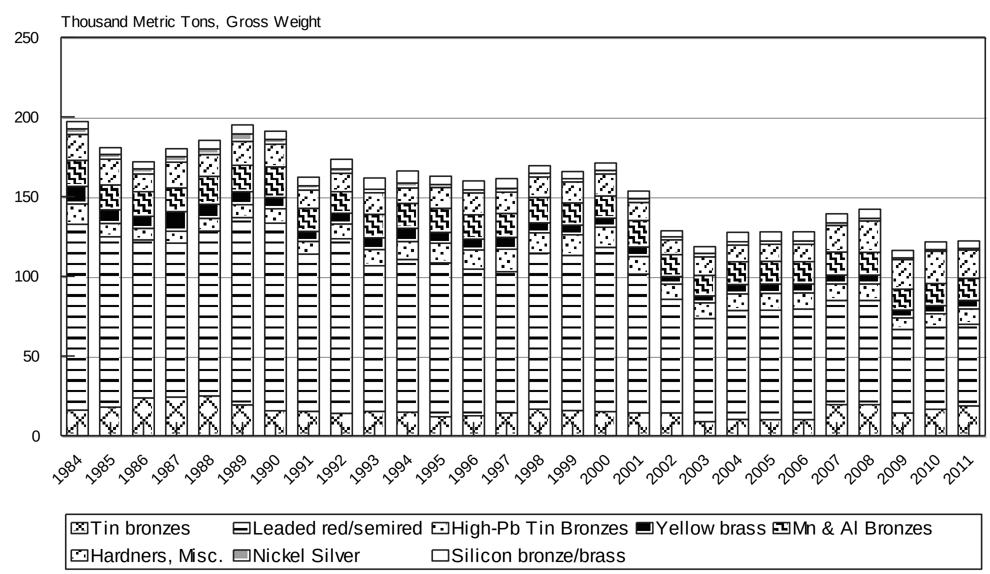
Ingot makers produce a wide range of cast copper alloys for the nonferrous foundries. Ingots weigh about 30 pounds each when cast, being of a small enough size to suit foundry furnaces. Production trends for several broad ingot groups are shown on Table 10 . The most important of these are the red brass, bronze, and yellow brass groups. **Figure 7** clearly shows the gradual decline in U.S. ingot production since the middle 1980's with another sharp drop since 2000. The leaded and semi-leaded red brass and the tin bronze categories of ingot seem to show the most volume decrease since the late 1980's. A decrease in hardeners and master alloys also has occurred since 2000. The general ranges in ingot compositions are shown on **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 have been 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 (ASTM) and the Society of Automotive Engineers (SAE). This system designates each alloy by 5 digits preceded by the letter C. The UNS system is administered by the Copper Development Association Inc.(CDA). There are about 370 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:

<u>Coppers:</u> Metals containing at least 99.3% copper. There are 44 numbered coppers, including oxygen-free, tough-pitch, and deoxidized varieties.

Figure 7: U.S. Copper Alloy Ingot Production

By Ingot Group, 1984-2011



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

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 5 families of cast brasses. EnviroBrass I, II and III were recently introduced in 1999 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 a melt. Master alloys are produced as 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, 39,000 tons of refined copper was produced from scrap in 2011 down significantly from 460,000 tons produced in 1993. Refined products formed include cathode, ingots, billets, shot (small metallic pellets), wire bar and continuous cast rod. In addition, only about 1,000 tons of copper powder was also produced from scrap in 2009. **Table 12** shows the manner in which copper is extracted from scrap and the form of recovery from 1999 through 2009. Owing to the few plants actually fire-refining, this data is currently withheld by the reporting agency (U.S. Geological Survey), but included in the total refined number. The historical production of refined secondary copper in the United States for the years 1968 through 2011 is shown on **Table 7**. The decreased recovery of secondary copper since 1980, from 30% to 3% in 2010 can be observed on **Table 7**.

Copper Anodes for Plating. Copper anodes are produced by ingot makers and foundries in several shapes designed for ease use in plating. Copper anodes that contain phosphorus are designed for use in copper sulfate plating systems. Pure copper anodes are used in copper cyanide and other alkaline plating systems. Selecting the correct anode for plating depends on the following characteristics: Anode area and copper concentration; the size and shape (balls, nuggets, bars), the potential for bridging (caused by small baskets and large nuggets), sludge build-up, the grain structure of the anode, the phosphorus content and lastly, the preparation of the anode (cleaning).

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 black copper 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, provides a mildly reducing condition, and facilitates 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, copper sludge, or from the process waste liquors associated with refining copper, copper etchants, brass pickle solutions, and other metal processing. 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.** Trade in these products are shown in **Tables 10A and 10B**.

According to the U.S. Geological Survey, copper sulfate production was down to 22,400 tons in 2009. This continues the significant decline in production that is down from 33,200 tons in 1989, and from about

55,000 tons produced in both 2000 and 2001. A copper sulfate production facility closed during t2004 when Griffin Corp closed its secondary chemical plant in Texas. In 2006, Phelps Dodge started a new primary leach, 40 million- pound, copper sulfate plant at Sierrita in Arizona. Exports of copper sulfate have increased since 2005 to around 8,000 tons (gross weight) in 2010. Imports of copper sulfate have decreased slightly over the same period, from 56,000 tons in 2004 to about 42,000 tons in 2011 (See **Table 10B**)

Copper powder production from scrap has ranged between 8 tons to 11.7 thousand tons in recent years, but was about 600 tons in 2009 (USGS 2009 MYB). A major decrease in production occurred in 2003, according to data published by the USGS (See **Table 12**). Even so, total copper powder exports (HTS 740610-20) were as high as 12,250 tons in 2005 (See **Table 10A**) , but have been decreasing since this time. Total copper powder exports were around 8.500 tons in 2011. About 4,000 tons of copper powders (both flakes and non-lamellar) were imported in 2011, but had been as high as 4,600 tons in 2006.

According to Queneau and Gruber (1997), about 13,320 metric tons of contained copper per year was being extracted from copper-based scrap as chemicals each year during the 1990s. The USGS (2008 Minerals Yearbook) reported copper recovered from scrap in chemical compounds as 5,000 metric tons in 2008. This copper was produced as copper oxides and hydroxides, copper sulfates and other copper chemicals extracted hydrometallurgically from copper-bearing scrap. In addition, a small amount of low-grade cathode is produced from electrowinning pickle liquors and sludge. According to U.S. ITC trade data, exports of copper oxides and hydroxides have been increasing since 2003, and were almost 28,000 tons per year in 2010 and 2011. Destinations were China, Canada, Korea, Sweden, Singapore, Portugal and the United Kingdom. Imports (see Table 10B), on the other hand, were extremely small. Copper hydroxide imports were less than 1,000 tons per year between 2007 and 2010. This would indicate that domestic annual production of oxides and hydroxides was at least 28,000 tons in 2010 and 2011, if all production was presumed to be exported.

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, slag 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 byproducts other than copper, such as precious metals, tin, antimony, lead, nickel or zinc, for example, which can be recovered and upgraded.

Copper slag resulting from fire-refining can run up to 65% copper, making them highly desirable and marketable products. This is especially true of slag resulting from fire-refining no. 1 scrap, where there are few 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 slag has been used for many non- metallurgical purposes when they are free of deleterious elements. Among other uses, slag has been used for the production of lightweight 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' sludge and residuals for copper, zinc, selenium and tellurium and other metals. A wide variety of metals and other products are recovered from chemical waste generated by various metal working industries, such as printed wire board manufacturers, electroplating shops, chemical milling operations, brass mills, and rotogravure plate producers. Problems associated with landfill disposal of waste materials are avoided by taking advantage of the benefits of recycling at these hydrometallurgical plants.

Waste treatment plant sludge 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. About 86% of U.S. recycled zinc in 2004 (USGS 2004 MYB, Table 9) was derived from the new scrap generated mainly in galvanizing and die casting plants and at brass mills. Recycled zinc was used for the production of zinc metal and alloys, and zinc oxide, zinc sulfate and other chemicals. The Zinc Corporation of America's plant in Monaca, PA, 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 to 61% zinc, 2 to 8% lead, 5% to 15% tin, 0.5% copper, 0.1% antimony, 0.1 to .5% chlorine, and some unburned carbon. When high (about 65% zinc) in zinc and low in lead (less than 3% Pb), 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-based alloys from scrap, notable amounts of other metals, such as tin, antimony, lead, zinc, nickel and aluminum are also recovered as part of the scrap consumed. According to the 2011 USGS Minerals Yearbook, Table 9, brass and bronze ingot production from scrap resulted in the recovery of 89,200 tons of copper, 3,800 tons of tin, 5,360 tons of lead, 9,310 tons of zinc, 106 tons of nickel and 13 tons of aluminum. Secondary metals content of brass mill products were estimated to be 578,000 tons of copper, 1,360 tons of tin, 2,310 tons of lead, and 118,000 tons of zinc, and smaller amounts of other metals. In addition to 41,800 tons of copper recovered at U.S. foundries, 1,090 tons of tin, 564 tons of lead, 1,370 tons of zinc and smaller amounts of other metals also were recovered from copper base scrap sources.

Items that go to the Landfill. While most low-grade residues have traditionally found markets for further processing or use, it sometime 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 being sent to a land fill must pass the USEPA TCLP test (see Chapter 4, this report) before a dumping permit is granted. Even so, at times, the landfilled material can serve 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 were also used in a similar way at some localities.

Some materials, such 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 land-filled 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 ingotmakers ship some spent furnace brick to the landfill, although some have indicated that the material also may be used as road material. Spent brick may also be 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-based 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 (2011 MYB, Table 11)), ingotmakers accounted for 12.6% of total copper recovered from U.S. copper-base scrap consumption in 2011, 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 sheets, tubes, rods, and pipe. Brass, copper tube, and wire-rod mills accounted for 75% of the copper recovered from copper-base scrap in 2011, only 2.5% of which was estimated to have come 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 number 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. Refineries accounted for only 4% of copper recovered from copper scrap in 2011, 49% of which was from "old" scrap.

The U.S. copper industry has undergone significant changes since the early 1980's. The extent of this change in productive capacity is shown in **Figure 8**. Most U.S. reverberatory furnaces closed in the early 1980's 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 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 1990's by Southwire. For several years, Southwire operated both its Carrolton, Georgia and Gaston, South Carolina secondary smelters and refineries. However, in 1995, Southwire closed the Gaston plant to concentrate its recycling efforts at Carrolton. In 1999, Southwire announced its intention to sell its Carrolton plant and, by 2000, had closed both its smelter and electrolytic refinery associated

Figure 8. Trends in U.S. Copper Smelter and Refinery Capacities

(Thousand Metric Tons, Copper)

	1982	1989	1994	2004	2010
Secondary Smelters	315	481	511	0	0
Secondary Refineries	545	315	311	123	123
Reverb. Smelters	1526	474	210	0	0
Primary Flash Smelters	173	868	1315	900	710

with its wire rod plant in Carrolton, Georgia.

In 1996, 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, there were about 23 ingot makers, 53 brass mills, 15 wire rod plants and about 600 foundries, chemical plants and other manufacturers that 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. It soon became a Superfund site (see Appendix B), along with many others of the same era.

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 retained use of its 30,000 ton-per-year fire refinery until 2001. The company now uses cathode rather than scrap as its raw material. The Sauget and Cahokia areas in Illinois were proposed in 2001 to the National Priorities List (NPL) of the Superfund. This site includes wastewater from Cerro Copper Company and the Monsanto Chemical Company (see Appendix B). Though in 2003, there were still five 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 2003. By 2006, U.S. primary smelter and refinery capacity had declined to 700,000 tons (see Table 8) and 2.1 million tons, respectively, owing to permanent closures. Four primary electrolytic refineries and 14 solvent extraction-electrowinning (SX-EW) facilities operated during 2006.

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. In 2001, the smelter at Chemetco in Illinois closed. Chemetco also had been under suit for potential water contamination associated with its operations. The Chemetco site was also added to the Superfund list, but was archived in late 1987. (See Appendix B) 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 the availability of copper from secondary sources.

There continued to be generally a shortage of scrap for fire refining in 2003. Although the fire-refinery at Warrenton, Missouri had closed in 1999 and reopened again in 2000 under new ownership, it was to close briefly again in 2003, but was operating again in 2004. There would appear to be still a large number of nonferrous foundries, but only the strongest of the ingot makers have done well under the difficult market conditions of the past few years. The ingot maker of Lavin & Sons closed at North Chicago during 2003.

Most high-grade U.S. copper base scrap is consumed at brass and copper sheet and tube mills. One copper 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 45 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. One copper rod mill closed in Chicago during 2008.

In 2011, Steel Dynamics Inc (SDI), a Fort Wayne-based steel producer announced plans to build a secondary copper smelter in New Haven, Indiana. This was to be a partnership with the Spanish firm La Farga Group. The joint venture (SDILaFarga LLC) will produce copper with products exclusively from copper scrap. (Recycling Today, Aug. 2011, p. 86) . The plant is expected to be operational by mid-2012.

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:

Ohio (4)	Missouri (2)
Michigan (2)	Tennessee (3)
Texas (1)	Alabama (1)

New York (2)	Oklahoma (1)
New Jersey (4)	Rhode Island (1)
Illinois (5)	Mississippi (2)
Pennsylvania (5)	Connecticut (4)
North Carolina (1)	Iowa (1)
Virginia (1)	Kentucky (2)
Arkansas (1)	

It should be noted that reroll, or redraw mills are not included in the above list. About 16 brass and tube mills have closed in the United States since 2002. See the list presented in **Table 13A**. There are apparently no brass or tube mills remaining in California, Indiana, Rhode Island or Massachusetts.

A Chinese-based company, Golden Dragon Precise Copper Inc., announced it would build a $100 million copper tube mill in Thomasville, Alabama. Construction was to begin in May 2011 and be completed in 18 months. (Recycling Today, Apr. 2011)

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,(2009 MYB, Table 12) about 66,500 tons of purchased copper and copper alloy scrap was processed by the foundry industry in 2009. Foundries prefer some types of scrap, such as No. 1 chopped wire, because of its small size and easy melting. 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. U.S. foundries consumed 58,500 tons of copper alloy ingot in 2009, and 49,500 tons of refined copper. 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, ingotmakers also purchase significant quantities of skimmings, grindings, high-grade drosses and other by-products for their metal content. There are about 21 currently operating ingot makers, down from the 28 counted in 1991. Two plants closed in 2003 and 2004. The active plants 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. ingotmakers are independent, largely family-owned and operated businesses.

Secondary Smelters and Refiners. From a 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, reopening in 2000 under new management, closed again briefly in 2003, but is currently operating. Four fire-refining furnaces are associated with tube and wire-rod plants, making a total of 5 fire-refineries remaining in the United States since 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 uses 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 9 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 maker, brass mills, foundries to final products. The domestic sources for low grade ashes and residues are the processing facilities (ingotmakers, secondary smelters & 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 run-a-round, 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 back to the brass mill casting shop, where 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 ingotmakers 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 run-a-round, 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 2009 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 (2009 Minerals Yearbook and Mineral Industry Surveys).

As a point of interest, it can be noted on the flow sheet that about 2.4 million tons of mill and foundry products equate to about 790.000 tons of new scrap returned for use in 2011. These figures would indicate about a 32% return of mill products as new scrap. Exports on this diagram are presumed to be mostly old scrap, since the amount of old scrap consumed by the domestic industry has decreased significantly in recent years. Most of the facilities that once processed significant quantities of old (end use) scrap have closed and, in large part, this scrap is being exported. Chemical products are generally used and dissipated. Copper sulfate is the only chemical product shown in this flow diagram but other products such as about 25,000 tons per year of copper oxides and hydroxides are also produced and generally dissipated where used. A large proportion of U.S. produced hydroxides and oxides are exported annually. See Table 10A, where about 26,320 tons of oxides and hydroxides were exported in 2011.

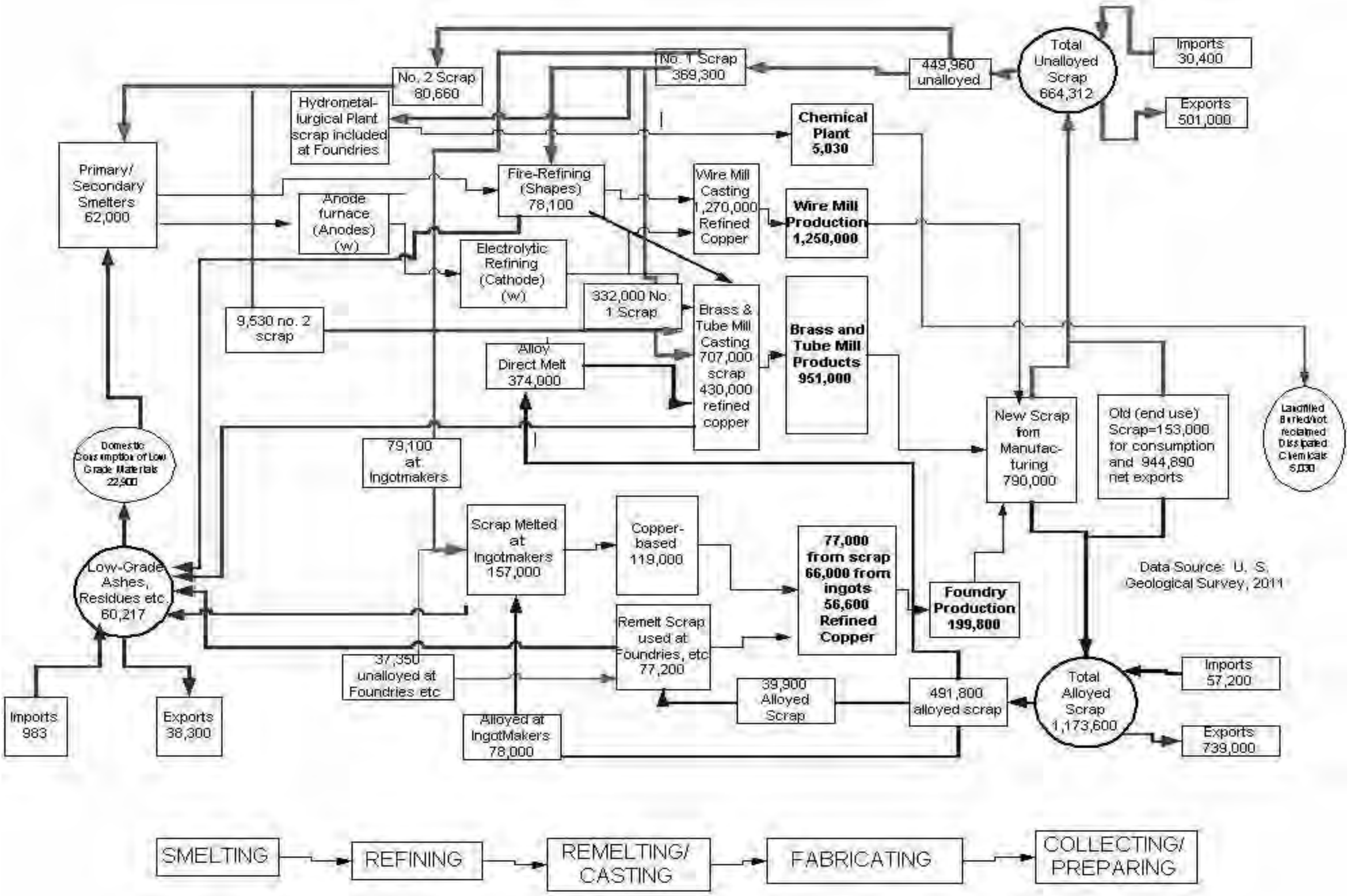


FIGURE 9. U.S. COPPER AND COPPER ALLOY PURCHASED SCRAP FLOW CHART for 2011 (metric tons, gross weight.)

Total U. S. Scrap Consumed: 942,300 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. 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, bus bars, clippings and tube. A relatively new scrap type, derived from aluminum/copper radiators, also is finding use among scrap remelters. As shown in **Table 16**, copper derived from new and old aluminum-based scrap has been increasing significantly since 1980. Copper from aluminum-based scrap increased from about 35,000 tons in 1980 to 71,600 tons in 2007. Copper from all scrap sources increased from 886,000 tons in 1950 to a peak of nearly 1.5 million tons in 1997. Since then, however, copper recovered from total U.S. scrap consumption has dropped to around 774,000 tons per year in 2009. 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 U.S. 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 they are 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 (Standard Industrial Trade Classification) 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 or 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 261.2 (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 is scrap metal as generated by mills, foundries and refineries, such as turnings, cuttings, punchings and borings. Prompt scrap 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.

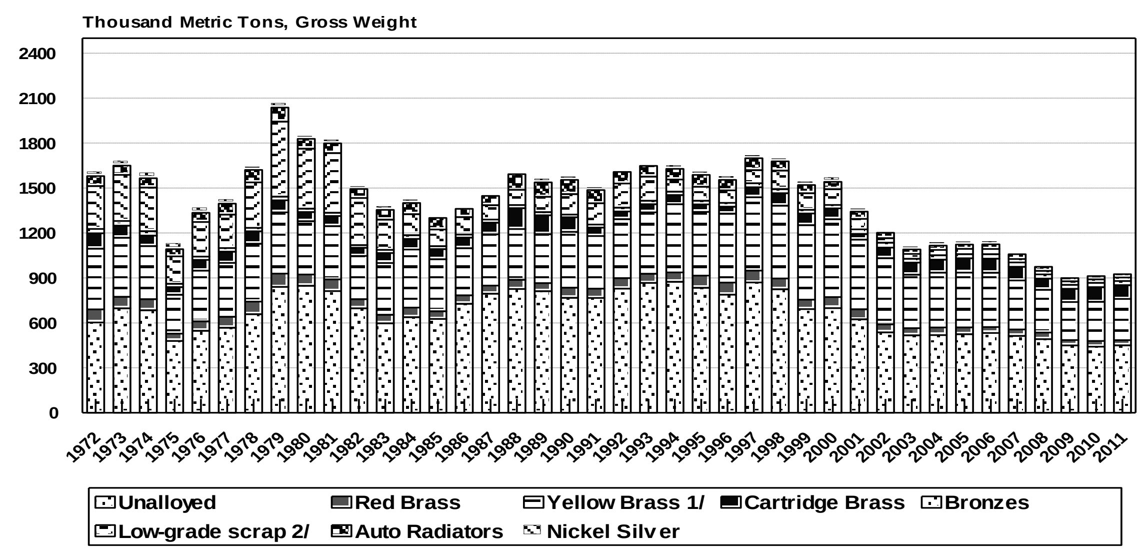
According to the U. S. Geological Survey, the major copper-base scrap types consumed in the United States during 2011 were: No. 1 copper, (39%); No. 2 copper (8.5%); yellow and low brass (29%); automobile radiators (2.4%); red brass (3.7%); cartridge brass (9.7%); and low-grade ashes and residues (2.4%) (see **Table 17B**). A wide variety of other alloy scraps makes up the remaining 7.7%. Brass and copper sheet, wire and, tube mills processed 88% of the No. 1 copper and most of the cartridge cases and yellow brass, while the fire refiners and ingot makers processed 77% of the No. 2 scrap and most of the auto radiators and red brass scrap (USGS 2011 MYB, Table 10). About 20% of the scrap consumed in 2011 was lead-bearing, including auto radiators using lead solder (22,400 tons), red and leaded-red brasses (34.600 tons) and leaded-yellow brasses (128,910 tons).

In recent years the amount of No. 2 scrap reported as consumed by the U.S. industry has been decreasing. The decrease in No. 2 scrap consumed by U.S. industry is related to several changing factors. One such factor is the significant increase in better quality wire and cable recovery by scrap choppers and processors. More chopped wire is converted to No. 1 scrap quality than has ever before been possible, owing both to an increase in this type of activity and to better technology. Other factors included the lower prices of 1998-2003 (**Table 1**) and increased export competition for such scrap in more recent years.

The consumption of No. 2 scrap decreased markedly at U.S. plants since 2002, as a result of secondary smelter and electrolytic refinery closure. Some primary smelters have been accepting limited tonnage of No. 2 scrap. However, apparently, scrap exports were filling the gap left by the loss of U.S. capacity, as discussed in the previous section on international trade. It has been 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 to compensate for the apparent loss, since these materials have not been always specifically defined as to type in trade 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 the 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 the ratio has been deteriorating since that time (see Table 17). In 1990, No. 2 was 45% of total unalloyed scrap consumed. Using 45% applied to 2004 exports (325,000 tons) of unalloyed scrap yields a total of 146, 250 tons of number 2 scrap exported. Recent data indicates that the percent of number 2 scrap exported in 2004 was much higher.

Recent U.S. trade reports have been breaking down scrap types exported. In 2004, the Harmonized Trade (HTS) items were reviewed and revised by the U.S. government. HTS 7404000020 (waste and refined scrap from refined copper) has been broken into two Number 1 scrap categories (HTS 7404000010 and --15), two Number 2 scrap categories (HTS 7404000025 and –30). The results of the new trade breakouts are shown for 2005 to 2009 in **Table 8A** of this report. From this table, it can be seen that Number 2 scrap comprised a large share (about 77%) of the unalloyed scrap exported. Of the total of 500,561 tons of unalloyed scrap exported in 2011, Number 2 scrap comprised 76% of the total. About 381,234 tons of number 2 scrap was exported in 2011. These scrap exports yield an average of about 32,000 tons per month that can be added to the

Figure 10: 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 Minerals Yearbooks and Mineral Industry Surveys, see Table 17B, this report domestic consumption of 3,400 tons per month for a total of 35,400 tons per month of number 2 scrap, compared with an estimate of 51,000 tons per month that was common domestic consumption in 1997 (See **Table 17B**).

A few trends in consumption rates, shown in **Table 17** and in **Figure 10**, 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 31,000 tons and 104,000 tons per year since 1970, with the peak occurring in 1988. That amount has been steadily decreasing since 1988 to the current rate of around 22,400 tons. Auto radiators were reported in tight supply by ingot makers during 2009. Yellow (including leaded-yellow) and low-brass scrap consumption steadily increased through 2000. Since 2000, however, yellow brass consumption has decreased to only 274,930 tons in 2011. The yellow brass 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 remained at a more or less constant rate of consumption, the number of plants using it has diminished, resulting in this statistic 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 94,000 tons, with the 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 slight increase in cartridge brass consumption from a low of 36,000 tons in 2001 to a high of 94,000 in 2006 may be the result of the military activity in Iraq and Afghanistan. In 2002, cartridge brass consumption nearly doubled to 70,900 tons from the low point of 36,400 tons in 2001. Cartridge brass consumption was 86,659 tons in 2004 and more than 94,000 tons in 2005 and 2006. In 2010, cartridge brass consumption was up to 98,200 tons.

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 10**). 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 annually since-2007 has been less than 24,000 tons per year, down significantly from 124,000 tons in 1998. This compares with 161,000 tons per year of low-grade scrap and residues processed in the United States in 1992 and 1993. Consumption of low-grade residues was reported to be 22,900 tons, according to the U.S. Geological Survey (2011 MYB).

Scrap consumption was lowest during the recession years of the middle 1970s, early 1980s, and again in 2001–2003. Some of the underlying causes for these trends are discussed in Chapter 1 and in Appendix A. In particular, lower copper prices and the closure of adequate processing capacity for domestic copper-bearing scrap has been responsible for many of the observed declining usage trends. In recent years, foreign competition for U.S. scrap materials also has been a considerable factor bearing on the reduction in scrap consumption by U.S. industry.

Scrap available for collection was also impacted by the slowdown in domestic manufacturing and construction activity over the period 2007-2011. Construction activity in North America began to taper down after a peak reached in 2007, even before the collapse of markets in late 2008. Since then, construction has dropped severely. New construction contract values were reported (Recycling Today, December 2010) to be $506. 9 billion for the first 9 months of 2007, but was valued at only $314.6 billion for the same 2010 period. This performance has played out in the form of less demolition scrap and less scrap from new construction or renovation projects over this period.

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 85.3 million tons by 2012 (See Table 6A) Of this amount, 56.6% (47.5 million tons) consumed 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 2011, (USGS, 2011MYB, Table 6) recycled copper was derived 81% from purchased new scrap generated in the process of manufacture and only 19% from old scrap derived from used products. Copper from scrap recovery exceeded l million tons per year in 1965 and continued to be above this level through 2002, dropping to 800,000 tons in only one year (1975). Copper recovered from scrap has been well below 1 million tons since 2003 (**Table 6**).

According to the U.S. Geological Survey, a total 802,000 tons of copper was recovered from copper base and non-copper-base scrap in 2011. Purchased new scrap (Table 7, 2011 MYB) derived from fabricating operations yielded about 618,000 tons of contained copper, 89% 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 semi fabricates. Secondary materials that require minimal processing commonly are called direct-melt scrap. In the United States, direct-melt scrap provided about 705,000 tons (**Table 2C**), in 2011. New scrap made up about 27% of U.S. apparent consumption of copper from all sources (primary and recycled) in 2011 (see **Table 6**). Copper in old and new scrap together comprised about 33% of U.S. apparent total copper consumption in 2011.

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 also should be emphasized that this number reflects only the marketed component of this material as it is consumed, it does not count the same material as it is generated and reused as home scrap. It also does not include exported materials.

The 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 low-grade scrap shipments are estimated to have ranged between 31,000 tons and 169,000 tons gross weight per year over the last 17 years (**Table 9**). Copper content of this material ranged between 11,000 tons and 60,000 tons per year. This is the approximate size of the purchased scrap market within the low-grade copper scrap category. 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, especially since 2001. This coincides with the shutdown of US secondary smelters, but is also, In part, a result of secondary plants recycling more of this type of material internally where possible. New production methods that have been implemented specifically to cut down on the volumes of residues created have also been responsible. 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 severe drop in domestic market consumption of low-grade reflected the closure of the last U.S. secondary smelter in 2001.

The data in **Table 17** show a distinct reduction in U.S. consumption of low-grade material as purchased scrap beginning in the early 1980s. Reduction in the use of low-grade material for industrial feed coincides with several events over the period: (1) capacity cutbacks and decreased use of reverberatory furnaces by the primary copper industry, and (2) 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 slag are currently exported or consumed by 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, and only 35,000 tons per year since 2001. 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**, for 1998 is similar to the total low-grade, purchased ashes and residues scrap data tracked by the U.S. Geological Survey (see Table 17B). 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 was 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 in this survey 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 was 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. l 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 slag, 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 depending upon its metal content, may also be reprocessed in the home plant, sold to other smelters 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, 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 generally 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 being recovered today is 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 it is generated, 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 copper (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 (**Table 6**).

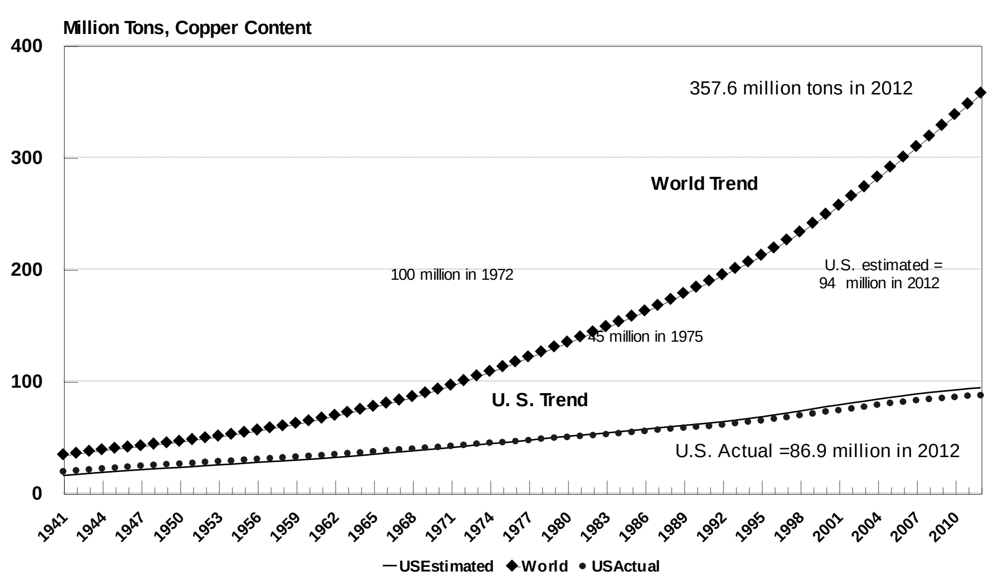
The current downward trend in scrap copper consumption was coincidental to the significant increase in consumption of primary (mined) copper since the early 1990s, and the lower copper prices 1998 through 2003. Following this trend was the decreasing rate of semi fabricate production in the United States since 2000. Semis production was 2.18 million tons in 2011, much below 3.9 million tons in 2000, see Table 10. Scrap comprised only 33% of total U.S. copper consumption in 2011(See **Table 6**).

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 not only small, but is diminishing. In 2011, about 5,000 tons (less than .05%) of copper chemicals produced from scrap may have been lost out of a total of 942,300 tons of copper scrap consumed.

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 (recycle or reuse) rate may be in excess of 70% for copper products no longer in use. Because, generally, it has been cost effective to

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

Pool of Copper Materials In Use



Sources: JJolly, Jan. 2013. 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 (1864-2009)

collect, prepare and sell copper-base scrap over recent 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 recovery cost and incentives are right.

The estimated resource calculations made below, and in **Table 6A** indicate that more than 64% of total primary copper consumed in the United States has been returned and reused as new and old scrap over time. This calculated scrap recovery rate was as high as 70% between 1989 and 1994, but has dropped currently to around 64%. This change undoubtedly is related to the drop in old scrap consumption, as reported for the United States. The rate of old scrap recovery (56.2%, including exports) from the calculated primary copper end-use resource has been decreasing since a peak of 54%, which was reached 1991- 1993.

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 (**Table 17B**) 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 decrease in adequate processing capacity 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. copper and copper alloy 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. Primary (mined) copper forms the only contribution to a theoretical accumulating resource base. Most of the copper ever extracted from the earth can be determined by using primary copper consumption or production statistics that have been collected and published over time. However, 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.

According to McMahon (1965), a large reserve for secondary (recyclable) copper, in the form of recoverable end-use products, has been accumulating in the United States and in the world. This end-use resource is continually being augmented because of consumption patterns and the indestructibility of copper. Each year, copper in the form of old scrap is recovered from this reservoir. In the United States, old scrap copper recovery in 1960 comprised about 21% of annual consumption, but more recently it has been much lower. Not counting old scrap in exports, old scrap comprised only 9% of U.S. apparent consumption in 2011 (see **Table 6A**) In 1960, McMahon also estimated about 25% of annual consumption was new scrap that was generated from fabricating and manufacturing semi finished 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 the fabricating and scrap reclamation industries.

The resource estimation procedure adopted by McMahon deducts an estimate of 25% annually from the cumulative series of primary copper consumed. McMahon (1965, Table 10, p. 77). The estimation procedure also purposely does not include old scrap in the calculations. Although McMahon 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 been dissipated, or lost, 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 93 million tons in 2011 (see **Figure 11**). According to McMahon (1965, Table 10, p.75), about 52% of the end-use reservoir so calculated had been returned and reused as old scrap by 1960.

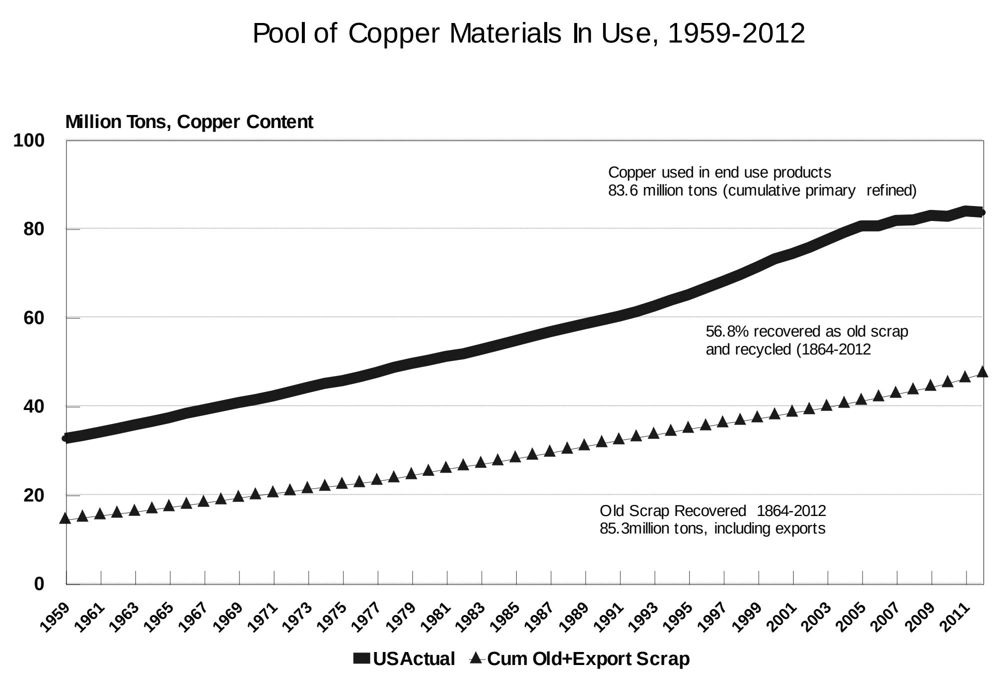
McMahon's method for estimating the world resource involved a simple ratio equation based on the assumption that the rest of the world consumes copper in much the same manner as the United States. Using this formula with cumulative world copper consumption, as McMahon suggests, yields some 314 million tons of copper for the resource base in 2002. This estimation is a little too high, however, because the consumption statistics used for the world 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 end-use (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. The primary world end-use reservoir also does not include the pool of new scrap that is recycled and reused every year. Therefore, 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% is 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 357.6 million tons of copper (**Figure 11**) by 2012.

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 for use in their semi fabricating processes. In 2010, the United States derived about 27% of its total copper (primary plus scrap) consumption from new purchased scrap (**Table 6**). See also the data on flow sheet **Figure 9** for gross weight new scrap returned (32%) from copper products produced in 2011.

It has been suggested (Thomas Baack, pers. Communication 2005) that because new scrap has a short life span, the potential exists for the same physical quantity to be recorded many times as it passes through a production stream during a year. It might therefore be possible that the real physical quantity of new scrap used each time over and over might be a fraction of the total amount reported as used for the entire year. Hence, if the scrap was returned and reused 4 times per year, for example, the total value for returned new scrap would be 25% of the cumulative amount . This would increase the cumulative end use pool by about 30.5 million tons and reduce the new scrap volume significantly. Application of this applied time philosophy is difficult, but may be worthy of consideration in future research.

Figure 12. U.S. Copper Resource for Old Scrap



Source: JJolly, Jan. 2013

USActual = Cumulative primary copper consumption increase less annual new scrap generated (1864-2010).
Old Scrap Cumulative = Cumulative recovery of copper in old scrap returned from end use sector and reused, plus copper in netexports ofscrap.

Based on reported U.S. annual data, the cumulative primary refined copper consumed in the United States since 1864 amounted to 133.5 million tons by 2012(**Table 6A**). From this initial mined source, a cumulative 85.3 million tons (64%) of copper from old and new scrap had been returned for consumption by the industry through 2012. New scrap was recycled at rates ranging between 4,000 and 1.6 million tons per year between 1906 and 2012. New scrap made up about 25% of the total copper consumed over the period (see **Table 6**). At the same time, old scrap from obsolete end uses was recovered at a rate ranging between 6,000 tons and 613,000 tons per year, 1906 through 2012. This resulted in a cumulative 47.5 million tons (56.8% of the end-use resource) of old scrap being returned for consumption by 2012(see **Table 6A**).

In the United States, old scrap copper estimated to be consumed by industry in 2011 was only 153,000 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 1.1 million tons may have been recovered as old scrap in the United States in 2011. Thus, it would appear that about 120 times the amount of old scrap recovered for use by the U.S. industry, also was exported. 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, as illustrated in **Figure 13**.

Old scrap derived from finished products has customarily been considered a new resource of copper in the year of reuse, as it re-enters the manufacturing stream. For the purposes of calculating a current year's copper consumption, old scrap is a legitimate augmentation to available primary copper. New scrap, on the other hand, is derived from manufacturing and processing. It 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, at any time, 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 the end-use market. Because of this phenomenon, new scrap also is excluded from total 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 86.3 million tons of copper accumulated over the period 1864 through 2012 as the U.S. resource of copper in manufactured products in use (**Figure 12**). Interestingly, about 56.8% (47.5 million tons) of this adjusted, theoretical end-use resource had been recovered and reused as old-scrap copper (including exports) through 2012. (**Table 6A**). Net exports of copper scrap were added to old scrap copper consumed by the U.S. industry to achieve a total old scrap yield. Calculations related to the cumulative primary copper resource yield an estimate of about 36% of the resource remains in products in use by 2012. This is derived by deducting the cumulative old scrap recycled from the cumulative end-use resource of 83.6 million tons. This estimate includes items that are still in use, buried or, to a much lesser extent, possibly dissipated. Copper used in chemicals can be presumed to have been dissipated, but beyond this, nothing can be definitively quantified as irretrievably lost. Furthermore, it should be noted 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 end-use products is not easily quantifiable or estimated.

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 56% of the cumulative resource since 1980 (see **Table 6A**). 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.

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 to 45 years, copper items produced in the 1960s and 1970s may only be in the recovery process today. It would appear that a sizeable portion of all copper consumed is still very much in use today. This would amount to around 40% of the so-called, end use resource base, as currently calculated.

Of all world copper (24.4 million tons) consumed in 2012, 33% was from direct melt and refined copper scrap sources (**Table 2A**). Of the total 7.9 million tons of world copper derived from all scrap sources (**Tables 2B** and 2D in 2011, only 3.7 million tons were recovered by refining (47%) and might be considered mostly from old scrap sources. Copper from refined scrap comprised about 18% of total world copper consumed from all sources in 2011. Another 7% of total world copper might also be presumed to be from old direct melt scrap, making a total of 25% of copper from old scrap sources in 2011.

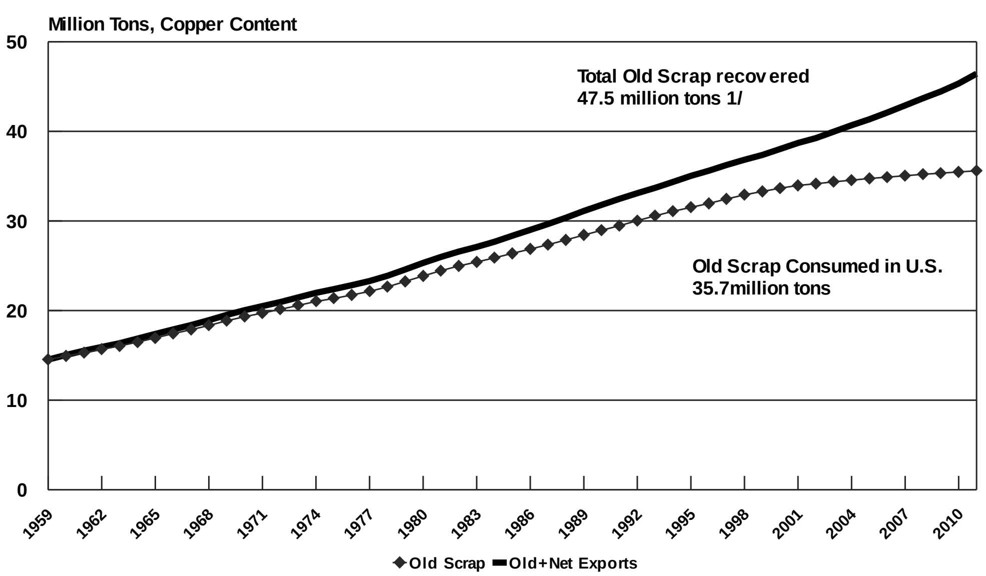
In a paper issued in 2002, several European analysts (Spatari, Bertram et al. 2002) traced the flow of copper as it entered and left the European economy during the course of one year. Russia was not included. Across the life cycle, a net total of 1.9 million tons of copper was imported into Europe. About 40% of cathode produced within the flow system was directly from old and new scrap. It was estimated that about 8 kilograms of copper per person enters the end-use market each year, only 30% of which is in alloy form. They also estimate that the waste management system in Europe recycles about 60% of the copper from "waste." The net addition of copper to the end-use "stock" in the copper flow system is about 6 kilograms per person per year. They conclude that given the in-service lifetime of the applications of copper identified in their flow model, most of the copper processed during the last few decades still resides in use, mostly in non-dissipative uses.

The International Copper Study Group recently (2004) completed a study on recycling in Western (ICSG's Copper Flow Model on Recycling Ratios in Europe). One consideration outlined in this paper is a statistical methodology for the estimation of a recycling input ratio (RIR). This recycling input ratio is derived by dividing the total scrap consumed in a region by the total semi fabricates produced. The RIR illustrates trends in the relative amount of scrap used versus primary material in semis production. The RIR calculation is put into perspective for the United States in **Table 6B** of this report and shows a consistent decrease from the mid-1980's through 2000. These statistical trends are the result of several significant events that have occurred in the United States over the past ten years or so.

In addition to a decreased amount of scrap consumed, relative to primary material, the U.S. recycling input ratio (RIR), as calculated above, has been much influenced by the increased amount of copper scrap exported since 2000. To calculate a more complete picture of U.S. scrap use and recovery, total copper scrap exports must be added to the amount of industry consumed scrap reported. Looking at **Table 6B**, a striking trend emerges of a decreasing recycling recovery ratio (ROR) from 1992 forward to 2004. Between the years 1981 through 1993, the rate of recovery (ROR) is consistently over 61%, reaching as high as 81% in 1986. From 1993 forward, however, the rate of recovery is shown to decrease to as low as 46% 1999 and 49.5% in 2002. The rates have been increasing since 2004, reaching 91.6% in 2011. The higher scrap recovery ratio undoubtedly relates to the higher copper prices since 2004 and the influence of higher scrap exports.

Figure 13. Cumulative Old Scrap Copper

In the United States, 1959-2012



Source: JJolly, Jan. 2013
1/ Copper in net scrap exports are added to old scrap consumption.

The decrease in RIR shown between 1993 and 2002 in **Table 6B** and rate of recovery (ROR) can be explained by at least two factors that affected the U.S. semi fabricating industry and scrap recovery trends over this period. One was the increased availability and use of primary copper in the production of semi fabricates over much of this period. The increase in primary copper consumption was partially attributable to an increase in wire rod production (which consumes less scrap) vis-à-vis a coincidental decline in secondary smelting of scrap for use in brass mill production (which customarily uses more scrap). Secondary smelting and refining of scrap for use in the U.S. industry has been impacted by plant closures and capacity loss over the past ten years (see **Table 17B**). In addition, primary copper was to become more available at a more reasonable price as copper supplies were in world surplus over much of the 1990's. The second factor is the reduction in amount of new scrap produced by the fabricators as processes became more efficient and streamlined. Because of the surplus supplies and consequent depressed copper prices, less old scrap also was returned to the market, as might be expected. This resulted in less scrap being made available to the U.S. industry for consumption, or for export, over the 1993-2001 period. If the years prior to 1993 can be presumed to be considered more normal, it would appear that a more normal rate for the recycling recovery ratio (ROR) in the United States was in excess of 63%.

During 2005, owing to near term copper market shortages, several articles appeared in the press regarding a possible high percentage of copper already mined as compared with an estimated total copper available in the earth's crust. Since the Paley Commission Report of 1950, there have been many such discussions and reports attempting to resolve the many issues involved with determining the amount of copper resources available in the world. One such report worth remembering is that appearing in U. S. Geological Survey Professional Paper 820, pp 21-25. This 1973 article, entitled "Crustal Abundance of Elements, and Mineral Reserves and Resources", by R. L. Erickson, proposes a methodology for estimating the recoverable amounts of several metals in the earth's crust. The potential recoverable resource for most elements should approach $R=2.45AX\ 10^{6}$, where A is the abundance expressed in grams per metric ton, or parts per million and R is the resource expressed in metric tons. Those metals whose reserves most closely approach the calculated potential recoverable resource are the metals that have been most diligently sought, such as copper. The formula calculates the minimum total resource available, largely because it relates to currently recoverable resources and does not include resources whose feasibility of economic recovery is not established.

Using this formula (called the McKelvey formula) assumes (1) the Bureau of Mines (now USGS) estimate for world reserves are the correct order of magnitude, (2) that McKelvey's relation of reserves to crustal abundance is valid, and (3) that trace elements are log-normally distributed in the earth's crust. Using the world copper reserves reported then by the Bureau of Mines, Erickson estimated that for 1970 the reported reserves of 200 million tons resulted in a recoverable resource potential of 2.12 billion tons of copper. This contrasts with reported world copper reserves (2005 Mineral Commodity Summary, USGS) for 2004 of 470 million metric tons of copper (and, a reserve-base of 940 million tons). Using this latest data with the McKelvey formula would yield about 5 billion tons of potential recoverable copper, more than double the amount estimated for 1970. Using this minimal resource calculation to compare with the accumulated world consumption figure of 282 million tons (2004) can give us a minimal percent of copper already used from an estimated world resource. The estimated world consumption of 282 million tons is only about 6% of the minimal estimated world resource. A more recent (1998) assessment of U.S. copper resources indicated 550 million tons in identified and undiscovered resources in the United States, more than double the previous estimate (USGS Circular 1178, 2000).

A word of caution -- It is obvious that these reserve/resource numbers are very fluid and change with time. One must read and understand the definitions for reserves, reserve-base and resources to understand the reasons underlying the near doubling of reserves between 1970 and 2004. Absolute amounts are impossible to quantify, thus a definitive statement about the percentage copper already used in the world, compared with that possibly available is at best, wildly speculative. Statements made about running out of the potential for copper ore are irresponsible and generally are made for various political and notoriety reasons.

In testimony before the Committee on Resources Subcommittee on Energy and Mineral Resources in the U.S. House of Representatives (May18, 2006), a spokesman for the U.S. Geological Survey reported that a current study estimated that about 1.1 billion tons of copper will be needed between 2000 and 2020 at current rates of consumption. This will necessitate additional producing reserves equivalent to three times the amount of copper as is contained in the 5 largest known deposits. Although some of this material exists in discovered deposits, much will need to come from yet undiscovered deposits. The need for active exploration and mine development continues.

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 sometimes 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.

After cable material travels through shredders and granulators, a variety of equipment – gravity or air density tables, washing systems, fluidized bed units – can be used to further ensure that metallic choppings are free of plastic. Finding a use for the “fluff” or discarded plastic materials also is not always easy. Some manufacturers of molded parts and auto and truck parts makers have been able to use certain types, but getting a pure mix of plastics is sometimes difficult.

In recent years, owing to the vast labor and copper price differences between China and India with North American or Western Europe scrap processors, some U.S. shredder operators were forced to rethink their downstream systems to determine whether or not it was worth the operating costs to purify metals to such an extent. Many scrap processors were accustomed to using automation to meet strict chemistry requirements for copper shipments, but exports to China and the Far East changed this with the willingness of foreign importers to buy mixed or crudely sorted loads of metal. It has steered some recyclers to do a lot less sorting of loose brass, copper and aluminum scrap with overseas customers able to do this sorting much more affordably.

In the past decade, as prices for nonferrous metals have climbed to new highs, methods for better extractions of these metals from auto shredding products have been developed and improved Optical sorting technology has evolved as an improved technique to separate metals. In addition to the magnets, eddy currents, X-ray Transmission (XRT) units, and inductive sorters, optical systems that work in near-infrared (NIR) wavelengths can prove valuable to separate insulated copper wire from the material flow. A camera sorter that uses a charge-coupled device (CCD) can differentiate between different colored metals. It can be used, for example, to separate the copper from aluminum. It can also be sued to detect shape of pieces, so wires can be separated from mixed metal fractions. Such plants in the future will allow recyclers to upgrade the value of the nonferrous metals, converting them into higher-valued products (Recycling Today,Nov 2011, p. 55-56). From heavy metals recovered, it is possible to select the mixed red metal fraction of copper and yellow brass, and further refine it to a dedicated copper and a dedicated yellow brass.

Over much of the past ten years, especially during the market turmoil of 2008-2009, as well as earlier in the decade, U.S. scrap recyclers of wire and cable were worried about their future. Brokers representing consumers in China were making generous offers and getting access to scrap that had previously gone to the choppers. giving stiff competition for feedstock. Though it was only temporarily, trading patterns shifted somewhat in 2004 when customs, trade and environmental regulations in China combined to slow down the buying pace of Chinese brokers. U.S. wire processors had an opportunity at this time to re-establish trading ties with customers (Recycling Today, October 2004). The renewed business allowed some processors in the United States to begin upgrading their systems. The objective was to remain competitive while recovering as much metal as possible, but keeping their costs down. Recent gains in volume allowed upgrade to larger shredding units and the conveying systems to match. The cost of blade replacement was also closely monitored.

In 2002, it was reported that lower grades of wire increasingly had been heading overseas for processing (Recycling Today, Feb. 2002). This may partially account for the increasing gap between what some countries report as exported (see Table 3) what other countries , particularly China, report as imported (see Table 4). There is obviously a difference in reporting scrap values, which seems to be worsening every year. Data reported by the USITC since 2006 show increased Number 2 scrap in U.S. exports (see **Table 8A**). No. 2 scrap comprised more than 77% of unalloyed copper scrap exported in 2012. Exports of low-grade copper ash and residues also increased from 8,340 tons in 2001 to 62,150 tons in 2007 and 38,000 tons in 2011 (see **Table 9**). Total alloy and mixed scrap comprise the largest share (60%) of total scrap exports in 2012 China was the destination for 75% of the U.S. scrap exported in 2011 (USGS 2011 MYB, Table 18). Hong Kong, Canada, Korea, Mexico, Spain, Belgium and Taiwan were also significant importers of U.S. copper and copper alloy scrap in 2010 and 2011.

While copper and aluminum have resale value to smelters, the plastic coating is often disposed, or burned away. In developing countries, plastics are disposed of not only through landfilling but also by open burning of the coated wire 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 for copper slags 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 was a strong demand for the reuse of Pentium 133s and above, 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.

The Institute of Scrap Recycling Industries released a comprehensive survey of U.S. electronics recycling companies at the 2011 E-Scrap Conference. One noteworthy find by the survey, which was conducted by International Data Corporation, determined that 182 US organizations reported that most end-of-life electronics are being processed in the United States and not dumped overseas. Seventy percent of collected e-scrap is processed in the United States and sold as commodity-grade materials including copper and precious metals. Some is resold as functioning equipment and nearly 18% is resold as equipment and components for further repair and refurbishment. (Resource Recycling, Nov 2011)

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 during smelting the material, 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.

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 wire bar. Air pollution control energy accounts for 0.21 million Btu per ton of wire bar, 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 wire bar 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. Copper from direct melt scrap comprised 94% of all copper from U.S. scrap consumed in 2006(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 electro refined, 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, whether 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 of 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 it 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, mill scale, and metallic iron. The resulting slag from a 60- to 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, or (2) 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 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 that of more volatile metals partially released during the melting of some copper alloys. 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 used. Particulate emissions associated with metal processing can be collected in mechanisms called bag houses. 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 six different types of furnaces are 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 popular at ingot plants and foundries where special alloys are made. These furnaces also are used for melting scrap and other materials in casting billet and other shapes.

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%. It's then moved 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 ingot makers 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 it 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 Corp., according to its Web site, where it claimed 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 cast able 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 (e.g. Kaldo or TBRC furnaces) 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 semi-continuous modes. Various feed materials can be used, such as primary and secondary base metals and anode slimes. Fine feed materials can be fed directly into the furnace without any pre-treatment, such as briquetting or screening. 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. A Kaldo furnace can meet stringent environmental standards as it produces very low metal content, inert slags. The furnace is compact and can be completely enclosed to prevent any stray emissions.

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.

Electric induction furnaces are often used for melting scrap and other metal materials in casting billet and other shapes.

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. Basel Convention is under the United Nations Environment Program. It has since been ratified by more than 130 countries, including the United States, although the United States has not passed legislation necessary to implement its participation in the Convention. The U.S. Senate has not ratified the treaty, thus although the United States signed onto the Basel Treaty, the U.S. is not a party to the treaty.

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 are 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 also was 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 took place in Geneva in May 2002.

In the current decade (2000-2010), the Convention planned on implementation and enforcement of treaty commitments. The other area of focus is the minimization of hazardous waste generation. A central goal of the Basel Convention is Environmentally Sound Management (ESM). ESM addresses the issue through an "integrated life-cycle approach." Transboundary movements of hazardous wastes can take place only upon prior written notification to the competent authorities of import and export. Shipments made without such documents are illegal. Basel partnership initiatives include one on mobile phones and another on personal computers. The purpose of these initiatives is to advance management of obsolete materials and wastes globally.

OECD Rulings. On June 14, 2001, the Organization for Economic Cooperation and Development (OECD) 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 it 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 establishes prohibitions and requirements concerning closed and abandoned hazardous waste sites, provides for liability of persons responsible for releases of hazardous waste at these sites, and establishes 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 is 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.

In 2011, EPA proposed a broad newly expanded definition of waste. Published in the Federal Register on July 22, 2011 EPA proposed to revise certain exclusions from the definition of solid waste for hazardous secondary materials intended for reclamation that would otherwise be regulated under Subtitle C of the Resource Conservation and Recovery Act (RCRA). The proposed rule would require all forms of hazardous waste recycling to meet requirements designed to ensure materials are legitimately recycled and not being disposed of illegally. Of concern to scrap recyclers is the potential breadth of the DSW rule as proposed. Among the list of 27 North American Industry Classification System (NAICS) sectors designated for the proposals is the secondary smelting, refining and alloying of nonferrous metal (331492) sector. The impact of this proposal on the scrap recycling industry seemed to be totally ignored by the EPA. ISRI estimated the rule change could cost the industry about$1.2 billion (Recycling Today, Nov. 2011, p. 87).

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 Drinking 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. It is 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 size reduction. The EP required particle size reduction through a 9.5-mm sieve. This requirement is 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 than 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 (F006, 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 the economic barriers to recycling of F006 waste through metals recovery, EPA feels 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 F006 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 Occupational 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 µg/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 it was technologically feasible to comply, it had not shown 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.

OSHA posted the top 10 most cited violations for fiscal year 2010 for various industry sectors (American Foundry Soc., Govt Affiars, 8/2011). The violations were not much different from past year's. However, for non-ferrous foundries, there was a large increase in the number of plants cited for overexposures to lead. The top 10 OSHA violations for Non-Ferrous facilities: (1) Lead, (2) Respiratory Protection,
(3) Machines – general, (4) Occupational Noise Exposure, (5) Hazard C9ommunication,
(6) Recordkeeping, (7) Annual Summary,
(8) Lockout/Tagout, (9) Design and construction requirements for Exit Routes , (10) Personal protective equipment – general.

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.

For current rules and regulations for clean air act ruling, seek www.epa.gov on the internet and select Clean Air Act. Information may also be found for the Clean Water Act on this site.

The U.S. EPA published new rules in the Federal Register for National Emission Standards for Hazardous Air Pollutants (NESHAP) on January 23, 2007 (Vol. 72, No. 14). The U.S. EPA's proposed guidance for regulating greenhouse gas emissions was released in Mid-November, 2010. (Research and Commentary, EPA) and was set to go into effect on January 2, 2011. A short commentary period was being allowed. This followed the proposed rules published on October 6, 2006 in the Federal Register. With regard to rules applying to the secondary copper smelter industry, both reports are worth reading. The principal observations called attention to the fact that there are currently no secondary copper smelting facilities operating in the United States that qualified for specific air quality applications. However, should any new facility be constructed, brief recommendations were proposed in both reports to ensure that any potential emissions will be appropriately controlled. Baghouses were identified as the most effective particulate matter (PM) control devices to be used on cupolas and other furnaces. Iron and steel scrap with baghouse control are subject to a PM limit of 0.002 gr/dscf, or less. EPA chose to apply a PM limit of 0.002 gr/dscf as GACT to all melting furnaces and other furnaces that process molten metal at a new secondary copper smelter. This is consistent with the UN Environment Programme's guidelines on performance standards for new secondary copper smelters (available at http://www.pops.int/documents). These guidelines recommend PM removal systems such as fabric filters or bag houses and state that these systems should achieve a PM level of 5 milligrams per cubic meter (.002gr/dscf) for new secondary copper smelters. The final rule (Jan 23, 2007) applies only to secondary copper smelters and does not apply to copper, brass, and bronze ingot makers or remelters that may also be included under this NAICS code.

As a result of the tightening in the federal National Ambient Air Quality Standard (NAAQS), the Illinois Environmental Protection Agency (EPA) brought a NAAQS lead suit against an Illinois-based ingot maker in 2011. The lead standard had been revised to 0.15 micrograms per cubic meter of air from the previous standard of 1.5 micrograms per cubic meter. The new standard was started in January 2009. (Recycling Today, May 2011)

The current popularized movement toward regulation of carbon dioxide emissions under the Clean Air Act, or through any new regulation (Carbon Cap and Trade Act) promises to have significant negative impact on the copper industry. The U.S. EPA's proposed guidance for regulating greenhouse gas emissions was released in mid-November, 2010 and is set to go into effect on January 2, 2011. Many analysts challenge EPA's authority to establish the mandate, which will increase economic regulation dramatically. Because the guidance will apply only to major modifications to existing plants and new construction, many manufacturers will forgo building newer, more innovative production plants and updating older, less efficient ones.

The State of Texas was suing the EPA, claiming the decision to regulate carbon dioxide is based on flawed science (www.examiner.com). The Competitive Enterprise Institute warned small businesses exempted by the "tailoring" rule. This rule temporarily exempts them from certain mandates, but businesses were warned to remember that Congress never authorized EPA to make climate change policy in the first place (Marlo Lewis. 2010 Cei.org/news releases/EPA Offers Draconian "Guidance" for Global Warming Energy Restrictions)

Given the unfair trade, environmental and tax effects on the industry over the past ten years, this may just be the "nail" in the coffin. In the opinion of the author, the notion that man-driven carbon dioxide generations are the cause of increased Global Warming, or of any significant worldwide climate change, is the world's greatest hoax of the century. That this philosophy should be used to levy unfair penalties on the U.S. manufacturing and metal industries is next to criminal in design. That man can control climate in the world is surely the most presumptuous assertion ever made.

For a discussion on this problem and the scientific facts relating to it, the reader is directed to the following internet links at www.globalwarmingheartland.org and at the US Senate Committee on Environment and Public Works: Matt_dempsey@epw.senate.gov. This committee has done a tremendous job of tracking and summarizing the scientific testimony on this issue. Of interest is the fact that solar irradiance correlates well with Arctic temperature, while hydrocarbon use does not (see Ref. 65, Robinson (2007)). In addition, a 650,000 year ice-core record does not agree with a hypothesis of "human-caused global warming, " but instead gives empirical evidence that invalidates this hypothesis.

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 refinery capacity has presented the remainder of the industry with several problems. Aside from the problem of finding new markets for the sale of 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 recent economic uncertainty of the international copper market, with its continuing over capacity and lower prices, has added extra penalties to the secondary market. Collection and use of old scrap, in particular, suffered in recent years; the supply was not as available for the domestic industry as it might have been under better circumstances.

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 scrap dealers 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). In the United States, between 14 and 20 million computers become obsolete every year. According to a recent USGS study (July 2001), obsolete computers contain significant amounts of recoverable materials, including metals. Although some of the metals are listed as hazardous by the RCRA, most are recoverable and sought after, such as copper and the precious metals. One metric ton of circuit boards can contain between 80 and 1,500 grams of gold and between 160 and 210 kilograms of copper. About 4.3 and 4.6 thousand metric tons of copper were recovered in the United States by recyclers in 1997 and 1998, respectively. In 1998, about 2.6 million personal computers were recycled in the United States.

Some recyclers have been shipping components overseas for dismantling by hand. Because labor is less expensive in China and Taiwan, 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. This did not have an immediate effect, since U.S. scrap exports to China continue unabated through 2007. China's scrap imports i through 2010 were at record levels (Table 4). In the meantime, with commodity prices at record highs and innovative electronics recycling methods becoming increasingly cost effective, new value is being found in all post-industrial and post-consumer scrap.

China began to implement its Waste Electrical and Electronic Equipment (WEEE) Recycling Management Regulations at the start of 2011. (Recycling Today, Nov. 2011, p. 87) China passed its own WEEE regulation because household electronics scrap generation is expanding at an annual rate of 20%, according to CNMIA reports.

In 1984, Noranda in Canada began processing small amounts of electronic scrap and, by 1999, was the largest electronics recycling plant in North America (USGS, 2001). There is value contained in the monitors and CRT's, but Noranda must charge a fee for cover the handling costs. The fee is normally several hundred dollars per metric ton.

A relatively new organization, Coalition for American Electronics Recycling (CAER), urged support for the Congressional Responsible Electronics Recycling Act (HR2284 and S1270), which calls for restrictions on export of electronic scrap to developing countries. The CAER includes a roster of 29 U.S. electronics recycling firms in 34 States, including refurbishers, scrap processors and refiners. CAER argues that current policy for export of electronics harms the domestic recycling industry by creating competitive jobs overseas. (Resource Recycling p.8. Dec. 2011)

Radioactive metals. As nuclear plants are decommissioned, storage and disposal of the slightly radioactive scrap metals derived from them become more of a problem. The Environmental Protection Agency (EPA) and Nuclear Regulatory Commission (NRC) have been concerned about risk imposed on the public from the recycling of radioactive contaminated metals. Since the mid-1990s, EPA has been studying the risk involved with recycling of slightly radioactive metals from NRC licensees. More recently, the NRC has been looking into the feasibility of recycling dismantled nuclear plant metal through commercial metal processors. Unfortunately, there are very few qualified secondary copper refiners remaining in the United States.

According to Bryan and Dudley (1974), approximately 694 tons of copper, 250 tons of bronze and 10 tons of brass are used to construct a typical light water reactor facility. Copper is used in turbine generators, reactor equipment, heat transfer systems and miscellaneous instrumentation and control systems. Much of the metal at DOE facilities and NRC licensed sites is not contaminated, and can be released without a problem. It is estimated that copper associated with electrical plant equipment amounts to about 557 tons and that the total mass of uncontaminated (clean) copper is about 580.3 tons. The remainder, only about 62 tons, is slightly contaminated. At the end of 1999, there were 104 operating nuclear power reactors and 37 operating non power reactors in the United States. The normal duration of a nuclear power reactor license is 40 years, some with 20 year extensions. Shutdown dates range from 2006 to 2030, among the facilities currently licensed to operate. The total amount of potentially contaminated recyclable metal is not much compared with the millions of tons of refined copper consumed by the U.S. industry each year. However, this small amount of contaminated metal is of great concern to the processing industry. According to some sources (www.sierraclub.org) more than 1.6 million tons of iron, steel, aluminum and copper metal were in storage by 1997 waiting for the EPA green light.

Increasingly, EPA has received complaints from scrap dealers and refiners that in receiving hot scrap, they are having to pay for cleanup when their scrap yards and plants become contaminated. As a general rule, copper refining facilities will not accept material that is radioactive. Those that have unwittingly done so by mistake have paid millions of dollars to undo the damage. One company in the early 1990s unknowingly shipped some radioactive slag, which resulted from fire-refining a contaminated bus bar, to a company in Canada for further processing. The

Canadian company did an analysis and refused the shipment, resulting in costly storage, permitting, shipment and hazardous dump fees for the victimized U.S. company.

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 have 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.

Electronic Scrap. Although handling electronic scrap has been a growing problem in the United States, new companies are being formed and improved methods are being adapted to address the problem. The International Association of Electronics Recyclers estimates that there are about 400 electronics recycling companies in the United States, and that the electronics recycling process yielded about 410,000 tons of recyclable materials in 2001 (http://www.iaer.org). The IAER estimates that 3 billion consumer electronic units will be scrapped during the rest of this decade, or an average of 400 million units per year. The electronics recycling industry is expected to increase capacity by a 4 or 5 times factor by the end of this decade.

Globally, e-scrap has become the fastest growing waste stream with 20-50 million tons of e-scrap reportedly generated worldwide annually. Increased awareness of potential hazards from electronic scrap and the need for efficient and cost effective disposal solutions are increasing.

The U.S. EPA provides information on how and where to donate, or to safely recycle old electronics – namely TVs, computers and cell phones—with links to vendor and retailer recycling program information. (www.epa.gov) Another site, E-cycling Central (www.eiae.org) from the Electronic Industries Alliance, offers a state-by-state recycling directory and information about national programs. The Environmental Issues Council of the Electronic Industries Alliance has organized the Consumer Education Initiative to inform consumers about recycling and reuses of used electronics, including computers.

Some U.S. and Canada scrap handlers 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.

A handful of states are mandating "take-back" programs and industry has begun to respond. Sony Corp announced in August 2007 a recycling scheme to process Sony-brand electronics castoffs. Waste Management Inc., Sony's partner in this venture already sells materials such as copper retrieved from e-waste. Sony will try to raise awareness and make recycling a lot more convenient than it is today. Treating recycling as a business, not a money pit, marks a turning point for the industry.

On April 1, 2011, New York State passed the Electronic Equipment Reuse and Recycling Act, a law requiring manufacturers of a host of electronic products to create and fund a plan to collect and recycle these at the end of their useful lives. This "extended producer responsibility" (EPR) law is the 22nd of its kind in the United States, but it is considered by many to be the most comprehensive.

A standard for electronics recycling was developed by the Basel Action Network (BAN) in Seattle, WA. Companies must be certified to the e-Stewards Standard for Responsible Recycling and Reuse of Electronic Equipment. This certification publicly validates and extends long-term policies of being a conscientious electronics recycling and end of life service company. (Recycling Today, 8/31/2011)

Lead in Potable Water. On September 20, 2007, the American Foundrymen's Society (AFS) held a meeting to discuss the implications of the recent potential California legislation (AB1953) that will further restrict the acceptable level of lead in potable water applications. The Copper Development Association and the industry have been working on lead substitution in several copper alloys for some time. Although bismuth (EnviroBrass I, II and III) and other alloys)alloys have been consistently suggested as leading candidates, the limited source of the metal has been a principal worry. There are several of these alloys now available on the market. The alloys known as EnviroBrass use a combination of bismuth and selenium to replace lead. These alloys were developed by a broad-based consortium led by the American Foundrymen's Society with funding and technical input from the CDA and the Brass and Bronze Ingot Manufacturers, and including several foundries and plumbing products producers. While the basic properties tend to be comparable to their leaded counterparts, they are more expensive. It is not known how widely these alloys can be practically applied.

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 2006, EPA awarded 8 brownfields grants to Illinois communities, including the bankrupt North Chicago Smelting and Refining of R. Lavin & Sons. A $200,000 grant was given to clean up hazardous material on the R. Lavin property in Chicago and to develop a brownfield site. (EPA News Release, 5/15/2006)

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 (SREA) 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. SREA was designed to protect recyclers who had acted in good faith. If a smelter site or landfill was later declared a Superfund site, the recycling industry was often cited as partially responsible parties (PRPs) because they had done business with them. The ISRI was key in getting this legislation passed. In 2010, EPA was reexamining Superfund sites. This included wood product manufacturing, fabricated metal product manufacturing, electronics and electrical equipment manufacturing and facilities engaged in the recycling of hazardous materials (CERCLA). The SREA may exempt some recycling activities from the additional EPA research.

A new EPA rule, intended to clarify RCRA, was proposed in June 2002. The new rule was expected to 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 the electronics waste issue in October 2001. 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).

OECD has been doing workshops since 2005 on its Sustainable Materials Management (SMM) initiative. The goal is to explore policy opportunities and barriers for SMM to demonstrate use of the SMM concept for policy making. In recent years, manufacturing companies have been redirecting efforts towards sustainable manufacturing to integrate approaches that take into account a product's life-cycle impacts. (www.oecd.org/sti/innovation/sustainale manufacturing)

In September 2003, California passed the Electronic Waste Recycling Act, the first law of its kind in the United States. It bans the export of e-waste to foreign countries that don't meet environmental standards. The law provides for collection of a surcharge from consumers at the point of purchase to fund recycling. It also requires manufacturers to eliminate certain hazardous ingredients from electronics sold in California.

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 have 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.

In 2009, the Department of Defense Surplus LLC started implementing new requirements for the mutilation of fired shell casings. These requirements would prevent shell casings from being reused or reconstructed. This meant that private citizens could no longer purchase this brass and most of this was to go to foundries to be melted and likely exported. This move effectively stopped the remanufacturing of ammunition for domestic civilian and law enforcement use. In 2010, however, the House of Representatives added language to this year's National Defense Authorization Act (HR5136) that would ensure serviceable surplus ammunition and once-fired small arms cartridge cases would be made available for domestic commercial sale. With widespread ammunition shortages for local sportsmen, reloaded ammunition costs considerably less, and is used widely for marksman ship training and competition by civilians. (American Rifleman, August 2010, p. 8)

Radioactive Metals. In July 1997, S. Cohen and Associates, under contract to EPA, produced a report on recycling of scrap metals from nuclear facilities (Evaluation of the Potential for Recycling of Scrap Metals from Nuclear Facilities, July 15, 1997). A further analysis containing revised impacts on the free release of scrap metal from nuclear facilities on exposed individuals and answering questions and concerns raised during the review process was issued in 2003. These investigations are ongoing, but a more recent report has not yet been released by the EPA or the U.S. Nuclear Regulatory Commission (NRC).

A report in the April 3, 2003, American Metal Market, indicates that a last minute amendment was added to the House Energy Policy Act of 2003 that could prevent radioactive scrap metals from being released into the commerce stream. While release of contaminated scrap is currently under a moratorium, metals interests have been lobbying for a more permanent solution. The Metals Industries Recycling Coalition (MIRC) urged support of the provision. MIRC felt that residual radioactive contamination in scrap metal imposed significant costs on metals producers in detection processes and in costly plant shutdowns and cleanup, if an undetected source was accidentally melted. MIRC's position was that radioactively contaminated scrap metal originating at impacted or restricted areas at NRC-licensed facilities must be disposed of in a way that prevents the release of this scrap into the stream of commerce – whether by requiring disposal at a licensed low-level radioactive waste facility or at an appropriate solid-waste landfill, or by requiring that the metal be recycled for restricted use within the NRC's licensing scheme.

Material Theft. During the period 2004-2008, and again in 2010-2011, higher copper prices prompted a severe uptick in theft of copper products. Theft had become a serious problem throughout the United States. To counteract this situation, many States have enacted legislation that would penalize scrap dealers for accepting illicit goods. The Michigan state law passed in 2008 is an example. In order to sell scrap metal, the new law required sellers to: present suitable ID, allow the buyer to take a thumbprint, sign a statement indicating they are the owner or are authorized to sell the metal, and, sign a statement that they have not previously been convicted of metal theft. The dealers are also required to maintain records of purchases and tag and hold nonferrous metal for 7 calendar days.

Some countries are taking more drastic measures to stem copper scrap thievery. Jamaica announced in July 2011 a ban on export of all scrap exports. Arrangements were made for companies generating their own scrap to obtain permits and have inspections of containers and scrap locations. (Recycling Today, 7/27/2011)
In September, 2011, California proposed stricter rules for the metal casters of San Francisco area. The Bay Area Air Quality Management District (BAAQMD)hoped to reduce air pollution through stricter requirements. The metal casters already follow strict environmental standards and the new rules would mean another significant financial investment, an estimated $20 million per plant. This could force some metal casting facilities to close or cut back on staff. (Modern Casting, Sept 2011, p. 3)

Table 1. LME, COMEX and U.S. Refined, Scrap and Ingot Prices
(U.S. currency)

	Market Prices		U.S. Buying Prices			
PERIOD	LME Grade A, Cash cts/lb	COMEX HG, 1st Pos. cts/lb	U.S. Producer Price cts/lb	Refiners #2 Scrap cts/lb	Brass Mill #1 Scrap cts/lb	Red Brass Turnings cts/lb
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
2002	71	72	76	59	70	37
2003	81	81	85	70	80	39
2004	130	129	134	108	126	55
2005	167	168	174	137	153	61
2006	305	309	316	261	291	105
2007	323	323	329	283	311	137
2008	315	313	319	279	301	144
2009	234	237	242	206	227	113
2010	342	343	NA	298	325	164
2011	400	398	NA	351	389	188
2012 1/	361	362	NA	324	356	195

Source: Metals Week, American Metal Market, ICSG Copper Bulletin, U. S. Geol. Survey Min. Ind. Survey and Compendium.
1/ Scrap prices are based on 9 months average of 2011. Refined prices are full year averages

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
1971	2,173	803	1,237	3,653	202	8,301	37
1972	2,242	894	1,359	4,047	208	9,061	35
1973	2,488	930	1,574	4,007	204	9,548	37
1974	2,400	1,025	1,695	4,029	220	9,753	35
1975	2,196	941	1,464	3,462	214	8,725	31
1976	2,385	1,001	1,638	3,827	213	9,527	33
1977	2,358	987	1,735	3,969	218	9,777	32
1978	2,316	933	1,811	4,225	213	10,065	34
1979	2,300	897	1,909	4,686	214	10,575	37
1980	2,456	952	2,058	4,375	209	10,657	38
1981	2,462	918	2,259	4,590	240	11,046	36
1982	2,432	969	2,258	4,029	224	10,510	36
1983	2,477	1,040	2,419	3,969	245	10,762	35
1984	2,504	1,023	2,421	4,141	245	10,962	36
1985	2,564	976	2,530	4,122	235	11,065	37
1986	2,659	963	2,718	4,163	223	11,395	36
1987	2,636	921	2,837	4,419	258	11,730	37
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	2,895	707	3,816	5,522	328	14,752	38
1993	2,905	635	4,043	5,674	343	15,028	38
1994	3,028	562	4,087	5,804	365	15,255	39
1995	3,256	530	4,700	6,090	291	16,308	40
1996	3,310	535	4,850	6,450	332	16,977	37
1997	3,554	507	4,775	7,143	292	17,876	36
1998	3,443	460	4,874	7,565	302	18,263	34
1999	3,352	423	5,285	7,571	444	18,922	34
2000	3,477	365	5,761	7,315	512	19,362	35
2001	3,551	416	5,865	7,495	582	20,052	32
2002	3,432	450	5,998	7,005	563	19,536	31
2003	3,275	454	6,531	6,665	504	19,514	31
2004	3,209	508	7,046	6,772	510	20,350	32
2005	3,077	509	7,973	6,731	484	21,093	32
2006	3,068	529	9,132	6,724	454	22,230	34
2007	2,928	589	9,442	6,703	460	22,397	32
2008	2,942	603	10,924	6,477	520	23,666	35
2009	2,522	709	9,727	6,395	452	21,914	30
2010	2,773	874	11,408	6,257	424	23,993	34
2011	2,847	969	11,649	6,155	477	24,271	33
2012	2,942	964	11,680	5,775	475	24,366	33

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

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

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
1970	5,071	1,199	33	6,302	19
1971	5,189	1,027	33	6,249	16
1972	5,827	1,046	28	6,902	15
1973	6,019	1,107	37	7,164	15
1974	6,270	1,193	31	7,494	16
1975	5,965	912	36	6,914	13
1976	6,334	1,018	78	7,430	14
1977	6,536	1,073	112	7,722	14
1978	6,507	1,202	124	7,832	15
1979	6,413	1,340	263	8,016	17
1980	6,368	1,371	286	8,025	17
1981	6,721	1,336	334	8,391	16
1982	6,453	1,337	318	8,109	16
1983	6,672	1,367	300	8,339	16
1984	6,741	1,240	317	8,298	15
1985	6,751	1,439	213	8,403	17
1986	7,050	1,313	279	8,643	15
1987	7,006	1,484	332	8,823	17
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	1,984	1,463	12,673	16
1997	9,627	2,109	1,759	13,495	16
1998	10,002	2,055	2,005	14,063	15
1999	10,129	2,103	2,316	14,548	14
2000	10,312	2,125	2,325	14,762	14
2001	11,122	1,862	2,599	15,583	12
2002	10,790	1,898	2,649	15,337	12
2003	10,745	1,786	2,723	15,254	12
2004	11,132	2,070	2,706	15,908	13
2005	11,718	2,164	2,694	16,576	13
2006	11,850	2,596	2,823	17,269	15
2007	12,130	2,747	3,004	17,881	15
2008	12,209	2,823	3,098	18,130	15
2009	12,077	2,839	3,283	18,199	16
2010	12,399	3,230	3,344	18,972	17
2011	12,684	3,484	3,483	19,651	18
2012	12,740	3,591	3,686	20,018	18

Data Source: International Copper Study Group.

[e] Estimated

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

(thousand metric tons, copper content)

Year	Europe	Africa	Asia	America	Oceania	World Total	United States 2/	
							1,000 tons	% of World
1969	914	10	352	834	42	2,152	778	36
1979	940	22	423	1,134	40	2,559	1,054	41
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	1,100	37	785	792	38	2,752	721	26
1987	1,121	38	825	874	50	2,907	799	27
1988	1,033	39	986	933	40	3,031	860	28
1989	1,051	41	898	925	41	2,956	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	1,308	35	1,367	976	25	3,712	844	23
1993	1,261	37	1,464	980	25	3,768	832	22
1994	1,420	32	1,573	1,097	25	4,146	936	23
1995	1,608	34	1,755	1,042	25	4,463	965	22
1996	1,463	16	1,773	1,030	21	4,303	975	23
1997	1,623	16	1,582	1,138	22	4,381	1,068	24
1998	1,564	17	1,476	1,127	17	4,200	1,073	26
1999	1,573	16	1,616	1,144	25	4,374	1,102	25
2000	1,682	15	1,651	1,228	25	4,601	1,102	24
2001	1,823	0	1,517	1,108	22	4,469	977	22
2002	1,585	0	1,516	1,078	20	4,200	960	23
2003	1,558	0	1,716	966	20	4,260	891	21
2004	1,564	0	1,868	990	20	4,442	914	21
2005	1,404	0	2,112	986	15	4,517	904	20
2006	1,346	0	2,547	1,043	25	4,961	909	18
2007	1,255	0	2,198	1,045	18	4,516	876	19
2008	1,148	0	3,570	802	18	5,537	738	13
2009	779	0	2,152	779	6	3,715	728	20
2010	930	0	3,350	741	0	5,021	694	14
2011	889	8	2,990	733	0	4,620	705	15
2012 e/	996	0	2,642	710	0	4,348	697	16

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

[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.

[e] Estimated on 9 months data.

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	America	Middle East & Asia	Oceania	Rest of World	World	Western Europe	America	Asia	Oceania
1970	1405	1211	482	58	192	3290	43	37	15	2
1971	1302	1171	476	75	229	3178	41	37	15	2
1972	1300	1285	490	69	237	3313	39	39	15	2
1973	1481	1299	584	59	240	3605	41	36	16	2
1974	1366	1339	603	58	261	3569	38	38	17	2
1975	1153	970	475	48	246	2844	41	34	17	2
1976	1319	1140	527	52	259	3244	41	35	16	2
1977	1263	1194	522	66	281	3261	39	37	16	2
1978	1311	1361	589	60	306	3567	37	38	17	2
1979	1362	1685	663	76	324	4034	34	42	16	2
1980	1512	1582	723	65	321	4138	37	38	17	2
1981	1436	1517	835	76	340	4128	35	37	20	2
1982	1382	1303	837	64	355	3877	36	34	22	2
1983	1436	1202	922	76	370	3929	37	31	23	2
1984	1485	1248	932	74	379	4045	37	31	23	2
1985	1611	1282	981	72	371	4245	38	30	23	2
1986	1522	1251	1048	59	388	4210	36	30	25	1
1987	1674	1357	1099	79	408	4538	37	30	24	2
1988	1631	1458	1329	67	370	4787	34	30	28	1
1989	1693	1480	1308	76	401	4882	35	30	27	2
1990	1717	1519	1414	64	366	5015	34	30	28	1
1991	1831	1409	1382	69	355	4977	37	28	28	1
1992	2014	1546	1815	57	282	5658	36	27	32	1
1993	2021	1513	1857	49	258	5648	36	27	33	1
1994	2129	1581	1998	49	245	5953	36	27	34	1
1995	2386	1540	2398	43	241	6564	36	23	37	1
1996	2211	1500	2359	21	218	6287	35	24	38	0
1997	2476	1687	2113	22	214	6490	38	26	33	0
1998	2380	1624	2012	17	239	6255	38	26	32	0
1999	2376	1532	2138	25	431	6476	37	24	33	0
2000	2480	1574	2213	25	459	6726	37	23	33	0
2001	2376	1392	2018	22	546	6331	38	22	32	0
2002	2273	1222	2199	20	404	6097	37	20	36	0
2003	2162	1098	2410	20	376	6046	36	18	40	0
2004	2152	1125	2731	20	503	6512	33	17	42	0
2005	1952	1115	3101	15	512	6681	29	17	46	0
2006	1894	1178	3849	25	641	7557	25	16	51	0
2007	1818	1209	3667	18	573	7263	25	17	50	0
2008	1779	968	5094	18	523	8360	21	12	61	0
2009	1386	917	3817	6	437	6553	21	14	58	0
2010	1569	870	5363	0	453	8251	19	11	65	0
2011	1599	877	5221	0	418	8103	20	11	64	0
2012 e/	1709	850	4952	0	432	7939	22	11	62	0

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

[e] Estimated on 9 months data.

Table 3. World Copper and Copper Alloy Scrap Exports
(thousand metric tons, gross weight)

	2005	2006	2007	2008	2009	2010	2011	2012 (e)
Australia	87	50	49	51	62	74	80	0
Austria	33	40	40	42	54	54	56	70
Belgium	178	162	189	153	108	150	166	146
Canada	120	165	165	152	148	158	182	171
Chile	37	55	102	72	69	120	69	19
China	6	7	5	3	2	2	2	2
Czech Rep.	54	57	58	60	105	122	85	72
Denmark	26	31	31	36	31	31	33	28
Finland	31	31	33	33	33	33	34	30
France	262	294	280	263	229	287	306	308
Germany	476	499	481	479	450	578	585	590
Greece	15	17	15	12	16	22	19	23
Hong Kong	121	130	153	116	70	130	85	78
Indonesia	32	51	55	41	35	46	43	39
Ireland	13	16	10	22	46	7	10	10
Italy	113	104	120	149	158	167	173	190
Japan	424	412	425	396	360	286	288	312
Kazakhstan	2	6	9	12	16	24	11	1
Malaysia	75	36	29	17	29	37	30	17
Mexico	105	126	122	129	109	126	116	143
Morocco	15	18	17	9	13	26	35	36
Netherlands	182	310	237	225	268	289	308	315
Norway	23	24	24	23	25	38	46	40
Peru	2	5	7	6	6	7	7	7
Philippines	15	26	20	19	23	21	26	26
Poland	48	55	69	87	54	55	60	50
Portugal	35	30	21	19	20	23	36	43
Rep. of Korea	161	202	216	192	187	100	85	92
Russian Fed.	2	4	0	3	1	2	0	0
Saudi Arabia	60	127	105	0	57	94	63	0
Singapore	43	35	28	20	9	14	18	34
Slovakia	15	19	22	21	15	15	20	21
South Africa	51	75	79	82	71	73	82	73
Spain	100	86	84	82	100	102	87	135
Sweden	44	46	55	61	56	43	58	60
Switzerland	75	74	76	83	71	76	84	86
Taiwan	107	125	128	130	110	87	73	62
Thailand	51	60	107	76	70	66	74	80
United Kingdom	235	310	339	357	429	419	513	392
United States	665	894	907	908	843	1,032	1,239	1,200
Other Countries	305	252	436	510	470	519	308	284
World Total	4442.1	5154.4	5386.9	5175.7	5051.8	5600.0	5627.0	5319.0

Source: International Copper Study Group, Oct. 2012.
[e] Estimated on partial-year data (Jan.-Aug.).

Table 4. World Copper and Copper Alloy Scrap Imports
(thousand metric tons, gross weight)

	2005	2006	2007	2008	2009	2010	2011	2012 (e)
Australia	2.3	2.0	7.5	2.9	1.3	1.8	1.0	0.0
Austria	82.8	89.5	88.5	114.2	132.4	146.2	131.3	137.0
Belgium	257.7	297.8	319.5	253.1	217.2	274.0	255.7	295.0
Brazil	1.6	0.7	2.9	4.3	0.5	1.5	5.2	17.4
Canada	48.0	56.2	143.8	51.8	41.3	73.7	64.4	55.0
China	4821.2	4942.9	5584.6	5577.0	3998.0	4364.4	4687.3	4451.0
Czech Rep.	6.2	8.4	8.8	8.4	9.5	11.6	18.9	19.7
Denmark	14.3	8.3	9.0	16.5	10.3	9.4	9.1	8.8
Finland	2.4	1.3	2.6	2.7	7.0	89.9	8.2	10.0
France	75.4	97.8	88.3	78.3	50.3	71.9	81.3	72.8
Germany	486.1	585.2	595.7	563.6	454.8	620.4	646.8	652.6
Greece	0.9	2.1	10.2	18.6	11.2	19.5	29.3	20.5
Hong Kong	123.4	146.9	189.6	210.4	190.4	155.3	127.3	57.5
Hungary	0.4	0.6	0.4	3.1	3.9	4.0	4.7	5.6
India	150.3	103.9	105.2	103.3	78.5	92.3	153.4	74.8
Indonesia	13.4	2.3	4.0	9.7	6.6	14.2	17.2	12.6
Italy	125.3	215.7	177.5	167.2	91.5	165.2	146.4	64.1
Japan	102.9	120.8	135.7	138.7	97.1	159.4	136.8	137.6
Malaysia	23.6	12.5	26.3	13.2	8.9	13.2	18.0	12.4
Mexico	14.1	17.7	16.8	28.6	32.7	49.6	28.5	12.4
Netherlands	76.7	110.8	108.0	116.8	127.7	141.0	193.9	210.0
New Zealand	0.5	0.4	0.6	0.9	1.0	1.4	1.6	0.0
Norway	12.4	12.8	13.5	11.2	10.0	9.9	12.5	0.0
Poland	5.7	14.6	16.8	18.1	21.9	24.3	26.2	50.0
Portugal	3.3	6.0	7.9	8.8	6.8	8.5	8.0	5.8
Rep. of Korea	205.9	205.3	221.1	216.8	163.1	203.0	263.3	312.0
Singapore	15.9	18.0	7.9	4.4	2.3	3.6	7.5	18.0
Slovakia	20.0	18.0	17.5	18.0	29.1	39.8	30.7	37.0
South Africa	2.1	2.1	2.6	2.5	1.3	1.2	1.4	2.0
Spain	84.8	86.5	56.1	63.2	68.1	82.9	89.5	87.0
Sweden	51.0	55.8	80.9	92.1	97.0	108.4	121.1	118.0
Switzerland	9.8	7.6	8.0	5.3	2.7	6.1	4.2	2.2
Taiwan	112.3	145.9	130.9	106.6	70.2	90.3	89.7	93.0
Thailand	5.0	6.4	7.6	9.2	9.4	10.3	9.7	13.0
United Kingdom	41.1	19.7	23.7	22.0	18.0	27.6	29.0	29.0
United States	113.8	117.5	133.1	106.3	71.8	95.8	109.8	105.8
Other countries	111.8	50.3	79.9	77.4	74.5	155.0	98.5	261.4
World	7224.4	7590.4	8433.2	8245.3	6218.3	7228.5	7667.8	7462.0

Source: International Copper Study Group, Nov. 2012, and U.S. Geological Survey.
[e] Estimated on partial year data (8 months).

Table 5. World Production of Copper and Copper Alloy Ingots[1]
(thousand metric tons)

	2002	2003	2004	2005	2006	2007	2008	2009	2010
Austria	1.8	2.0	2.2	2.5	2.6	2.0	2.0	2/	2/
Denmark	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
Finland	0.8	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
France	12.5	12.3	13.0	11.4	12.5	11.0	9.9	9.9	9.9
Germany	56.1	43.7	44.1	53.6	57.2	53.6	41.7	30.7	35.1
Italy	103.3	96.5	95.0	89.0	91.8	83.4	76.9	52.7	60.6
Japan	86.6	90.0	86.2	85.4	89.7	90.5	94.2	81.4	81.9
Kazakhstan	1.1	1.6	0.0	0.0	0.0	0.0	0.0	0.0	0.0
Mexico	52.0	52.8	0.0	0.0	0.0	0.0	0.0	0.0	0.0
Netherlands	2.3	2.4	2.4	2.6	2.7	2.1	2.7	2/	2/
Poland	13.6	14.4	13.4	12.1	11.2	11.3	10.5	7.5	6.5
Portugal	4.5	5.3	6.0	6.7	6.8	7.0	7.4	0.0	0.0
Romania	2.9	3.7	2.7	2.2	0.0	0.0	0.0	0.0	0.0
Spain	13.3	15.5	16.8	15.6	16.7	14.1	15.2	14.3	17.2
Scandinavia	11.0	9.3	9.0	8.7	8.7	6.4	6.3	0.0	0.0
Turkey	0.0	0.0	11.4	18.5	17.5	16.6	17.1	22.6	26.2
United Kingdom 2/	34.5	32.5	34.5	27.0	22.8	22.1	23.7	20.1	20.2
United States	123.1	114.0	122.1	122.3	120.3	118.3	118.2	96.5	100.5
World	517.5	494.4	455.8	457.6	460.5	438.4	426.3	333.6	333.5
Europe	255.8	237.6	236.1	231.4	233.0	213.0	196.3	137.2	151.5
Mid East & Asia	86.6	90.0	97.6	103.9	107.2	107.1	111.3	104.0	108.1
America	175.1	166.8	122.1	122.3	120.3	118.3	118.2	96.5	100.5

Source: International Copper Study Group. United States - USGS Minerals Yearbook, var. issues.

1/ Master Alloys not included.

2/ Data aggregated in 2009 - U.K., Netherlands and Austria.

Table 5A. World Copper Alloy Foundry Production
(thousand metric tons, gross weight)

	2001	2002	2003	2004	2005	2006	2007	2008	2009	2010
Argentina	0.0	2.9	3.4	3.9	0.0	0.0	0.0	0.0	0.0	0.0
Austria	3.2	3.3	3.4	3.3	5.5	2.7	0.0	0.0	2.2	2.3
Belgium	0.5	0.5	0.5	0.5	0.5	1.0	0.0	0.0	0.0	0.0
Brazil	14.1	13.7	0.0	19.5	19.0	20.3	19.8	19.9	12.1	16.5
Canada	0.0	0.0	0.0	18.6	18.6	18.6	18.6	17.7	17.7	12.1
China	125.0	137.2	157.0	327.6	416.1	470.2	571.3	600.0	600.0	700.0
Croatia	0.7	0.6	0.7	0.7	1.1	0.8	0.7	0.5	0.5	0.5
Czech Rep.	1.5	1.8	1.5	1.1	1.7	1.8	1.8	2.7	0.9	4.5
Denmark	1.1	1.3	1.6	1.3	1.1	0.8	0.8	1.4	1.4	1.4
Finland	3.8	3.9	3.8	4.0	4.0	4.3	3.5	4.6	3.1	3.9
France	25.9	29.4	28.3	27.2	26.3	25.5	25.4	24.7	18.8	19.4
Germany	88.5	90.0	91.3	88.5	84.4	98.1	96.6	94.6	76.7	77.2
Hungary	2.7	2.3	1.9	2.1	2.1	4.3	1.8	1.9	1.4	1.3
Iran	25.0	0.0	27.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
Italy	114.5	110.0	106.1	97.8	83.0	92.0	86.7	81.0	59.9	69.0
Japan	86.6	86.7	100.6	105.5	97.8	105.9	106.9	98.8	75.3	79.3
Rep. Of Korea	20.8	21.6	22.2	22.9	23.2	23.6	23.9	24.1	24.5	25.1
Mexico	80.0	175.0	175.0	180.0	180.0	0.0	0.0	202.4	126.5	140.7
Netherlands	2.8	2.7	2.5	2.4	1.9	0.0	0.0	0.0	0.0	0.1
Norway	3.4	3.5	2.6	2.7	4.7	5.3	5.0	3.3	2.2	1.8
Poland	17.2	16.8	6.3	7.4	6.3	7.3	7.0	8.2	0.0	7.9
Portugal	6.0	6.6	6.0	7.8	8.7	10.8	11.1	11.4	10.8	12.7
Romania	9.8	10.0	10.0	4.1	2.7	3.4	3.8	3.5	1.8	5.5
Russian Fed.	0.0	0.0	0.0	0.0	160.0	160.0	200.0	200.0	90.0	90.0
Slovenia	3.4	3.5	3.0	0.0	6.7	0.0	7.8	0.0	3.0	1.0
South Africa	0.0	0.0	14.5	14.9	14.9	3.0	3.0	3.0	17.2	16.7
Spain	13.1	13.0	6.3	7.9	7.9	9.1	9.3	9.5	6.8	7.8
Sweden	10.6	10.0	10.9	12.0	11.2	11.9	12.5	12.5	8.4	9.6
Switzerland	2.5	2.3	2.4	3.0	2.7	3.1	3.1	2.3	1.8	2.2
Taiwan	50.0	49.0	46.4	41.8	42.0	40.9	41.3	35.6	33.2	36.5
Thailand	0.0	0.0	0.0	0.0	28.6	28.6	28.6	28.6	28.6	28.6
Turkey	2.8	2.1	2.8	8.5	16.0	17.5	19.0	16.0	12.5	12.0
Ukraine	21.0	11.0	0.0	11.0	11.0	11.0	11.0	11.0	0.0	0.0
United Kingdom	25.5	20.5	15.0	15.7	15.0	13.0	13.0	12.0	8.0	9.5
United States [1/]	252.5	254.1	246.0	235.3	234.5	209.8	197.4	190.3	174.5	194.0
World	1017.0	1087.6	1113.2	1279.0	1539.2	1402.0	1528.1	1719.6	1418.4	1584.0
Europe [2/]	360.25	345.30	317.00	315.10	463.00	463.60	498.40	482.60	296.30	322.60
Mid East & Asia	310.20	296.60	356.00	506.60	624.00	686.70	790.90	803.10	774.10	881.40
America	346.55	445.73	440.19	457.29	452.13	248.70	235.80	430.90	330.80	363.30

Data Source: International Copper Study Group Bulletin, Table 18. February 2011

[1/] Source: U.S. Geological Survey, Minerals Yearbook, Table 12. Consumption of raw materials at foundrys

[2/] Includes Russian Federation.

Table 5B. World Copper, Copper Alloy and Master Alloy Ingot Imports[1] (thousand metric tons)

	2005	2006	2007	2008	2009	2010	2011	2012 (e)
Australia	2.9	4.1	4.5	2.6	5.1	2.6	4.8	0.0
Austria	2.3	2.9	2.5	2.2	1.7	1.5	1.5	2.8
Canada	14.5	12.4	10.5	12.3	4.9	5.7	4.7	4.8
China	63.6	54.8	59.8	48.2	53.0	60.8	39.8	65.7
Finland	3.2	4.0	4.2	3.2	2.3	2.7	2.5	2.0
France	10.1	11.0	14.3	8.9	8.0	9.3	9.1	9.3
Germany	28.8	38.9	47.7	40.1	38.4	36.2	35.3	36.6
Hong Kong	7.6	7.7	4.6	2.5	2.8	1.4	0.1	1.4
India	6.3	3.2	3.6	4.3	3.6	0.9	4.1	5.3
Italy	8.1	15.2	25.1	18.5	8.2	14.7	15.9	14.8
Japan	3.8	3.2	3.0	2.9	1.1	2.4	5.4	6.0
Mexico	6.3	6.8	6.6	8.2	7.4	3.7	8.8	8.8
Poland	3.2	4.1	4.1	3.2	2.3	2.5	2.9	3.5
Portugal	4.5	5.7	4.1	4.3	3.8	3.9	4.4	4.3

Table 5C. World Copper, Copper Alloy and Master Alloy Ingot Exports[1] (thousand metric tons)

	2005	2006	2007	2008	2009	2010	2011	2012 (e)
Australia	4.6	5.0	4.9	5.2	4.2	6.0	6.3	0.0
Belgium	14.5	13.4	14.8	12.7	9.5	12.1	11.8	14.8
Canada	3.5	7.5	6.3	4.6	2.0	2.9	2.7	3.7
France	9.9	9.7	13.1	13.1	9.4	13.6	10.6	11.6
Germany	21.0	23.4	20.9	16.5	9.8	12.2	12.3	15.3
Hong Kong	11.1	11.0	9.0	3.2	2.6	1.9	1.0	1.6
Italy	14.2	15.3	21.0	15.3	12.8	15.6	20.0	22.7
India	12.4	10.6	11.2	7.1	3.6	1.4	2.3	0.0
Japan	29.9	33.9	33.1	32.8	31.8	25.5	21.8	24.4
Netherlands	3.0	5.7	5.7	6.4	4.0	3.2	3.9	1.6
Poland	6.2	6.2	6.4	4.9	2.4	1.1	1.3	1.3
Rep. of Korea	20.2	20.6	17.7	17.1	15.2	20.7	21.2	23.2
Russian Fed.	7.8	7.2	5.4	4.6	9.9	4.8	0.9	2.8
Singapore	8.1	7.5	6.9	7.7	7.3	2.5	5.8	6.1
South Africa	5.0	4.4	27.0	2.5	1.3	0.6	2.6	2.3
Spain	9.8	10.7	12.6	11.9	12.0	15.9	16.0	20.3
Sweden	5.3	6.4	8.8	5.6	3.3	8.6	5.6	4.0
Switzerland	0.9	0.9	0.8	1.1	0.5	0.3	1.0	0.9
Taiwan	7.3	10.1	7.9	6.0	6.7	4.1	4.9	4.1
Turkey	2.2	0.0	5.6	6.9	2.3	3.6	10.1	7.6
Ukraine	7.8	12.4	19.8	11.2	7.0	2.0	0.0	0.0
United Kingdom	15.0	17.2	18.1	17.7	11.3	12.7	16.9	15.9
United States	35.4	40.1	40.4	38.9	27.6	36.2	35.7	34.8
Rest of World	63.8	84.6	114.6	96.2	51.5	37.8	95.0	54.9
World Total	318.7	363.8	413.8	349.2	248.1	245.3	309.9	273.6

[1]Data includes both copper alloy and master alloy ingots. Source: ICSG Monthly Bulletin, Oct. 2012. [e] Estimated on 7 months 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
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	13,468,100	2,888,600	12	465,894	33	67	1,422,223	3,941,118	36	24
1999	14,278,000	2,980,384	8	380,833	29	71	1,331,409	3,996,918	33	24
2000	15,185,000	3,022,654	7	358,392	27	73	1,310,000	4,099,105	32	23
2001	15,014,300	2,620,322	7	316,617	28	72	1,150,000	3,123,572	37	27
2002	15,210,000	2,365,194	3	208,219	20	80	1,029,622	3,298,121	31	25
2003	15,717,100	2,295,300	2	206,053	22	78	944,337	3,361,546	28	22
2004	16,832,700	2,414,800	2	191,210	20	80	965,094	3,431,398	28	23
2005	16,683,300	2,274,000	2	182,499	19	81	952,503	3,191,319	30	24
2006	17,034,400	2,110,000	2	151,000	16	84	968,499	3,010,356	32	27
2007	18,196,600	2,137,000	2	158,000	17	83	933,000	3,032,253	31	25
2008	18,053,100	2,020,000	3	156,000	18	82	859,000	2,696,100	32	26
2009	18,070,200	1,650,000	3	138,000	18	82	777,000	2,236,893	35	29
2010	19,346,400	1,760,000	2	143,000	18	83	785,000	2,418,800	32	27
2011	19,864,500	1,761,000	2	153,000	17	83	802,000	2,400,700	33	27
2012 e/	20,522,000	1,793,000	2	150,000	17	83	786,320	2,050,320	38	31

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

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

Table 6A. U.S. Cumulative Copper Calculations, 1955–2012
(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 US Consumption	Cum Resource (less annual new Scrap)	Cumulative U.S. Consumption of old and new scrap, 1906-2009	Percent All Scrap from Cum. Primary	Cumulative U.S. Recovery of Cu in Old Scrap plus net exports	Percent Old Plus Net Exports from Cum. Primary less New Scrap
1955	1,626,799	466,823	1,159,976	35,879,129	29,915,218	22,575,374	63	12,897,499	43.1
1956	1,641,023	425,006	1,216,017	37,095,146	30,662,288	23,419,658	63	13,322,505	43.4
1957	1,451,195	403,237	1,047,958	38,143,104	31,350,319	24,183,405	63	13,725,742	43.8
1958	1,304,939	373,186	931,753	39,074,857	31,932,028	24,906,783	64	14,098,928	44.2
1959	1,547,231	427,291	1,119,940	40,194,797	32,634,526	25,750,982	64	14,526,219	44.5
1960	1,452,182	389,514	1,062,668	41,257,465	33,296,124	26,541,492	64	15,041,122	45.2
1961	1,517,154	372,953	1,144,201	42,401,666	34,043,174	27,311,637	64	15,528,785	45.6
1962	1,639,881	377,093	1,262,788	43,664,454	34,846,958	28,147,906	64	15,938,552	45.7
1963	1,712,345	382,690	1,329,655	44,994,109	35,675,090	29,031,891	65	16,355,766	45.8
1964	1,776,341	429,571	1,346,770	46,340,879	36,460,395	30,023,463	65	16,872,279	46.3
1965	1,981,932	465,781	1,516,151	47,857,030	37,305,040	31,160,393	65	17,388,022	46.6
1966	2,216,369	485,217	1,731,152	49,588,182	38,310,863	32,370,804	65	17,894,957	46.7
1967	1,835,788	437,861	1,397,927	50,986,109	39,094,184	33,423,054	66	18,378,479	47.0
1968	1,909,069	472,436	1,436,633	52,422,742	39,898,102	34,528,314	66	18,931,537	47.4
1969	2,058,319	521,531	1,536,788	53,959,530	40,709,177	35,776,141	66	19,509,294	47.9
1970	1,818,866	457,286	1,361,580	55,321,110	41,396,092	36,907,947	67	20,043,030	48.4
1971	1,886,418	403,812	1,482,606	56,803,716	42,192,010	37,996,678	67	20,496,343	48.6
1972	2,142,445	415,667	1,726,778	58,530,494	43,152,220	39,176,901	67	20,950,635	48.6
1973	2,223,351	441,086	1,782,265	60,312,759	44,126,162	40,426,237	67	21,470,476	48.7
1974	2,144,892	438,562	1,706,330	62,019,089	45,041,942	41,645,784	67	21,978,496	48.8
1975	1,473,444	334,908	1,138,536	63,157,625	45,633,001	42,527,536	67	22,394,379	49.1
1976	1,923,872	380.225	1,543,647	64,701,272	46,518,134	43,566,511	67	22,827,177	49.1
1977	2,069,701	409,928	1,659,773	66,361,045	47,516,417	44,651,936	67	23,293,894	49.0
1978	2,369,537	501,650	1,867,887	68,228,932	48,647,169	45,899,171	67	23,885,326	49.1
1979	2,434,234	604,301	1,829,933	70,058,865	49,528,785	47,451,696	68	24,590,717	49.6
1980	2,178,849	613,458	1,565,391	71,624,256	50,270,463	48,889,123	68	25,319,992	50.4
1981	2,271,416	591,805	1,679,611	73,303,867	51,134,116	50,296,520	69	25,989,194	50.8
1982	1,762,385	517,726	1,244,659	74,548,526	51,709,035	51,483,986	69	26,585,582	51.4
1983	2,012,739	449,478	1,563,261	76,111,787	52,662,949	52,567,565	69	27,101,892	51.5
1984	2,116,058	460,695	1,655,363	77,767,150	53,655,093	53,687,479	69	27,679,845	51.6
1985	2,144,436	503,407	1,641,029	79,408,179	54,660,443	54,826,563	69	28,350,784	51.9
1986	2,138,223	477,469	1,660,754	81,068,933	55,669,897	55,953,091	69	29,004,126	52.1
1987	2,196,540	497,937	1,698,603	82,767,536	56,652,718	57,167,150	69	29,665,031	52.4
1988	2,213,768	518,179	1,695,589	84,463,125	57,560,996	58,474,041	69	30,359,678	52.7
1989	2,184,534	547,561	1,636,973	86,100,098	58,436,904	59,782,496	69	31,111,624	53.2
1990	2,168,179	535,656	1,632,523	87,732,621	59,295,555	61,092,025	70	31,800,027	53.6
1991	2,090,000	518,000	1,572,000	89,304,621	60,177,412	62,292,715	70	32,473,337	54.0
1992	2,300,000	555,000	1,745,000	91,049,621	61,205,578	63,569,792	70	33,098,069	54.1
1993	2,510,000	543,000	1,967,000	93,016,621	62,433,501	64,855,487	70	33,703,793	54.0
1994	2,690,000	500,000	2,190,000	95,206,621	63,790,004	66,183,384	70	34,358,907	53.9
1995	2,540,000	442,509	2,097,491	97,304,112	65,010,718	67,500,179	69	35,034,133	53.9
1996	2,830,000	428,362	2,401,638	99,705,750	66,519,028	68,819,331	69	35,608,661	53.5
1997	2,950,000	497,670	2,452,330	102,158,080	67,992,502	70,283,927	69	36,246,330	53.3
1998	3,027,355	465,894	2,561,461	104,719,541	69,555,373	71,706,150	68	36,831,273	53.0
1999	3,127,206	380,936	2,746,270	107,465,811	71,275,683	73,034,756	68	37,366,834	52.4
2000	3,090,537	358,392	2,732,145	110,197,956	73,105,750	74,347,756	67	38,026,342	52.0
2001	2,508,768	317,212	2,191,556	112,389,512	74,246,084	75,497,981	67	38,710,326	52.1
2002	2,610,866	190,135	2,420,731	114,810,243	75,673,696	76,528,203	67	39,247,783	51.9
2003	2,427,975	206,842	2,221,133	117,031,376	77,353,824	77,472,432	66	39,968,339	51.7
2004	2,554,431	191,210	2,363,221	119,394,597	79,046,244	78,437,526	66	40,684,629	51.5
2005	2,387,306	182,499	2,204,807	121,599,404	80,515,056	79,390,029	65	41,353,044	51.4
2006	2,192,857	151,000	2,041,857	123,641,261	80,515,056	80,358,528	65	42,102,421	52.3
2007	2,272,504	162,000	2,110,504	125,751,765	81,739,478	81,291,528	65	42,897,175	52.5
2008	1,996,100	159,000	1,837,100	127,588,865	81,853,560	82,150,526	64	43,702,268	53.4
2009	1,597,893	138,000	1,459,893	129,048,758	82,876,578	82,927,528	64	44,459,171	53.6
2010	1,776,800	143,000	1,633,800	130,682,558	82,674,453	83,712,528	64	45,365,722	54.9
2011	1,751,700	153,000	1,598,700	132,281,258	83,868,378	84,514,526	64	46,463,615	55.4
2012	1,414,000	150,000	1,264,000	133,545,258	83,624,153	85,300,848	64	47,529,207	56.8

[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 1864-2012 data. [e] Estimated on partial year data.

Table 6B. Estimation of the Recycling Input Ratio (RIR)[1] and Recovery Ratio for the United States[2], 1981–2011 (thousand metric tons)

Year	Brass & Wire Mill Production	Foundry Production	Total Semis	Gross Weight Scrap 3/	Recycling Input Ratio (Percent)	Copper Scrap Exports	Total Scrap Recovered	Recycling Recovery Ratio (Percent) 4/
1981	2784.2	312.8	3096.9	1825.6	58.9	146.2	1971.8	63.7
1982	2102.4	251.5	2353.9	1514.8	64.4	146.0	1660.8	70.6
1983	2278.4	229.3	2507.7	1381.6	55.1	128.2	1509.8	60.2
1984	2567.7	243.5	2811.2	1433.5	51.0	189.6	1623.1	57.7
1985	2401.3	264.1	2665.4	1411.8	53.0	280.2	1692.0	63.5
1986	1969.1	248.8	2218.0	1495.0	67.4	289.4	1784.4	80.5
1987	2783.8	243.3	3027.1	1578.6	52.1	293.8	1872.4	61.9
1988	2810.1	258.3	3068.4	1619.2	52.8	320.5	1939.7	63.2
1989	2776.4	251.0	3027.4	1620.6	53.5	367.5	1988.0	65.7
1990	2707.6	185.9	2893.5	1607.9	55.6	324.4	1932.3	66.8
1991	2623.0	214.3	2837.3	1553.0	54.7	306.6	1859.6	65.5
1992	2783.1	220.4	3003.5	1668.5	55.6	246.6	1915.2	63.8
1993	2998.9	214.5	3213.4	1696.7	52.8	262.1	1958.8	61.0
1994	3334.6	230.7	3565.3	1710.0	48.0	359.9	2069.9	58.1
1995	3297.2	225.3	3522.5	1652.5	46.9	456.2	2108.7	59.9
1996	3584.1	229.8	3813.9	1625.3	42.6	392.7	2018.0	52.9
1997	3721.9	237.2	3959.1	1755.7	44.3	379.6	2135.3	53.9
1998	3807.5	224.2	4031.7	1720.0	42.7	307.5	2027.5	50.3
1999	3926.2	258.1	4184.3	1630.0	39.0	314.7	1944.7	46.5
2000	3916.5	278.3	4194.8	1587.2	37.8	485.5	2072.7	49.4
2001	3306.2	252.5	3558.7	1376.8	38.7	534.0	1910.8	53.7
2002	3257.2	254.1	3511.3	1227.9	35.0	511.0	1738.8	49.5
2003	3075.4	246.0	3321.4	1113.9	33.5	689.0	1802.9	54.3
2004	3435.6	235.3	3670.9	1143.9	31.2	714.0	1857.9	50.6
2005	3208.2	234.5	3442.7	1148.1	33.3	657.9	1806.0	52.5
2006	3061.1	209.8	3270.9	1150.1	35.2	803.1	1953.2	59.7
2007	2946.9	197.4	3144.3	1079.8	34.3	906.5	1986.3	63.2
2008	2670.2	190.9	2846.3	997.6	35.0	908.1	1905.7	67.0
2009	2043.9	174.5	2218.4	914.3	41.2	842.6	1756.9	79.2
2010	1934.2	194.0	2128.2	930.2	43.7	1033.0	1963.2	92.2
2011	2181.4	199.8	2381.2	942.3	39.6	1239.3	2181.6	91.6

p/ preliminary
1/ Recycling Input Ratio (RIR) = Total Scrap Consumed/Total Semis Produced
methodology after ICSG Special Paper, 2004 , "Recycling in Western Europe"
2/ Data sources: U. S. Dept of Commerce, U.S. Bureau of Mines, U. S. Geological Survey
and International Copper Study Group publications.
3/ Gross weight scrap consumed by U.S. brass mills, wire mills, foundries and miscellaneous manufacturers.
4/ Recycling Recovery Ratio (ROR)= total scrap recovered/total semis produced.

Table 7. U.S. Production of Refined Copper, by Source
(thousand metric tons)

Year	Primary Refined	Secondary Refined	SX-EW Refined	Total Refined	Percent Secondary Refined
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	1,000	172	628	1,801	10
2002	841	70	601	1,512	5
2003	662	53	591	1,307	4
2004	671	51	584	1,306	4
2005	654	47	554	1,255	4
2006	675	45	530	1,250	4
2007	702	46	504	1,252	3
2008	603	54	507	1,164	4
2009	558	46	476	1,080	4
2010	608	18	430	1,054	3
2011	545	37	449	1,031	4
2012 e/	435	38	469	942	4

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

e/ Estimated on partial years data.

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

YEAR	UNALLOYED 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 EXPORTS GROSS WT.	COPPER ALLOY SCRAP EXPORTS COPPER CONT.	UNALLOYED SCRAP EXPORTS	TOTAL COPPER SCRAP EXPORTS GROSS WT.	TOTAL COPPER IN SCRAP EXPORTS
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
2002	29,253	70,857	51,017	100,110	80,270	297,762	214,389	213,203	510,965	427,592
2003	19,600	70,981	51,106	90,581	70,706	373,423	268,865	315,555	688,978	584,420
2004	23,400	78,300	56,376	101,700	79,776	388,689	279,856	325,118	713,807	604,974
2005	30,067	83,700	60,264	113,767	90,331	291,481	209,866	366,381	657,862	576,247
2006	24,927	92,598	66,671	117,525	91,598	404,091	290,946	399,029	803,120	689,975
2007	58,293	74,781	53,842	133,074	112,135	577,184	415,572	329,327	906,511	744,899
2008	32,785	73,547	52,954	106,332	85,739	629,638	453,339	278,493	908,131	731,832
2009	16,299	55,534	39,984	71,833	56,283	597,811	430,424	244,762	842,573	675,186
2010	21,380	74,459	53,610	95,839	74,990	701,447	505,042	333,539	1,034,986	838,581
2011	30,359	79,444	57,197	109,803	87,556	738,730	531,886	500,563	1,239,293	1,032,449
2012 e/	29,860	75,356	54,256	105,216	84,116	716,114	515,602	484,106	1,200,220	999,708

Sources: U.S. Dept. of Commerce, U.S. Bureau of Mines and U.S. Geological Survey.
[e]Estimated on partial year data.

Table 8A. U.S. Domestic Exports of Copper and Copper Alloy Scrap[1]
(metric tons)

Type of Scrap	2006	2007	2008	2009	2010	2011
No 1	67,319	47,834	63,711	66,574	64,644	119,327
No 2 and nonspecified	331,710	281,493	214,782	178,188	268,895	381,234
Total unalloyed scrap:	399,029	329,327	278,493	244,762	333,539	500,561
Red, SemiRed Brass >0.3%Pb	4,952	6,898	5,298	6,425	4,964	4,234
Red Brass < 0.3%Pb	24,940	22,568	26,565	41,568	36,619	41,207
Yellow Brass > 0.3% Pb	57,054	73,540	59,436	30,414	26,653	41,668
Yellow Brass < 0.3% Pb	35,384	28,609	29,605	21,408	41,190	59,215
Other copper scrap nesoi	85,490	96,291	105,590	116,040	198,244	165,224
Mixed copper & copper alloy	196,271	349,278	403,144	381,956	391,777	427,182
Total alloy & mixed scrap:	404,091	577,184	629,638	597,811	699,447	738,730
Grand Total Scrap Exports:	803,120	906,511	908,131	842,573	1,032,986	1,239,291

Data does not include reexports
[e]Sources: USITC data webb, 2012, US Dept of Commerce.

Table 9. U.S. Trade and Consumption of Copper Ash and Residues[1] and Zinc Products from Scrap. (thousand metric tons)

Product	1993	1994	1995	1996	1997	1998	1999	2000	2001	2002	2003	2004	2005	2006	2007	2008	2009	2010	2011
Exports:																			
Copper Ash & Residues (Gross Wt)	12.27	23.36	28.11	21.15	25.87	11.42	14.00	12.99	8.34	2.95	7.08	19.04	20.84	50.81	62.15	46.18	40.92	43.96	38.30
Zinc Dross, Skimmings, Residues (262019)																			
Zinc Content of Dross, etc.	12.10	18.21	17.77	14.02	11.33	8.70	4.56	14.15	16.59	25.38	17.69	13.22	8.77	4.22	14.14	10.36	6.91	9.35	15.46
Imports:																			
Copper Ash & Residues[2]	1.55	1.06	1.74	1.68	0.49	1.20	0.66	0.76	0.63	0.70	1.00	1.47	1.59	1.67	1.63	1.10	0.74	0.84	0.00
Zinc Content of Product:																			
Zinc Dross & Skimmings (26201930)	13.62	13.91	13.29	15.99	18.66	23.83	22.66	17.59	13.69	17.30	15.79	18.50	17.76	33.07	16.90	13.98	10.28	11.13	9.72
Zinc Ash and Residues (26201960)	1.25	1.70	0.79	1.74	1.08	0.46	0.31	0.16	0.02	0.16	0.87	0.83	0.54	0.68	0.73	0.08	0.02	1.43	0.19
Total Zinc in Dross, etc.	14.87	15.60	14.08	17.73	19.74	24.30	22.97	17.75	13.71	17.46	16.66	19.33	18.31	33.75	17.62	14.06	10.30	12.56	9.90
Zinc Recovered from Scrap:																			
Zinc Recovered as Pb-free Zinc Oxide	36.00	36.80	33.60	47.10	47.90	64.20	35.90	23.10	19.70	15.60	14.90	15.00	15.00	15.0 e/	15.0 e/	15.0 e/	15.0 e/	15.0 e/	15.0 e/
Zinc Recovered from All Scrap	355.00	361.00	353.00	379.00	374.00	434.00	399.00	439.00	368.00	366.00	345.00	349.00	368.43	346.52	234.00	339.00	273.00	331.00	330.00
Zinc Recovered in Copper Alloys[3]	153.76	172.68	169.63	179.63	193.97	201.00	206.70	223.00	205.00	198.00	176.00	168.00	176.00	159.00	149.20	130.02	119.29	124.80	124.00
Purchased Copper-base Scrap:																			
Lowgrade Copper Ash, Residues, etc.																			
Gross Weight Scrap	161.31	81.40	92.60	83.10	87.10	124.00	111.00	105.00	70.24	30.20	32.16	35.26	34.96	35.20	23.50	23.30	23.30	23.00	22.90
Copper Content[4]	56.46	28.49	32.41	29.09	30.49	43.40	38.85	36.75	24.58	10.57	11.25	12.34	12.23	12.32	8.23	8.16	8.16	8.05	8.02
Low Grade Copper Base Shipments[5]																			
Copper Content of Shipments	59.21	35.61	40.50	34.81	39.05	46.20	43.09	40.54	26.87	10.90	12.73	17.54	17.94	28.43	28.35	23.21	21.74	22.60	21.42
Gross Weight of Shipments[4]	169.16	101.73	115.72	99.46	111.56	131.99	123.11	115.82	76.78	31.14	36.39	50.11	51.25	81.23	80.99	66.33	62.12	64.56	61.20

Data sources: USGS, USBM Minerals Yearbooks and Mineral Industry Surveys, Bureau of Census Trade Data.
NA = not available

[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	2000	2001	2002	2003	2004	2005	2006	2007	2008	2009	2010	2011
Alloy Ingots:												
Leaded & semi-red brass	103.0	87.1	88.6	64.7	68.4	68.7	69.4	65.3	65.3	52.4	51.4	51.2
Yellow Brass	5.7	6.0	4.7	4.4	5.9	5.9	5.6	5.6	5.6	4.9	5.1	5.3
Tin & High Leaded Tin Bro	27.8	25.3	23.8	18.7	20.6	20.6	20.2	19.5	19.5	14.2	16.6	18.7
Nickel Silver	2.3	2.5	1.9	2.3	2.1	2.0	2.1	1.6	1.6	1.1	1.0	1.0
Aluminum & Manganese B	13.9	16.6	13.8	12.9	14.3	14.2	14.0	14.4	14.3	13.1	13.8	13.8
Other Alloy Ingots	8.2	8.4	7.6	10.3	10.8	10.9	9.1	12.0	12.0	10.8	12.6	12.5
Hardeners and Master Allo	13.8	11.3	5.4	5.4	5.5	5.8	7.6	7.7	7.7	7.7	7.7	5.3
Total Ingots	174.6	157.1	128.6	118.6	127.6	128.1	128.0	126.0	125.8	104.1	108.2	107.8
Foundry Castings [2/]	278.3	252.5	254.1	246.0	235.3	234.5	209.8	197.4	190.9	174.5	194.0	199.8
Copper Sulfate (Gross Wei	55.5	55.2	49.2	32.1	25.1	25.6	19.5	22.6	22.0	22.4	23.7	22.8
Copper & Copper Alloy Po	7.7	7.6	7.6	6.9	0.1	0.4	0.2	1.3	1.1	0.6	0.0	0.0
Total Semifabricates	3,916.5	3,306.2	3,257.2	3,075.4	3,435.6	3,208.2	3,061.1	2,946.9	2,670.2	2,043.9	1,934.2	2,181.4
Copper Semis	3,012.5	2,634.9	2,532.6	2,404.4	2,708.1	2,514.1	2,359.1	2,328.5	2,115.4	1,634.1	1,612.3	1,709.0
Copper Alloy Semis	904.0	671.3	724.6	671.0	727.5	694.1	702.0	618.4	554.8	409.8	321.9	472.4

Data Sources: U.S. Geological Survey, U.S. Bureau of Mines, International Copper Study Group, Copper Development Assn.
[1]Copper powder from scrap only. Some firms also used ingot to produce powder, amounts not shown here. U.S. Geol. Survey.
[2]Consumption of raw materials at foundries. USGS Mineral Yearbook var. issues, Table 12.

Table 10a. U.S. Exports of Copper and Copper Alloy Semis, and Copper Sulfate, Powder and Hydroxides (Thousand metric tons)

	2004	2005	2006	2007	2008	2009	2010	2011	2012[1/]
Total Copper Semis Exports	205.50	221.80	233.80	224.10	200.40	170.90	204.30	195.10	206.00
Total Copper Alloy Semis Exports	91.60	104.30	99.90	90.70	82.40	57.40	68.00	63.70	64.00
Total Semis Exports	297.20	326.20	333.80	314.80	282.80	228.30	272.30	258.70	270.00
283325 - Copper Sulphate (G.W.) Exports	1.44	3.22	3.29	4.77	5.43	5.88	7.97	6.52	6.49
Copper Sulphate (Copper Content)	0.56	1.25	1.28	1.86	2.12	2.29	3.10	2.54	2.53
74061 - Copper Powder Non-Lamellar Structure	8.29	10.82	10.44	9.92	7.38	5.81	9.10	7.54	7.47
74062 - Copper Powder Flakes Exports	0.90	1.43	1.03	1.35	1.32	0.63	1.00	0.68	1.16
7406 - Total Copper Powder Exports	9.18	12.25	11.47	11.27	8.70	6.44	10.10	8.22	8.63
2825503 - Copper Oxides & Hydroxides Exports	20.70	19.63	21.71	21.95	26.76	22.46	27.66	26.32	23.13

Table 10b. U.S. Imports of Copper and Copper Alloy Semis, and Copper Sulfate, Powder and Hydroxides (Thousand metric tons)

	2004	2005	2006	2007	2008	2009	2010	2011	2012 1/
Total Copper Semis Imports	423.60	554.30	562.00	409.40	340.10	250.30	245.10	273.00	265.00
Total Copper Alloys Semis Imports	146.60	117.30	114.60	98.10	99.80	63.40	95.40	97.20	104.00
Total Semis Imports	570.10	671.60	676.60	507.50	439.90	313.80	340.50	370.10	369.00
283325 - Copper Sulphate (G.W.) Imports	56.05	55.85	53.61	57.01	56.77	49.34	47.98	38.61	38.36
Copper Sulphate (Copper Content)	21.84	21.77	20.89	22.22	22.12	19.23	18.70	15.05	14.95
2825503 - Copper Hydroxides Imports	3.75	3.00	1.45	0.43	0.41	0.25	0.24	0.75	0.42
74062 - Copper Powder Flakes Imports	0.79	0.91	1.57	0.79	0.99	0.63	0.67	0.88	0.75
74061 - Copper Powder Non-Lamellar Structure Imports	2.02	2.81	3.02	3.65	2.61	2.38	3.19	3.29	2.86
7406 - Total Copper Powder Imports	2.82	3.72	4.59	4.44	3.60	3.01	3.86	4.18	3.61

[1/] Based on 8 months data. Source U.S. Dept of Commerce and the U.S. International Trade Commission.
Major export destinations in 2009 and 2010 were:
Hyrdroxides/oxides: China, Canada, Korea, Sweden, Singapore, Portugal and United Kingdom.
Copper sulfate : Canada, Israel, Ireland and China.

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

Data Source: Copper Development Association Inc.
[1] May include columbium.
[2] Includes beryllium copper and chromium copper.
[3] Special alloys include Incramet 8009, Incramute 1, while tombasil, etc.

Table 12. Copper Recovered from Scrap in the United States and Form of Recovery
(metric tons, copper)

Form of Recovery	2001	2002	2003	2004	2005	2006	2007	2008	2009	2010	2011
Electrolytic Refined	172,474	69,923	53,281	50,761	47,208	44,800	42,100	53,800	46,400	37,700	37,300
Fire-Refined	(w)	(w)	(w)	(w)	(w)	(w)	(w)	(w)	(w)	(w)	(w)
Copper Powder	7,452	7,439	8	48	314	134	1,240	1,070	587	1,230	1,030
Copper Castings	323	300	338	574	547	612	114	136	82	82	124
Total unalloyed	180,249	77,662	53,627	51,383	48,069	45,546	42,351	55,006	47,069	39,000	38,400
In Brass and Bronze	893,363	876,216	818,087	839,975	836,591	846,000	799,000	731,000	675,000	689,000	701,000
In Alloy Iron and Steel	506	425	974	1,017	985	792	890	677	673	731	692
In Aluminum Alloys	64,006	63,177	59,258	60,446	53,401	68,800	72,600	60,700	46,100	51,600	59,600
In Other Alloys	117	122	27	28	32	36	13	8	8	9	12
In Chemical Compounds[1]	11,248	12,022	12,255	12,255	12,255	8,210	5,040	5,040	5,030	5,030	5,030
Total	1,149,489	1,029,624	944,228	965,094	951,332	968,546	925,000	852,000	774,000	785,000	602,000

Source: USGS Minerals Yearbook, Copper Chapter
[1] 1999-2009 reflect addition of copper sulfate and other copper chemical producers, not included in previous data.
(w) Fire Refined included in electrolytic refined total. Data withheld.

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

COMPANY NAME	CITY	STATE
1. Ampco Metal Inc. (Hdqs Switzerland)	Chicago	Illinois
3. Ansonia Copper & Brass	Ansonia	Connecticut
4. Ansonia Copper & Brass Inc.	Waterbury	Connecticut
5. Brush Wellman Inc.	Elmore and Lorain	Ohio
6. Brush Wellman Alloy Products	Reading	Pennsylvania
7. Cambridge Lee Industries (Grupo Iusa)	Reading	Pennsylvania
8. Cerro Flow Products.(Copper tube)	Sauget	Illinois
9. Cerro Flow Products (Copper tube)	Shelbina and Mexico	Missouri
10. Chase Copper & Brass (Div. Global Brass and Copper)	Montpelier	Ohio
11. Chicago Extruded Metals	Cicero	Illinois
12. CMC Howell Metal (Commercial Metals)	New Market	Virginia
13. Concast Metal Products	Birmingham	Ohio
14 Drawn Metal Tube Co.	Tomaston	Connecticut
15. The Electric Materials Co.(United Stars)	Northeast	Pennsylvania
16. Freeport McMoRan Bayway Operations	Elizabeth	New Jersey
17. Fushi Copperweld Bimetallics (Fushi Internat. 2007)	Fayetteville	Tennessee
18. Hussey Copper Ltd.	Leetsdale	Pennsylvania
19. Hussey Copper Ltd.	Eminence	Kentucky
20. Weiland Copper Products (Weiland Gp, Germany)	Wheeling	Illinois
21. Weiland Copper Products (Weiland Gp, Germany)	Pine Hall	North Carolina
22. Little Falls Alloys	Paterson	New Jersey
23. Luvata Grenada LLC (Heatcraft)	Grenada	Missouri
24. Luvata Buffalo Inc. (Nordic Capital)	Buffalo	New York
25. Luvata Franklin Inc. (Outukumpu)	Franklin	Kentucky
26. Luvata Appleton LLC (Valleycast Inc.)	Appleton	Wisconsin
27. MAC Metals Inc.	Kearny	New Jersey
28. MAC Metals Inc. (Kearney Smelting & Refining)	Kearny	New Jersey
29. The Miller Co. (Diehl Metall Corp., Germany)	Meriden	Connecticut
30 Mueller Brass Products (Rod) (Mueller Industries)	Port Huron	Michigan
31. Extruded Metals (Mueller Industries Brass Rod)	Belding	Michigan
32. Mueller Copper Tube Products Co. (Mueller Industries)	Fulton	Mississippi
33. Mueller Copper Tube Products Co. (Mueller Industries)	Wynne	Arkansas
34. National Copper Products, Inc. (Tube Mill)	Dowagiac	Michigan
35. National Copper & Smelting (Nat Copper Products)	Huntsville	Alabama
36. NGK Berylco (NGK Metals Corp.)	Sweetwater	Tennessee
37. Olin Corp.(Div Global Brass & Copper)	E. Alton	Illinois
38. Olin Corp.(Div Global Brass & Copper)(Bryan Metals)	Bryan	Ohio
39. Olin Corp.(Div Global Brass & Copper)	Cuba	Missouri
40. PMX Industries Inc. (Poongsan Corp. S.Korea)	Cedar Rapids	Iowa
41. Revere Copper Products	Rome	New York
42. Small Tube Products Inc. (Wolverine Tube)	Altoona	Pennsylvania
43. Winchester Olin (Div of Global Brass and Copper)	Oxford	Mississippi
44. Wolverine Tube Inc. (Hdqs Huntsville, Ala)	Carrolton	Texas
45. Wolverine Tube Inc.	Shawnee	Oklahoma
46. Wolverine Joining Technologies (Wolverine Tube Inc.)	Warwick	Rhode Island
47. Wolverine Tube Inc.	Ardmore	Tennessee

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

Company Name	City	State	Remarks	Status
American Nickel Alloy Mfg. Corp	New York	New York	Cast alloys, copper anodes	Operating
Atlas Pacific Corporation	Altadena	California	Copper alloy ingots	Operating
Belmont Smltg & Refg. Works, Inc	Brooklyn	New York	Copper alloy ingots/powder	Operating
Bolton Metal Products	Bellefonte	Pennsylvania	Custom fusible alloys	Operating
Brush Wellman Inc.	Cleveland	Ohio	Beryllium Master Alloy	Operating
California Metal - X	Los Angeles	California	Copper base & copper nickel	Operating
Colonial Metals Co.	Columbia	Pennyslvania	Brass & bronze ingots	Operating
Concast Metals	Mars	Pennsylvania	Phos copper, copper anodes	Operating
Federal Metal Co.	Bedford	Ohio	Ingots, continuous cast billets	Operating
H. Kramer & Co.	Chicago	Illinois	Copper alloy ingots	Operating
Handy & Harman	Attleboro	Maine	Precious metals, copper	Closed
I Schumann & Co.	Bedford	Ohio	Copper alloy ingots, Enviro Alloy	Operating
Kearny Smelting & Refining Corp.	Kearny	New Jersey	Ingot making closed 2003	Closed 2003
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	Master alloys	Operating
National Bronze & Metals	Houston	Texas	Founded 1983, Ohio foundry	Operating
National Metals Inc.	Leeds	Alabama	Brass and Bronze ingots	Operating
R. Lavin & Sons, Inc.	North Chicago	Illinois	N. Chicago Ref. & Smelters	Closed 2003
River Smelting & Refining Co.	Cleveland	Ohio	Ohio Superfund Site	Closed 2004
SIPI Metals Corp.	Chicago	Illinois	Brass, Bronze, Master Alloys	Operating
Specialloy Copper (IBC Adv.Alloys)	New Madrid	Missouri	Copper Alloy, Be Alloy ingot	Operating
Univertical Corporation	Angola	Indiana	Phos copper, copper anodes	Operating
Avril G.Z. Brass & Bronze	Cincinnati	Ohio	Copper alloy ingots	Operating
W.J. Bullock	Fairfield	Alabama	Brass and Bronze ingots	Operating
Secondary Smelters and Refiners:				
Warrenton Copper LLC (AIM)	Warrenton	Missouri	Fire Refinery, ingot, wirebar	Operating
Amrod Corp	Newark	New Jersey	Wirerod casting, cathode	Operating
Cambridge-Lee Industries	Reading	Pennsylvania	Fire Refinery, billet casting	Operating
Cerro Flow Products	E. St Louis	Illinois	Fire Refinery, billet casting	Closed 2001
Cerro Flow Casting Co.	Mexico	Missouri	Billet casting, uses cathode	Operating
Cerro Copper Products	E. St Louis	Illinois	Electrolytic refinery/smelter	Closed, 1998
Chemetco (Concorde Metals)	Alton	Illinois	Secondary smelter, anode	Closed, 2001
Superior Essex (LS Cable Ltd)	Ft Wayne	Indiana	Fire Refinery, cont. cast wire roc	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 Chemical and Hydrometallurgical Recovery Plants				
American Chemet	Helena	Montana	Copper Chemicals, Powder	Operating
Encyle Texas (Div. Of Asarco)	Corpus Christi	Texas	Processes cu-bearing waste	Closed 2007
Griffin Corp.(Kocide Chemical)	Several Plants	GA, TX	Copper Chemicals	Operating
Hydromet Environmental Inc.	Newman	Illinois	Processes cu-bearing waste	Operating
Old Bridge Chemicals Inc	Old Bridge	New Jersey	Copper Sulfate, Copper Carbona	Operating
Peninsula Copper Inc.	Hubbell	Michigan	Copper Chemicals	Operating
Phibro-Tech(4 US, 1 French Plant)	Santa Fe Springs	California	Copper Chemicals	Operating
also (Phibro Animal Health Corp)	Garland	Texas	Copper Chemicals	Operating
(Micronutrients purchased	Joliet	Illinois	Copper Chemicals	Operating
Illinois and S.C. plants in 2003)	Sumter	South Carolina	Copper Chemicals	Operating
SCM Metals Products(Gibraltar Ind)	Research Triangle	North Carolina	Copper Powder/pastes/oxides	Operating
U.S. Filter Recovery Service	Vernon	California	Processes cu-bearing waste	Operating
(Siemens Water Technologies)	Minneapolis	Minnesota	Processes cu-bearing waste	Operating

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

	Copper		Tin		Lead		Zinc		Aluminum		Nickel/Cobalt		Manganese		Other	
Scrap Type	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

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

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

Copper from Type of Scrap	1950	1960	1970	1980	1990	2000	2002	2003	2004	2005	2006	2007	2008	2009	2010	2011
New Scrap:																
Copper-base	440	396	664	804	751	906	802.9	700.9	735.1	729.6	773	723	659	608	612	618
Aluminum-base	6	5	10	20	23	45.5	37.14	36.45	38.76	39.31	46.7	44.4	37.7	29.4	30.1	41.7
Nickel-base	0.2	0.1	0.1	0.2	0.04	0.018	0.018	0.018	0.018	0.018	0.018	0.018	0.018	0.018	0.018	0.018
Zinc & tin-base	<.01	0.03	0.01	0.02	nil	nil	nil	nil	nil	nil	nil	nil	nil	nil	nil	nil
Total	446	401	674	824	774	952	840.1	737.4	773.9	769	819	767	697	638	642	649
Old Scrap:																
Copper Base	437	387	453	596	502	334	165.4	184.9	168.8	167.9	128	131	133	120	121	124
Aluminum-base	2	2	4	15	34	28.4	23.98	21.74	22.12	14.18	22.4	27.2	22.9	16.7	21.7	28.7
Nickel-base	1.00	0.50	0.70	0.10	0.08	0.17	0.148	0.213	0.279	0.214	0.197	0.275	0.275	0.267	0.267	0.267
Zinc- & tin-base	0.09	0.08	0.04	0.1	0.03	0.032	0.029	0.027	0.029	0.033	0.038	0.013	0.009	0.009	0.009	0.013
Total	440	390	458	611	536	363	189.5	206.8	191.2	182.4	151	158	156	137	143	153
Total Copper	886	791	1,132	1,435	1,310	1,310	1,030	944	965	951	969	925	852	774	785	802

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, 1976–1992[1]
(metric tons)

Scrap Consumption by:	1977	1978	1979	1982	1983	1984	1985	1986	1987	1988	1989	1990	1991	1992	1993	1994
Plant type:																
Brass Mill	615,205	637,942	703,138	508,478	624,466	675,472	621,023	627,628	683,431	757,047	725,586	754,386	695,200	854,771	744,000	862,000
Secondary Smelters & Refiners	745,980	918,238	1,281,257	946,480	693,678	689,375	736,034	804,344	823,032	797,682	828,905	777,833	802,139	748,953	892,000	779,000
Foundries and misc. plants	67,238	86,799	88,831	59,889	63,472	68,610	54,722	63,037	72,173	64,507	66,097	75,654	55,680	64,800	60,700	67,000
Total, gross weight:	1,428,423	1,642,979	2,073,226	1,514,847	1,381,616	1,433,457	1,411,779	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
Source: [1]																
Old Scrap	555,140	664,289	830,335	659,574	574,376	572,311	570,923	612,896	675,088	644,314	673,258	696,125	696,125	731,596	741,817	669,000
New Scrap	873,283	978,690	1,242,891	855,273	807,240	861,146	840,856	882,113	903,548	974,916	943,501	856,892	856,892	936,928	954,883	1,040,000
Ratio Old/New	0.64	0.68	0.67	0.77	0.71	0.66	0.68	0.69	0.75	0.66	0.71	0.81	0.81	0.78	0.78	0.64
Type of Scrap:																
Unalloyed copper:																
No. 1 scrap	304,928	331,910	392,112	279,877	271,990	270,228	348,087	389,198	410,636	416,655	418,893	424,128	430,790	448,285	480,600	513,900
No. 2 scrap, mixed	262,413	326,112	447,267	417,004	324,665	367,436	278,047	338,031	383,862	409,332	392,755	342,658	335,456	380,284	385,690	361,350
Total Unalloyed:	567,341	658,022	839,379	696,881	596,655	637,664	626,134	727,229	794,498	825,987	811,648	766,786	766,246	828,569	866,290	875,250
Red Brass [2]	73,452	84,052	89,427	61,264	57,277	64,496	56,196	54,592	61,222	53,638	68,448	74,954	62,126	70,151	61,400	62,340
Cartridge brass	74,601	82,852	80,520	54,057	66,534	70,781	67,221	71,549	78,461	139,074	126,224	97,726	56,068	51,619	54,300	61,100
Yellow and low Brass [3]	359,569	385,836	408,392	288,327	345,638	387,165	347,074	314,405	341,347	338,949	326,167	371,656	351,351	393,268	409,560	454,850
Automobile Radiators	73,051	83,453	94,123	58,942	64,814	75,440	77,230	55,555	62,260	104,364	96,395	94,947	88,621	77,129	71,800	70,970
Bronze	24,413	23,299	24,574	18,195	20,949	24,593	19,994	20,030	21,050	21,296	21,092	18,608	20,683	25,001	23,600	23,200
Nickel silver/cupronickel	28,247	18,894	28,449	17,564	22,912	21,811	15,819	13,229	9,617	14,968	23,619	21,303	17,952	14,708	14,800	21,900
Aluminum bronze	1,043	941	1,605	1,396	1,136	972	969	970	965	1,005	2,696	2,246	w	w	w	w
Low-grade scrap and residue [4]	223,403	303,337	500,872	315,294	202,094	140,318	111,243	115,937	95,266	101,223	102,448	136,395	141,250	161,785	161,000	81,400
Refinery brass and other scrap	3,302	2,293	5,885	2,927	3,607	10,217	89,899	125,555	113,950	18,732	41,806	31,102	48,721	46,516	33,710	57,180
Total Alloyed Scrap	861,082	984,957	1,233,847	817,966	784,961	795,793	785,645	767,780	784,138	793,249	808,940	841,087	786,773	839,955	830,410	832,750
Copper recovered from scrap:																
Refined from scrap	349,646	420,103	498,459	467,549	401,668	306,537	371,787	406,000	415,000	446,000	480,000	440,757	417,757	433,223	459,788	391,000
Unalloyed powder & castings	15,075	17,017	17,812	14,016	17,186	31,652	15,882	8,446	8,757	10,478	9,282	9,143	8,330	9,316	9,182	11,297
Total unalloyed products	364,721	437,120	516,271	481,565	418,854	338,189	387,669	414,446	423,757	456,478	489,282	449,901	426,087	442,539	469,601	403,000
Brass and bronze	670,712	755,978	976,402	660,152	625,349	735,154	716,833	662,242	736,725	800,221	774,770	800,772	727,618	776,295	753,968	861,000
In aluminum alloys	44,218	48,153	53,608	41,930	36,704	43,511	29,423	45,171	47,932	45,632	41,719	56,489	44,277	55,607	61,049	62,800
From other alloys & chemicals	5,774	5,984	6,244	3,819	2,672	3,060	5,159	4,669	4,672	3,797	2,684	3,412	2,708	1,986	1,077	334
Total copper from scrap:	1,085,425	1,247,235	1,552,525	1,187,466	1,083,579	1,119,914	1,139,084	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

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.

Table 17B. U.S. Copper Scrap and Copper Alloy Consumption, 1995–2011[1]
(metric tons)

Scrap Consumption by:	1995	1996	1997	1998	1999	2000	2001	2002	2003	2004	2005	2006	2007	2008	2009	2010	2011 p
Plant type:																	
Brass Mill	886,000	909,000	1,010,000	1,020,000	1,046,800	1,070,000	918,508	929,616	840,921	880,291	874,019	895,437	828,960	739,000	688,000	698,500	707,700
Secondary Smelters & Refiners	695,000	655,000	693,000	644,000	501,000	421,000	370,051	211,283	187,082	182,893	192,465	179,247	181,300	193,800	159,200	156,900	157,400
Foundries and misc. plants	71,500	61,300	62,700	58,700	79,900	96,200	87,478	86,959	85,888	80,742	81,671	75,461	69,500	64,800	67,100	74,800	77,200
Total, gross weight:	1,652,500	1,625,300	1,765,700	1,722,700	1,627,700	1,587,200	1,376,037	1,227,858	1,113,891	1,143,926	1,148,155	1,150,145	1,079,760	997,600	914,300	930,200	942,300
Source: [1]																	
Old Scrap	621,000	583,000	594,000	574,000	464,000	414,000	257,875	200,290	224,742	202,441	201,286	159,000	165,000	161,000	134,000	149,000	152,000
New Scrap	1,030,000	1,040,000	1,170,000	1,150,000	1,164,000	1,170,000	1,119,121	1,027,566	889,149	941,485	946,869	991,000	915,000	836,000	780,000	781,000	790,000
Ratio old/new	0.60	0.56	0.51	0.50	0.40	0.35	0.23	0.19	0.25	0.22	0.21	0.16	0.18	0.19	0.17	0.19	0.19
Type of Scrap:																	
Unalloyed copper:																	
No. 1 scrap	572,000	533,500	597,800	583,900	538,000	566,900	512,117	484,839	478,724	480,020	478,890	486,114	466,700	433,800	393,800	364,100	369,300
No. 2 scrap, mixed	262,090	254,480	271,670	240,500	154,000	132,120	111,416	51,694	38,032	38,602	45,370	45,890	45,730	57,730	55,640	77,400	80,660
Total Unalloyed:	834,090	787,980	869,470	824,400	692,000	699,020	623,533	536,533	516,756	518,622	524,260	532,004	512,430	491,530	449,440	441,500	449,960
Red Brass [2]	81,910	81,090	79,650	71,700	62,800	73,430	67,359	53,185	47,782	50,331	45,159	40,107	43,320	43,780	35,780	37,690	34,690
Cartridge brass	49,900	46,100	66,800	82,600	78,400	72,600	36,430	70,881	80,538	86,659	94,639	94,084	90,700	74,100	87,800	98,200	91,800
Yellow and low Brass [3]	424,220	459,930	488,630	486,200	497,200	518,980	464,569	441,930	356,916	366,239	366,308	362,542	327,380	285,170	253,970	260,971	274,930
Automobile Radiators	79,910	70,400	79,870	61,610	55,200	49,450	48,223	36,202	30,409	29,276	29,345	31,139	31,680	27,750	22,100	22,400	22,400
Bronze	25,000	25,900	27,400	27,500	23,670	22,700	31,841	32,481	25,630	29,504	28,208	29,533	29,200	28,800	26,600	28,500	28,300
Nickel silver/cupronickel	20,500	23,300	17,800	17,400	22,300	28,100	19,281	15,430	17,371	20,906	18,683	19,114	14,200	13,100	8,460	9,740	9,620
Aluminum bronze	w	w	w	w	w	w	w	w	w	w	w	w	w	w	w	w	w
Low-grade scrap and residue [4]	92,600	83,100	87,100	124,000	111,000	105,000	70,240	30,196	32,157	35,261	34,955	34,839	23,500	23,300	23,300	23,000	22,900
Refinery brass and other scrap	45,840	48,180	45,070	27,000	19,060	18,910	15,367	11,019	6,331	7,127	6,581	6,763	6,300	6,140	6,380	6,630	7,160
Total Alloyed Scrap	818,410	837,320	896,230	898,010	841,000	889,170	753,310	691,324	597,134	625,303	623,878	618,121	566,280	502,140	464,390	487,131	491,800
Copper recovered from scrap:																	
Refined from scrap	352,000	345,000	396,000	349,000	229,919	208,000	172,474	69,923	53,281	50,761	47,207	44,777	46,000	53,800	46,400	37,700	37,300
Unalloyed powder & castings	11,299	10,806	10,619	8,305	8,062	8,349	7,775	7,439	346	622	861	746	1,354	1,206	669	1,312	1,154
Total unalloyed products	364,000	355,000	407,000	357,000	237,981	216,349	180,249	77,362	53,627	51,383	48,068	45,523	47,400	55,000	47,100	39,000	37,400
Brass and bronze	887,000	892,000	981,000	987,432	1,000,462	1,010,000	893,363	876,216	818,087	839,975	836,646	845,976	799,000	731,000	675,000	689,000	699,000
In aluminum alloys	64,600	70,700	75,000	76,600	78,200	73,900	64,006	63,177	59,258	60,436	54,517	67,964	72,600	60,700	46,100	51,600	59,600
From other alloys & chemicals [5]	307	415	365	215	11,925	14,023	11,871	12,144	13,256	13,300	13,272	9,036	5,943	5,048	5,038	5,039	5,042
Total copper from scrap:	1,320,000	1,320,000	1,460,000	1,422,000	1,328,568	1,314,272	1,149,490	1,029,623	944,228	965,094	952,503	968,499	924,943	851,748	773,238	784,639	801,042

W= Withheld, data in other scrap

Source: USGS and USBM Minerals Yearbooks and Mineral Industry Surveys

p Preliminary data (2011 Minerals Yearbook, USGS)

1/ Gross Weight scrap

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/ From 1999 forward, 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

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 ingotmaker 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.

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 inhouse.

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

1. Source unpublished data, US 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, US EPA 450/4-90-003, March 1990.

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

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 and copper scrap during the 1941-1970 period is extracted from the copper chapters of the U.S. Bureau of Mines Minerals Yearbooks.

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. Refer to Figure 15 for a review of major historical events related to the industrial consumption of copper in the United States. Because of the periodic shortage of copper supplies, all 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 during the World War II period 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, and 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.

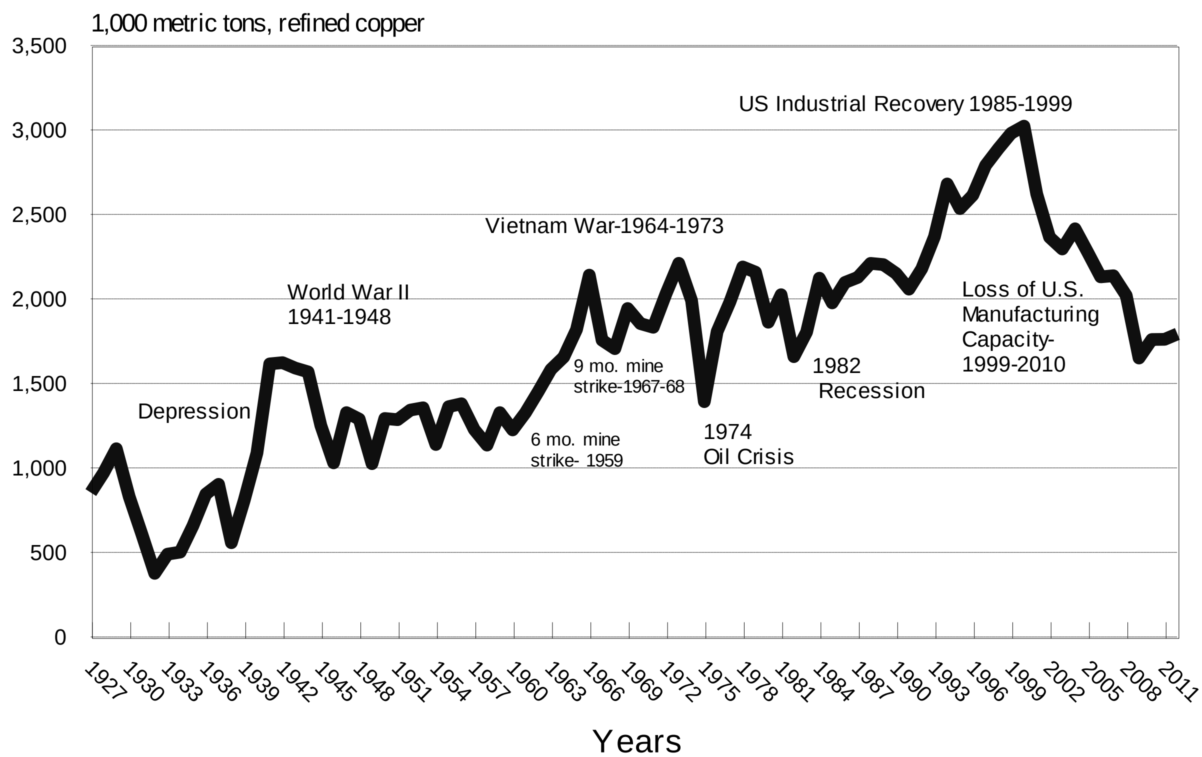
Copper supply continued to be inadequate in 1952, with less copper available in 1952 than in 1951. A further release of 22,000 tons of copper was authorized from the National Stockpile, to meet the temporary emergency. Following the Office of Price Stabilization permission to raise prices for foreign copper and to pass on to consumers most of the costs, the situation improved, so that copper was nearly in balance by year-end. 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 third 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

Figure 14. U.S. Industrial Copper Consumption Trends and Response to Major Historical Events, 1927-2012



Sources: U.S. Bureau of Mines, U.S. Geological Survey, Statistical Publications 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 six fold. 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 in 1967, 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, owing largely 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 master alloys. 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 year-end. 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 of 1968 were set at 25,000 tons of copper-base scrap. Export quotas were also set for refined copper, semifabricated productions and other copper materials. Owing to the large increase in exports of copper scrap to Canada during 1969, Canada was added to the quota list near year-end and allotted only 2,400 tons for the year. Despite these restrictions, 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 export quota on refined copper from domestic primary sources was set at 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 1970. The improved supply situation led to removal of the 1965 export controls by September 1970. At this point, a total of 260,467 short tons of copper remained in the stockpile.

World copper was in oversupply over most of the period 1975-1988. The excess world copper inventories, which had accumulated over the 1970s, were finally worked down by 1988 to below 1 month of world supply. Increased World industrial demand was underway by the mid-1990s, and the new mine capacity that had been 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.

On April 7, 2004, the Copper and Brass Fabricators Council (CBFC), the Non-Ferrous Founders’ Society and members of these societies filed short supply petition under the Export Administration Act, requesting imposition of monitors and controls on the export of copper-based scrap. The Institute of Scrap Recycling Industries, Inc. (ISRI) and its broker and scrap trader members took an opposition stand to the request stating that restricting exports would have eliminated the market for a large proportion of scrap that was not likely to be used domestically. Underlying the petition was the belief by U.S. copper scrap consumers that China had been applying unfair trade practices and essentially was cornering the market for copper scrap, Depressed copper prices and the unfair competition for domestic scrap by exporters to China since 1999 had placed some scrap processing (wire choppers, secondary smelters and others) and consuming (brass mills etc.) facilities at a competitive disadvantage. Ingot production dropped sharply by 2002, (see Figure 7, this report) and by late 2003, scrap supplies were so tight as to cause some local mills and wire choppers to cut back capacity or to close. The Export Administration Act allows the U.S. Government to impose export controls on scrap metals under specific circumstances when scrap availability is an issue, or where the price is significantly impacting inflation. ISRI felt that neither of these situations were the case and stated that it would have preferred to have brought redress through the Section 301 of the trade law for trade violations (American Recycler, Sept 2004). The Commerce Department, after a hearing in May 19, 2004 where all parties testified, issued its decision in August, 2004 citing that there was no need for controls, or monitoring of exports of copper-based scrap. As copper supplies tightened, China began institutional changes of its own in 2004 that would only temporarily ease the tight supply situation in the United States. Even so, scrap exports to the Far East continued unabated at high rates through 2007. See further discussions elsewhere in this paper.

The marked decrease in U. S. industrial consumption of copper is visible on the graph shown in Figure 15 since 1999, and is coincidental to the massive export of scrap supplies to the Far East. U.S. import reliance for copper also increased over this period from 2% in 1993 to over 40% in 2006, owing to the significant increase of copper-based imports into the United States and concurrent decrease in U.S. mine production and availability of secondary material recycle. This has occurred despite the ongoing needs of the current war in Iraq and a booming housing cycle until mid-2007.

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, Pennsylvania ROD 9/30/97 ESD 4/19/01.(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. About 110 parties have been named responsible parties (PRPs) owing to shipments of materials to this firm for treatment. Early phase I cleanup was completed August 9, 2001. On November 18, 2004, the pre-final inspection was done and the EPA finished the Preliminary Close-Out Report for Jacks Creek on December 23, 2004.

Major remedies for the site included: 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 ingot maker until 1996, when the plant closed. Emergency soil and brick removal was done in 1996-1997.

(3) Kearsarge Metallurgical Corp., Conway, New Hampshire. 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-year floodplain of the Saco River. The ground water in the upper aquifer under the site was determined to be contaminated.

(4) Metal Banks, Philadelphia, Pennsylvania Discovery 6/1/77. On the Final NPL, ROD 12/31/97, EPA/541/R-98/012. ESD 12/15/00. 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. Final design almost complete, construction should start Fall 2006.

(5) Tex-Tin Corp. (Gulf Chemical & Metallurgical). Texas City, Texas Currently on the Final NPL. Discovery 11/1979. Final NPL on 9/18/98. ROD 9/29/2000. Consent decree 10/2000. Was a copper scrap fire refinery (1989-1991), and a tin smelter earlier.

(6) Eastern Diversified Metals. Hometown, Pennsylvania. Currently on the Final NPL. ROD 3/91, 7/92, 9/93. From 1966-1977, copper and aluminum was reclaimed from wire and cable. Contaminants include metals, PCBs and dioxins. Stripping waste, plastic fluff, was disposed behind facility in 40-ft high mounds. Nassau Metals named as a PRP for cleanup.

(7) C&D Recycling. Foster Township, Pennsylvania. Currently on Final NPL. ROD 9/30/1992. Contaminants include Cu, Sb, Pb and other metals. C&D recovered copper and/or lead from cable or scrap metal in 5 onsite furnaces used to burn cable from the 1960's to 1980's. The furnaces have been demolished. Starting in 1998, Lucent Tech. stabilized and disposed off site 90,000 tons of contaminated soils and sediment. The site has been regraded and seeded.

(8) Franklin Slag Pile. Philadelphia, PA. Final rule NPL on 09/25/2002. EPA has stablized the site and there is no current threat to the environment. The slag pile is now covered with a thick plastic cover. The next step will be to complete Remedial Investigation and propose a plan for cleanup. Associated with Franklin Smelter.

(9) Franklin Burn Site. Franklin, New Jersey. Final NPL date 6/17/96. Copper wire was burned to remove plastic coatings and other electrical components for the recovery and sale of copper. The burning resulted in ash piles containing hazardous substances. Burning ceased in 1988.

(10) Curcio Scrap Metal. Inc. Bergen County, New Jersey.

Final NPL date 07/01/87. Burn site for scrap iron, copper and other metals. While cutting 50 electrical transformers in 1982, PCBs containing oil spilled on the ground. Some 3,000 people live close by and the site is located above the Brunswick Aquifer. Final remedial design report detailed March 1993. Long-term monitoring started on March 2000.

Not listed on the NPL:

(1) Franklin Smelting and Refining, Philadelphia, Pennsylvania. Not on the NPL. Franklin was an active secondary smelter for years at this site. The plant closed in 1998.

(2) Talco Metals, Philadelphia, Pennsylvania. No action listed.

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

(4) Eastern Smelting and Refining (Metals Refining Co.), Los Angeles, California Discovery 2/15/96. Prelim. Assessment 6/30/98. Not on the NPL.

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

(6) Kocide Chemical, Casa Grande, AZ. Not on the NPL Discovery 1/87. .Site reassessment 6/2000. Was a copper sulfate plant. Deferred to RCRA.

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

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

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

(10) Vulcan-Louisville Smelting Co. (Lavin & Sons),(North Chicago Refiners & Smelters), North Chicago, Illinois. 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. This plant closed in 2003.

(11) Southwire Co. Copper Division., Carrolton, Georgia Discovery 8/01/80. Preliminary assessment 6/17/85. Not on the NPL. Deferred to RCRA.

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

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

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

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

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

(17) Phelps Dodge Refining Corp. Maspeth, New York. Not on the NPL. Discovery 5/79. Site inspection 8/83. Closed copper refinery.

(18) Nassau Recycle Corp. Staten Island, New York. Not on the NPL. Discovery 1/80. Proposal to NPL 2/92. Processed copper wire scrap.

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

(20) CMX., Los Angeles, California. Not on the NPL. Discovery, 12/07/1999. Preliminary assessment start 8/15/2000, completed 6/29/2001. This plant is an active ingot maker.

(21) Federal Metals. Los Angeles, California. Not on the NPL. Discovery 1/1/1987. Site inspection 9/24/1991. Site reassessment completed 6/7/2001.

(22) Anchor Metals. Anniston, Alabama. Not on the NPL. Assessment complete. Decision needed.

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

(24) Chicago Copper and Chemical Co. Calumet Park, Illinois. Not on NPL.

(25) C&P Chemical Company. Sumter, South Carolina. South Carolina Superfund site. Produces copper chemicals.

(26) Sauget Area 1. Sauget and Cahokia, Illinois. Site was proposed to the NPL 9/13/2001. Site comprises 7 sources including wastewater from Cerro Copper Co. and Monsanto Chemical Co.

(27) Ward Transformer. Raleigh, North Carolina. Proposed for the NPL 4/30/2003. Transformer parts were burned in open air to reclaim copper. An incinerator is currently used.

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*. California Works. Newark, California. Discovery 12/01/1979. Archive site 7/20/1990.*

(10) Cerro Metal Prod*. Plant #1, Bellefonte, Pennsylvania. Discovery 6/11/1991. Assessment 12/15/1992.*

(11) 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. Abandoned foundry.*

(12) SCM Corp. Chem. Metallurgical. *Ashtabula, Ohio. Archived 12/02/1991.*

(13) Kearny Smelting & Refining. *936 Harrison Ave, Kearny, New Jersey. Discovery 6/27/1986. Archive Site 9/26/1994. NFRAP status.*

(14) Chemetco. *Hartford, Illinois. Not on the NPL. Discovery 8/1980, Archived 11/87.*

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