### 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.

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 reestablish 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. Though domestic markets had not improved in 2009. some wire chopping companies reported that they were getting increased inquiries from overseas.

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 2005 show increased Number 2 scrap in U.S. exports (see **Table 8A**). No. 2 scrap comprised more than 78% of unalloyed copper scrap exported in 2008. Exports of low-grade copper ash and residues also increased from 8,340 tons in 2001 to 62,150 tons in 2007 and 46,000 tons in 2008 (see **Table 9**). Total alloy and mixed scrap comprise the largest share (70%) of total scrap exports in 2008. China was the destination for 80% of the scrap exported in 2009. Hong Kong, Canada, Korea, Belgium and Taiwan were also significant importers of U.S. copper and copper alloy scrap in 2008 and 2009.

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

Flotation may be used 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. Bervllium copper clips gleaned from these electronics are sorted and sent back to beryllium copper producers in Ohio and Pennsylvania. Handling these materials must be done carefully, since any hazardous materials from landfilled electronics can leach into the soil, and, when burned, toxins can be released into the air.

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

### **Laboratory Testing**

Several standard methods of testing scrap materials. ingots and other alloy products are used. Methods such as chemical analysis, optical emission spectroscopy, x-ray fluorescence, atomic absorption analysis, inductively coupled plasma-emission spectrometry analysis and various types of mechanical testing are used. Details for conducting wet chemical analysis on copper-based alloys are given in several ASTM standards (E 478, E 54, E 75, E 88). The wet chemical methods are slow and make it difficult to obtain results for production heats until well after the metal has been cast. limiting their value as a process control tool. More commonly, chemical methods are used for analyzing the composition of raw materials (ingot and scrap) before being melted. The mechanical tests usually associated with copperbased 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, copperbearing 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, copperbearing 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 lowgrade 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.

<u>Oxidizing melt covers</u> (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.

<u>Reducing melt covers</u> (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 <u>containing 10–11% coke, will have the following</u> approximate composition: FeO (29%), CaO (19%), SiO<sub>2</sub> (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 overdeoxidization. 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.

<u>Vapor Losses</u>. 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 (dryvibration, 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 coketo-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 chromemagnesite 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 semicontinuous 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 byproducts, 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. Longterm 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.

## 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 codisposed with municipal solid waste (MSW) in a landfill with actively decomposing material overlying an aguifer. 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 codisposed 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.

<u>Kinetics</u>: 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-tosolid 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.

<u>pH</u>: 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.

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

<u>Aging</u>: 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.

<u>Volatile Losses</u>: 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 cosolvents, solubility of the organic phase, rather than the aqueous phase, may control the leachate concentration. Surfactants may also mobilize hydrophobic contaminants.

<u>Field Validation of the Tests</u>: 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.

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 landdisposed. 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 Rightto-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<sup>3</sup> 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 8hour TWA airborne concentration of lead of 75 µg/m<sup>3</sup> (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<sup>3</sup> 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<sup>3</sup> 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<sup>3</sup> 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<sup>3</sup> solely by engineering and work practice controls, and to 50 µg/m<sup>3</sup> by some combination of engineering and work practice controls and respiratory protection. Six years after the judicial stay of the Lead Standard is lifted by the court, the Compliance and Safety and Health Officer (CSHO) shall determine whether the employer in the brass and bronze ingot manufacturing industry is in compliance with all provisions of the Lead Standard.

### Clean Air Act Ruling.

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

For current rules and regulations for clean air act ruling, seek <u>www.epa.gov</u> 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 bachouse 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.

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. industry 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 <u>www.globalwarmingheartland.org</u> and at the US Senate Committee on Environment and Public Works: <u>Matt\_dempsey@epw.senate.gov</u>. 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 byproducts 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 Guivu, 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 in 2007 and 2008 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 postindustrial and post-consumer scrap.

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.

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 <u>compliance with ISO 14001 standards. ISO 14001</u> 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 (<u>http://www.iaer.org</u>). The IAER estimates that 3 billion consumer electronics recycling industry is expected to increase capacity by a 4 or 5 times factor by the end of this decade.

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.

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 Foundryman'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 byproducts 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, 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.

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

	Market Prices		U.	S. Buying Pric	0S	
	LME	COMEX	U.S. Producer	Refiners	Brass Mill	Red Brass
PERIOD	Grade A, Cash	HG, 1st Pos.	Price	#2 Scrap	#1 Scrap	Turnings
	cts/lb	cts/lb	cts/lb	cts/lb	cts/lb	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	241	206	227	113
2010 <sup>1/</sup>	335	336	340	289	314	163

Source: Metals Week, American Metal Market, ICSG Copper Bulletin, U. S. Geol. Survey Min. Ind. Survey and Compendium.

<sup>1/</sup> Scrap prices are based on 6 months average of 2010. Refined prices are full year averages

### Table 2A. World Copper Recovery from All Sources<sup>1</sup>

(thousand metric tons)

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	Western		Middle East			Total	Percent
Year	Europe	Africa	and Asia	America	Oceania	World	Scrap
1970	2,173	670	1,252	3,861	162	8,845	37
1971	2,173	803	1,237	3,653	202	8,876	36
1972	2,242	894	1,359	4,047	208	9,676	34
1973	2,488	930	1,574	4,007	204	10,210	35
1974	2,400	1,025	1,695	4,029	220	10,438	34
1975	2,196	941	1,464	3,462	214	9,430	30
1976	2,385	1,001	1,638	3,827	213	10,252	32
1977	2,358	987	1,735	3,969	218	10,523	31
1978	2,316	933	1,811	4,225	213	10,833	33
1979	2,300	897	1,909	4,686	214	11,361	36
1980	2,456	952	2,058	4,375	209	11,457	36
1981	2,462	918	2,259	4,590	240	11,856	35
1982	2,432	969	2,258	4,029	224	11,328	34
1983	2,477	1,040	2,419	3,969	245	11,631	34
1984	2,504	1,023	2,421	4,141	245	11,953	34
1985	2,564	976	2,530	4,122	235	12,108	35
1986	2,659	963	2,718	4,163	223	12,655	33
1987	2,636	921	2,837	4,419	258	13,042	35
1988	2,651	908	3,028	4,803	263	13,541	35
1989	2,691	892	3,054	5,021	296	13,868	35
1990	2,665	809	3,112	5,223	314	13,863	36
1991	2,653	713	3,227	5,220	313	13,721	36
1992	2,895	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	418	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	2,933	567	9,453	6,763	460	22,451	32
2008	2,957	582	10,838	6,663	520	23,761	35
2009	2,494	672	9,753	6,520	452	22,119	30
2010	2,494	816	10,485	6,438	359	22,999	34

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

<sup>1/</sup> Includes primary and secondary copper production in refined and direct melt scrap.

# Table 2B.World Production of Refined Copper by Source<br/>(thousand metric tons and percent of total)

					Percent
Year	Primary	Secondary	SX-EW	Total	Secondary
	Refined	Refined	Refined	Refined	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	6,768	1,449	213	8,430	17
1986	7,066	1,323	279	8,669	15
1987	7,023	1,494	332	8,850	17
1988	8,335	1,773	431	10,539	17
1989	8,454	1,943	543	10,939	18
1990	8,197	1,960	660	10,817	18
1991	8,064	1,947	689	10,700	18
1992	8,352	1,963	754	11,069	18
1993	8,628	1,892	763	11,283	17
1994	8,483	1,820	830	11,133	16
1995	8,685	2,113	1,069	11,867	18
1996	9,241	1,997	1,463	12,701	16
1997	9,645	2,122	1,759	13,526	16
1998	10,015	2,067	2,005	14,087	15
1999	10,130	2,104	2,316	14,550	14
2000	10,312	<u>2,125</u>	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	11,152	2,069	2,706	15,928	13
2005	11,717	2,161	2,694	16,572	13
2006	11,852	2,613	2,826	17,291	15
2007	12,198	2,743	2,993	17,934	15
2008	12,286	2,823	3,092	18,201	16
2009	11,709	2,831	3,256	18,296	16
2010	12,046	3,242	3,248	18,535	17

Data Source: International Copper Study Group <sup>e</sup> Estimated

Year							United Stat	es <sup>2/</sup>
	Europe	Africa	Asia	America	Oceania	World Total	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	1,167	0	3,484	870	18	5,539	806	15
2009	823	0	2,108	833	6	3,769	758	20
2010 <sup>e/</sup>	1,175	0	2,426	863	0	4,464	774	17

# Table 2C.World Consumption of Copper in Direct Melt Scrap1<br/>(thousand metric tons, copper content)

Data sources: Int. Copper Study Gp., U.S. Bur. Mines, U. S. Geological Survey.

<sup>1/</sup> Reported for some countries, such as the United States, but estimated for others based on semis production.

<sup>2/</sup> Revised to include copper from other than copper-base scrap.

<sup>e</sup> Estimated on 9 months data

		Copper Fr	om Direct Me		Percent of World Copper Scrap					
Year	Western		Middle		Rest of		Western			
	Europe	America	East & Asia	Oceania	World	World	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	637	7557	25	16	51	0
2007	1827	1205	3667	18	569	7268	25	17	50	0
2008	1788	1037	5008	18	534	8367	21	12	60	0
2009	1400	972	3807	6	500	6678	21	15	57	0
2010 <sup>°/</sup>	1623	1010	4441	0	632	7706	21	13	58	0

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

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)

	2003	2004	2005	2006	2007	2008	2009	2010
	2000	2004	2000	2000	2001	2000	2000	(e)
Australia	59	54	87	50	49	51	63	59
Austria	24	34	33	40	40	42	54	58
Belgium	152	169	178	162	189	153	108	131
Canada	70	81	120	165	165	152	148	144
Chile	25	38	37	55	102	72	69	49
China	8	9	6	7	5	3	2	2
Czech Rep.	37	53	54	57	58	60	105	130
Denmark	42	38	26	31	31	36	31	15
Finland	20	24	31	31	33	33	33	27
France	180	243	262	294	280	263	229	270
Germany	364	374	476	499	481	479	450	571
Greece	10	9	15	17	15	12	16	25
Hona Kona	337	340	121	130	153	116	70	139
Indonesia	22	18	32	51	55	41	35	84
Ireland	18	16	13	16	10	22	46	0
Italy	53	99	113	104	120	149	158	202
Japan	307	329	424	412	425	396	360	288
Kazakhstan	2	2	2	6	9	12	16	24
Malavsia	47	0	75	36	29	17	29	23
Mexico	76	173	105	126	122	129	109	77
Netherlands	11	13	15	18	17	9	13	16
Norway	125	106	182	310	237	225	268	306
Peru	17	21	23	24	24	23	25	0
Philippines	2	2	2	5	7	6	6	7
Poland	20	21	15	26	20	19	23	13
Portugal	41	43	48	55	69	87	68	62
Rep. of Korea	25	36	35	30	21	19	20	26
Russian Fed.	94	167	161	202	216	192	187	72
Saudi Arabia	0	40	60	127	105	0	57	0
Singapore	56	50	43	35	28	20	9	7
Slovakia	9	12	15	19	22	21	15	13
South Africa	40	36	51	75	79	82	71	42
Spain	64	79	100	86	84	82	75	115
Sweden	36	44	44	46	55	61	56	40
Switzerland	56	69	75	74	76	83	71	75
Taiwan	76	61	107	125	128	130	110	86
Thailand	55	46	51	60	107	76	70	61
United Kingdom	211	243	235	310	339	357	429	422
United States	689	714	665	894	907	908	843	962
Other Countries	418	487	312	246	436	451	362	125
World Total	3,897	4,394	4,449	5,149	5,387	5,117	4,934	4,770

Source: International Copper Study Group, November 2010

(e) Estimated on partial year data (Jan-Aug)

# Table 4.World Copper and Copper Alloy Scrap Imports<br/>(thousand metric tons, gross weight)

	2003	2004	2005	2006	2007	2008	2009	2010
								(e)
Australia	3	4	2	2	8	3	1	3
Austria	57	72	83	90	89	114	132	130
Belgium	226	257	258	298	320	253	217	242
Brazil	0	0	2	1	3	4	1	1
Canada	37	55	48	56	144	52	41	48
China	3,162	3,957	4,821	4,943	5,585	5,577	3,998	4,025
Czech Rep.	2	6	6	8	9	8	10	10
Denmark	16	18	14	8	9	17	10	5
Finland	3	2	2	1	3	3	7	8
France	70	79	75	98	88	78	50	65
Germany	380	427	486	585	596	564	455	607
Greece	2	2	1	2	10	19	11	15
Hong Kong	111	107	123	147	190	210	190	169
India	92	110	150	104	105	103	79	47
Indonesia	3	3	13	2	4	10	7	7
Italy	165	131	125	216	178	167	92	110
Japan	122	145	103	121	136	139	97	140
Malaysia	22	26	24	13	26	13	9	7
Mexico	9	20	14	18	17	29	33	20
Netherlands	80	90	77	111	108	117	128	137
New Zealand	0	0	1	0	1	1	1	0
Norway	11	11	12	13	14	11	7	0
Poland	6	15	6	15	17	18	22	30
Portugal	2	2	3	6	8	9	7	8
Rep. of Korea	153	205	206	205	221	217	163	150
Singapore	19	21	16	18	8	4	2	2
Slovakia	8	20	20	18	18	18	29	44
South Africa	3	3	2	2	3	3	1	7
Spain	58	115	85	87	56	63	68	95
Sweden	52	77	51	56	81	92	97	111
Switzerland	10	12	10	8	8	5	3	5
Taiwan	81	121	112	146	131	107	70	91
Thailand	5	6	5	6	8	9	9	8
United Kingdom	18	15	41	20	24	22	18	26
United States	91	102	114	118	133	106	72	89
Other countries	104	136	91	34	40	39	42	62
World	5,182	6,369	7,203	7,581	8,430	8,245	6,189	6,699

Source: International Copper Study Group, December 2010 and U.S. Geological Survey. (e): Estimate based on partial year data ( 8 months)

# Table 5.World Production of Copper and Copper Alloy Ingots1<br/>(thousand metric tons)

	2000	2001	2002	2003	2004	2005	2006	2007	2008
Austria	3.3	2.5	1.8	2.0	2.2	2.5	2.6	2.0	2.0
Denmark	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
Finland	1.9	1.2	0.8	0.0	0.0	0.0	0.0	0.0	0.0
France	13.3	12.5	12.5	12.3	13.0	11.4	12.5	11.0	9.9
Germany	62.6	63.4	56.1	43.7	44.1	53.6	57.2	53.6	51.4
Italy	116.1	112.0	103.3	96.5	95.0	89.0	91.8	83.4	76.9
Japan	86.4	87.9	86.6	90.0	86.2	85.4	89.7	90.5	94.2
Kazakhstan	1.0	0.8	1.1	1.6	0.0	0.0	0.0	0.0	0.0
Mexico	56.9	50.9	52.0	52.8	0.0	0.0	0.0	0.0	0.0
Netherlands	2.6	2.4	2.3	2.4	2.4	2.6	2.7	2.1	2.7
Poland	21.5	16.0	13.6	14.4	13.4	12.1	11.2	11.3	10.5
Portugal	1.5	3.1	4.5	5.3	6.0	6.7	6.8	7.0	7.4
Romania	0.0	0.0	2.9	3.7	2.7	2.2	0.0	0.0	0.0
Spain	14.0	13.8	13.3	15.5	16.8	15.6	16.7	14.1	15.2
Scandinavia	13.6	12.0	11.0	9.3	9.0	8.7	8.7	6.4	6.3
Turkey	0.0	0.0	0.0	0.0	11.4	18.5	17.5	16.6	17.1
United Kingdom	34.0	37.5	34.5	32.5	34.5	27.0	22.8	22.1	23.7
United States	160.8	145.8	123.1	114.0	122.1	122.3	120.3	118.3	119.1
World	588.3	543.6	517.5	494.4	455.8	457.6	460.5	438.4	436.4
Europe	284.2	275.2	255.8	237.6	236.1	231.4	233.0	213.0	206.0
Mid East & Asia	86.4	87.9	86.6	90.0	97.6	103.9	107.2	107.1	111.3
America	217.7	196.7	175.1	166.8	122.1	122.3	120.3	118.3	119.1

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

1/ Master Alloys not included.

## Table 5A. World Copper Alloy Foundry Production

(thousand metric tons, gross weight)

	1999	2000	2001	2002	2003	2004	2005	2006	2007	2008
Argentina	0.0	0.0	0.0	2.9		3.9	0.0	0.0	0.0	0.0
Austria	3.3	3.4	3.2	3.3	3.4	3.3	5.5	2.7	0.0	0.0
Belgium	0.7	0.6	0.5	0.5	0.5	0.5	0.5	1.0	0.0	0.0
Brazil	15.7	15.3	14.1	13.7	0.0	19.5	19.0	20.3	19.8	19.9
Canada	12.0	0.0	0.0	0.0	0.0	18.6	18.6	18.6	18.6	17.7
China	107.9	119.9	125.0	137.2	157.0	327.6	416.1	470.2	571.3	600.0
Croatia	0.7	0.6	0.7	0.6	0.7	0.7	1.1	0.8	0.7	0.5
Czech Rep.	2.9	2.0	1.5	1.8	1.5	1.1	1.7	1.8	1.8	2.7
Denmark	1.5	1.3	1.1	1.3	1.6	1.3	1.1	0.8	0.8	1.4
Finland	4.3	3.8	3.8	3.9	3.8	4.0	4.0	4.3	3.5	4.6
France	24.1	25.3	25.9	29.4	28.3	27.2	26.3	25.5	25.4	24.7
Germany	84.5	91.2	88.5	90.0	91.3	88.5	84.4	98.1	96.6	94.6
Hungary	2.9	3.1	2.7	2.3	1.9	2.1	2.1	4.3	1.8	1.4
Iran	0.0	0.0	25.0	0.0	27.0	0.0	0.0	0.0	0.0	0.0
Italy	124.5	123.7	114.5	110.0	106.1	97.8	83.0	92.0	86.7	81.0
Japan	82.7	87.1	86.6	86.7	100.6	105.5	97.8	105.9	106.9	98.8
Rep. Of Korea	18.5	19.6	20.8	21.6	22.2	22.9	23.2	23.6	23.9	24.1
Mexico	124.8	135.0	80.0	175.0	175.0	180.0	180.0	0.0	0.0	202.4
Netherlands	2.5	2.4	2.8	2.7	2.5	2.4	1.9	0.0	0.0	0.0
Norway	3.0	3.4	3.4	3.5	2.6	2.7	4.7	5.3	5.0	3.3
Poland	21.0	20.5	17.2	16.8	6.3	7.4	6.3	7.3	7.0	8.2
Portugal	4.0	4.7	6.0	6.6	6.0	7.8	8.7	10.8	11.1	11.4
Romania	9.6	9.7	9.8	10.0	10.0	4.1	2.7	3.4	3.8	3.5
Russian Fed.	0.0	0.0	0.0	0.0	0.0	0.0	160.0	160.0	200.0	200.0
Slovenia	3.4	3.4	3.4	3.5	3.0	0.0	6.7	0.0	7.8	0.0
South Africa	4.0	5.0	0.0	0.0	14.5	14.9	14.9	3.0	3.0	3.0
Spain	13.5	16.1	13.1	13.0	6.3	7.9	7.9	9.1	9.3	9.5
Sweden	10.3	10.1	10.6	10.0	10.9	12.0	11.2	11.9	12.5	12.5
Switzerland	2.8	2.9	2.5	2.3	2.4	3.0	2.7	3.1	3.1	2.3
Taiwan	48.0	50.0	50.0	49.0	46.4	41.8	42.0	40.9	41.3	35.6
Thailand	0.0	0.0	0.0	0.0	0.0	0.0	28.6	28.6	28.6	28.6
Turkey	0.9	1.3	2.8	2.1	2.8	8.5	16.0	17.5	19.0	16.0
Ukraine	8.0	10.0	21.0	11.0	0.0	11.0	11.0	11.0	11.0	11.0
United Kingdom	29.6	25.0	25.5	20.5	15.0	15.7	15.0	13.0	13.0	12.0
United States "	258.1	278.3	252.5	254.1	246.0	235.3	234.5	209.8	197.4	190.3
World	1032.4	1076.9	1017.0	1087.6	1113.2	1279.0	1539.2	1402.0	1528.1	1717.8
<b>2</b> /	262.0	070 40	200.05	24E 20	247.00	24E 40	462.00	402.00	400.40	404 40
Europe	303.8	3/0.40	360.25	345.30	317.00	515.10	403.00	403.00	498.40	401.40
IVIIC East & Asla	258	277.90	310.20	290.00	350.00	500.60	024.00	040.70	/ 90.90	803.10
America	410.6	428.60	346.55	445.73	440.19	457.29	452.13	248.70	235.80	430.30

Data Source: International Copper Study Group Bulletin, Table 18. February 2010

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

<sup>2/</sup> Includes Russian Federation.

## Table 5B. World Copper, Copper Alloy and Master Alloy Ingot Imports<sup>1</sup> (thousand metric tons)

	2003	2004	2005	2006	2007	2008	2009	2010 (e)
Australia	4.9	5.0	2.9	4.1	4.5	2.6	2.6	2.6
Austria	3.2	2.4	2.3	2.9	2.5	2.2	1.7	1.3
Canada	7.6	14.9	14.5	12.4	10.5	12.3	4.9	5.0
China	82.4	66.5	63.6	54.8	59.8	48.2	53.0	72.7
Finland	4.3	2.8	3.2	4.0	4.2	3.2	2.3	2.6
France	10.4	7.6	10.1	11.0	14.3	8.9	8.0	10.4
Germany	44.7	24.1	28.8	38.9	47.7	40.1	38.4	34.0
Hong Kong	7.2	10.5	7.6	7.7	4.6	2.5	2.8	1.4
India	3.7	6.7	6.3	3.2	3.6	4.3	3.6	1.9
Italy	22.0	16.7	8.1	15.2	25.1	18.5	8.2	16.3
Japan	3.4	3.1	3.8	3.2	3.0	2.9	1.1	1.7
Mexico	13.5	7.0	6.3	6.8	6.6	8.2	7.4	4.3
Poland	1.8	2.1	3.2	4.1	4.1	3.2	2.3	2.9
Portugal	5.3	6.0	4.5	5.7	4.1	4.3	3.8	4.2
Rep. Of Korea	5.3	2.7	0.9	4.3	13.0	26.8	21.4	8.2
Singapore	5.9	22.7	10.0	12.1	7.8	4.6	3.8	4.3
Spain	4.2	5.8	4.4	6.0	5.3	4.3	3.3	3.9
Sweden	3.3	2.8	3.0	4.0	7.2	5.2	2.1	2.8
Switzerland	3.5	4.5	3.9	8.3	4.0	3.9	3.3	3.7
Taiwan	20.0	12.6	10.0	14.3	11.9	14.8	9.8	12.6
Thailand	11.9	11.7	10.6	9.8	10.0	6.9	6.1	9.5
Turkey	3.8	4.7	3.8	2.8	0.2	3.1	3.0	5.0
United Kingdom	7.9	8.1	6.2	6.4	5.9	6.1	4.0	5.0
United States	4.1	6.0	5.8	10.2	9.2	9.0	4.6	6.8
Rest of World	15.2	30.3	31.4	43.3	55.2	57.5	22.0	12.6
World	299.4	287.3	255.0	295.2	324.1	303.6	223.2	235.5

<sup>1</sup>Data includes both copper alloy and master alloy ingots. Source: ICSG Monthly Bulletin, Dec. 2009. \*Estimated on 8 months data.

### Table 5C. World Copper, Copper Alloy and Master Alloy Ingot Exports<sup>1</sup> (thousand metric tons)

	2003	2004	2005	2006	2007	2008	2009
Australia	6.6	4.1	4.6	5.0	4.9	5.2	4.2
Belgium	32.2	13.6	14.5	13.4	14.8	12.7	9.5
Canada	2.6	3.5	3.5	7.5	6.3	4.6	2.0
France	6.7	11.9	9.9	9.7	13.1	13.1	9.4
Germany	23.8	21.0	21.0	23.4	20.9	16.5	9.8
Hong Kong	8.8	13.1	11.1	11.0	9.0	3.2	2.6
Italy	12.3	17.0	14.2	15.3	21.0	15.3	12.8
India	7.1	9.6	12.4	10.6	11.2	7.1	3.4
Japan	31.3	25.0	29.9	33.9	33.1	32.8	31.8
Netherlands	5.3	3.6	3.0	5.7	5.7	6.4	4.0
Poland	5.3	5.0	6.2	6.2	6.4	4.9	2.4
Rep. of Korea	13.8	19.2	20.2	20.6	17.7	17.1	15.2
Russian Fed.	12.3	6.4	7.8	7.2	5.4	4.6	6.8
Singapore	4.5	5.5	8.1	7.5	6.9	7.7	7.3
South Africa	4.6	6.0	5.0	4.4	27.0	2.5	1.3
Spain	9.8	11.7	9.8	10.7	12.6	11.9	12.1
Sweden	7.1	5.0	5.3	6.4	8.8	5.6	3.3
Switzerland	1.0	0.8	0.9	0.9	0.8	1.1	0.5
Taiwan	6.7	9.7	7.3	10.1	7.9	6.0	6.7
Turkey	2.9	7.3	2.2	0.0	5.6	6.9	2.3
Ukraine	0.0	4.7	7.8	12.4	19.8	11.2	7.0
United Kingdom	27.3	22.0	15.0	17.2	18.1	17.7	11.3
United States	29.4	33.7	35.4	40.1	40.4	38.9	27.6
Rest of World	26.4	43.4	63.8	84.4	69.8	62.3	48.7
World Total	287.7	303.1	318.7	363.8	413.8	348.2	243.0

<sup>1</sup>Data includes both copper alloy and master alloy ingots. Source: ICSG Monthly Bulletin, Dec. 2009. • Estimated on 8 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									
	World	U.S. Refined	Percent Scrap	Copper in	Percent	Percent	Cu in Total	Apparent Total	Percent	Percent new	
Year	Refined Copper	(Reported)	in U.S. Refined	Old U.S.	Old in All	New in All	U.S.	Consumption	all scrap in	scrap in U.S.	
	Consumption	Consumption	Consumption	Scrap	Scrap	Scrap	Scrap <sup>1</sup>	including all scrap	Consumption	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	
<b>20</b> 05	16,683,300	2,274,000	2	182,499	19	81	951,122	3,164,659	30	24	
2006	17,058,400	2,110,000	2	151,000	16	84	968,546	3,010,467	32	27	
2007	18,239,400	2,137,000	2	161,000	18	82	919,254	3,028,452	30	25	
2008	18,055,700	2,020,000	2	143,000	15	85	935,000	2,847,252	33	27	
2009	18,198,200	1,628,500	4	153,472	19	81	803,900	2,724,100	30	24	
2010 <sup>e/</sup>	19,400,000	1,750,000	3	150,000	18	82	811,000	2,400,000	34	27	

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

<sup>1</sup>Includes copper from other than copper-base scrap.

\* Estimated on partial year data.

## Table 6A.U.S. Cumulative Copper Calculations, 1952–2010<br/>(metric tons, copper content)

Annual Statistics **Resource Calculations Cumulative U.S. Statistics** Cumulative U.S. Percent All Cumulative U.S. Percent Old Year U.S. Apparent Coppe Primary Cumulative Cum Resource In Old Consumption Copper **Primary US** (less annual **Consumption** of Scrap Recovery of **Plus Net Exports** Consumed <sup>3</sup> Scrap Consumption new Scrap) old and new from Cun Cu in Old Scrap from Cum. Primary scrap, 1906-2009 Primary plus net exports less New Scrap 20,046,709 1952 32,591,356 1.615.743 376.151 1.239.592 27,911,261 62 11,671,858 41.8 1953 1,563,781 389,534 1,174,247 33,765,603 28,605,538 20,916,213 62 12,061,392 42.2 1954 1,322,834 369,284 953,550 34,719,153 29,166,421 21,676,164 62 12,430,676 42.6 1,626,799 1955 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 43.4 403,237 1957 1,451,195 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 44.2 14,098,928 1959 1.547.231 427.291 1 119,940 40,194,797 25,750,982 64 32.634.526 14,526,219 44.5 1960 1,452,182 389,514 1,062,668 41,257,465 26,541,492 64 33,296,124 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 1,712,345 382,690 1963 1.329.655 44,994,109 35.675.090 29.031.891 65 16.355.766 458 429.571 1964 1.776.341 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 47.0 18.378.479 1968 1,909,069 472,436 1,436,633 52.422.742 39.898.102 34,528,314 66 18,931,537 47.4 2,058,319 1969 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 20,043,030 484 1971 1.886,418 403,812 1,482,606 56,803,716 42,192,010 37,996,678 67 48.6 20.496.343 1972 2,142,445 415,667 1,726,778 58,530,494 43,152,220 39,176,901 67 20,950,635 48.6 2.223.351 60,312,759 1973 441 086 1 782 265 44,126,162 40,426,237 67 21,470,476 48.7 1974 2,144,892 438,562 1,706,330 62,019,089 41,645,784 45,041,942 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 69 50,296,520 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 77,767,150 1.655.363 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 86,100,098 547,561 1,636,973 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 95,206,621 1994 2.690.000 500.000 2.190.000 63,790.004 66,183,384 70 34,358,907 53.9 1995 2,540,000 442,509 2,097,491 97,304,112 69 65.010.718 67.500.179 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 2,191,556 2,508,768 317.212 112.389.512 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 2,427,975 117,031,376 206,842 2,221,133 77,355,180 77,472,432 66 39,968,339 51.7 2,554,431 2004 191 210 2 363 221 119.394.597 79,047,600 78,437,526 66 40,684,629 51.5 2005 2,387,306 182,499 2,204,807 121,599,404 80.493.512 79,390,029 65 41,353,044 51.4 2006 2,192,857 151,000 2,041,857 123,641,261 81,717,870 80,358,528 65 42.102.421 51.5 2007 2.270.291 161,000 2,109,291 125,750,552 83,063,908 81,282,791 65 42,896,185 51.6 2008 2,024,704 168,140 1.856.564 127.607.116 82,882,294 82,143,051 64 43,710,418 52.7 2009 1,700,422 153,496 1.546.926 129.154.042 83,960,430 82,946,961 64 44,487,817 53.0 2010 1,652,582 147.310 1,505,272 130.659.314 83,723,076 83,758,761 64 45,365,802 54.2

<sup>1</sup>Annual Statistics from U.S. Bureau of Mines, U.S. Geological Survey. <sup>2</sup>Consumption = primary refined production + old scrap + net imports + stock change <sup>3</sup>Primary copper = consumption less old scrap. <sup>4</sup>Series based on 1864-2007 data. <sup>e</sup>Estimated on partial year data.

	Brass & Wire	Foundry	Total	Gross Weight	Recycling	Copper Scrap	<b>Total Scrap</b>	Recycling
Year	Mill	Production	Semis	Scrap 3/	Input Ratio	Exports	Recovered	<b>Recovery Ratio</b>
	Production				(Percent)			(Percent) <sup>4/</sup>
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. <b>7</b>	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	1068.5	34.0	906.5	1975.0	62.8
2008	2000.0	190.3	2846.3	1156.0	40.6	908.1	2064.1	72.5
2009	2098.0	180.0	22/8.0	939.0	41.2	842.6	1781.6	78.2
2010~	2223.0	180.0	2403.0	958.0	39.9	962.0	1920.0	79.9

#### Estimation of the Recycling Input Ratio (RIR)<sup>1</sup> and Recovery Ratio Table 6B. for the United States<sup>2</sup>, 1981–2010 (thousand metric tons)

<sup>p/</sup> preliminary
 <sup>1/</sup> Recycling Input Ratio (RIR) = Total Scrap Consumed/Total Semis Produced
 <sup>1/</sup> "Recycling in Western Europe"

methodology after ICSG Special Paper, 2004, "Recycling in Western Europe"

<sup>2/</sup> Data sources: U. S. Dept of Commerce, U.S. Bureau of Mines, U. S. Geological Survey

and International Copper Study Group publications. <sup>3/</sup> 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<br/>(thousand metric tons)

					Percent
Year	Primary	Secondary	SX-EW	Total	Secondary
	Refined	Refined	Refined	Refined	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	764	42	504	1,311	3
2008	718	54	508	1,280	4
2009	639	46	475	1,161	4
2010 <sup>e/</sup>	640	40	440	1,120	4

Data Source: U.S. Bureau of Mines and U.S. Geological Survey. \*Estimated on partial year data.

# Table 8.U.S. Exports and Imports of Copper and Copper Alloy Scrap<br/>(metric tons)

	UNALLOYED SCRAP	COPPER ALLOY	COPPER ALLOY	TOTAL COPPER	TOTAL COPPER	COPPER ALLOY	COPPER ALLOY	UNALLOYED	TOTAL COPPER	TOTAL COPPER
YEAR	IMPORTS	SCRAP IMPORTS	SCRAP IMPORTS	SCRAP IMPORTS	IN SCRAP	SCRAP EXPORTS	SCRAP EXPORTS	SCRAP	SCRAP EXPORTS	IN SCRAP
		GROSS WEIGHT	COPPER CONT.	GROSS WT.	IMPORTS	GROSS WT.	COPPER CONT.	EXPORTS	GROSS WT.	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, <b>8</b> 67	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, <b>9</b> 00	112,800	81,216	143,700	112,116	257, <b>8</b> 00	1 <b>8</b> 5,616	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, <b>8</b> 62	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	249,762	847,573	680,186
2010 e/	20,406	70,543	50,791	90,949	71,197	684,994	493,196	308,676	993,670	801,872

Sources: U.S. Dept. of Commerce, U.S. Bureau of Mines and U.S. Geological Survey. \*Estimated on partial year data.

### Table 8A. U.S. Domestic Exports of Copper and Copper Alloy Scrap<sup>1</sup> (metric tons)

Type of Scrap	2005	2006	2007	2008	2009	2010 e/
No 1	106,802	67,319	47,834	63,711	66,574	56,771
No 2 and nonspecified	259,579	331,710	281,493	214,782	178,188	251,905
Total unalloyed scrap:	366,381	399,029	329,327	278,493	244,762	308,676
Red, SemiRed Brass >0.3%Pb	15,381	4,952	6,898	5,298	6,425	4,950
Red Brass < 0.3%Pb	24,270	24,940	22,568	26,565	41,568	32,787
Yellow Brass > 0.3% Pb	37,586	57,054	73,540	59,436	30,414	25,315
Yellow Brass < 0.3% Pb	27,781	35,384	28,609	29,605	21,408	38,025
Other copper scrap nesoi	58,216	85,490	96,291	105,590	116,040	199,605
Mixed copper & copper alloy	128,247	196,271	349,278	403,144	381,956	384,312
Total alloy & mixed scrap:	291,481	404,091	577,184	629,638	597,811	684,994
Grand Total Scrap Exports:	657,862	803,120	906,511	908,131	842,573	993,670

<sup>1</sup>/ Source: USITC data webb, Nov 2010, US Dept of Commerce.

Data does not include reexports.

e/ Estimate based on Jan-Sept exports

#### U.S. Trade and Consumption of Copper Ash and Residues<sup>1</sup> and Zinc Products Table 9. from Scrap. (thousand metric tons)

Product	1993	1994	1995	1996	1997	1998	1999	2000	2001	2002	2003	2004	2005	2006	2007	2008	2009
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
Zinc Dross, Skimmings, Residues (26201	9)				00000000000000000000000000000000000000					Adak Carmit Satisfican and car						in the second	
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
Imports:																***************************************	************
Copper Ash & Residues <sup>2</sup>	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
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
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
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
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/
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	297.00	300.00
Zinc Recovered in Copper Alloys <sup>3</sup>	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	128,47	128.00
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	23.60
Copper Content <sup>4</sup>	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	8.26
Low Grade Copper Base Shipm	nents <sup>5</sup>																
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	21.85
Gross Weight of Shipments <sup>4</sup>	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	62.42

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

<sup>14</sup> Skimmings, drosses, ashes & residues containing 20-65% copper
 <sup>24</sup> Reported in copper content of material shipped.
 <sup>34</sup> Composition of secondary copper alloy production; 96% from scrap, 4% from other

<sup>4</sup> Assumption of 35% copper. USGS published series is gross weight.
 <sup>5</sup> 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 SulfateProduction in the United States(thousand metric tons)

Type of Product	1996	1997	1998	1999	2000	2001	2002	2003	2004	2005	2006	2007	2008
Alloy ingots:								******					
Leaded & semi-red brass	92.0	88.6	97.9	97.3	103.0	87.1	88.6	64.7	68.4	68.7	69.4	65.3	65.3
Yellow Brass	6.8	7.4	6.2	6.0	5.7	6.0	4.7	4.4	5.9	5.9	5.6	5,6	5.6
Tin & High Leaded Tin Bronze	24.5	28.4	29.4	28.8	27.8	25.3	23.8	18.7	20.6	20.6	20.2	19,5	19.5
Nickel Silver	1.9	2.3	2.4	2.1	2.3	2.5	1.9	2.3	2.1	2.0	2.1	1.6	1.6
Aluminum & Manganese Bron	15.3	15.0	15.9	13.9	13.9	16.6	13.8	12.9	14.3	14.2	14.0	14.4	14.3
Other Alloy Ingots	5.6	7.3	6.0	4.7	8.2	8.4	7.6	10.3	10.8	10.9	9.1	12.0	12.0
Hardeners and Master Alloys	13.7	13.4	12.9	13.2	13.8	11.3	5.4	5.4	5.5	5.8	7.6	7.7	7.7
		*******											
Total Ingots	160.0	162.4	170.7	166.0	174.6	157.1	128.6	118.6	127.6	128.1	128.0	126.0	126.0
2/													
Foundry Castings -	229.8	237.2	224.2	258.1	278.3	252.5	254.1	246.0	235.3	234.5	206.6	197.4	190.3
Copper Sulfate (Gross Weight	43.6	48.4	44.0	52.7	55.5	55.2	49.2	32.1	25.1	25.6	19.5	22.6	22.0
Copper & Copper Alloy Powde	10.7	10.6	7.7	7.6	7.7	7.6	7.6	6.9	0.1	0.4	0.2	1.3	1.1
							an a						
Total Semifabricates	3,584.1	3,721.9	3,807.5	3,926.2	3,916.5	3,306.2	3,257.2	3,075.4	3,435.6	3,208.2	3,061.1	2,946.9	2,946.9
Copper Semis	2,768.5	2,846.5	2,933.4	3,028.1	3,012.5	2,634.9	2,532.6	2,404.4	2,708.1	2,514.1	2,359.1	2,328.5	2,328.5
Copper Alloy Semis	815.6	875.4	874.1	898.1	904.0	671.3	724.6	671.0	727.5	694.2	702.0	618.4	618.4

Data Sources: U.S. Geological Survey, U.S. Bureau of Mines, International Copper Study Group, Copper Development Assn. <sup>1</sup>Copper powder from scrap only. Some firms also used ingot to produce powder, amounts not shown here. U.S. Geol. Survey. <sup>2</sup>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,<br/>Powder and Hydroxides (Thousand metric tons)

	1999	2000	2001	2002	2003	2004	2005	2006	2007	2008	2009
Total Copper Semis Exports	114.50	184.60	133.50	162.70	160.70	205.50	221.80	233.80	224.10	200.40	170.90
Total Copper Alloy Semis Exports	92.80	88.00	80.20	69.60	78.60	91.60	104.30	99.90	90.70	82.40	57.40
Total Semis Exports	207.30	272.60	213.70	232.30	239.30	297.20	326.20	333.80	314.80	282.80	228.30
											•
283325 - Copper Sulphate (G.W.) Exports	1.08	0.93	0.97	1.65	2.07	1.44	3.22	3.29	4.77	5.43	5.88
Copper Sulphate (Copper Content)	0.42	0.36	0.38	0.64	0.81	0.56	1.25	1.28	1.86	2.12	2.29
74061 - Copper Powder Non-Lamellar Structure	5.60	5.41	4.89	5.44	5.11	8.29	10.82	10.44	9.92	7.38	5.81
74062 - Copper Powder Flakes Exports	1.27	1.02	0.85	0.85	0.60	0.90	1.43	1.03	1.35	1.32	0.63
7406 - Total Copper Powder Exports	6.87	6.43	5.74	6.29	5.71	9.18	12.25	11.47	11.27	8.70	6.44
2825503 - Copper Oxides & Hydroxides Exports	10.57	10.27	11.00	12.98	17.62	20.70	19.63	21.71	21.95	26,76	22.48

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

	1999	2000	2001	2002	2003	2004	2005	2006	2007	2008	2009	2010 <sup>1/</sup>
Total Copper Semis Imports	345.50	462.30	411.00	407.00	377.80	423.60	554.30	562.00	409.40	340.48	250.30	251.92
Total Copper Alloys Semis Imports	152.80	196.30	138.00	128.70	122.20	146.60	117.30	114.60	98.10	99.80	63.40	58.13
Total Semis Imports	498.30	658.70	549.00	535.80	500.00	570.10	671.60	676.60	507.50	439.90	313.80	310.05
283325 - Copper Sulphate (G.W.) Imports	26.72	33.24	40.24	45.41	50.93	56.05	55.85	53.61	57.01	56.77	49.34	49.75
Copper Sulphate (Copper Content)	10.41	12.95	15.68	17.70	19.85	21.84	21.77	20.89	22.22	22.12	19.34	19.39
2825503 - Copper Hydroxides Imports	0.85	1.39	1.55	1.94	3.67	3.75	3.00	1.45	0.43	0.41	0.25	0.24
74062 - Copper Powder Flakes Imports	0.95	1.06	0.92	1.23	0.81	0.79	0.91	1.57	0.79	0.99	0.63	0.73
74061 - Copper Powder Non-Lamellar Structure Imports	1.24	1.22	1.01	1.39	2.71	2.02	2.81	3.02	3.65	2.61	2.38	3.35
7406 - Total Copper Powder Imports	2.19	2.27	1.92	2.62	3.51	2.82	3.72	4.59	4.44	3.60	3.01	4.08

"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

Hyrdroxides/oxides: China, Canada, Korea, Sweden, Singapore, Portugal and United Kingdom.

Copper sulfate : Mexico, Canada, Chile, China, Russia, Germany, Taiwan, Malaysia and Peru.

Table 11.	Standard	Designations	for	<b>Cast Copper</b>	Alloys
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		Percent (range) of principal metals in cast alloys							
Alloy Class	UNS Range	Copper	Tin	Lead	Zinc	Aluminum	Nickel <sup>1</sup>	Other	
High copper alloys <sup>2</sup>	81300-82800	94.2-98.5	0.1	0.02	0.1	.1015	.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	.00550	
Semired brasses & leaded semired brasses	84200-84800	75.0-82.0	2.0-6.0	2.0-9.0	7.0-17.0	.00501	.8-1.0	.0240	
Yellow brasses & leaded yellow brasses	84200-85800	57.0-75.0	.7-3.0	.8-5.0	20.0-41.0	.0058	.2-1.0	.0058	
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	.158	.2050	.01-5.5	
Tin bronzes	90200-91700	79.0-94.0	6.0-20.0	.2050	.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	.00550	
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	.00530	
Aluminum bronzes	95200-95900	71.0-88.0	.1-1.0	.0310	.35	6.0-13.5	.25-5.5	.05-14.0	
Copper nickels	96200-96800	65.0-69.0		.00503			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 <sup>3</sup>	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.

<sup>1</sup> May include columbium.

<sup>2</sup> Includes beryllium copper and chromium copper.
 <sup>3</sup> Special alloys include Incramet 8009, Incramute 1, while tombasil, etc.

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

Form of Recovery	1999	2000	2001	2002	2003	2004	2005	2006	2007	2008
Electrolytic Refined	156,196	128,000	172,474	69,923	53,281	50,761	47,208	44,800	42,100	53,800
Fire-Refined	73,723	80,000	(w)	(w)	(w)	(w)	(w)	(w)	(w)	(w)
Copper Powder	7,415	7,510	7,452	7,439	8	48	314	134	1,240	1,070
Copper Castings	647	839	323	300	338	574	547	612	114	136
Total unalloyed	237,981	217,000	180,249	77,662	53,627	51,383	48,069	45,546	42,351	55,006
In Brass and Bronze	1,000,462	1,010,000	893,363	876,216	818,087	839,975	836,591	846,000	799,000	730,000
In Alloy Iron and Steel	599	549	506	425	974	1,017	985	792	890	677
In Aluminum Alloys	78,200	74,900	64,006	63,177	59,258	60,446	53,401	68,800	72,600	60,400
In Other Alloys	125	125	117	122	27	28	32	36	13	8
In Chemical Compounds <sup>1</sup>	11,775	11,700	11,248	12,022	12,255	12,255	12,255	8,210	5,040	5,040
									-	
Total	1,329,142	1,314,274	1,149,489	1,029,624	944,228	965,094	951,332	968,546	925,000	851,000

Source: USGS Minerals Yearbook (1999-2008), Copper Chapters

<sup>1/</sup> 1999-2006 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.

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 lusa)	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	lowa
41. Revere Copper Products	Rome	New York
42. Small Tube Products Inc. (Wolverine Tube)	Altoona	Pennsylvania
43. vvincnester Olin ( Div of Global Brass and Copper)	Uxtord	Mississippi
44. vvoiverine Tube Inc. (Hags Huntsville, Ala)	Carrolton	Texas
45. vvoiverine Tube Inc.	Snawnee	Oklahoma
40. vvolverine Joining Technologies (Vvolverine Tube Inc.)	VVarwick	Rhode Island
47. vvoiverine Tube Inc.	Ardmore	Tennessee

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

# Table 14.List of U.S. Ingot makers, Secondary Smelters and Refiners, and Secondary<br/>Chemical and Hydrometallurgical Plants

Company Name	ompany Name City		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 Smitg & 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						
l 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:	percenterior de la companya de la co									
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 roo	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	lexas	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<br/>(in percent metal content)

	Cop	per	Т	in	Le	ad	Zir	10	Alum	inum	Nickel	Cobalt	Mang	anese	Ot	her
Scrap Type	Low	High	Low	High	Low	High	Low	High	Low	High	Low	High	Low	High	Low	High
Unalloyed Copper Scrap												gen Million en anteres			-	
No. 1 Copper	99.00	99.90														
No. 2 Copper, mixed, light	94.50	99.00										and the second		-manananana		
Other	94.00	99.00														- particular and the second
Copper-base Alloy Scrap														r		
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		<b> </b>	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 <sup>1</sup>	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 <sup>2</sup>	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 <sup>3</sup> (Grape)	65.00	77.00	0.00	2.00	2.00	6.00	15.00	33.00			х				x	
Cartridge cases and brass	68.50	71.50			0.07	0.07	28.40	31.40								
Refinery brass <sup>4</sup> (drink)	61.30															39.00
Aluminum/copper radiators		45.60				0.02		0000170-000110-000		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.

<sup>1</sup> Be, Cd, Cr coppers

<sup>2</sup> Al, Fe, Ni alloys

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

<sup>4</sup> Limit 5% iron, includes copper, brass and bronze alloyed metal.

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