RECYCLING—METALS

By Staff

Introduction[1]

Recycling, a significant factor in the supply of many of the key metals used in our society, provides environmental benefits in terms of energy savings, reduced volumes of waste, and reduced emissions associated with energy savings. The reusable nature of metals contributes to the sustainability of their use. Table 1 shows salient U.S. apparent supply and recycling statistics for selected metals. The value of the 80 million metric tons of domestically recycled metals reported for 1997 in table 1 was about $22 billion.

The U.S. Geological Survey (USGS) provides information and analysis on 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 hardcopy publications as well as the Internet and MINES FaxBack automated retrieval system. This Mineral Industry Surveys Annual Review summarizes metal recycling. Separate annual reviews are published for each of the metals summarized in this report. Those separate reviews contain more detailed information about individual metals and the recycling of the metals.

The primary sources of minerals and metals are ore deposits. The secondary sources of metals and other materials are recycled materials. Recycling practices, and the description of those practices, differ substantially among the metal industries covered in this chapter. Generally, scrap is categorized as new or old, where new indicates preconsumer sources and old 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 shapes—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 are an example of old consumer scrap; used jet engine blades and vanes are also an example of old industrial scrap. A wide variety of descriptive terms including home scrap, mill scrap, purchased scrap, prompt scrap, etc. have evolved in response to the wide variety of industry practices.

Aluminum[2]

Aluminum scrap, in one form or the other, is recovered by almost every segment of the domestic aluminum industry. Integrated primary aluminum companies, independent secondary smelters, fabricators, foundries, and chemical producers can recover aluminum from scrap. Integrated primary aluminum companies and independent secondary smelters, however, are the major consumers of 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 set up thousands of collection centers around the country for used aluminum beverage cans.

Used beverage can (UBC) scrap is the major component of processed old aluminum scrap, accounting for approximately one-half of the old scrap consumed in the United States. Most UBC scrap is recovered as aluminum sheet and is manufactured again as 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.

Aluminum scrap has become an important component of the supply and demand relationship in the United States. The aluminum recycling industry has grown dramatically over the last 30 years, increasing from a total metal recovery of 900,000 metric tons in 1970 to almost 3.7 million tons in 1997, according to data derived by the USGS from its "Aluminum Scrap" survey.

According to figures released by the Aluminum Association Inc., the Can Manufacturers Institute, and the Institute of Scrap Recycling Industries, 66.8 billion aluminum UBC's were recycled in the United States during 1997. The recycling rate, based on the number of cans shipped during the year, was 66.5%, an increase from the 63.5% recycling rate reported in 1996. According to the organizations joint press release, aluminum beverage cans produced domestically in 1997 had an average 54.7% postconsumer recycled content, the highest recycled content percentage of all packaging materials (Aluminum Association Inc., 1998).

Purchase prices for aluminum scrap, as quoted by American Metal Market (AMM), followed the general trend of primary ingot prices. Scrap prices closed the year at slightly higher levels than those at the beginning of the year. The yearend price ranges for selected types of aluminum scrap were as follows: mixed low-copper-content aluminum clips, 56 to 57 cents per pound; old sheet and cast, 49 to 50 cents per pound; and clean, dry aluminum turnings, 50 to 51 cents per pound.

Aluminum producers' buying price range for processed and delivered UBC's, as quoted by AMM, fluctuated during the year. The price range began the year at 53 to 54 cents per pound, reached a high of 59 to 61 cents per pound in April and in

[1]Prepared by John F. Papp.
[2]Prepared by Patricia A. Plunkert.

August, and closed the year at 55 to 56 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 1997 was 60.3 cents per pound, an increase from the 1996 annual average of 54.7 cents per pound.

The yearend indicator prices, as published in AMM, for selected secondary aluminum ingots also increased compared with those of 1996 and were as follows: alloy 380 (1% zinc content), 81.31 cents per pound; alloy 360 (0.6% copper content), 86.53 cents per pound; alloy 413 (0.6% copper content), 86.35 cents per pound; and alloy 319 (3.5% copper content), 84.71 cents per pound. Platt's Metals Week published an annual average U.S. price of 75.5 cents per pound for A-380 alloy (3% zinc content). The average annual London Metal Exchange (LME) cash price for a similar 380 alloy was 66 cents per pound.

Beryllium[3]

Beryllium is used in a wide number of applications where light weight and stiffness properties are important. The United States is one of only three countries that can process beryllium ore and concentrates into beryllium products, and it supplies 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 average about 75% of annual U.S. consumption on a beryllium-metal-equivalent basis. Beryllium metal composes about 10% of annual U.S. beryllium demand and is used principally in aerospace
and defense applications. Beryllium oxide composes about 15% of U.S. beryllium demand and serves 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. Substitutes such as graphite composites, phosphor bronze, steel, and titanium exist for certain beryllium applications, but with a substantial loss in performance.

In 1997, U.S. apparent consumption of beryllium totaled about 205 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, smaller quantities of obsolete military equipment containing beryllium were recycled.

Cadmium[4]

Recycled cadmium is derived either from old scrap or, to lesser degree, new 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 of cadmium are in low concentrations, therefore difficult to recycle. Consequently, much of this cadmium is dissipated.

Recycling of cadmium is a young and 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 nickel-cadmium batteries and because it is the easiest form to recycle, most recycled cadmium comes from spent Ni-Cd batteries.

Cadmium is recovered by a limited number of companies using pyrometallurgical or hydrometallurgical methods. The annual rate of secondary production in the United States amounts to about 500 tons. The largest recycling company, International Metals Reclamation Co. Inc. (Inmetco), is in Ellwood City, PA. Although the plant was established in 1978, cadmium recovery there began in 1996, using the High Temperature Metal Recovery (HTMR) process. Large batteries, usually weighting 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 furnace, where cadmium is reduced 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). The act requires uniform battery labeling by May 1998 and provides for streamlining of regulatory requirements governing battery collection and recycling. It is estimated that by 2005 roughly 70% of spent Ni-Cd batteries in the United States will be recycled.

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

Scrap is generated during the manufacturing process (new scrap) and as a result of recycling obsolete manufactured products (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. A study of the domestically produced stainless steel found that its average chromium content is about 17% (Papp, 1991).

[3]Prepared by Larry D. Cunningham.

[4]Prepared by Jozef Plachy.

[5]Prepared by John F. Papp.

Cobalt[6]

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

In 1997, scrap consumption reported by U.S. cobalt processors and consumers increased 26% to 2,530 tons of contained cobalt from a revised 2,000 tons in 1996. U.S. imports of cobalt waste and scrap decreased 21% to 448 tons, gross weight, valued at $7.9 million. Eight countries supplied 93% of these materials—the United Kingdom (26%), Germany (16%), Belgium (13%), Canada and the Netherlands (each 9%), South Africa (8%), France (7%), and Japan (5%). U.S. exports of cobalt waste and scrap are reported in combination with exports of unwrought cobalt metal and metal powders.

Copper and Copper Alloy Scrap[7]

According to data compiled by the International Copper Study Group, estimated world production of secondary refined copper in 1997 was 2.1 million tons, an increase of about 100,000 tons from 1996, but slightly below the record-high level in 1995. This secondary refined copper accounted for about 15% of total world production of refined copper (International Copper Study Group, 1998). According to data compiled by the World Bureau of Metal Statistics, an additional 3.3 million tons of copper was recovered from the direct remelting of copper scrap (World Bureau of Metal Statistics, 1998). Following 3 years of decline, secondary refined production in the United States increased by about 15%, or 50,000 tons, in 1997. 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 1997, higher prices during the first half of the year, coupled with forecasts of a future decline in prices, encouraged the recycling of stockpiled copper scrap.

In 1997, copper recovered from all refined or remelted scrap (about one-third from old scrap and two-thirds from new scrap) comprised 37% of the total U.S. copper supply and had an equivalent refined value of $3.4 billion. Copper recovered from old scrap increased by 16%, to 496,000 tons, the highest level since 1994. Purchased new scrap, derived from fabricating operations, yielded 956,000 tons of copper, a 7% increase from that of 1996. Consumption of new scrap has trended upward over the past 6 years, both in quantity and as a percentage of total scrap consumption, increasing by 40% since 1991. This large increase in new scrap consumption reflects the increased domestic consumption of mill products. About 85% of the copper recovered from new scrap in 1997 was consumed at brass mill and wire-rod mills. Copper recovery from new scrap at refineries, ingot makers, and other consumers of scrap, declined in 1997.

During the year, 7 primary and 4 secondary smelters, 8 electrolytic and 6 fire refineries, and 14 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. In September, Franklin Smelting and Refining Co. in Philadelphia, a relatively small secondary smelter with the capacity to produce about 15,000 tons per year of blister copper, closed as a result of the high cost of environmental compliance.

Copper was consumed, both as refined copper and as direct melt scrap, at about 35 brass mills, 15 wire rod mills, and 600 foundries, chemical plants, and other miscellaneous consumers. Of the total copper recovered from copper-, aluminum-, nickel-, and zinc-based scrap, brass mills recovered 55%; copper smelters and refiners, 27%; brass and bronze ingot makers, 9%; and miscellaneous manufacturers, foundries, and chemical plants, 9%. Unalloyed scrap accounted for 49% of copper-based scrap consumed.

Copper scrap prices trended upward during the first half of 1997, following the upward trend in refined copper. The U.S. producer price for refined copper averaged $1.16 per pound for the first half of the year. The New York average buying price for No. 1 scrap at brass mills, and for No. 2 scrap at refiners, averaged $1.08 and $0.90 per pound, respectively. In July, refined and scrap prices began a downward spiral in response to rising global copper inventories. The refined copper price averaged only $0.98 per pound during the second half of the year, and the No. 1 and No. 2 scrap prices, $0.91 and $0.74, respectively. The margin between refined copper and No. 2 scrap averaged $0.26 per pound during the first half of the year and narrowed with lower prices, averaging only $0.24 per pound during the second half of the year. In December, when the producer price averaged only $0.83, the margin shrank to $0.21 per pound.

The United States was one of the largest international sources for copper scrap, followed closely by Germany and Russia, whose exports of scrap rose substantially in 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 42% of the total. Canada and Mexico were the leading sources for U.S. imports of copper and copper alloy scrap and accounted for 81% of imports in 1996.

In 1989, the Basel Convention on the Control of Transboundary Movements of Hazardous Wastes and their Disposal came into force. It has since been ratified by more than 100 countries, including the United States, although the latter has not passed legislation necessary to implement its participation in the Convention. In 1997, the Convention's Technical Working Group completed recommendations for assigning materials to the A list, wastes characterized as hazardous, and the B list, wastes not inherently hazardous. Copper scrap, copper slags, and copper

[6] Prepared by Kim B. Shedd.

[7] Prepared by Daniel L. Edelstein.

oxide mill scale were placed in the B list, the list of materials not covered by the Basel Convention as hazardous and, thus, not subject to any export ban.

Gallium[8]

Substantial quantities of new scrap are generated during the processing of gallium into optoelectronic devices or integrated circuits. These wastes have varying gallium and impurity contents, depending upon the processing step from which they result. Gallium arsenide (GaAs)-based scrap, rather than metallic gallium, represents the bulk of the scrap that is recycled. 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. 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, the ingot is considered to be scrap. Also, some GaAs remains in the reactor after the ingot is produced and 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 occur at the seed end. These ends represent as much as 25% of the ingot weight. 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. The gallium content of these waste materials ranges 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.

In processing GaAs scrap, the material is crushed, if necessary, then dissolved in a hot acidic solution. This acidic 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.

Some GaAs manufacturers 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% gallium metal. Also, prices are dependent on the type and gallium content of the scrap.

[8]Prepared by Deborah A. Kramer.

Gold[9]

Old scrap generally contributes 13% to 18% of the total U.S. supply of gold. New scrap remains the property of the manufacturers, so 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 relatively crude gold jewelry, changes hands both locally and internationally from purchasers to goldsmiths and back again to purchasers. 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 in manufacturing operations, but because of tight controls over waste materials in precious metals plants, nearly all of this “home-generated” scrap can be recovered. Probably the greatest loss in gold fabrication occurs in gold plating plants where fouled or depleted solutions are sometimes discarded. Some old scrap, on the other hand, is lost because in practice gold cannot be economically recovered from all manufactured products.

Gold-bearing scrap is paid for on the basis of gold content, 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, there are no markets for gold scrap. 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 gold refiners to separate the constituents of scrap to assure meeting karat standards.

Refiners throughout the world recover secondary gold from scrap. In the United States, about two-thirds of the scrap comes from current manufacturing operations, and the remainder comes from old scrap in the form of items such as discarded jewelry and dental materials, used plating solutions, and junked electronic equipment. A few dozen companies, out of several thousand companies and artisans, dominate the fabrication of gold into commercial products. Most of the domestic scrap is processed by refiners centered in the New York, NY, and Providence, RI, areas, with concentrations also in 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. Other Federal Government agencies either participate in the DOD recovery program or have their own programs.

Data for domestic consumption of new and old scrap, collected by the USGS, are currently under review for future publication. In 1997, U.S. exports of gold scrap decreased, after 5 consecutive years of increase, while imports increased. As it has been for many years, the United States was a net exporter of gold scrap in 1997.

[9]Prepared by Earle B. Amey.

Prices for gold waste and scrap imported and exported in 1997 averaged $173 and $277 per troy ounce, respectively; the average price for refined gold was $332 per ounce.

Indium[10]

Domestic production of secondary indium decreased from the unusually high level of 1996, when high prices temporarily had 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 for such products as flat television screens. In 1997, as in most past years, most of the secondary indium was recovered from new scrap. The actual quantity of secondary indium produced in 1997 is not available, but it was small; only in 1996, for the first time, did the quantity become significant.

Iron and Steel Scrap[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 in buildings, bridges, highways, vehicles, machinery, tools, appliances, and containers. 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. About 65% of the steel produced in the United States is recycled. Every year, more steel is recycled than paper, aluminum, glass, and plastic combined.

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 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 from manufacturing plants that make steel products is the most important source of recycled iron. Because its chemical and physical characteristics are known, it is usually transported quickly back to steel plants for remelting to avoid storage and inventory control costs. Obsolete, old, or post-consumer scrap is also available for recycling. The largest source of obsolete scrap is junked automobiles, followed by demolished steel structures, worn-out railroad cars and tracks, appliances, and machinery. Obsolete scrap requires more preparation, such as sorting, detinning, and dezincing, because of its wide variety of chemical and physical characteristics.

The Steel Recycling Institute lists for public benefit more than 30,000 recycling collection locations where used steel products may be deposited. More than 3,000 dealers and as many as 30 brokers, ranging in size from large corporations to small family units, play an integral role in the steel industry by collecting and preparing scrap for transport to steel mills. Scrap dealers process scrap using a variety of equipment, such as large magnets, shredders, and balers 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. About 60% of all cans are recycled. Cans are crushed, using balers, into heavy cubes called bales that weigh as much as a ton. There are about 12,000 automobile dismantlers and 250 shredders in the United States. Scrap yards recycle nearly 100% of more than 8 million vehicles they receive each year. About 70% of a typical automobile is recoverable iron and steel. Scrap yards crush automobiles and shred them into fist-sized pieces, which are then passed by powerful magnets to segregate steel from plastics, aluminum, and other materials. Passenger car and light truck tires contain about 1 kilogram of high grade steel. Truck tires can contain as much as 9 kilograms of steel for recycling. Appliances, bicycles, and other steel products are also shredded for recycling. About 81% of appliances were recycled in 1997. By weight, the typical appliance is about 75% steel. 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 and chemical characteristics related 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, copper, lead-tin alloy, nickel, 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) and electric arc furnaces (EAF) and, to a minor extent, in blast furnaces. The proportion of scrap in the charge in a BOF is limited to less than 30%, whereas the charge in the EAF can be as much as 100% scrap. Steel and iron foundries use scrap in EAF's and cupola furnaces. In 1997, BOF's were used to produce 56% of total steel in the United States, while using only 22% of total scrap consumed. During the same period, EAF's produced 44% of total steel, while using 67% of total scrap consumed.

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 1.5 tons of iron ore, 0.6 tons of coal, and 54 kilograms of limestone. One pound of recycled steel represents the saving of enough energy to light a 60-watt light bulb for more than 26 hours.

Ferrous scrap is traded worldwide. Because scrap comes from such sources as old buildings, industrial machinery, discarded cars, consumer durables, and manufacturing operations, the mature industrialized economies are the main exporters of scrap. The United States continued to be the leading exporting country of iron and steel scrap in 1997. 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

[10]Prepared by Robert D. Brown, Jr..
[11]Prepared by Michael D. Fenton.

Korea, Spain, Belgium-Luxembourg, and the Netherlands. Other Asian importers were China, India, and Japan, which individually imported only about one-fourth of the quantity imported by the Republic of Korea.

The U.S. trade surplus for all classes of ferrous scrap was 6.1 million tons in 1997 (Bureau of the Census, unpub. data, 1997). Total U.S. exports of carbon steel and cast-iron scrap (excluding used rails for rerolling and other uses; ships, boats, and other vessels for scrapping; stainless steel; and alloy steel) went to 59 countries (2 fewer than in 1996) and totaled 7.62 million tons (a 2% increase) valued at $974 million (a 1% decrease) for an average of $127 per ton (Bureau of the Census, unpub. data, 1997). The largest tonnages went to the Republic of Korea, 3.07 million tons; Mexico, 1.36 million tons; Canada, 978,000 tons; Turkey, 555,000 tons; and Taiwan, 521,000 tons. These countries received 85% of the total quantity, valued at $801 million, which was 82% of the total value.

Total U.S. exports of stainless steel scrap went to 38 countries (4 fewer than in 1996) and consisted of 370,000 tons (a 22% increase) valued at $231 million (1% decrease) averaging $623 per ton (19% decrease) (Bureau of the Census, unpub. data, 1997). The largest tonnages went to the Republic of Korea, 114,000 tons; Spain, 59,600 tons; Taiwan, 49,300 tons; Mexico, 49,200 tons; and Canada, 40,000 tons. These countries received 84% of the total quantity, valued at $197 million, which was 85% of the total value.

U.S. exports of alloy steel scrap (excluding stainless steel) were shipped to 45 countries (2 more than in 1996) and consisted of 964,000 tons (a 43% increase) valued at $145 million (an 18% decrease) for an average of $150 per ton (an 18% decrease) (Bureau of the Census, unpub. data, 1997). The largest tonnages went to Canada, 477,000 tons (a 49% increase) and Mexico, 348,000 tons (a 29% increase). These countries received 86% of the total quantity, valued at $112 million, which was 77% of the total value.

Lead[12]

About 76% of the refined lead produced in the United States in 1997 was recovered from recycled scrap, 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, as well as the industrial-type used in applications such as uninterruptible power-supply equipment, load-leveling equipment for commercial electrical power systems, industrial forklifts, airline ground equipment, and mining vehicles. Slightly more than 10% of the recycled lead was recovered from other lead-based sources including solder, cable covering, building construction materials, and drosses and residues (new scrap) from primary smelter-refinery operations.

Recycled lead currently is produced by 25 companies operating 32 lead recovery plants. Of the total lead recycled in 1997, about 98% was produced by 10 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 either as soft lead or lead alloys to be reused in the manufacture of lead-acid storage batteries. Consumption of lead in storage batteries accounted for nearly 88% of the reported consumption of lead in the United States in 1997. During the period 1993-97, the United States exported an average of about 84,000 tons per year of lead-bearing scrap including battery as well as non-battery forms. Only minimal quantities of lead-bearing scrap were imported during this period. The spot price for smelter's heavy soft lead scrap averaged about $0.19 per pound during this period. The average North American Producer price for refined lead was about $0.41 per pound.

In late 1997, the supply of spent (scrap) lead-acid batteries for secondary smelters was tight. The shortage of spent batteries was attributed to the slower rate of failure of automotive batteries during nearly 2 years of relatively moderate temperatures in the more-heavily-populated regions of the United States. Counter to the short supply of spent batteries, stocks of refined secondary lead and replacement automotive batteries increased by 23% and 3%, respectively, in 1997. At yearend, the market price for whole scrap batteries averaged about $0.08 per pound, translating to a lead price of $0.16 per pound, assuming the average weight of lead in such batteries to be about 50%.

One U.S. company reported engineering design difficulties at its new secondary smelter, which had opened in mid-1995. The difficulties prevented the company from achieving the 90,000-ton-per-year production capacity for which the plant was designed. The company continued to evaluate the progress toward alleviating the problems and was expected to make a decision in 1998 on the status of the plant. The new facility replaced the company's 35-year-old smelter located nearby, which had produced about 20,000 tons of recycled lead per year (American Metal Market, 1997).

Magnesium[13]

Recycled magnesium is derived from two sources—aluminum- and magnesium-base scrap. Aluminum-base scrap consists of new and old scrap of aluminum-magnesium alloys. The primary component of this magnesium-bearing aluminum scrap is used 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; rather 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, gates, runners, drippings, turnings, and drosses 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 closely resembles aluminum chemically, there is usually a certain percentage of aluminum scrap mixed in with the magnesium scrap. The aluminum scrap is hand-sorted from the magnesium scrap, and the magnesium scrap then is sorted by

[12]Prepared by Gerald R. Smith.

[13]Prepared by Deborah A. Kramer.

alloy. Sorting is a critical step in producing a product of desired specifications.

In melting, sorted scrap is fed to a steel crucible and 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 a flux 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 either hand ladling, pumping, or tilt pouring.

In addition to melting, magnesium scrap can 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 these types of scrap 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-based scrap. In general, imports and exports of magnesium waste and scrap have been equivalent over the past 5 years. In 1996 and 1997, however, a sharp increase in exports of scrap to Canada has contributed to a level of exports that has been 2 to 2.5 times higher than the level of imports.

As more magnesium is used in automotive applications, North American firms plan to construct 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.

Manganese[14]

Scrap recovery specifically for manganese is insignificant. Manganese 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. Manganese is ubiquitous throughout the various grades of steel, which contain on average 0.7% manganese. Manganese that is recycled to steelmaking within steel scrap largely is lost because of its removal in the decarburization step of steelmaking, and then has to be added back. Manganese is recycled in the aluminum industry as a component of scrap of certain manganese-bearing aluminum alloys, principally used beverage cans, 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. Currently, 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.

[14]Prepared by Thomas S. Jones.

Mercury[15]

In response to Federal and State regulations, U.S. industry is reducing discharge or disposal of mercury-containing products. As a result, secondary mercury is recovered from a variety of source materials. Electronic devices including rectifiers, switches, thermostats, and relays; dental amalgams; batteries; and other instruments such as thermometers are processed to recover any contained mercury. However, the largest source of secondary mercury remains the spent catalysts used in the production of chlorine and caustic soda. Three companies, one each in Illinois, New York, 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]

Secondary molybdenum in the form of metal or superalloys was recovered in small quantities. About 1,000 tons of molybdenum was reclaimed from spent catalysts. Although some molybdenum was recycled as a minor constituent of scrap alloy steels and iron, the use of such scrap did not generally 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 85% of the 68,800 tons of nickel reclaimed in 1997. The 85% 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 small percentage came from the recycling of alloy steel scrap. Both old and new scrap are used by stainless steel producers, who are more concerned about the grade of the scrap and levels of critical impurities than about its origin. The five leading producers of austenitic stainless steel in the United States all 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. A facility at Ellwood City, PA, converts a variety of nickel and chromium wastes into a remelt alloy suitable for stainless steelmaking.

Copper-nickel alloy scrap and aluminum scrap accounted for about 9% of the nickel reclaimed in 1997. Scrap in this category comes from a myriad of sources and includes cupronickel (a series of copper alloys containing 2% to 45% nickel), the Monels (a group of alloys typically containing 65% nickel and 32% copper), nickel-silver (a misnomer for a series of copper-zinc-nickel alloys), 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.

[15]Prepared by Robert G. Reese, Jr.
[16]Prepared by John W. Blossom.
[17]Prepared by Peter H. Kuck.

Nickel-silver—a white brass—is used for rivets, screws, camera parts, and optical equipment.

The remaining 6% 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. However, because of the stringent specifications for superalloys, much of the superalloy and other nickel-base scrap is not suitable for direct recycling and is sold to stainless steel producers, steel foundries, or specialty alloy casting companies. Aircraft engine repair facilities are an important source of obsolete superalloy scrap. The U.S. collection and recycling program for nickel-cadmium and nickel-metal hydride batteries is in a period of rapid expansion. Federal legislation passed in 1996 helped spur the program. The program is administered by the Rechargeable Battery Recycling Corporation, a nonprofit public service corporation funded by manufacturers, importers, and distributors of batteries and battery-operated products.

Several scrap metal recyclers merged or acquired smaller processors of stainless steel, superalloys, and titanium during 1997 and early 1998. Many of the acquisitions took place in the Pittsburgh area and were designed to provide synergy for cost reduction. Significant consolidations of metal recycling companies also took place in Chicago, Hartford, Houston, and Los Angeles. The closure of smaller processing yards, the sharing of sales expertise, the integration of computer databases, and reduced management overhead helped lower operating costs. One-stop shopping for scrap consumers was expected to make U.S. scrap metals operations more competitive and efficient and make the industry better able to cope with large fluctuations in commodity prices.

Platinum-Group Metals[18]

The major industrial use of platinum-group metals (PGM) is for the catalytic converters used to decrease nitrogen oxides, carbon monoxide, and hydrocarbon emissions from automotive vehicle exhausts. PGM recycled from catalytic converters has grown into an important source of PGM supply. Most of the catalytic converters collected in the United States have been decanned and the catalyst shipped to Europe or Japan for processing. The United States exported about 13 tons of PGM scrap in 1997. However, after years of research by the U.S. Bureau of Mines and other research facilities, more of this material is being processed in the United States. A sampling facility for secondary materials was completed by the Stillwater Mining Co. in Columbus, MT, in late 1997. The facility was designed to accept spent catalyst that can be crushed and charged to an electric furnace. Several test lots were processed successfully. Stillwater expected to begin processing shipments of spent auto catalyst during 1998.

Spent auto catalysts account for most of the 14 to 15 tons of PGM recovered in the United States in 1997. Substantial quantities were recovered from spent petroleum refining catalysts and smaller amounts from chemical process catalysts.

[18]Prepared by Henry E. Hilliard.

Selenium[19]

Most selenium, except that used on the surfaces of the photoreceptor drums in plain paper copiers, is dissipated as process waste or is sent to a landfill as a minor constituent of a waste 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. Meanwhile, high processing costs have made it uneconomical to recover the metal from scrapped rectifiers.

Currently, no secondary selenium is recovered in the United States. Worn-out photoreceptor drums and scrap generated in the manufacture of new drums are exported for the recovery of the selenium content. An estimated 45 metric tons of secondary selenium was imported in 1997, or about 13% of all selenium imports. Practically all of the selenium used in photoreceptor drums is recovered through very efficient recycling programs. Secondary selenium is recovered in Canada, Japan, the Philippines, and several European countries. The photocopier market for selenium, still the main feed source for secondary selenium, is expected to continue 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 U.N. Environmental Program, which could restrict the international movement of certain scrap materials, such as selenium scrap. The shrinking market, together with low prices and surplus foreign secondary capacity, discourages the redevelopment of domestic secondary capacity.

Silver[20]

About 1,360 tons of silver, valued at $200 million, was recovered from scrap in 1997. Photographic scrap was estimated to have generated 1,000 tons of silver, the largest part coming from spent fixer solutions and from X-ray and graphic arts wastes, and a small quantity directly from color film negatives. The remainder was recovered from jewelers' sweepings, spent catalysts, electronic scrap, and other heterogeneous silver-bearing materials. U.S. industrial consumption of silver in 1997 was about 5,000 tons; mine production was 2,150 tons.

Tantalum[21]

In 1997, U.S. apparent consumption of tantalum totaled about 500 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 indirectly in the form of used tantalum-bearing cutting tools and high-temperature alloy melting scrap. In recent years,

[19]Prepared by Robert D. Brown, Jr.
[20]Prepared by Henry E. Hilliard.
[21]Prepared by Larry D. Cunningham.

the recycling of tantalum in tantalum capacitors from carefully collected and sorted electronic components has acquired considerable significance. Tantalum recovery from tantalum capacitor scrap requires special techniques owing to the different types of capacitor scrap. Tantalum can be recovered from certain capacitor scrap by electrolysis and acid leaching.

Tin[22]

About 25% of the domestic apparent supply of tin metal is recovered from scrap. In 1997, 12,000 metric tons of tin metal, valued at an estimated $100 million, was recovered from new and old tin scrap. Old tin scrap is collected at hundreds of domestic scrap yards, at seven detinning plants, and at 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 solder-making plants. Most tin scrap processing facilities are close to the tin-using industries and to densely populated areas. Most are in the Midwest and Northeast.

Detinning facilities are unique to the tin scrap industry in that no other major metal industry has large-scale facilities to remove plated metal. Detinning operations are performed on new tin-plate scrap from tin mills or canmaking plants and on old tin-plate scrap in the form of used (post-consumer) tin cans. Over the years, 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 over the past 15 years have become an important raw material for the Nation’s steel industry. SRI announced that the steel can recycling rate had grown from 15% in 1988 to 60% in 1997 (Container Recycling Report, 1997).

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

Titanium[23]

About 95% of titanium domestic consumption is in the form of titanium dioxide, which is employed as a pigment in paints, paper, plastics, etc., none of which is directly recycled. Most of the remaining 5% of domestic consumption is in the form of metal primarily used in aerospace applications. The extensive processing of titanium metal generates large quantities of scrap compared to most other metals.

Titanium scrap comprises about one-half of the feedstock for titanium ingot production. New scrap is generated during the melting, forging, rolling, casting, and fabrication of titanium components. In addition, some obsolete or old 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, it has been estimated that less than 2% of titanium ingot production is derived from old scrap.

Scrap is recycled with or without virgin metal by titanium ingot producers using vacuum-arc reduction or cold-hearth melting practices. Prior to melting, scrap must be analyzed, classified, and processed to remove impurities. Several companies have proprietary processes to accomplish this task.

Titanium scrap is consumed by the steel industry as scrap or it may first be converted to ferrotitanium. Titanium scrap is also used to produce aluminum-titanium master alloys for the aluminum industry. Titanium improves casting and reduces cracking in aluminum alloys.

Although consumption of titanium sponge increased by about 13% in 1997, consumption of titanium scrap was nearly unchanged. While producer receipts of home scrap rose slightly, receipts of purchased scrap decreased about 17%. Meanwhile, yearend prices for unprocessed scrap turnings fell 18% and yearend stocks decreased 4% compared with 1996 levels. The apparent fall in scrap utilization was driven in part by the availability of competitively priced imports of titanium sponge.

Tungsten[24]

An estimated 30% of world tungsten supply is from recycled materials. Tungsten-bearing scrap originates during manufacture and/or after use in the following applications: cemented carbides used for cutting and wear-resistant applications; powder metallurgy products, such as filaments and electrodes for lamps and various heavy metal alloy products; 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, used as a source of tungsten by another consuming industry, or used as a substitute for tungsten concentrate by tungsten processors.

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 chemicals, metal powder, or carbide powder can be produced. Tungsten metal scrap from the manufacture of mill products is used to make superalloys, tool steel, cast carbides, and ferrotungsten. 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 used to produce tool steel, or be chemically converted to ammonium paratungstate. Tungsten-bearing steel scrap and superalloy scrap are recycled by the steel and superalloy industries, respectively.

In 1997, scrap consumption reported by U.S. tungsten processors and consumers increased 10% to 2,930 tons of contained tungsten, from a revised 2,670 tons in 1996. U.S. imports of tungsten waste and scrap decreased 18% to 1,510 tons of contained tungsten, valued at $10.4 million. Nearly 70% of these imports were supplied by five countries (Japan, 23%;

[22]Prepared by James F. Carlin, Jr.
[23]Prepared by Joseph M. Gambogi.
[24]Prepared by Kim B. Shedd.

Germany, 19%; Russia, 11%; the United Kingdom, 9%; and Israel, 7%). U.S. exports of tungsten waste and scrap decreased 10% to an estimated 507 tons of contained tungsten, valued at $3.3 million. An estimated 63% of these exports was sent to Germany.

Vanadium[25]

The principal use of vanadium is as an alloying element. Very small quantities of vanadium, often less than 1%, are alloyed with other metals to produce various ferrous and nonferrous alloys. Owing to the relatively 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. It is estimated that catalyst consumption accounts for less than 1% of the total U.S. vanadium consumption. However, processing spent vanadium catalysts 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 reused internally.

Zinc[26]

About 30% of world's zinc is produced from secondary materials—from brass, galvanizing residues, diecasting scrap, zinc sheet, and flue dust. In the United States, about one-fourth of the 1.5 million tons of zinc consumed annually by domestic industries is secondary zinc. Nearly three-quarters of recycled zinc in 1997 was derived from new scrap, generated mainly in galvanizing and diecasting plants and brass mills. The remaining one-quarter was obtained from old diecasts, brass products, old rolled zinc articles, and flue dust. 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. The Zinc Corporation of America's plant in Monaca, PA, is by far the largest processor of secondary zinc.

Because of wide differences in the character and zinc content of scrap, the recycling processes for zinc-bearing scrap vary widely. Clean new scrap, mainly brass, rolled zinc clippings, and rejected diecastings, usually require only remelting. In the case of mixed nonferrous shredded metal scrap, zinc is separated from other materials either by hand, by magnetic separation, or by the flotation method. Most of the zinc recovered from flue dust is recovered 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.

Trade in zinc scrap, measured in gross weight, is relatively small. About 87% of imported zinc scrap in 1997 was supplied by Canada, while the major destination of U.S. exports was Taiwan (68%). Prices for scrap vary 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 is about three-fourths of the London Metal Exchange price for refined zinc metal.

Zirconium[27]

Zirconium scrap comprises about one-half of the feedstock for ingot production. New scrap is generated during the melting, forging, rolling, casting, and fabrication of zirconium components. In addition, some obsolete or old 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, it is estimated that less than 2% of ingot production is 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, Wah Chang, Albany, OR, and Western Zirconium, Ogden, UT, using vacuum-arc-reduction melting practices.

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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/									
1993	1,310,000	1,630,000	2,940,000	7,920,000	37	$1,540,000	$1,920,000	$3,460,000	$9,300,000
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
1995	1,680,000	1,510,000	3,190,000	8,010,000	40	3,190,000	2,850,000	6,040,000	15,200,000
1996	1,730,000 r/	1,580,000 r/	3,310,000 r/	8,330,000 r/	40 r/	2,730,000 r/	2,480,000 r/	5,200,000 r/	13,100,000
1997	2,160,000	1,530,000	3,690,000	8,880,000	42	3,670,000	2,590,000	6,260,000	15,100,000
Chromium: 8/									
1993	NA	NA	92,000	484,000	19.0	NA	NA	62,500	328,000
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 r/
1996	NA	NA	98,400	480,000	20.5	NA	NA	96,000 r/	456,000 r/
1997	NA	NA	120,000	488,000	24.7	NA	NA	123,000	497,000
Copper: 9/									
1993	748,000	543,000	1,290,000	3,260,000	39.6	1,510,000	1,100,000	2,610,000	6,590,000
1994	827,000	500,000	1,330,000	3,510,000	37.9	2,030,000	1,230,000	3,250,000	8,580,000
1995	874,000	443,000	1,320,000	3,410,000	38.6	2,670,000	1,350,000	4,020,000	10,400,000
1996	891,000 r/	428,000	1,300,000	3,720,000 r/	35.3 r/	2,140,000 r/	1,030,000	3,160,000 r/	8,950,000 r/
1997	956,000	496,000	1,450,000	3,900,000	37.2	2,250,000	1,170,000	3,420,000	9,200,000
Iron and steel: 10/									
1993	NA	NA	68,000,000	107,000,000 r/	63 r/	NA	NA	7,650,000 r/	12,000,000 r/
1994	NA	NA	70,000,000	122,000,000 r/	57 r/	NA	NA	8,880,000 r/	15,500,000 r/
1995	NA	NA	72,000,000	114,000,000 r/	63 r/	NA	NA	9,720,000 r/	15,400,000 r/
1996	NA	NA	71,000,000 r/	121,000,000 r/	59 r/	NA	NA	9,270,000 r/	15,800,000 r/
1997	NA	NA	73,000,000	127,000,000	57	NA	NA	9,520,000	16,600,000
Lead: 11/									
1993	55,000	838,000	893,000	1,380,000	64.7	38,500	587,000	625,000	966,000
1994	54,200	877,000	931,000	1,540,000	60.5	44,400	719,000	763,000	1,260,000
1995	46,400	926,000	972,000	1,580,000	61.5	43,300	863,000	906,000	1,470,000
1996 r/	37,500	1,030,000	1,060,000	1,660,000	63.9	40,400	1,110,000	1,140,000	1,790,000
1997	54,000	1,050,000	1,090,000	1,660,000	65.7	55,400	1,070,000	1,120,000	1,700,000
Magnesium: 12/									
1993	28,300	30,600	58,900	176,000	34	81,700	88,400	170,000	508,000
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 r/	30,100	71,200 r/	205,000	35	159,000 r/	125,000	283,000 r/	872,000 r/
1997	49,700	30,500	80,200	235,000	34	181,000	111,000	292,000	854,000
Nickel: 13/									
1993	NA	NA	54,000	158,000	34.1	NA	NA	286,000	839,000
1994	NA	NA	58,600	164,000	35.8	NA	NA	371,000	1,040,000
1995	NA	NA	64,500	181,000	35.6	NA	NA	531,000	1,490,000
1996	NA	NA	59,300 r/	181,000 r/	32.8 r/	NA	NA	445,000 r/	1,350,000 r/
1997	NA	NA	68,800	193,000	32.7	NA	NA	477,000	1,340,000
Tin: 14/									
1993	4,190	6,950	11,100	43,300	26	32,300	53,500	85,800	334,000
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 r/	3,930	7,710	11,600	37,400	31	35,600	69,900	106,000	339,000
1997	4,520	7,830	12,400	48,500	25	37,900	65,600	104,000	406,000
Titanium: 15/									
1993	NA	NA	15,300	W	50	NA	NA	14,300 e/	NA
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	26,400	W	45	NA	NA	41,900 e/	NA

See footnotes at end of table.

TABLE 1-Continued
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/
Zinc: 16/									
1993	246,000	109,000	355,000	1,370,000	26.0	250,000	111,000	361,000	1,400,000
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 r/	113,000 r/	379,000	1,450,000	26.1	274,000 r/	114,000 r/	388,000	1,640,000
1997	286,000	88,800	374,000	1,510,000	24.8	376,000	117,000	493,000	1,990,000

e/ Estimated. r/ Revised. NA Not available. W Withheld to avoid disclosing company proprietary data.

1/ Data are rounded to 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/ 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 above but calculated on a monetary value basis.

7/ Scrap quantity is the calculated metallic recovery from reported purchased new and old aluminum-based 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 at 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 produce, consumer, and goverment stocks. Value calculated from quantity using the average annual value of high-carbon ferrochromium as follows in dollars per metric ton of contained chromium: 1993--679; 1994--638; 1995--1,216; 1996--976; 1997--1,020.

9/ Includes copper recovered from unalloyed and alloyed copper-based scrap, as refined copper or in alloy forms, as well as copper recovered from aluminum-, nickel- and zinc-based 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: (1) reported reclaimed nickel; (2) estimated nickel content of reported alloy and stainless steel scrap receipts; (3) reported nickel content of recovered copper-based scrap; (4) reported nickel content of obsolete and prompt purchased nickel scrap (except stainless and alloy steel scrap); and (5) 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: (1) reported and estimated nickel content of scrap stocks (except copper); (2) reported nickel content in stocks of nickel cathode, powder, oxide, and chemcials; (3) reported nickel content in consumer stocks of various nickel materials; (4) and reported government nickel stocks. Monetary value based on annual average LME cash price of nickel cathode.

14/ Monetary value based on Platt's Metals Week Composite price for tin.

15/ Percent recycled based on titanium scrap consumed divided by primary sponge and scrap consumption.

16/ Monetary value based on annual average Platt's Metal Week metal price for North American special high grade zinc.