RECYCLING—METALS

Introduction[1]

Metals are important, reusable resources. Although the ultimate supply of metal is fixed by nature, human ingenuity plays a role in determining the quantity of supply available for use by developing economic processes for the recovery of primary (i.e., from the Earth) and secondary (i.e., from the use process stream) metals. Their reusability contributes to their sustainability.

Recycling, a significant factor in the supply of many of the metals used in our society, provides environmental benefits in terms of energy savings, reduced emissions associated with energy savings, and reduced volumes of wastes. Table 1 lists salient U.S. apparent supply and recycling statistics for some metals. Apparent metal supply of 150 million metric tons was valued at $43.2 billion in 1998. By weight, iron and steel accounted for 88.6% of apparent supply. By value, iron and steel accounted for 40.1% of apparent supply, and aluminum, for 30.2%. Recycling contributed about 80 million tons of metal worth about $17.7 billion, or more than one-half of metal apparent supply. Thus, recycling accounted for 53% of apparent metal supply by weight and 41% by value.

The U.S. Geological Survey (USGS) collects, analyzes, and distributes information about more than 100 raw and/or processed minerals. Mineral commodity specialists assess collected data, and information is disseminated to Government, industry, academia, and the general public through more than 100 periodical minerals information series publications. This report summarizes metal recycling. For each of the metals summarized in this report, separate reports, which contain more-detailed information about individual metals and the recycling of those metals, are published as chapters in USGS Minerals Yearbooks and as Annual Reviews in the USGS Mineral Industry Surveys series.

Recycling practices and their descriptions vary substantially among the metal industries covered in this report. Generally, scrap is categorized as new, which indicates preconsumer sources, or old, which suggests postconsumer sources. The many stages of industrial processing that precede an end product are the sources of new scrap. For example, when metal is converted into such shapes as plates, sheets, bars, rods, etc., new scrap is generated in the form of cuttings, trimmings, and off-specification materials. When these shapes are converted to parts, new scrap is generated in the form of turnings, stampings, cuttings, and off-specification materials. Similarly, when parts are assembled into products, new scrap is generated. Once a product completes its useful product life, it becomes old scrap. Used beverage cans (UBC) are an example of old consumer scrap; used jet engine blades and vanes are examples of old industrial scrap. A wide variety of descriptive terms for scrap, including “home,” “mill,” “purchased,” “prompt,” etc., have evolved to describe scrap generated by a wide variety of industry practices.

Aluminum[2]

Various forms of aluminum scrap are recovered by almost every segment of the domestic aluminum industry. Integrated primary aluminum companies, independent secondary smelters, fabricators, foundries, and chemical producers are known to recover aluminum from scrap. Integrated primary aluminum companies and independent secondary smelters, however, are the major consumers of the scrap.

The independent secondary aluminum smelters consume scrap and produce alloys for the diecasting industry. A cursory look at the distribution of these smelters in the United States reveals a heavy concentration of smelters in the automotive and appliance manufacturing areas of the country.

The other major consumers of aluminum scrap are the integrated aluminum companies. The integrated companies frequently purchase scrap from their industrial customers directly or on a contract conversion basis. Major integrated aluminum companies also operate can recycling programs and have established thousands of collection centers around the country for used aluminum beverage cans.

UBC scrap is the major component of processed old aluminum scrap, accounting for approximately one-half of the old aluminum scrap, by weight, consumed in the United States. Most UBC scrap is recovered as aluminum sheet and then is manufactured back into aluminum beverage cans. Most of the other types of old scrap are recovered in the form of alloys used by the diecasting industry; the bulk of these diecasts are used by the automotive industry.

Scrap has become an important component of aluminum supply and demand in the United States. The aluminum recycling industry has grown dramatically during the past 30 years. According to data derived by the USGS from its Aluminum Scrap survey, recycling increased from a total metal recovery of 900,000 metric tons in 1970 to more than 3.4 million tons in 1998 (table 1).

According to figures in a joint press release by the Aluminum Association Inc., the Can Manufacturers Institute, and the Institute of Scrap Recycling Industries, 64 billion aluminum UBC’s were recycled in the United States in 1998 (Aluminum Association Inc., 1999). The recycling rate, based on the number of cans shipped during the year, was 62.8%, a modest decrease from the 66.5% recycling rate reported in 1997, although 1998 was the 10th consecutive year in which the aluminum can recycling rate was greater than 60%. Aluminum beverage cans produced domestically in 1998 had an average 51.4% postconsumer recycled content, the highest recycled content percentage of all packaging materials.

[1]Prepared by John F. Papp (703) 648-4963; Fax (703) 648-7757.

[2]Prepared by Patricia A. Plunkert (703) 648-4979; Fax (703) 648-7757.

Purchase prices for aluminum scrap, as quoted by American Metal Market, followed the general trend of primary ingot prices. Scrap prices closed the year at significantly lower levels than those at the beginning of the year. The yearend price ranges for selected types of aluminum scrap, in cents per pound, were as follows: mixed low-copper-content aluminum clips, 43 to 44; old sheet and cast, 37 to 39; and clean, dry aluminum turnings, 35 to 37.

Aluminum producers' buying price range for processed and delivered UBC's, as quoted by American Metal Market, also trended downward during the year. The price range began the year at 55 to 56 cents per pound and closed the year at 44 to 45 cents per pound. Resource Recycling published a monthly transaction price for aluminum UBC's in its Container Recycling Report. The average annual UBC transaction price for 1998 was 50 cents per pound, a significant decrease from the 1997 annual average of 60.3 cents per pound.

The yearend indicator prices for selected secondary aluminum ingots, as published in American Metal Market, also decreased significantly, averaging more than 16 cents per pound lower than those of 1997. The closing prices for 1998, in cents per pound, were as follows: alloy 380 (1% zinc content), 65.05; alloy 360 (0.6% copper content), 70.06; alloy 413 (0.6% copper content), 69.94; and alloy 319, 67.69. Platt's Metals Week published an annual average U.S. price of 63.56 cents per pound for A-380 alloy (3% zinc content). The average annual London Metal Exchange cash price for a similar 380 alloy was 54.6 cents per pound.

Beryllium[3]

Beryllium is used in many applications where such properties as light weight and stiffness are important. In 1998, the United States, one of only three countries that processed beryllium ores and concentrates into beryllium products, supplied most of the rest of the world with these products.

Beryllium-copper alloys, most of which contain approximately 2% beryllium, are used in a wide variety of applications and account for the largest share of annual U.S. apparent consumption on a beryllium-metal-equivalent basis. Beryllium metal is used principally in aerospace and defense applications, and beryllium oxide serves mainly as a substrate for high-density electronic circuits. Because of its high cost, beryllium use is restricted to those applications in which its properties are crucial. Such substitutes as graphite composites, phosphor bronze, steel, and titanium are available for certain beryllium applications but with a substantial loss in performance.

In 1998, U.S. apparent consumption of beryllium totaled about 260 tons. Unknown quantities of new scrap generated in the processing of beryllium metal and beryllium-copper alloys were recycled. The new scrap generated during the machining and fabrication of beryllium metal and alloys was returned to the metal-alloy producers for recycling. The beryllium in beryllium-copper fabricated parts was so widely dispersed in products and so highly diluted when those products were recycled that it was essentially dissipated. Additionally, small quantities of obsolete military equipment containing beryllium were recycled (Cunningham, 1999a; Petkof, 1985).

Cadmium[4]

Recycled cadmium is derived from either old (used) scrap or, to lesser degree, new (unused) scrap. The easiest forms of old scrap to recycle are spent nickel-cadmium (Ni-Cd) batteries, some alloys, and dust generated during steelmaking in electric arc furnaces. Most of the new scrap is generated during manufacturing processes, such as diecasting. All other applications use materials that are low in cadmium concentration and, therefore, are difficult to recycle for cadmium. Consequently, much of this cadmium is dissipated.

Recycling of cadmium is a young but growing industry spurred by environmental concerns and regulatory moves to limit dissipation of cadmium into the ground from discarded cadmium products. Because about three-fourths of cadmium is used in Ni-Cd batteries and because Ni-Cd batteries are the easiest form to recycle, most recycled cadmium comes from spent Ni-Cd batteries.

The few companies that recover cadmium use pyrometallurgical or hydrometallurgical methods. In 1998, the annual rate of secondary production in the United States amounted to about 500 tons. The largest recycling company, International Metals Reclamation Co. Inc. (Inmetco), was located in Ellwood City, PA. Although the plant was established in 1978, cadmium recovery, using the High Temperature Metal Recovery (HTMR) Process, did not begin until 1996. In the process, large batteries, usually weighing more than 2 kilograms and containing an average of 15% cadmium, are emptied of their electrolyte and dismantled; the cadmium and nickel plates are separated. Detached cadmium plates then go directly into the HTMR Process furnace, where cadmium is reduced by using carbon. Cadmium in smaller sealed batteries is recovered by burning off the castings and separators at a lower temperature than is used in the HTMR Process. The resulting 99.95% pure cadmium is shipped to battery manufacturers for reuse.

Future collection and recycling of batteries may be further spurred by the Mercury-Containing and Rechargeable Battery Act of 1996 (Public Law 104-142). By 2002, an estimated 50% of spent Ni-Cd batteries in the United States will be recycled (Manousoff, 1997).

Chromium[5]

The major end use of chromium is in stainless steel, and it is in this form that chromium is recycled. Chromite ore is smelted to make ferrochromium, a chromium-iron alloy that results from the removal of oxygen from chromite. Ferrochromium is then added to iron at steel-producing plants

[3]Prepared by Larry D. Cunningham (703) 648-4977; Fax (703) 648-7757.

[4]Prepared by Jozef Plachy (703) 648-4982; Fax (703) 648-7757.

[5]Prepared by John F. Papp (703) 648-4963; Fax (703) 648-7757.

to make the iron-chromium alloy that is commonly called stainless steel. Stainless steel scrap can substitute for ferrochromium as a source of chromium. Stainless steel comprises two broad categories—austenitic and ferritic. The names are related to the molecular structure of the steel but also identify which grades contain nickel (austenitic) and which do not (ferritic). Nickel content increases the price of the alloy and its resulting scrap.

Scrap is generated during the manufacturing process (new scrap) and as a result of recycling obsolete equipment (old scrap). Scrap from these sources is collected and sorted by grade (i.e., chemical composition) in scrap yards. Scrap brokers play a role in moving material from where it is recovered to where it is consumed. The steel industry consumes stainless steel scrap as a source of chromium and nickel units. Thus chromium units are recycled when stainless steel is reused. A study of domestic stainless steel found that its average chromium content is about 17% (Papp, 1991, p. 1).

Cobalt[6]

Cobalt-bearing scrap originates during manufacture and/or following use in these applications—catalysts used by the petroleum and chemical industries; cemented carbides used in cutting and wear-resistant applications; rechargeable batteries; and superalloys, magnetic and wear-resistant alloys, and tool steels. Depending on the type and quality of the scrap, it might be recycled within the industry sector that generated it, processed to reclaim the cobalt as a cobalt chemical or metal powder, downgraded by using it as a substitute for nickel or iron in an alloy with a lower cobalt content, or processed to an intermediate form that would then be either further refined or downgraded. The products of recycled cobalt scrap include alloys; mixed metal residues; pure cobalt metal, metal powder, or chemicals; and tungsten carbide-cobalt powders.

In 1998, scrap consumption reported by U.S. cobalt processors and consumers was 3,080 tons of contained cobalt, an increase of 12% compared with that of 1997. U.S. imports of cobalt waste and scrap increased by 91% to 857 tons, gross weight, valued at $10.8 million. Eight countries supplied 97% of these materials—Japan (22%), Finland (20%), Germany (17%), the United Kingdom (14%), Belgium and the Netherlands (8% each), and Canada and France (4% each). U.S. exports of cobalt waste and scrap are reported in combination with exports of unwrought cobalt metal and metal powders.

Copper[7]

According to data compiled by the International Copper Study Group (1999, p. 16), estimated world production of secondary refined copper in 1998 was 1.88 million tons, a decline of 9%, or about 180,000 tons, from that of 1997, and accounted for only about 13% of total world production of refined copper. According to data compiled by the World Bureau of Metal Statistics (1999, p. 42), an additional 3.23 million tons of copper was recovered from the direct remelting of copper scrap, a decline of about 2%, or 70,000 tons, from that of 1997. Secondary refined production in the United States declined by about 12%, or 50,000 tons, in 1998. With the exception of 1997, when higher prices during the first half of the year encouraged the recycling of stockpiled copper scrap, secondary refined production has trended downward since 1994. The decline in 1994-95 was attributed to closure of a major secondary refinery in 1994. In 1996, lower copper prices further discouraged scrap copper recovery. In 1998, low copper prices resulted in the closure of Cerro Copper Products' smelter and its associated electrolytic refinery and a significant cutback at its fire refinery in Alton, IL. By yearend 1998, only two secondary smelters remained in operation, down from five in 1994.

In 1998, copper recovered from all refined or remelted scrap (about one-third from old scrap and two-thirds from new scrap) declined by about 3%, but still composed 36% of the total U.S. copper supply. The equivalent refined value of copper recovered from scrap, $2.4 billion, however, declined by almost 30% owing to a significant drop in copper prices. Copper recovered from old scrap declined by about 6% owing to low prices and the aforementioned closures. Purchased new scrap, derived from fabricating operations, yielded 942,000 tons of copper, an amount essentially unchanged from that of 1997 despite a 3% growth in reported refined consumption. Consumption of new scrap trended upward, growing by 40% between 1991 and 1997, increasing in absolute terms and as a percentage of total scrap consumption.

Copper recovered from new scrap at brass and wire-rod mills rose nominally in 1998 and accounted for about 87% of the copper recovered from new copper-base scrap. Copper recovery from new scrap at refineries, ingot makers, and other consumers of scrap declined in 1998.

During the year, 7 primary and 3 secondary smelters, 8 electrolytic and 4 fire refineries, and 16 electrowinning plants operated in the United States. Two of the electrolytic refineries were dedicated facilities associated with secondary smelters and mostly processed anode derived from scrap; several refineries principally associated with primary smelters processed some secondary anode. All the fire refineries processed copper scrap.

Copper was consumed as refined copper and direct melt scrap at about 35 brass mills, 15 wire rod mills, and 600 foundries, chemical plants, and miscellaneous consumers. Of the total copper recovered from copper-, aluminum-, nickel-, and zinc-base scrap, brass and bronze ingot makers recovered, 9%; brass mills, 58%, copper smelters and refiners, 23%; and miscellaneous manufacturers, foundries, and chemical plants,10%. Unalloyed scrap accounted for 48% of the gross weight of the copper-base scrap consumed.

Copper scrap prices followed the downward trend in refined copper prices, which, with the exception of a brief rally at the end of the second quarter, steadily declined from the already low values at the end of 1997. The low prices squeezed processing margins, and the discount to refined copper narrowed for all scrap types. The average discount to the

[6]Prepared by Kim B. Shedd (703) 648-4974; Fax (703) 648-7757.

[7]Prepared by Daniel L. Edelstein (703) 648-4978; Fax (703) 648-7757.

Platt's Metals Week producer price for refined copper for No. 1 and No. 2 scrap, as published in American Metal Market, fell to 5.3 and 14.9 cents per pound, respectively, in 1998 from 7.3 and 21.6 cents per pound, respectively, in 1997. In December, the average discount for No. 1 scrap fell to 4.5 cents per pound.

U.S. exports of copper scrap fell for the third consecutive year, declining to 308,000 tons, a decrease of 72,000 tons , 19%, from 1997. As a result, the United States relinquished its position as the largest international source for copper scrap to Russia, whose exports rose to 357,000 tons. German exports of copper scrap closely followed those of the United States, falling to 306,000, a decrease of 36,000 tons from those of 1997. Canada, France, and the United Kingdom were also large sources of internationally traded scrap. China, including Hong Kong, was the largest recipient of scrap, accounting for about one-third of global scrap imports. Canada retained its position as the largest recipient of U.S. scrap exports, accounting for 35% of the total (International Copper Study Group, 1999, p. 40-43). U.S. imports of copper scrap declined to 211,000 tons, a decrease of 56,000 tons from those of 1997. Canada and Mexico were the leading sources for U.S. imports of copper and copper alloy scrap and accounted for 82% of imports in 1998.

Gallium[8]

Because of the low yield in processing gallium to optoelectronic devices or integrated circuits, substantial quantities of new scrap are generated during the various processing stages. These wastes have varying gallium and impurity contents, depending upon the processing step from which they result. Gallium-arsenide (GaAs)-base scrap, rather than metallic gallium, represents the bulk of the scrap that is recycled. During the processing of gallium metal to a GaAs device, waste is generated in several stages. If the ingot formed does not exhibit single crystal structure or if it contains excessive quantities of impurities, then the ingot is considered to be scrap. Also, some GaAs remains in the reactor after the ingot is produced, which may be recycled. During the wafer preparation and polishing stages, significant quantities of wastes are generated. Before wafers are sliced from the ingot, both ends of the ingot are cut off and discarded because impurities are concentrated at the tail end of the ingot, and crystal imperfections are at the seed end. These ends represent up to 25% of the weight of the ingot. As the crystal is sliced into wafers, two types of wastes are generated—saw kerf, which is essentially GaAs sawdust, and broken wafers. When the wafers are polished with an abrasive lapping compound, a low-grade waste is generated. During the epitaxial growth process, various wastes are produced, depending on the growth method used. Because GaAs is a brittle material, wafers may break during the fabrication of electrical circuitry on their surfaces. These broken wafers also may be recycled. Gallium content of these waste materials varies from less than 1% to as much as 99.99%. In addition to metallic impurities, the scrap may be contaminated with other materials introduced during processing such as water, silicone oils, waxes, plastics, and glass (Kramer, 1988, p. 15).

In processing GaAs scrap, the material is crushed, if necessary, and then dissolved in a hot acidic solution. This acid solution is neutralized with a caustic solution to precipitate the gallium as gallium hydroxide, which is filtered from the solution and washed. The gallium hydroxide filter cake is redissolved in a caustic solution and electrolyzed to recover 99.9% to 99.99% gallium metal (Kramer, 1988, p. 15).

Some GaAs manufacturers may recycle their own scrap, or scrap may be sold to metal traders, to a company that specializes in recycling GaAs, or to the GaAs manufacturer's gallium supplier, who can recover the gallium and return it to the customer. Generally, the prices commanded by GaAs scrap parallel the price fluctuations of 99.99%-pure gallium metal. Also, prices are dependent on the type and gallium content of the scrap. GaAs scrap that is recycled is new scrap, which means that it has not reached the consumer as an end product, and it is present only in the closed-loop operations between the companies that recover gallium from GaAs scrap and the wafer and device manufacturers (Kramer, 1988, p. 15).

Gold[9]

Old scrap, which consists of gold-containing products that have been discarded after use, generally contributes from 13% to 25% of the total U.S. supply of gold. New scrap is generated during manufacturing processes and, for the most part, remains the property of the manufacturers; it is not counted as part of the market supply. The scrap component of the gold supply is perhaps the most difficult of all metal supply components to quantify. In many areas of the world, especially in those areas where the holding of gold is encouraged by tradition, secondary gold, especially that derived from gold jewelry, changes hands locally and internationally after using goldsmiths as collection sites. This flow is often in response to variations in the gold price and usually cannot be followed statistically.

A considerable quantity of scrap is generated during manufacturing, but because of tight controls over waste materials in precious metals plants, nearly all this "home-generated" scrap can be recovered. Probably the greatest loss in gold fabrication takes place in gold-plating plants where fouled or depleted solutions are sometimes discarded. Some old scrap, however, is lost because, in practice, gold cannot be economically recovered from all manufactured products.

Gold-bearing scrap is purchased on the basis of gold content, as determined by analytical test, and the market price for gold on the day that the refined product is available for sale. Processing charges and adjustments for processing losses are deducted from the total value in settling payments. Aside from dealer-processors and refiners, scrap gold has no market. The Federal Trade Commission requirement for karat identification of jewelry alloys effectively forces gold refiners to know the chemical analysis of the alloys they purchase and to separate

[8]Prepared by Deborah A. Kramer (703) 648-7719; Fax (703) 648-7722.

[9]Prepared by Earle B. Amey (703) 648-4969; Fax (703) 648-7757.

the constituents of scrap to assure meeting karat standards (Public Law 226, An act forbidding the importation, exportation, or carriage in interstate commerce of falsely or spuriously stamped articles of merchandise made of gold or silver or their alloys, and for other purposes, 1906).

Refiners throughout the world recover secondary gold from scrap. In the United States, about two-thirds of the scrap comes from manufacturing operations, and the remainder comes from old scrap in the form of such items as discarded jewelry and dental materials, used plating solutions, and junked electronic equipment. A few dozen companies, among the several thousand companies and artisans, dominate the fabrication of gold into commercial products. Most of the domestic scrap is processed by refiners centered in New York, NY, and Providence, RI; refiners are also concentrated in areas of California, Florida, and Texas, although the current trend seems to be toward a less centralized industry. Scrap dealers may process the scrap and then ship the upgraded product to refiners and fabricators for further treatment and refining. The U.S. Department of Defense (DOD) recovers significant quantities of gold from military scrap (Laura Green, Precious Metals Specialist, Defense Logistics Agency, oral communication, 1998). Other Federal Government agencies either participate in the DOD recovery program or have one of their own.

Domestic consumption of new and old scrap was 81,000 and 98,000 kilograms, respectively. These data were collected in 1998 by the USGS and include 17,000 kilograms of imported scrap. In 1998, U.S. exports of gold scrap decreased for the second consecutive year after five straight years of increase, and imports increased to their highest level since 1995. As it has been for many years, the United States was a net exporter of gold scrap in 1998.

Value of gold waste and scrap imported and exported in 1998 averaged $190 and $197 per troy ounce, respectively; at the same time, the average price for gold was $295 per troy ounce (Platt's Metals Week, 1999).

Indium[10]

Domestic recovery of secondary indium remained low for the second year since the unusually high level of 1996, when high prices temporarily encouraged the recycling of more old scrap—mainly spent sputtering targets that had been used in the deposition of indium-tin oxide thin-film-coatings for liquid crystal displays in such products as flat television screens.

In 1998, as in many other years, most of the secondary indium was recovered from new scrap. The actual quantity of secondary indium produced is not known, but it was small; only in 1996 was the quantity significant, following a $12 per troy ounce price increase in 1995 that resulted from concern over supply. In 1996, recycling provided much of domestic supply (Fineberg, 1996).

[10]Prepared by Robert D. Brown, Jr. (703) 648-4984; Fax (703) 648-7757.

Iron and Steel[11]

Iron, including its refined product steel, is the most widely used of all the metals, and the recycling of iron and steel scrap (ferrous scrap) is an important activity worldwide. Iron and steel products are used in many construction and industrial applications, such as appliances, bridges, buildings, containers, highways, machinery, tools, and vehicles. Because it is economically advantageous to recycle iron and steel by melting and recasting into semifinished forms for use in the manufacture of new steel products a significant industry has developed to collect used and obsolete iron and steel products, and the ferrous scrap generated in steel mills and steel-product manufacturing plants.

The vast quantity of ferrous scrap available for recycling comprises home, prompt, and obsolete scrap. Home, or mill, scrap is generated within the steel mill during production of iron and steel. Trimmings of mill products and defective products are collected and quickly recycled back into the steel furnace because their chemical compositions are known. The availability of home scrap has been declining as new and more-efficient methods of casting have been adopted by the industry. Prompt, or industrial, scrap is generated from manufacturing plants that make steel products. Its chemical and physical characteristics are known, and it is usually transported quickly back to steel plants for remelting to avoid storage space and inventory control costs. Obsolete, old or postconsumer scrap is also available for recycling. The largest source is junked automobiles, followed by demolished steel structures, wornout railroad cars and tracks, appliances, and machinery. Because of the wide variety of chemical and physical characteristics, obsolete scrap requires more preparation, such as sorting, detinning, and dezincing.

More than 3,000 establishments ranging in size from large corporations to small private dealers, play an integral role in the steel industry by collecting and preparing scrap for transport to steel mills needing raw materials (Wulff, 1997). Scrap dealers process scrap by using a variety of equipment into a physical form and chemical composition that steel mill furnaces can consume. Dealers specializing in the processing of steel cans receive loads of these from smaller dealers or have partnership arrangements with neighborhood waste removers. By using balers, cans are crushed into cubes called bales that weigh as much as a ton.

Recycled automobiles accounted for about one-sixth of the ferrous scrap recycled by the United States steel industry in 1998. About 12,000 automobile dismantlers and 250 shredders in the United States disassembled and shredded automobiles into fist-sized pieces, which were then passed by powerful magnets to segregate steel from aluminum, plastics, and other materials (Recycling Today, 1998). Appliances, bicycles, and other steel products are also shredded for recycling. More than 1,500 scrap yards process steel from construction and demolition sites by shearing, shredding, and baling.

Manufactured steel products have a wide range of physical

[11]Prepared by Michael D. Fenton (703) 648-4972; Fax (703) 648-7757.

and chemical characteristics according to relative contents of the alloying elements carbon, chromium, cobalt, manganese, molybdenum, nickel, silicon, tungsten, and vanadium. Also, some steel products are coated with aluminum, chromium, lead-tin alloy, tin, or zinc. For these reasons, scrap dealers must carefully sort the scrap they sell, and steelmakers must be careful to purchase scrap that does not contain undesirable elements, or residuals, that exceed acceptable levels, which vary according to the product being produced.

Steel mills melt scrap in basic-oxygen furnaces (BOF's), electric-arc furnaces (EAF's), and, to a minor extent, blast furnaces. The proportion of scrap in the charge in a BOF is limited to less than 30%, whereas that in an EAF can be as much as 100%. Steel and iron foundries use scrap in EAF's and cupola furnaces. In 1998, BOF's were used to produce 55% of the total steel in the United States while using only 19% of total scrap consumed (American Iron and Steel Institute, 1998, p. 75). During the same period, EAF's produced 45% of total steel while using 62% of total scrap consumed. Scrap was also melted in blast furnaces and other types of furnaces.

Iron and steel scrap is an additional resource for steelmakers that is more than just economically beneficial. Recycling conserves natural resources, energy, and landfill space. Recovery of 1 ton of steel from scrap conserves an estimated 2,500 pounds of iron ore, 1,400 tons of coal, and 120 pounds of limestone. Each year, steel recycling saves the energy equivalent to power electrically about one-fifth of the households in the United States (about 18 million homes) for one year (Steel Recycling Institute, A few facts about steel—North America's #1 recycled material, fact sheet, accessed July 13, 1999, at URL http://www.recycle-steel.org/fact/main.html).

During 1998, steel recycling rates were 92% for automobiles, 88% for construction plate and beams, 72% for appliances, 56% for steel cans, and 64% overall (Institute of Scrap Recycling Industries, Scrap fact, Fact sheet, accessed October 15, 1999, at URL http:www.isri.org/viewpage.cfm?pgname =2.0).

Ferrous scrap is an important raw material for the steel and foundry industries and is traded worldwide. Because scrap comes from such sources as consumer durables, discarded cars, industrial machinery, manufacturing operations, and old buildings, the mature industrialized economies are the main exporters of scrap. The main trade flows of scrap are from the heavily industrialized and developed countries of North America and northern Europe to the lesser developed countries of southern Europe and the Pacific Rim. The United States continued to be the leading exporting country of iron and steel scrap in 1997, the latest year for which data are available, as reported by the International Iron and Steel Institute (1998, p. 221). Other major exporters of ferrous scrap were France, Germany, the Netherlands, and the United Kingdom. The most significant importing nations were, in decreasing order of magnitude, Turkey, Italy, the Republic of Korea, Spain, Belgium-Luxembourg, and the Netherlands (International Iron and Steel Institute, 1998, p. 223). Other Asian importers were China, India, and Japan, which individually imported only about one-fourth of that imported by the Republic of Korea.

The U.S. trade surplus for all classes of ferrous scrap was 2.2 million tons in 1998 (Bureau of the Census, unpub. data, 1998). Total U.S. exports of carbon steel and cast-iron scrap went to 61 countries in 1998 and totaled 4.53 million tons. The largest tonnages went to the Canada, the Republic of Korea, Mexico, Taiwan, and Turkey. Total U.S. exports of stainless steel scrap went to 52 countries and consisted of 298,700 tons. The largest tonnages went to the Republic of Korea, Spain, Italy, and Taiwan. U.S. exports of alloy steel scrap (excluding stainless steel) in 1998 were shipped to 43 countries and consisted of 742,000 tons. The largest tonnages went to Canada and Mexico.

Lead[12]

About 76% of the 1.45 million tons of refined lead produced in the United States in 1998 was recovered from recycled scrap (table 1), of which a major source was spent lead-acid storage batteries. The recycled batteries consisted of the starting-lighting-ignition type used in automotive applications, and the industrial-type used in such applications as airport ground-support equipment, bicycles, floor sweepers and scrubbers, golf cars and other human and materials transport vehicles, industrial forklifts, lawn equipment, load-leveling equipment for commercial electrical power systems, mining vehicles, and uninterruptible power-supply equipment (EPRI, 1998; Powers and MacArthur, 1999, p. 42-44). About 9% of the recycled lead was recovered from other lead-base sources, including building construction materials, cable covering, drosses and residues (new scrap) from primary smelter-refinery operations, and solder.

In 1998, recycled lead was produced by 20 companies operating 29 lead recovery plants. Of the 1.10 million tons of lead recycled in 1998 (table 1), about 98% was produced by 9 companies operating 17 secondary smelter-refineries in Alabama, California, Florida, Georgia, Indiana, Louisiana, Minnesota, Missouri, New York, Pennsylvania, Tennessee, and Texas. Most of the recycled lead was recovered as either soft lead or lead alloys to be reused in the manufacture of lead-acid storage batteries. Consumption of lead in storage batteries accounted for 88% of the reported consumption of lead in the United States in 1998.

From 1994 to 1998, the United States exported an average of about 93,000 metric tons per year of lead-bearing scrap, including battery and nonbattery forms. Only minimal quantities of lead-bearing scrap were imported. The spot price for smelters' heavy soft lead scrap averaged about 20 cents per pound. The average North American Producer price for refined lead was 45 cents per pound (Platt's Metals Week, 1999).

During 1998, the supply of spent (scrap) lead-acid batteries for secondary smelters remained tight. With the exception of a brief increase in supply at the end of the summer, the rate of failure of automotive batteries remained low, as moderate temperatures continued in the more heavily populated regions of the United States for the third consecutive year. Although

[12]Prepared by Gerald R. Smith (703) 648-4983; Fax (703) 648-7757.

secondary smelters were able to maintain production levels equivalent to that of the 1997, battery manufacturers reported a growth in finished battery inventories by yearend as they continued high production rates in preparation for a possible higher demand later in the winter (Ryan's Notes, 1998a). Stocks of refined secondary lead declined by 13%, owing not only to the increased battery inventories, but also to the increased demand for new batteries in the growing industrial battery sector. At yearend, the market price for whole scrap batteries averaged about 6 cents per pound, translating to a lead price of 12 cents per pound, assuming the average amount of lead in such batteries to be about 50%.

In 1998, one company initiated reconstruction and expansion of an operating secondary-lead-processing facility it had acquired at yearend 1997. The company reportedly planned to double the capacity of the plant to 32,000 tons per year through the addition of a reverberatory furnace and the refurbishing of the current blast furnace. A battery breaker was to be added to the facility to diversify its feed sources further (Ryan's Notes, 1997).

Another company temporarily closed its newly purchased secondary lead smelter to upgrade the facility. Improvements to the plant were expected to begin in early 1999. Under plans released by the company, the facility would be reopened upon completion of the upgrading work. The smelter, purchased in early 1998, had a production capacity of about 23,000 tons per year, requiring nearly 2.5 million spent lead-acid batteries as feedstock to operate each year (American Metal Market, 1998a).

During the year, a secondary lead producer in the United States continued its efforts to finalize the purchase of another large producer's secondary lead production facilities, as well as the latter's lead-acid battery manufacturing plants. Yet to be resolved were questions pertaining to the ownership of two large secondary smelters in same region by one company (Ryan's Notes, 1998b).

Magnesium[13]

Recycled magnesium is derived from two sources—aluminum- and magnesium-base scrap. Aluminum-base scrap consists of new and old aluminum-magnesium alloy scrap. The primary component of aluminum-base scrap, from which magnesium is recovered, is aluminum beverage cans. Although only about 75% of the magnesium originally present in these types of alloys is recovered, it represents a substantial source of secondary magnesium. Magnesium in these aluminum alloys is not separated from the aluminum; most of it remains as an alloying constituent when the beverage can scrap is recycled.

Magnesium-base scrap generally is in forms similar to those of other nonferrous metals. Castings, drippings, drosses, gates, runners, and turnings from processing operations are the principal sources of new scrap. Old scrap comes from a variety of sources, including aircraft parts, military applications, and discarded power tools.

Melting is the most common process used to recycle magnesium because it allows almost all types of scrap to be processed into various secondary end products. Because magnesium resembles aluminum closely, a certain percentage of aluminum scrap is usually mixed in with the magnesium scrap. The aluminum scrap is hand-sorted from the magnesium scrap, and the magnesium scrap is then sorted by alloy. Sorting is a critical step in producing a product of desired specifications.

In melting, sorted scrap is charged to a steel crucible heated to 675° C. As the scrap at the bottom begins to melt, more scrap is added. The liquid magnesium at the bottom is covered with aflux or inhibitive gas to control surface burning. After any alloying elements are added, such as aluminum, manganese, or zinc, and melting is complete, molten magnesium is transferred to ingot molds by hand ladling, pumping, or tilt pouring.

In addition to melting, magnesium scrap may be recycled by direct grinding of the scrap into powder for iron and steel desulfurization applications. This method is limited to using only specific types of clean scrap. Drosses and other contaminated scrap are not used because they can introduce impurities into the finished product and can increase the danger of fire in the direct grinding.

Trade in magnesium scrap represents a small portion of the overall U.S. supply of magnesium-base scrap. In general, imports and exports of magnesium waste and scrap have been equivalent during the past 5 years. From 1996 to 1998, however, sharp increases in exports of scrap to Canada have contributed to a level of exports that has been two to three times higher than the level of imports. Much of this scrap is reprocessed by primary producers in Canada and returned to the United States as diecasting alloys.

As more magnesium is used in automotive applications, North American firms are constructing new magnesium recycling plants. These plants primarily are expected to process new scrap resulting from automotive component diecasting operations, although many of them also will be able to process less-pure grades of scrap (Kramer, 1998).

Manganese[14]

Scrap recovery specifically for manganese is insignificant. To a large extent, it is recycled incidentally as a minor component within scrap of another metal, particularly steel and, to a much lesser degree, aluminum. High-manganese (Hadfield) steel, which has a manganese content of about 12%, is recovered for its manganese content, but the quantity of such scrap is believed to be well below 1% of the total quantity of purchased steel scrap. Recycling of aluminum and steel are discussed in the respective sections of this chapter. Manganese is ubiquitous throughout the various grades of steel, which, on average, contains about 0.7% manganese (Jones, 1994, p. 10). Manganese that is recycled to steelmaking within steel scrap

[13]Prepared by Deborah A. Kramer (703) 648-7719; Fax (703) 648-7722.

[14]Prepared by Thomas S. Jones (703) 648-4973; Fax (703) 648-7757.

largely is lost because of its removal in the decarburization step of steelmaking but needs to be added back. Manganese is recycled in the aluminum industry as a component of scrap of certain manganese-bearing aluminum alloys, principally as UBC in which the manganese content is about 1%. Melting and processing of aluminum is nonoxidizing toward manganese, so that most of the manganese is retained. The amount of manganese being recycled in the aluminum industry is estimated to be in the vicinity of 1% of manganese apparent consumption. In the future, small additional amounts of manganese could be recovered through widespread recycling of dry cell batteries (Watson, Andersen, and Holt, 1998).

Mercury[15]

Secondary mercury is recovered from a variety of source materials in response to Federal and State regulations to reduce the discharge and disposal of mercury-containing products (Roskill Information Services, Ltd., 1990, p. 102). Electronic devices (e.g., rectifiers, relays, switches, and thermostats), dental amalgams, batteries, and other instruments (e.g., thermometers) are processed to recover any contained mercury. The largest source of secondary mercury, however, remains the spent catalysts used in the production of chlorine and caustic soda. Three companies, one each in Illinois, Minnesota, and Pennsylvania, produce the bulk of secondary mercury in the United States. Mercury waste generated in the manufacturing of products (new scrap) is either reused internally or collected for reprocessing.

Molybdenum[16]

An insignificant amount of pure molybdenum scrap was used in superalloys. About 1,500 tons of molybdenum was recycled from spent catalysts. Also, molybdenum was recycled as a minor constituent of scrap alloy steels and iron. The use of such scrap did not depend on its molybdenum content.

Nickel[17]

U.S. industry recycles a broad spectrum of nickel-bearing materials. The largest source of secondary nickel is stainless steel scrap, which accounted for about 80% of the 63,300 tons of nickel reclaimed in 1998 (table 1). The 80% represents not only scrap used in raw steel production, but also lesser amounts of scrap consumed by steel and iron foundries, as well as nickel reclaimed from stainless steelmaking residues (e.g., furnace dust, grindings, and mill scale). An additional 2% came from the recycling of alloy steel scrap. Old and new scrap are used by stainless steel producers, who are more concerned about the grade of the scrap and the levels of critical impurities than about its origin. The five leading producers of austenitic stainless steel in the United States have their principal meltshops in Pennsylvania. An additional nine companies have medium to small meltshops scattered throughout the Eastern United States that make austenitic stainless products largely for niche markets.

Inmetco converted a variety of chromium and nickel wastes at Ellwood City, PA, into a remelt alloy suitable for making stainless steel. The Ellwood City operation was set up in 1978 to reclaim chromium and nickel from emission control dusts, grindings, mill scale, swarf, and other wastes generated by the stainless steel industry. During the past 20 years, Inmetco has made a number of improvements to its Pennsylvania facility and can process catalysts, nickel- and/or chromium-bearing filter cakes, plating solutions and sludges, refractory brick, and spent batteries.

Copper-nickel alloy scrap and aluminum scrap accounted for about 10% of the nickel reclaimed in 1998. Scrap in this category comes from a myriad of sources and includes cupronickel (a series of copper alloys containing 2% to 46% Ni), the Monels (a group of alloys typically containing 65% Ni and 32% Cu), nickel-silver (a misnomer for a series of copper-zinc-nickel alloys; actually a white brass), and nickel-aluminum bronze. Cupronickel is stronger and more resistant to oxidation at high temperatures than pure copper, making it desirable for saltwater piping and heat exchanger tubes. Nickel-silver is used for camera parts, optical equipment, rivets, and screws.

The remaining 8% of reclaimed nickel came from pure nickel scrap and nickel-base alloy scrap. Superalloy producers and downstream fabricators of turbine engines and chemical-processing equipment generate a large part of this material, some of which is sent to scrap processors for salvaging and cleaning and later returned to the producers for remelting. Because of the stringent specifications for INCONEL 718, WASPALOY, and similar aerospace-grade superalloys, however, much of that scrap is not suitable for direct recycling and is sold to stainless steel producers, steel foundries, or specialty-alloy-casting companies. Significant amounts of superalloy scrap are intentionally generated during the forging and machining of turbine parts for aircraft engines. As little as 1 out of 7 kilograms of superalloy may end up in a finished turbine part (Lane, 1998). Superalloy scrap is an important source of revenue for most aerospace machine shops. Proper segregation of turnings and grindings, onsite recovery of cutting fluids, and timely shipping of the scrap can make the difference between profitability and bankruptcy for a small to medium machine shop. Inclusion of a pea-sized piece of bismuth, lead, or tungsten alloy can put an entire truckload of superalloy scrap out of specification. Aircraft engine repair facilities are an important source of obsolete superalloy scrap. Discarded engine parts are deliberately nicked with a saw to prevent them from illegally entering the replacement parts market.

The U.S. collection and recycling program for Ni-Cd and nickel-metal hydride (Ni-Mh) batteries is in a period of rapid expansion. Federal legislation passed in 1996 has helped spur the program, which is administered by the Rechargeable Battery Recycling Corporation (RBRC), a nonprofit public service corporation funded by more than 285 manufacturers

[15]Prepared by Robert G. Reese, Jr. (703) 648-4981; Fax (703) 648-7757.

[16]Prepared by John W. Blossom (703) 648-4964; Fax (703) 648-7757.

[17]Prepared by Peter H. Kuck (703) 648-4965; Fax (703) 648-7757.

and marketers of portable rechargeable batteries and battery-operated products. The program is primarily designed to recycle the more-than-75 million small, sealed, rechargeable Ni-Cd batteries sold each year to U.S. and Canadian businesses and consumers for use in cordless products. More than 25,000 retail stores or communities in the United States now accept spent Ni-Cd batteries. Some 3,000 retail outlets in Canada also serve as collection sites for the RBRC program. The bulk of the collected batteries are sent to Inmetco for reclamation (England, 1996, p. 199).

Nickel- and precious-metals-bearing electronic scrap is a small but rapidly growing source of the metal. A recent National Safety Council report estimated that only 11% to 14% of obsolete electronics products are being recycled (Scrap, 1999). The U.S. electronics recycling industry is dominated by several large firms, some of which are subsidiaries of electronics manufacturers. In 1998, 10 companies accounted for 75% of the 125,000 tons of electronic products recycled in the United States. Nickel alloys are used to coat the aluminum substrate in many of the hard-disk-drive platters found inside personal computers. A cobalt-base alloy—enhanced with platinum to give the alloy superior magnetic properties—is overlain on the nickel, creating a data storage device.

The North American scrap-metal-processing industry has undergone a major restructuring since 1996. Many of the smaller, family-owned scrap-processing companies have been taken over by one of the five rapidly growing conglomerates. Several scrap metal recyclers merged or acquired smaller processors of stainless steel, superalloys, and titanium during 1997 and the first half of 1998. Prices for nickel and other base metals, however, weakened in the second half of 1998, creating financial problems for many recyclers and slowing the rate of acquisitions (Platt's Metals Week, 1998). Several of the acquisitions were in the Pittsburgh area and were designed to provide synergies for cost reduction. Significant consolidations of metal recycling companies also took place in Chicago, IL, Hartford, CT, Houston, TX, and Los Angeles, CA. The closure of smaller processing yards, the integration of computer data bases, one-stop shopping for scrap consumers, reduced management overhead, and the sharing of sales expertise should make U.S. scrap metals operations more competitive and efficient, so that the industry will be better able to weather large fluctuations in commodity prices.

Metal Management Inc. continued to acquire smaller scrap processors across the United States despite weak metal prices and other near-term market problems (Marley, 1998a). In December 1997, the Chicago-based conglomerate merged with Cozzi Iron & Metal Inc., another large scrap processor in the Chicago area. New agreements negotiated with Miller Compressing Co. of Milwaukee, WI, and others could make Metal Management the dominant scrap processor and trader in the upper Midwest (Marley, 1998c). In January 1998, Metal Management acquired Aerospace Metals Inc. of Hartford for $14.4 million in cash and company stock valued at $5 million (Metal Bulletin, 1998a). Aerospace Metals had two principal subsidiaries—Suisman & Blumenthal, a leading processor of aircraft scrap, and Suisman Titanium Corp., a titanium alloy scrap processor. Suisman & Blumenthal, in the scrap business since 1899, specialized in the recovery of nickel- and cobalt-base superalloy scrap, particularly material generated in the manufacturing of aircraft engines, airframes, and helicopter parts. Aerospace Metals employed about 150 people at a 30-acre complex close to the main operations of Pratt & Whitney Co., Inc. in East Hartford. Pratt & Whitney was part of United Technologies Corporation and one of three leading jet engine manufacturers in the Western World. Prior acquisitions of Metal Management included Reserve Iron & Metal LP of Cleveland, OH, and Hou-Tex Metals Co. Inc. of Houston, both of which processed the more-traditional types of nonferrous scrap. In mid-March, Metal Management announced an agreement to purchase Michael Schiavone & Sons Inc., a prominent scrap processor and exporter operating from a 25-acre site in North Haven, CT (Marley, 1998d). Schiavone & Sons, in the scrap business for more than 100 years, had a loading yard and deep-water port facilities in nearby New Haven Harbor.

In April, Metal Management attempted to acquire Universal Scrap Metals Inc. of Chicago, IL. Negotiations continued throughout the summer but reportedly broke down in September (Metal Bulletin, 1998b). Universal Scrap Metals was a major processor of copper and aluminum scrap. Metal Management was more successful with two other takeover bids—Charles Bluestone Co. and Nicroloy Co. Inc. during the summer (Marley, 1998b). Charles Bluestone processed cobalt, nickel, and titanium scrap in Charlotte, NC, and Elizabeth, PA. Nicroloy processed primarily nickel-chromium alloy scrap and stainless steel in Carnegie and Pittsburgh, PA.

In early August, ELG Haniel Metals Corp. acquired three U.S. operations owned by Ireland Alloys Ltd. (United Kingdom)—Astromet Inc. of Schereville, IN, Ireland Alloys, Inc. of Houston, TX, and National Nickel Alloy Corp. of Greenville, PA. The purchase price was not disclosed. Ireland Alloys, Inc. specialized in aerospace metal scrap, including superalloys and titanium, and added about 25,000 tons per year of stainless-steel-processing capability to ELG's U.S. operations (Roggio, 1998).

ELG Haniel Metals Corp. was a subsidiary of ELG Haniel GmbH., one of the world's larger processors of stainless steel scrap. ELG Haniel GmbH.'s parent, Franz Haniel & Cie. GmbH., is headquartered in Duisburg, Germany. ELG Haniel GmbH.'s British subsidiary, ELG Haniel Metals Ltd. of Sheffield, was a leading recycler of stainless steel and also specialized in nickel-chromium superalloy scrap. ELG Haniel GmbH. made several major acquisitions in the past 5 years. In 1996, it acquired Jewo Stainless Processing BV of Rotterdam, the Netherlands: this included Jewo USA Inc., a scrap trader based in White Plains, NY. In 1995, it completed its acquisition of Steelmet, Inc., a long-established scrap processor based in McKeesport, PA; they had an interest in Steelmet since 1985. Steelmet handled a broad spectrum of metal scrap, including cobalt carbide, high-speed tool steel, nickel-chromium, nickel-copper, stainless steel, titanium, tungsten alloy, and tungsten carbide. ELG Steelmet Inc. had seven additional processing plants or depots scattered across the United States prior to the acquisition of Ireland Alloys Inc.

ELG Haniel GmbH.'s U.S. operations will be reorganized into four regional operations—ELG Metals Inc., ELG Metals Southern Inc., ELG Metals West Coast Inc., and ELG Ireland Alloys. West Coast and ELG Ireland Alloys will specialize in aerospace and superalloy scrap, and the southern group will handle bulk stainless scrap.

Platinum-Group Metals[18]

Despite their limited availability, platinum-group metals (PGM) and the chemical compounds containing them are extremely useful as catalysts in the chemical and petroleum industries, as conductors, in dental and medical prostheses, in the electronics industry, in extrusion devices, and in jewelry.

Since the beginning of the 1975 model year, new automobiles sold in the United States have been equipped with catalytic converters whose purpose is the chemical removal of polluting substances from engine exhausts. The amount of PGM required in these devices is more than the total amount of all other U.S. uses combined (Johnson Mathey, 1999, p. 22-29).

For most PGM applications, the actual loss during use of the metal is small, and, hence, the ability to recover the metal efficiently contributes greatly to the economics of PGM use. Typical sources of PGM for secondary refining include catalysts, electronic scrap, jewelry, and used equipment (e.g., from the glass industry). Spent automotive catalysts have emerged as a significant potential source of secondary palladium, platinum, and rhodium. In 1998, an estimated 10 tons of platinum, 6 tons of palladium, and 2 tons of rhodium were available in the United States for recycling from auto catalysts.

Selenium[19]

Most selenium, except that applied to the surfaces of the photoreceptor drums in plain paper copiers, is dissipated as process waste or is eventually sent to a landfill as a minor constituent of a used product. The small quantities that are added to glass as a decolorant and to ferrous and nonferrous metal alloys to improve metalworking properties are not accounted for in the recycling of those materials and are probably volatilized during remelting. Selenium rectifiers, once a major source of old scrap, generally have been replaced by silicon rectifiers. High processing costs, however, have made it uneconomical to recover selenium from scrapped rectifiers.

In 1998, no secondary selenium was recovered in the United States. Wornout photoreceptor drums and scrap generated in the manufacture of new drums are exported for the recovery of the selenium content. An estimated 50 tons of secondary selenium was imported; this was about 15% of all selenium imports. Practically all the selenium used in photoreceptor drums is recovered through very efficient recycling programs (Hoffman and King, 1997, p. 704). Secondary selenium was recovered in Canada, Japan, the Philippines, and a number European countries. The photocopier market for selenium, still the main feed source for secondary selenium, has continued its decline owing to competition from other technologies, mainly organic photoreceptors. A further possible impediment to the recycling of selenium is the Basel Convention of the United Nations Environmental Program, which, if implemented, would restrict the international movement of certain scrap materials, including selenium (Metal Bulletin, 1997). The shrinking market, together with low prices and surplus foreign secondary capacity, discourages the redevelopment of domestic secondary capacity.

Silver[20]

About 1,700 tons of silver valued at $300 million was recovered from scrap in 1998 (Silver Institute, 1999, p. 70). Photographic scrap was estimated to have generated 1,300 tons of silver, the largest part coming from spent fixer solution, some from X-ray and graphic arts wastes, and a small quantity directly from color film negatives. The remainder was recovered from electronic scrap, jewelers’ sweepings, spent catalysts, recycled gold, and other heterogeneous silver-bearing materials. U.S. industrial demand for silver in 1998 was about 7,000 tons; mine production was 2,060 tons.

Tantalum[21]

Tantalum is ductile, easily fabricated, highly resistant to corrosion by acids, a good conductor of heat and electricity, and has a high melting point. The major use for tantalum, as tantalum metal powder, is in the production of electronic components, mainly tantalum capacitors. Alloyed with other metals, tantalum is also used in making carbide tools for metalworking equipment and in the production of superalloys for jet engine components. Substitutes, such as aluminum, rhenium, titanium, tungsten, and zirconium, can be used in place of tantalum but are usually made at either a performance or economic penalty.

In 1998, U.S. apparent consumption of tantalum totaled about 525 tons, with consumed scrap (from various sources) accounting for an estimated 20% of the total. Recycling of tantalum, mostly from new scrap, takes place largely within the processing and end-product industries. In addition, quantities of tantalum are recycled in the form of used tantalum-bearing cutting tools and high-temperature alloy melting scrap (Cunningham, 1985, 1999b; Tantalum-Niobium International Study Center, 1996). In recent years, the recycling of tantalum in tantalum capacitors from carefully collected and sorted electronic components has attained considerable significance. Tantalum recovery from tantalum capacitor scrap requires special techniques owing to the different types of scrap. Tantalum can be recovered from certain capacitor scrap by electrolysis and acid leaching.

---

[18]Prepared by Henry E. Hilliard (703) 648-4970; Fax (703) 648-7757.

[19]Prepared by Robert D. Brown, Jr. (703) 648-4984; Fax (703-648-7757.

[20]Prepared by Henry E. Hilliard (703) 648-4970; Fax (703) 648-7757.

[21]Prepared by Larry D. Cunningham (703) 648-4977; Fax (703) 648-7757.

Tin[22]

In 1998, about 30% of the domestic apparent supply of tin metal was recovered from scrap (table 1). Old tin scrap is collected at hundreds of domestic scrap yards, seven detinning plants, and most municipal collection-recycling centers. New tin scrap is generated mainly in the tin mills at six steel plants, scores of canmaking facilities, numerous brass and bronze plants, and many soldermaking plants. Most tin-scrap-processing facilities are close to the tin-using industries and to densely populated areas, most of which are in the Midwest and the Northeast.

Detinning facilities are unique to the tin scrap industry in that no other major metal industry has numerous large-scale plants to remove plated metal. Detinning operations are performed on new tin-plate scrap from tin mills or canmaking plants and old tinplate scrap in the form of used (postconsumer) tin cans. For most of this century, the detinning process has been the only technique in the secondary tin industry by which free tin metal sees its way to the marketplace. The bulk of the secondary tin industry works with the various alloy forms of tin (brass, bronze, solder, etc.); the tin is recycled within its own product-line industries and thus reappears in regenerated alloys.

The Steel Recycling Institute (SRI) continued to promote the recycling of used tin cans, which have become an important raw material for the Nation's steel industry during the past 15 years. SRI announced that the steel can recycling rate had grown to 56% in 1998 from 15% in 1988 (Steel Recycling Institute, 1999).

Tin scrap prices are rarely published but generally approximate the prices for primary tin metal.

Titanium[23]

Titanium scrap supplies about one-half of the feedstock for titanium ingot production. New scrap is generated during the melting, forging, casting, and fabrication of titanium components. In addition, some old, or obsolete, scrap is recycled from old aircraft components, heat exchangers, etc. Although no data are available as to the percentage breakdown of sources of titanium scrap, less than 2% of titanium ingot production has been estimated to have been derived from old scrap.

Scrap is recycled with or without virgin metal by titanium ingot producers by using vacuum-arc-reduction (VAR) or cold hearth melting processes. In general, cold hearth melting techniques use higher levels of titanium scrap than traditional VAR. Two new cold hearth furnaces were being brought into operation in 1998.

Titanium scrap is consumed by the steel industry as scrap or it may be first converted to ferrotitanium. In 1998, two domestic companies produced ferrotitanium. Consumption by the steel industry is largely associated with the production of stainless steels where it is used as an alloying ingredient or as a gas scavenger. Titanium scrap is also used to produce aluminum-titanium master alloys for the aluminum industry. Titanium improves casting and reduces cracking in aluminum alloys.

In 1998, decreased demand for titanium metal from the commercial aircraft industry resulted in a slight to moderate decrease in demand for titanium metal products. However, consumption of scrap increased by about 9% compared with that of 1997. This continued a 5-year trend of increased scrap consumption. In 1998, scrap consumption was about 82% higher compared with that of 1994. Scrap supplied 50% of titanium ingot feedstock, a moderate increase compared with that of 1997. Compared with those of 1997, imports of titanium scrap decreased by 9%, and exports increased by 27%. Because of a significant decrease in prices, the estimated value of recycled metal decreased 41% compared with that of 1997.

Metal Management acquired Aerospace Metals, a major processor of titanium scrap and superalloys based in Hartford, CT. Aerospace Metals recently increased its ability to process titanium turnings by 50%. Metal Management was a growing company in the scrap metal industry whose subsidiary companies included an array of ferrous metals recycling operations (Metal Management Inc., January 21, 1998, Metal Management completes acquisition of one of the world's leading recyclers of superalloys and titanium, press release, accessed May 11, 1998, at URL http://biz.yahoo.com/prnews/980121/il_metal_m_1.html).

Titanium Hearth Technologies Inc., a subsidiary of Titanium Metals Corporation, commissioned a new cold hearth melting furnace at its Morgantown, PA, operation. The new furnace was expected to produce up to 10,000 tons per year of titanium ingot by using electron beam cold hearth technology. In addition, new VAR melting capacity was expected to be operational in Morgantown by the end of the first quarter of 1999. The new VAR furnace capacity is expected to exceed 4,500 tons per year (Titanium Metals Corporation, March 18, 1999, Advancing titanium technology and capacity—Production, annual report, accessed May 22, 1999, at URL http://www.timet.com/pdfs/98annual.pdf).

Oremet-Wah Chang, an Allegheny Teledyne Incorporated company, commissioned its International Hearth Melting (IHM) facility at Richland, WA. The IHM facility was expected to produce up to 10,000 tons per year of titanium ingot by using electron beam technology (Allegheny Teledyne Incorporated, March 30, 1999, annual report, accessed on May 22, 1999, at http://www.alleghenyteledyne.com/pages/investors/annual.html).

Tungsten[24]

In 1998, an estimated 30% of world tungsten supply was from recycled materials (International Tungsten Industry Association, 1997). Tungsten-bearing scrap originates during manufacture and/or after use in the following applications:

[22]Prepared by James F. Carlin, Jr. (703) 648-4985; Fax (703) 648-7757.

[23]Prepared by Joseph Gambogi (703) 648-7718; Fax (703) 648-7722.

[24]Prepared by Kim B. Shedd (703) 648-4974; Fax (703) 648-7757.

cemented carbides used for cutting and wear-resistant applications; mill products made from metal powder, such as filaments and electrodes for lamps and heavy metal alloys; and alloys, such as tool steels, high-speed steels, and superalloys. Depending on the type and quality of the scrap, it can be recycled by the industry sector that generated it or used as a source of tungsten by another consuming industry or as a substitute for tungsten concentrate by tungsten processors (Smith, 1994, p. 4-14).

Cemented carbide scrap is recycled by several different processes. Some processes result in tungsten carbide powder combined with cobalt, which can be used to make new cemented carbide parts. In other processes, the cobalt is recovered separately, and the tungsten is converted to the intermediate product ammonium paratungstate from which tungsten carbide powder, chemicals, or metal powder can be produced. Tungsten metal scrap from the manufacture of mill products is used to make cast carbides, ferrotungsten, superalloys, and tool steel. It can also be processed chemically to produce ammonium paratungstate. Most heavy metal alloy manufacturing scrap is recycled as home scrap to a prealloyed powder, but it can also be chemically converted to ammonium paratungstate or used to produce tool steel (Kieffer, 1982, p. 102-107). Steel scrap and superalloy scrap are recycled by the steel and superalloys industries, respectively.

In 1998, scrap consumption reported by U.S. tungsten processors and consumers was 3,350 tons of contained tungsten, an increase of 14% compared with that of 1997. U.S. imports of tungsten waste and scrap decreased by 4% to 1,450 tons of contained tungsten valued at $10.0 million. Five countries supplied almost three-fourths of these imports—Russia, 19%; Germany and Japan, 17% each; the United Kingdom, 11%, and China, 7%. U.S. exports of tungsten waste and scrap increased by 57% to an estimated 794 tons of contained tungsten valued at $5.0 million. The leading destinations for these exports were Germany, 40%; Taiwan, 12%; and the United Kingdom, 10%.

Vanadium[25]

The principal use of vanadium is as an alloying element (Gupta and Krishnamurthy, 1992, p. 103-104). Very small quantities of vanadium, often less than 1%, are alloyed with other metals to produce various ferrous and nonferrous alloys. Owing to the small amount of vanadium involved, these alloys in general do not lend themselves to recycling for vanadium recovery. Vanadium is also used as a catalyst. Catalyst consumption has been estimated to account for less than 1% of the total U.S. vanadium consumption. Processing spent vanadium catalysts, however, accounts for the only significant source of refined secondary vanadium. Three plants located in Arkansas, Louisiana, and Texas accounted for most of the recycled vanadium catalyst. Any new scrap generated in either the production of alloys or catalysts is likely to be reused internally.

[25]Prepared by Robert G. Reese, Jr. (703) 648-4981; Fax (703) 648-7757.

Zinc[26]

In 1998, about 30% of world's zinc was produced from secondary materials—brass, diecasting scrap, flue dust, galvanizing residues, and zinc sheet. In the United States, more than one-fourth of the 1.6 million tons of zinc consumed by domestic industries is secondary zinc. More than three-quarters of the recycled zinc was derived from new scrap generated mainly in galvanizing and diecasting plants and brass mills. The remaining one-quarter was obtained from brass products, flue dust, old diecasts, and old rolled zinc articles from EAF. Recycled zinc was used by 11 primary and secondary smelters mainly for production of zinc metal, including alloys; an additional 12 plants produced zinc chemicals, mainly zinc oxide. IMCO Recycling Inc., Midwest Zinc Corp., and the Zinc Corporation of America are the largest users of secondary zinc (American Metal Market, 1998b).

Because of wide differences in the character and zinc content of scrap, the recycling processes of zinc-bearing scrap vary widely. Clean new scrap, mainly brass, rolled zinc clippings, and rejected diecastings, usually requires only remelting. In the case of mixed nonferrous shredded metal scrap, zinc is separated from other materials by the flotation method, hand, or magnetic separation. Most of the zinc recovered from EAF dust is recovered in rotary kilns by using the Waelz process. Because the most common use of zinc is for galvanizing, the latest research is aimed mainly at stripping zinc from galvanized steel scrap.

In 1998, trade in zinc scrap, measured in gross weight, was small—about 2% of total domestic zinc consumption. About 91% of imported zinc scrap was supplied by Canada, and the major destination of U.S. exports was Taiwan (69%). Prices for scrap varied according to quality, presence of other components, geographic location, and environmental difficulties in handling, transporting, or treating. The price for a ton of zinc metal contained in scrap was about three-fourths of the London Metal Exchange price for refined zinc metal.

Zirconium[27]

In 1998, zirconium scrap composed about one-third of the feedstock for ingot production. New scrap is generated during the melting, forging, rolling, casting, and fabrication of zirconium components. In addition, some old, or obsolete, scrap is recycled from dismantled process equipment, vessels, heat exchangers, etc. Although no data are available as to the percentage breakdown of sources of scrap, less than 2% of ingot production was estimated to have been derived from old scrap. Prior to melting, scrap must be analyzed, classified, and processed to remove impurities. Several companies have proprietary processes to accomplish this task. Scrap is initially melted without virgin metal by the two domestic ingot producers, Oremet-Wah Chang, Albany, OR, and Western Zirconium, a subsidiary of Westinghouse Electric Co., Ogden,

[26]Prepared by Jozef Plachy (703) 648-4982; Fax (703) 648-7757.

[27]Prepared by James B. Hedrick (703) 648-7725; Fax (703) 648-7722.

UT, by using vacuum-arc-reduction melting practices.

References Cited

Aluminum Association Inc., 1999, Aluminum can recycling rate comes in at 62.8 percent for 1998: Washington, DC, Aluminum Association Inc. press release, March 26, 1 p.
American Iron and Steel Institute, 1998, Annual report 1998: American Iron and Steel Institute, 122 p.
American Metal Market, 1998a, Exide closes lead smelter: American Metal Market, v. 106, no. 150, August 6, p. 6.
———1998b, U.S. Zinc buy makes Imco top zinc recycler: American Metal Market, v. 106, no. 142, July 27, p. 7.
Cunningham, L.D., 1985, Tantalum, *in* Mineral facts and problems: U.S. Bureau of Mines Bulletin 675, p. 811-822.
———1999a, Beryllium, *in* Mineral commodity summaries 1999: Washington, D.C., U.S. Geological Survey, p. 34-35.
———1999b, Tantalum, *in* Mineral commodity summaries 1999: Washington, D.C., U.S. Geological Survey, p. 172-173.
England, C.N., 1996, Recycling America's rechargeable batteries, *in* Organisation for Economic Co-operation and Development, Sources of Cadmium in the Environment—Proceedings of the OECD Cadmium Workshop, Saltsjöbaden, Sweden, October 16-20, 1995: Paris, Organization for Economic Co-operation and Development, p. 195-200.
EPRI, 1998, The changing world of industrial and recreation electric vehicles: National Conference on non-road electric vehicles, 1st, August 20-21, Lake Buena Vista, FL, Preprints, non-paginated.
Fineberg, Seth, 1996, Indium can't find bottom; growth in recycling: American Metal Market, v. 104, no. 201, October 16, p. 1.
Gupta, C.K., and Krishnamurthy, N., 1992, Extractive metallurgy of vanadium: New York, Elsevier Science Publishers B.V., 689 p.
Hoffman, J.E., and King, M.G., 1997, Selenium and selenium compounds: Kirk-Othmer encyclopedia of chemical technology, 4th Ed., v. 21, John Wiley & Sons, p. 686-719.
International Copper Study Group, 1999, Copper bulletin: Lisbon, Copper Bulletin, v. 6, no. 9, 47 p.
International Iron and Steel Institute, 1998, Steel statistical yearbook 1998: International Iron and Steel Institute, December, 257 p.
International Tungsten Industry Association, 1997, Tungsten: London, International Tungsten Industry Association, 33 p.
Johnson Mathey, 1999, Platinum 1999: Johnson Mathey, May, 52 p.
Jones, T.S., 1994, Manganese material flow patterns: U.S. Bureau of Mines Information Circular 9399, 57 p.
Kieffer, B.F., 1982, Recycling systems with particular reference to the zinc process, *in* Tungsten - 1982: International Tungsten Industry Association, San Francisco, CA, June 1-5, Proceedings, p. 102-114.
Kramer, D.A., 1988, Gallium and gallium arsenide—Supply, technology and uses: U.S. Bureau of Mines Information Circular 9208, 25 p.
———1998, Magnesium: U.S. Geological Survey Minerals Yearbook 1996, v. I, p. 537-545.
Lane, John, 1998, Recycling of superalloys for gas turbines, *in* Superalloys for gas turbines, Tampa, FL, June 15-17, 1998, Proceedings: Gorham, ME, Gorham Advanced Materials Inc., separately paginated.
Manousoff, Margaret, 1997, NiCd battery recycling growing industry in U.S.: American Metal Market, v. 105, no. 60, March 27, p. 7.
Marley, Michael, 1998a, Glitches slow pace of Metal Management's buying spree: American Metal Market, v. 106, no. 50, March 17, p. 1.
———1998b, Metal Management set to merge: American Metal Market, v. 106, no. 41, March 4, p. 6.
———1998c, Metal Mgmt. buy seen step toward Midwest strength: American Metal Market, v. 106, no. 158, August 18, p. 1, 16.
———1998d, More scrap buy-ups—Metal Management adds two acquisitions: American Metal Market, v. 106, no. 51, March 18, p. 1, 12.
Metal Bulletin, 1997, EU environmental ministers move to extend export ban: Metal Bulletin, no. 8239, December 22, p. 12.
———1998a, Metal Management buys Aerospace Metals: Metal Bulletin, no. 8247, January 26, p. 10.
———1998b, Universal Scrap spurns Metal Management takeover bid: Metal Bulletin, no. 8310, September 17, p. 12.
Papp, J.F., 1991, Chromium, nickel, and other alloying elements in U.S.-produced stainless and heat-resisting steel: U.S. Bureau of Mines Information Circular 9275, 41 p.
Petkof, Benjamin, 1985, Beryllium, *in* Mineral facts and problems: U.S. Bureau of Mines Bulletin 675, p. 75-82.
Platt's Metals Week, 1998, U.S. scrap metal consolidation slows on prices, Philip: Platt's Metals Week, v. 69, no. 37, September 14, p. 1, 7.
———1999, Platt's Metals Week annual metal averages for 1998: Platt's Metals Week, v. 70, no. 8, February 22, p. 4.
Powers, R.A., and MacArthur, D.M., 1999, 1998 Battery industry developments: Privately published by Robert A. Powers, [89] p.
Recycling Today, 1998, Potential scrap shortage no hindrance to steel industry: Recycling Today, v. 36, no. 1, January, p. 14.
Roggio, Armando, 1998, ELG boosts US holdings by buying Ireland units: American Metal Market, v. 106, no. 151, August 7, p. 1.
Roskill Information Services Ltd., 1990, The economics of mercury 1990: London, Roskill Information Services Ltd., 153 p.
Ryan's Notes, 1997, Metalico—A new factor in the Pb market: Ryan's Notes, v. 3, no. 50, December 15, p. 4.
———1998a, Lead in the hot seat: Ryan's Notes, v. 4, no. 49, December 7, p. 4.
———1998b, Quexco gets FTC nod with conditions: Ryan's Notes, v. 4, no. 36, September 7, p. 3.
Scrap, 1999, An electronics recycling challenge: Scrap, v. 56, no. 5, September-October, p. 126-127.
Silver Institute, 1999, World Silver Survey: Silver Institute, Washington, 84 p.
Smith, G.R., 1994, Materials flow of tungsten in the United States: U.S. Bureau of Mines Information Circular 9388, 23 p.
Tantalum-Niobium International Study Center, 1996: Tantalum—Niobium International Study Center, Quarterly Bulletin, no. 86, June, p. 1-11.
Watson, N.J., Andersen, R.W., and Holt, G., 1998, Battery recycling in the metals industry from Europe to the USA, *in* International Seminar on Battery Waste Management, 10th, Deerfield Beach, FL, October 26-28, 1998, Proceedings: Boca Raton, FL, Florida Educational Seminars Inc., unpaginated.
World Bureau of Metal Statistics, 1999, World metal statistics: London, World Bureau of Metal Statistics, v. 52, no. 7, 150 p.
Wulff, S.W., 1997, The coming metallics surplus—Heresy or inevitability?: Steel Times International, v. 21, no. 6, p. 10.

SOURCES OF INFORMATION

U.S. Geological Survey Publications

Mineral Commodity Summaries, annual.[28]
Mineral Industry Surveys, monthly and annual.[28]
Minerals Yearbook, annual.[28]
United States mineral resources, U.S. Geological Survey Professional Paper 820, 1973.

Other

ABMS Non-Ferrous Metal Data.
Aluminum Association Inc. Aluminum Statistical Review, annual.
American Metal Market, daily.
Battery Council International, special reports.
Brass and Bronze Ingotmakers Association.
Copper and Brass Fabricators Council, Inc.
CRU. Aluminum Metal Monitor (monthly).
Institute of Scrap Recycling Industries.
Lead and Zinc Statistics (monthly bulletin of the International Lead and Zinc Study Group).
Metal Bulletin (London).
Mineral facts and problems, U.S. Bureau of Mines Bulletin 675, 1985.
Platt's Metals Week.
Resource Recycling.
Roskill Information Services Ltd. Zinc 1997, 6th Ed.
U.S. Department of Commerce News.

[28]Prior to January 1996, prepared by the U.S. Bureau of Mines.

TABLE 1
SALIENT U.S. RECYCLING STATISTICS FOR SELECTED METALS 1/

	Quantity of metal (metric tons)					Value of metal (thousands)			
Year	Recycled from new scrap 2/	Recycled from old scrap 3/	Recycled 4/	Apparent supply 5/	Percent recycled	Recycled from new scrap 2/	Recycled from old scrap 3/	Recycled 4/	Apparent supply 6/
Aluminum: 7/									
1994	1,580,000	1,500,000	3,090,000	8,460,000	36	$2,480,000	$2,360,000	$4,840,000	$13,300,000 r/
1995	1,680,000	1,510,000	3,190,000	7,980,000 r/	40	3,190,000	2,850,000	6,040,000	15,100,000 r/
1996	1,730,000	1,570,000 r/	3,310,000	8,340,000 r/	40	2,730,000	2,480,000	5,200,000	13,100,000 r/
1997	2,020,000 r/	1,530,000	3,550,000 r/	8,740,000 r/	41 r/	3,430,000 r/	2,590,000	6,020,000 r/	14,800,000 r/
1998	1,950,000	1,500,000	3,440,000	9,040,000	38	2,810,000	2,160,000	4,970,000	13,100,000
Chromium: 8/									
1994	NA	NA	99,000	390,000	25.4	NA	NA	63,100	249,000
1995	NA	NA	112,000	566,000	19.8	NA	NA	136,000	687,000
1996	NA	NA	98,400	480,000	20.5	NA	NA	96,000	456,000
1997	NA	NA	120,000	488,000	24.7	NA	NA	123,000	497,000
1998	NA	NA	105,000	331,000	19.8	NA	NA	94,400	478,000
Copper: 9/									
1994	827,000	500,000	1,330,000	3,510,000	37.8 r/	2,030,000	1,230,000	3,250,000	8,600,000 r/
1995	874,000	442,000	1,320,000	3,410,000	38.6	2,670,000	1,350,000	4,020,000	10,400,000
1996	891,000	428,000	1,320,000 r/	3,720,000	35.4 r/	2,140,000	1,030,000	3,170,000 r/	8,950,000
1997	953,000 r/	496,000	1,450,000	3,900,000	37.2	2,250,000	1,170,000	3,420,000	9,200,000
1998	942,000	466,000	1,410,000	3,950,000	35.6	1,630,000	808,000	2,440,000	6,850,000
Iron and steel: 10/									
1994	NA	NA	70,000,000	122,000,000	57	NA	NA	8,880,000	15,500,000
1995	NA	NA	72,000,000	114,000,000	63	NA	NA	9,720,000	15,400,000
1996	NA	NA	71,000,000	121,000,000	59	NA	NA	9,270,000	15,800,000
1997	NA	NA	73,000,000	127,000,000	58 r/	NA	NA	9,520,000	16,500,000 r/
1998	NA	NA	73,000,000	133,000,000	55	NA	NA	7,910,000	17,300,000
Lead: 11/									
1994 r/	45,900	868,000	914,000	1,530,000	59.7	37,600	711,000	749,000	1,250,000
1995 r/	49,600	954,000	1,000,000	1,630,000	61.7	46,200	890,000	935,000	1,520,000
1996	37,500	1,020,000 r/	1,050,000 r/	1,660,000	63.7 r/	40,400	1,090,000 r/	1,140,000	1,790,000
1997	54,000	1,030,000 r/	1,090,000	1,660,000	65.4 r/	55,400	1,060,000 r/	1,120,000	1,700,000
1998	45,800	1,050,000	1,100,000	1,740,000	63.1	45,700	1,050,000	1,100,000	1,740,000
Magnesium: 12/									
1994	32,500	29,600	62,100	182,000	34	103,000	94,000	197,000	578,000
1995	35,400	29,800	65,100	206,000	32	150,000	126,000	276,000	872,000
1996	41,100	30,100	71,200	205,000	35	159,000	125,000	283,000	872,000
1997	47,000 r/	30,500	77,600 r/	221,000 r/	35 r/	171,000 r/	111,000	282,000 r/	804,000 r/
1998	44,600	31,800	76,400	230,000	33	155,000	111,000	266,000	801,000
Nickel: 13/									
1994	NA	NA	58,600	164,000	35.7 r/	NA	NA	371,000	1,040,000
1995	NA	NA	64,500	181,000	35.7 r/	NA	NA	531,000	1,490,000
1996	NA	NA	59,300	181,000	32.9 r/	NA	NA	445,000	1,350,000
1997	NA	NA	68,400 r/	191,000 r/	35.8 r/	NA	NA	474,000 r/	1,320,000 r/
1998	NA	NA	63,300	186,000	34	NA	NA	293,000	863,000
Tin: 14/									
1994	4,290	7,380	11,700	41,900	28	34,800	59,900	94,800	340,000
1995	3,880	7,720	11,600	43,300	27	35,800	70,800	107,000	397,000
1996	3,930	7,710	11,600	37,400	31	35,600	69,900	106,000	339,000
1997	4,540 r/	7,830	12,400	48,600 r/	25	38,200 r/	65,600	104,000	409,000 r/
1998 15/	8,440	7,710	16,100	54,600	30	69,400	63,400	133,000	449,000
Titanium: 16/									
1994	NA	NA	15,700	W	48	NA	NA	26,800 e/	NA
1995	NA	NA	20,500	W	49	NA	NA	41,800 e/	NA
1996	NA	NA	26,300	W	48	NA	NA	50,700 e/	NA
1997	NA	NA	28,200 r/	W	46 r/	NA	NA	37,600 e/	NA
1998	NA	NA	28,600	W	50	NA	NA	22,100 e/	NA
Zinc: 17/									
1994	245,000	116,000	361,000	1,400,000	25.9	208,000	126,000	335,000	1,510,000
1995	242,000	111,000	353,000	1,460,000	24.2	298,000	137,000	435,000	1,800,000
1996	266,000	113,000	379,000	1,450,000	26.1	274,000	114,000	388,000	1,640,000
1997	286,000	89,700 r/	376,000 r/	1,490,000 r/	25.2 r/	376,000	118,000 r/	495,000 r/	1,960,000 r/
1998	344,000	82,400	427,000	1,580,000	27.0	352,000	84,400	437,000	1,620,000

See footnotes at end of table.

TABLE 1-Continued
SALIENT U.S. RECYCLING STATISTICS FOR SELECTED METALS 1/

e/ Estimated. r/ Revised. NA Not available. W Withheld to avoid disclosing company proprietary data.
1/ Data are rounded to not more than three significant digits; may not add to totals shown.
2/ Scrap that results from the manufacturing process, including metal and alloy production. New scrap of aluminum, copper, lead, tin, and zinc excludes home scrap. Home scrap is scrap generated in the metal producing plant.
3/ Scrap that results from consumer products.
4/ Metal recovered from new plus old scrap.
5/ Apparent consumption is production plus net imports plus stock changes. Production is primary production plus recycled metal. Net imports are imports minus exports. Apparent supply is calculated on a contained weight basis.
6/ Same as apparent supply defined in footnote 5 above but calculated on a monetary value basis.
7/ Scrap quantity is the calculated metallic recovery from reported purchased new and old aluminum-base scrap, estimated for full industry coverage. Monetary value is estimated based on average U.S. market price for primary aluminum metal ingot.
8/ Chromium scrap includes estimated chromium content of stainless steel scrap receipts where chromium content was estimated to be 17% (reported by the iron and steel and pig iron industries.) Trade includes reported or estimated chromium content of chromite ore, ferrochromium, chromium metal and scrap, and a variety of chromium-containing chemicals. Stocks include estimated chromium content of reported and estimated producer, consumer, and Government stocks. Value calculated from quantity by using the average annual value of high-carbon ferrochromium, in dollars per metric ton of contained chromium as follows; 1994--638; 1995--1,216; 1996--976; 1997--1,020; 1998--901.
9/ Includes copper recovered from unalloyed and alloyed copper-base scrap, as refined copper or in alloy forms, as well as copper recovered from aluminum-, nickel- and zinc-base scrap. Monetary value based on annual average refined copper prices.
10/ Iron production measured as shipments of iron and steel products plus castings corrected for imported ingots and blooms. Secondary production measured as reported consumption. Apparent supply includes production of raw steel. Monetary value based on U.S. annual average composite price for No. 1 heavy melting steel calculated from prices published in American Metal Market.
11/ Lead processors are segregated by primary and secondary producers. This segregation permits inclusion of stocks changes for secondary producers. Monetary value of scrap and apparent supply estimated upon average quoted price of common lead.
12/ Includes magnesium content of aluminum-base scrap. Monetary value based on the annual average Platt's Metals Week's U.S. spot Western price.
13/ Nickel scrap includes reported reclaimed nickel; estimated nickel content of reported alloy and stainless steel scrap receipts; reported nickel content of recovered copper-base scrap; reported nickel content of obsolete and prompt purchased nickel scrap (except stainless and alloy steel scrap); and estimated nickel content of various types of reported new and old aluminum scrap. Trade includes estimated nickel content of nickel cathode, pellets, briquettes, powder, and flake, ferronickel, metallurgical grade nickel oxide, a variety of nickel containing chemicals, nickel waste and scrap, and stainless steel scrap. Stocks include reported and estimated nickel content of scrap stocks (except copper); reported nickel content in stocks of nickel cathode, powder, oxide, and chemicals; reported nickel content in consumer stocks of various nickel materials; and reported Government nickel stocks. Monetary value based on annual average London Metals Exchange cash price nickel cathode.
14/ Monetary value based on Platt's Metals Week Composite price for tin.
15/ 1998 new scrap data includes data unavailable for 1994 to 1997.
16/ Percentage recycled based on titanium scrap consumed divided by primary sponge and scrap consumption.
17/ Monetary value based on annual average Platt's Metal Week metal price for North American special high-grade zinc.