RECYCLING—METALS

By Staff, Minerals Information Team

Introduction[1]

Materials consumed by society include reusable resources, such as metals. The supply of metals is ultimately fixed by nature, but human ingenuity plays a role in determining quantity of supply by developing economic processes for the recovery of primary metal (i.e., from the earth) and secondary metal (i.e., from the use process stream). The reusable nature of metals contributes to the sustainability of their use.

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. These reductions, in turn, result in reduced disturbance of land, reduced pollution, and reduced energy use. Table 1 shows salient U.S. apparent supply and recycling statistics for selected metals. The value of the 78 million metric tons of domestically recycled metals reported for 1996 in table 1 was about $18 billion.

The U.S. Geological Survey (USGS) provides information and analysis on more than 100 raw and/or processed minerals. Collected data are assessed by commodity specialists, and information is disseminated to government, industry, academia, and the general public through more than 100 periodical publications.

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 both the commodity and recycling of the commodity.

As noted above, the primary source of minerals and metals is mining. The secondary source of metals and other materials is 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 cutting, 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 parts. Similarly, when parts are assembled into products, new scrap is generated. Once a product completes its useful life, it becomes old scrap. Used beverage cans 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 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, and independent secondary smelters, fabricators, foundries, and chemical producers 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. In the United States, there is 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 beverage can recycling programs and have set up literally thousands of collection centers around the country for used aluminum beverage cans.

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

Metal recovered from scrap has become an important component of aluminum supply in the United States. The aluminum recycling industry has grown dramatically over the last 25 years, increasing from a total metal recovery of 900,000 metric tons in 1970 to almost 3.3 million tons in 1996, 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 Inc., 62.8 billion aluminum beverage cans were recycled in the United States during 1996. The recycling rate, based on the number of cans shipped during the year, was 63.5%, a slight increase from the 62.2% recycling rate reported

[1]Prepared by John F. Papp.

[2]Prepared by Patricia A. Plunkert.

in 1995. According to the organizations' joint press release, aluminum beverage cans produced domestically in 1996 had an average 51.6% postconsumer recycled content, the highest recycled content percentage of all packaging materials (Aluminum Association, 1997).

Purchase prices for aluminum scrap, as quoted by American Metal Market (AMM), followed the trend of primary ingot prices and closed the year at slightly lower 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, 52 to 52.5 cents per pound; old sheet and cast, 47 to 49 cents per pound; and clean, dry aluminum turnings, 48 to 48.5 cents per pound.

Aluminum producers' buying price range for processed and delivered UBC's, as quoted by AMM, fluctuated during the year from a high of 58 to 60 cents per pound at the beginning of the year and during the months of April and May to a low of 47 to 48 cents per pound during June and July. At yearend, the price ranged from 53 to 54 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 1996 was 54.7 cents per pound, a substantial decrease from the 1995 annual average of 66.7 cents per pound.

The yearend indicator prices, as published by AMM, for selected secondary aluminum ingots also decreased compared with those of 1995 and were as follows: alloy 380 (1% zinc content), 79.37 cents per pound; alloy 360 (0.6% copper content), 84.44 cents per pound; alloy 413 (0.6% copper content), 84.66 cents per pound; and alloy 319, 81.50 cents per pound. Platt's Metals Week published an annual average U.S. price of 67.3 cents per pound for A-380 alloy (3% zinc content). The average annual London Metal Exchange cash price for a similar 380 alloy was 59 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 averages about 10% of annual U.S. beryllium demand and is used principally in aerospace and defense applications. Beryllium oxide averages about 15% of U.S. beryllium demand and serves as a substrate for high-density electronic circuits. Because of its high cost compared to those of other materials, beryllium is used in 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 1996, U.S. apparent consumption of beryllium totaled about 204 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 is returned to the metal-alloy producers for recycling. The beryllium in beryllium-copper fabricated parts is so widely dispersed in products, and so highly diluted when those products are recycled, that it is essentially dissipated. Additionally, smaller quantities of obsolete military equipment containing beryllium were recycled.

Cadmium[4]

Cadmium recycling has been practical only for nickel-cadmium batteries, some alloys, and dust generated during steelmaking in electric arc furnaces (old scrap) and waste from manufacturing processes (new scrap). In other applications cadmium is used at low concentrations and is almost impossible to recycle; consequently, much of this cadmium is dissipated into the environment.

Cadmium from spent industrial nickel-cadmium batteries and cadmium alloys 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, located in Pennsylvania, is using a pyrometallurgical method. There, the larger batteries, usually weighing more than 2 kilograms and containing an average of 15% cadmium, are emptied of their electrolyte, and dismantled mechanically; the remaining cadmium and nickel plates are separated. Detached cadmium plates then go directly into an electric distillation furnace. The plastic castings and separators of the smaller sealed batteries are burned off at a lower temperature before being fed into the furnace. The resulting 99.95% pure cadmium is shipped to battery manufacturers for reuse.

Future collection and recycling of batteries may be spurred by signing into law of The Mercury-Containing and Rechargeable Battery Act of 1996 (Public Law 104-142). The act establishes uniform labeling requirements by May 1998 and provides for streamlining of regulatory requirements governing battery collection and recycling. It is estimated that by the year 2005 roughly 70% of spent nickel-cadmium 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

[3]Prepared by Larry Cunningham.

[4]Prepared by Peter H. Kuck.

[5]Prepared by John F. Papp.

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).

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 1996, scrap consumption reported by U.S. cobalt processors and consumers increased 8% to 1,670 tons of contained cobalt. U.S. imports of cobalt waste and scrap decreased 36% to 566 tons of contained cobalt, valued at $11.7million. Eight countries supplied 93% of these materials: the United Kingdom (21%), Japan (13%), Germany (12%), South Africa (11%), Canada and Finland (each 10%), Brazil (9%), and Russia (7%). 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]

Estimated world production of secondary refined copper in 1996 of 2 million tons, a decline of about 100,000 tons from the record-high level in 1995, accounted for about 16% of total world production of refined copper. According to data compiled by the World Bureau of Metal Statistics, an additional 3 million tons of copper were recovered from the direct remelting of copper scrap (World Metal Statistics, 1997). Secondary refined production in the United States declined for the third consecutive year. 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 1996, copper recovered from all old and new refined or remelted scrap comprised 35% of total U.S. copper supply and had an equivalent refined value of $3.1 billion. Conversion of old scrap to alloys and refined copper declined for the fourth consecutive year, falling by 15,000 tons, but contributed 428,000 tons of copper to the market, a quantity equivalent to about 15% of U.S. apparent consumption.

Purchased new scrap, derived from fabricating operations, yielded 872,000 tons of copper, an amount essentially unchanged from that of 1995, and accounted for 67% of copper recovered from all scrap. Consumption of new scrap had trended upward over the preceding 4 years, in both absolute terms and as a percentage of total scrap recovery, increasing by almost 200,000 tons, or 28%, since 1991. This large increase in new scrap consumption reflects the increased domestic consumption of mill products. About 79% of the copper contained in new scrap was consumed at brass mills and wire rod mills.

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 other refineries that mainly processed primary anode purchased or tolled some secondary anode. All of the fire refineries processed copper scrap.

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 miscellaneous manufacturers. Of the total copper recovered from copper-, aluminum-, nickel-, and zinc-based scrap, copper smelters and refiners recovered 26%; brass mills, 55%; brass and bronze ingot makers, 10%; and miscellaneous manufacturers, foundries, and chemical plants, 9%. Unalloyed scrap accounted for 49% of copper-based scrap consumed.

Copper scrap prices trended downward in 1996, following the decline in refined copper prices. However, while the average producer price for refined copper declined by about 29 cents per pound from that of 1995, the refiners buying price for No. 2 scrap declined by only about 20 cents per pound. Thus, the average margin between refined copper and No. 2 scrap declined from 34 cents per pound in 1995 to 25 cents per pound in 1996. In September, the discount averaged only 21 cents per pound. Historically, because of the inherent costs associated with the initial collection and processing of scrap, low refined copper prices squeeze processing and profit margins and reduce the quantity of scrap that can be recovered economically.

The United States was one of the largest international sources for copper scrap, followed by France, Germany, and the United Kingdom. Canada retained its position as the largest recipient of U.S. scrap exports, accounting for 37% of the total.

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[6]Prepared by Kim B. Shedd.

[7]Prepared by Daniel L. Edelstein.

Canada and Mexico were the leading sources for U.S. imports of copper and copper alloy scrap and accounted for 78% of imports in 1996.

Gallium[8]

Virtually all of the gallium used domestically goes into optoelectronic devices and integrated circuits, about 95% of it in the form of gallium arsenide.

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)-based 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, the ingot is considered to be scrap. Also, there is some GaAs that remains in the reactor after the ingot is produced, and this may be recycled. During the epitaxial growth process, various wastes are produced, depending on the growth method used. 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 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. 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 may vary from less than 1% to as much as 99.99%. Liquid-phase epitaxy wastes normally have the highest gallium content, varying between 98% and 99.99%. Ingot ends and wafers broken during processing generally contain from 39% to 48% gallium, vapor-phase epitaxy exhaust gases contain from 6% to 15% gallium, saw kerf contains up to 30% gallium (wet basis), and lapping compound wastes contain less than 1% gallium. These wastes are contaminated with small quantities of many metallic impurities. 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 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% 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. Because this closed loop occasionally crosses international boundaries, it is difficult to distinguish between gallium recovered from scrap and virgin gallium when evaluating the gallium supply of an individual country.

Gold[9]

Old scrap is gold-containing products that have been discarded after use, and generally contributes 5% to 10% of the total U.S. supply of gold. New scrap is gold scrap generated during the manufacturing process, and for the most part 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 recycled gold. 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.

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[8]Prepared by Deborah A. Kramer.

[9]Prepared by Earle B. Amey.

Refiners throughout the world recover secondary gold from scrap. In the United States, about two-thirds of the scrap comes from the 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, junked electronic equipment which includes computers, etc. Most of the domestic scrap is processed by approximately two dozen refiners located in the Northeastern States, although the current trend seems to be toward a less centralized industry. The number of domestic fabricators approaches 3,000. 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 one of their own.

Data for domestic consumption of new and old scrap, collected by the USGS, are currently under review for future publication. The United States has for many years been a net exporter of gold scrap. In 1996, the United States continued for the fifth straight year to increase its exports while decreasing its role as a scrap importer.

Prices for gold waste and scrap imported and exported in 1996 averaged $244 and $295 per troy ounce, respectively; at the same time, the average price for gold was $389 per ounce.

Indium[10]

Recycling of indium became significant for the first time in 1996 and was said by industry sources to have affected the market and prices. The increase in recycling was a result of the rapid increase in indium prices in 1995. The addition of secondary metal to the supply brought the domestic indium price down in 1996, from $16.25 per troy ounce at the beginning of the year to $6.53 per ounce at yearend. Nearly one-half of the indium consumed domestically goes into indium-tin-oxide thin-film coatings used for liquid crystal displays in such products as flat television screens. A sputtering process is used in manufacturing the thin-films; most of the augmented secondary indium production was derived from used sputtering targets and scrap from their manufacture. Old scrap was available for recycling only in very small quantities. An estimate of the amount of refined indium produced through recycling is not available.

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 vehicles, buildings, bridges, highways, 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 ferrous scrap generated in steel mills and steel-product manufacturing plants.

A vast quantity of ferrous scrap available for recycling is comprised of home, prompt, and obsolete scrap. Home or mill scrap is generated within the steel mill during production of iron and steel. Trimmings of 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 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 space 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, wornout railroad cars and tracks, appliances, and machinery. Obsolete scrap requires more processing for steel mill buyers by scrap collectors, such as sorting, de-tinning, and de-zincing, because of the wide variety of chemical and physical characteristics.

About 5,000 establishments, ranging in size from large corporations to small family dealers, play an integral role in the steel industry by collecting and preparing scrap for transport to steel mills needing raw materials. Scrap dealers process scrap, using a variety of equipment, into a physical form and chemical composition that steel mill furnaces can consume. Dealers specializing in the processing steel cans receive loads of these from smaller dealers or have partnership arrangements with neighborhood waste removers. Cans are crushed, using balers, into heavy 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 1996. More than 200 scrapyards crushed automobiles and shredded them into fist-sized pieces, which were then passed over by powerful magnets to segregate steel from plastics, aluminum, and other materials. Appliances, bicycles, and other steel products are also shredded for recycling. More than 1,500 scrapyards process steel from construction and demolition sites by shearing, shredding, and baling.

Manufactured steel products have a wide range of physical 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, 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 differ according to the product being produced.

Steel mills melt scrap in basic-oxygen furnaces (BOF) and

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

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 1996, BOF's were used to produce 57% of total steel in the United States, while using only 22% of total scrap consumed. During the same period, EAF's produced 43% of total steel, while using 64% 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 2,500 pounds of iron ore, 1,400 pounds of coal, and 120 pounds of limestone. One pound of recycled steel saves enough energy to light a 60-watt 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 main trade flows of scrap are from 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 1996. 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. 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 5.6 million tons in 1996 (Bureau of the Census, unpub. data, 1996). Total U.S. exports of carbon steel and cast-iron scrap went to 61 countries in 1996 and totaled 7.46 million tons. The largest tonnages, in declining order of size, went to the Republic of Korea, Canada, Mexico, Turkey, Malaysia, and India. Total U.S. exports of stainless steel scrap went to 42 countries and consisted of 303,000 tons. The largest tonnages, in declining order of size, went to the Republic of Korea, Spain, Canada, Taiwan, and Japan. U.S. exports of alloy steel scrap (excluding stainless steel) in 1996 were shipped to 43 countries and consisted of 674,000 tons. The largest tonnages went to Canada and Mexico.

Lead[12]

About 75% of the refined and alloyed lead produced in the United States in 1996 was recovered from recycled scrap, of which the 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. Less 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 31 secondary lead smelter-refinery plants. More than 95% of the recycled lead is produced by 18 companies. Most of the recycled lead is recovered either as soft lead or lead alloys to be reused in the manufacture of lead-acid storage batteries. Storage batteries accounted for nearly 88% of the reported consumption of lead in the United States in 1996.

During the period 1992-96, the United States exported an average of about 80,000 tons per year of lead-bearing scrap including battery as well as nonbattery forms. Only minimal quantities of lead-bearing scrap were imported during this period. The spot price for smelter's scrap lead averaged about 16 cents per pound during this period. The average North American Producer price for refined lead was about 39 cents per pound.

The completed expansion of one secondary lead smelter in 1996 effectively increased production capacity by 11,000 tons. Two new smelters were in either the construction or planning stage during the year, and upon completion were expected to add another 64,000 tons of smelter capacity by the end of 1998.

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 aluminum-base scrap, from which magnesium is recovered, 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. Magnesium scrap normally is received loose on trailers. Because magnesium resembles aluminum closely, there is usually a certain percentage of aluminum scrap mixed in the with magnesium scrap. The aluminum scrap is hand-sorted from the

[12]Prepared by Gerald R. Smith.

[13]Prepared by Deborah A. Kramer.

magnesium scrap, and the magnesium scrap then is 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 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 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 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-base scrap. In general, imports and exports of magnesium waste and scrap have been equivalent over the last 5 years.

As more magnesium is used in automotive applications, North American firms plan to construct new magnesium recycling plants. These plants are expected to process primarily 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. Recycling of steel and aluminum are discussed in the respective sections of this report. Manganese is ubiquitous throughout the various grades of steel, which on average contain about 0.7% manganese. Although the quantity of manganese units being returned to steelmaking corresponds to about two-thirds of a current U.S. apparent consumption of manganese of about 700,000 metric tons, the manganese in recycled steel scrap can be thought of as providing only a baseline level of manganese. Contents above this are removed in the decarburization step of steelmaking, and then have 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]

The current trend in the United States is to avoid the discharge or disposal of mercury-containing products. As a result, secondary mercury is recovered from a wide-range of source material. Electronic devices including rectifiers, switches, thermostats, and relays; dental amalgams; batteries; and other instruments such as thermometers are all 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. Over the period 1992-96, in the United States, the recovery of secondary mercury has increased as industrial consumption has declined. Thus, in both 1995 and 1996, more mercury was recovered than was consumed. In 1996, 446 tons was recovered and 372 tons was consumed.

Molybdenum[16]

Secondary molybdenum in the form of metal or superalloys was recovered, but the amount is small. 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 80% of the 59,200 tons of nickel reclaimed in 1996. 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 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 melt shops in Pennsylvania. An additional 10 companies have medium to small melt shops scattered

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

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 10% of the nickel reclaimed in 1996. 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. Nickel-silver—a white brass—is used for rivets, screws, camera parts, and optical equipment. The remaining 10% 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 superalloy 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 has 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.

Platinum-Group Metals[18]

In the United States, there was an increase in the average platinum-group metals (PGM) loading of spent automobile catalysts collected in 1996, as the proportion of recent models, which carry a higher PGM content, increased. As a result, PGM recoveries increased to about 14.6 tons in 1996. Historically, about 70% of new cars registered in the United States eventually become available as scrap. If certain assumptions are made about the types of catalysts used in the converters and the amounts of PGM contained, it can be assumed that the scrapped converters contained about 16.2 tons of palladium, platinum, and rhodium. Most cars dismantled in 1996 were equipped with three-way catalytic converters. Although only small quantities of PGM were recovered from catalysts used by the chemical process industry, substantial quantities of platinum were recovered, on a toll basis, from spent petroleum refining catalysts, and then reused in catalysts.

[18]Prepared by Henry E. Hilliard.

Selenium[19]

Most selenium, except for that used in photocopiers, is dissipated or reaches a final disposition as a minor constituent of products that are landfilled. The small quantities added to clear glass as a decolorant or to ferrous and nonferrous metal alloys are not accounted for during the recycling of these 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 have made it uneconomical to recover the metal from scrapped rectifiers.

While there is currently no domestic secondary selenium recovery, manufacturing scrap generated in the production of selenium-coated photoreceptor drums for plain paper copiers (new scrap) and worn out or obsolete photoreceptor drums (old scrap) are exported for recovery of the contained selenium. It is estimated that as much as about 100 metric tons, or one-fourth of the selenium metal imported annually, is refined from scrap. Practically all of the selenium used in photoreceptor drums is recovered through very efficient recycling programs. Secondary selenium is recovered by Canadian, European, Japanese, and Philippine refiners. The photocopier market for selenium, currently the main feed source for secondary selenium, is expected to continue its decline owing to competition from other technologies, mainly organic photoreceptors. This, combined with low prices and surplus foreign secondary capacity, discourages the redevelopment of domestic secondary production capacity.

Silver[20]

Photographic scrap is estimated to have generated about 1,000 tons of silver in 1996. The major part of this was recycled from spent fixer solutions but a significant quantity also came from solid waste including X-ray and graphic arts film, “wool” from solution tanks, and a small quantity directly from color film negatives.

Nearly all silver that goes into catalysts is recycled, with typical losses being 2% or less. Usually catalysts are scrapped on a 1- to 3-year basis. The worldwide recycling of spent silver catalysts is dominated by a few specialized companies in Europe and the United States. Total supply of silver from the recycling of old silver scrap in the United States in 1996 is estimated at about 1,300 tons.

Tantalum[21]

Tantalum is a refractory metal that is ductile, easily fabricated, has a high melting point, is highly resistant to corrosion by acids, and is a good conductor of heat and electricity. Tantalum is also critical to the United States because

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

of its defense-related applications in aircraft, missiles, and radio communications. Currently 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, ceramics, columbium (niobium), platinum, titanium, and tungsten exist for tantalum but are usually made at either a performance or economic penalty. There has been no significant mining of tantalum in the United States since the 1950's. Most domestic resources of tantalum are of a low grade and not currently commercially recoverable. Consequently, the United States is highly import dependent for its tantalum raw material supply. Australia is the major source for U.S. tantalum imports.

Recycling of tantalum largely takes place within the processing and product producing industry and is mostly new scrap that is consumed internally. 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, 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 scrap. Tantalum can be recovered from certain capacitor scrap by electrolysis and acid leaching. In 1996, U.S. apparent consumption of tantalum totaled about 490 tons, with consumed scrap (from various sources) accounting for an estimated 20% of the total.

Tin[22]

About 25% of the domestic supply of tin metal is recovered from scrap. In 1996, 11,000 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. The detinning process is 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.

[22]Prepared by James F. Carlin, Jr.

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 58% in 1996 (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. Currently, there are two domestic producers of ferrotitanium. 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.

Demand for titanium from commercial aerospace and golf club markets resulted in a 28% annual increase in titanium scrap consumption in 1996. However, imports of scrap increased 48% and producer in-house receipts of titanium scrap increased 22%. Meanwhile, 1996 yearend stocks rose 69% compared with those at yearend 1995. Owing to the increased abundance of titanium scrap in spite of high demand, prices for scrap turnings and ferrotitanium decreased 5% and 2%, respectively.

Tungsten[24]

An estimated 30% of world tungsten supply is from recycled

[23]Prepared by Joseph Gambogi.
[24]Prepared by Kim B. Shedd.

materials. Tungsten-bearing scrap originates during manufacture and/or after use in the following applications: 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, 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. Steel scrap and superalloy scrap are recycled by the steel and superalloy industries, respectively.

In 1996, scrap consumption reported by U.S. tungsten processors and consumers increased 7% to 2,560 tons of contained tungsten. U.S. imports of tungsten waste and scrap decreased 13% to 1,840 tons of contained tungsten, valued at $11.0 million. Two-thirds of these imports were supplied by four countries (Japan, 19%; the United Kingdom, 17%; Russia, 16%; and Germany, 15%). U.S. exports of tungsten waste and scrap decreased 19% to an estimated 565 tons of contained tungsten, valued at $3.6 million. An estimated 60% of these exports were 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.

[25]Prepared by Robert G. Reese, Jr.

Zinc[26]

About 30% of the world's zinc is produced from secondary materials, recovered from brass, galvanizing residues, diecasting scrap, zinc sheet, and flue dust. In the United States, about one-fourth of the 1.45 million tons of zinc consumed annually by domestic industries is secondary zinc. Nearly two-thirds of recycled zinc in 1996 was derived from new scrap, generated mainly in galvanizing and diecasting plants and brass mills. The remaining one-third was obtained from old diecasts, brass products, old rolled zinc articles, and flue dust from EAF. Recycled zinc was used by 11 primary and secondary smelters for production of zinc metal, including alloys, and 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 content of zinc-bearing scrap, zinc recycling processes 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 floatation method. Most EAF 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 3% of total scrap consumption. Around 85% of imported zinc scrap was supplied by Canada, while the major destination of U.S. exports was Taiwan. 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.

[26]Prepared by Jozef Plachy.

[27]Prepared by Joseph Gambogi.

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[1]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/									
1992	1,140,000	1,610,000	2,760,000	6,870,000	40	$1,450,000	$2,040,000	$3,500,000	$8,710,000
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	1,710,000	1,570,000	3,290,000	8,340,000	39	2,690,000	2,470,000	5,160,000	13,100,000
Chromium: 8/									
1992	NA	NA	102,000	378,000	27.0	NA	NA	89,400	331,000
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	688,000
1996	NA	NA	98,400	480,000	20.5	NA	NA	95,100	464,000
Copper: 9/									
1992	723,000	555,000	1,280,000	3,030,000	42.2	1,710,000	1,310,000	3,030,000	7,170,000
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 r/	1,320,000	3,410,000 r/	38.6	2,670,000	1,350,000	4,020,000	10,400,000
1996	872,000	428,000	1,300,000	3,700,000	35.1	2,100,000	1,030,000	3,120,000	8,910,000
Iron and steel: 10/									
1992	NA	NA	63,000,000	139,000,000	45	NA	NA	5,960,000	13,200,000
1993	NA	NA	68,000,000	167,000,000	41	NA	NA	6,440,000	18,800,000
1994	NA	NA	70,000,000	178,000,000	39	NA	NA	6,630,000	22,600,000
1995	NA	NA	72,000,000	180,000,000	40	NA	NA	6,820,000	24,300,000
1996	NA	NA	72,000,000	183,000,000	39	NA	NA	6,820,000	23,900,000
Lead: 11/									
1992	55,400	861,000	916,000	1,330,000	69.1	42,900	666,000	709,000	1,030,000
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	36,600	1,050,000	1,090,000	1,630,000	66.8	39,400	1,130,000	1,170,000	1,750,000
Magnesium: 12/									
1992	26,200	30,800	57,000	168,000	34	78,000	91,700	170,000	500,000
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	40,800	30,100	70,900	205,000	35	169,000	125,000	294,000	850,000
Nickel: 13/									
1992	NA	NA	55,900	159,000	35.1	NA	NA	391,000	1,120,000
1993	NA	NA	54,000	158,000	34.1	NA	NA	286,000 r/	839,000
1994	NA	NA	58,600	164,000	35.8 r/	NA	NA	371,000	1,040,000
1995	NA	NA	64,500 r/	181,000 r/	35.6 r/	NA	NA	531,000 r/	1,490,000 r/
1996	NA	NA	59,200	183,000	32.4	NA	NA	444,000	1,370,000
Tin: 14/									
1992	4,890	8,850	13,700	37,300	37	43,400	78,400	122,000	331,000
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 r/	7,720 r/	11,600 r/	43,300 r/	27	35,800 r/	70,800 r/	107,000 r/	397,000 r/
1996	3,460	7,580	11,000	37,700	29	31,400	68,800	100,000	342,000
Titanium: 15/									
1992	NA	NA	14,800	W	51	NA	NA	23,600 e/	NA
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
Zinc: 16/									
1992	234,000	132,000	366,000	1,280,000	28.7	301,000	170,000	471,000	1,640,000
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 r/	111,000 r/	353,000	1,460,000	24.2	298,000 r/	137,000 r/	435,000	1,800,000
1996	265,000	114,000	379,000	1,450,000	26.1	273,000	115,000	388,000	1,640,000

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 three significant digits; may not add to totals shown.

2/ Scrap that results from the manufacturing process, including metal and alloy production. Aluminum, copper, lead, tin, and zinc new scrap 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/ Secondary production measured as chromium contained in reported stainless steel scrap receipts where chromium content was estimated at 17%. Value calculated from quantity using the average annual value of high-carbon ferrochromium as follows in dollars per metric ton of contained chromium: 1992--875; 1993--679; 1994--638; 1995--1,216; 1996--731.

9/ 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/ Scrap is nickel contained in scrap consumed by producers of stainless and alloy steels, supperalloys, and aluminum-base, copper-base, or nickel-base alloys. 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.