RECYCLING—METALS

Introduction[1]

Metals are essential, reusable resources. Although the ultimate supply of metal is fixed by nature, human ingenuity helps to determine the quantity of supply available for use at any point in time 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 metals used in our society, provides environmental benefits in terms of energy savings, reduced volumes of waste, and reduced emissions associated with energy savings. Table 1 shows salient U.S. apparent supply and recycling statistics for selected metals upon which the following comments are based. Apparent metal supply of 134 million metric tons (Mt) was valued at $32.0 billion in 2001. By weight, iron and steel accounted for 88.6% of apparent metal supply. By value, aluminum accounted for 38.0% of apparent metal supply and iron and steel accounted for 27.7%. Recycling contributed 76.9 Mt of metal, valued at about $14.2 billion, or 58% of apparent metal supply by weight. As measured by recycled metal as a percent of apparent metal supply for each metal, lead was the most recycled metal at 65% followed by iron and steel at 60%; the least recycled were zinc at 26.3% and tin at 27%.

This report summarizes metal recycling. The U.S. Geological Survey publishes separate annual reviews for each of the metals summarized in this report. Those reviews contain more detailed information about individual metals and recycling of those metals.

Primary indicates material from ore deposits; *secondary*, from recycled materials, including used products and residual materials from manufacturing. Recycling practices, and the description of those practices, vary substantially among the metal industries covered in this report. 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 and junked automobiles and appliances are examples of old consumer scrap; used jet engine blades and vanes, junked machinery and ships, and metal recovered from commercial buildings or industrial plants are examples of old industrial scrap. A wide variety of descriptive terms including home scrap, mill scrap, purchased scrap, prompt scrap, etc. have evolved to describe scrap generated by a wide variety of industry practices.

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Aluminum[2]

Various forms of aluminum scrap are recovered by almost every segment of the domestic aluminum industry. Integrated primary aluminum companies, independent secondary smelters, fabricators, foundries, and chemical producers are known to recover aluminum from scrap. Integrated primary aluminum companies and independent secondary smelters, however, are the major consumers of 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. These companies frequently purchase scrap from their industrial customers directly or on a contract-conversion basis. Major integrated aluminum companies also operate can recycling programs.

Used beverage cans (UBCs) are the major component of processed old aluminum scrap, accounting for approximately one-half of the old scrap consumed in the United States. Most UBCs are recovered as aluminum sheet and manufactured 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 die casts is used by the automotive industry.

Aluminum recovered from purchased scrap decreased by 14% in 2001 compared with that of 2000. Of the 2.98 Mt of recovered metal, 60% came from new (manufacturing) scrap, and 40%, from old (discarded aluminum products) scrap.

According to figures released by the Aluminum Association Inc., the Can Manufacturers Institute, and the Institute of Scrap Recycling Industries, 55.6 billion aluminum UBCs were recycled in the United States in 2001, for a beverage can recycling rate of 55.4%. For 20 of the past 21 years, the rate has exceeded 50% (Aluminum Association Inc., 2002).

Purchase prices for aluminum scrap, as quoted by American Metal Market, fluctuated during the year. The yearend price ranges for selected types of aluminum scrap were as follows: mixed low-copper-content aluminum clips, 44 to 45 cents per pound; old sheet and cast aluminum, 41 to 42 cents per pound; and clean, dry aluminum turnings, 40.5 to 41.5 cents per pound.

Aluminum producers' buying price range for processed and delivered UBCs, as quoted by American Metal Market, closed lower at yearend. The price range began the year at 53 to 54 cents per pound and closed the year at 44 to 45 cents per pound. Resource Recycling published a monthly transaction price for aluminum UBCs in its Container Recycling Report. During the year, the monthly average decreased significantly from 56.6 cents per pound in January to 46.3 cents per pound in December. The annual average price for aluminum UBCs decreased from 57.7 cents per pound in 2000 to 50.2 cents per pound in 2001.

The yearend indicator prices for selected secondary aluminum

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ingots, as published in American Metal Market, also decreased compared with those at the end of 2000. The closing prices for 2001 were as follows: alloy B380 (1% zinc content), 68.2 cents per pound; alloy A360 (0.6% copper content), 71 cents per pound; alloy A413 (0.6% copper content), 70.9 cents per pound; and alloy 319, 70 cents per pound. Platts Metals Week published an average annual U.S. price of 63.5 cents per pound for A380 alloy (3% zinc content). The annual average London Metal Exchange (LME) cash price for a similar A380 alloy was 53.2 cents per pound.

Beryllium[3]

Beryllium (Be) is used in many applications where such properties as light weight and stiffness are important. In 2001, the United States, one of only three countries that processed beryllium ores and concentrates into beryllium products, supplied most of the rest of the world with these products.

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

In 2001, U.S. apparent consumption of beryllium totaled about 230 metric tons (t). Unknown quantities of new scrap generated in the processing of beryllium metal and beryllium-copper alloys were recycled. The new scrap generated during the machining and fabrication of beryllium metal and alloys was returned to the metal-alloy producers for recycling. The beryllium in beryllium-copper fabricated parts was so widely dispersed in products, and so highly diluted when those products were recycled, that it was essentially dissipated. Additionally, small quantities of obsolete military equipment containing beryllium were recycled (Petkof, 1985; Cunningham, 2002a).

Cadmium[4]

The amounts of secondary or recycled cadmium are difficult to estimate for several reasons. In the recycling of baghouse dusts from lead and copper smelters, for example, the recovered cadmium subsequently enters primary cadmium production circuits at zinc refining operations and is included in the production statistics for primary cadmium metal. There are no firm figures on the amounts of cadmium recovered from sources such as electroplating waste, filter cakes, sludges, and other cadmium-containing wastes. The total amount of cadmium recycled in 2001, as estimated by the International Cadmium Association, was about 10% of world primary production.

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 (NiCd) batteries, and because batteries are easy to recycle, most of the secondary cadmium comes from spent NiCd batteries. Another form of old scrap that is easy to recycle is the flue dust generated during recycling of galvanized steel scrap in electric arc furnaces. Most of the new scrap for recycling is generated during manufacturing processes, such as die casting. All other applications use materials that are low in cadmium content and, therefore, are difficult to recycle for cadmium. Consequently, much of this cadmium is dissipated.

In 2001, secondary production in the United States amounted to about 200 t. The International Metals Reclamation Co. Inc. (Inmetco) in Ellwood City, PA, is the only cadmium recycling company in the United States. Although the plant was established in 1978, cadmium recovery did not begin until 1996. Large batteries, usually weighting more than 2 kilograms (kg) and containing an average of 15% cadmium, are emptied of their electrolyte and dismantled. Detached cadmium plates then go directly into the furnace, using the high temperature metal recovery process (HTMR). Cadmium in smaller sealed batteries is recovered by burning off the castings and separators at a lower temperature than used in the HTMR process. The resulting 99.95% pure cadmium is shipped to battery manufacturers for reuse.

Chromium[5]

The major end use of chromium is in stainless steel, and this is the major form in which 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 iron-chromium alloy stainless steel. Stainless steel scrap can substitute for ferrochromium as a source of chromium. Stainless steel is composed of two broad categories—austenitic and ferritic. The names are related to the molecular structure of the steel but also identify which grades require nickel (austenitic) and which do not (ferritic). Nickel content increases the price of the alloy and its resulting scrap.

Scrap is generated during the manufacturing process (new scrap) and as a result of recycling obsolete equipment (old scrap). Scrap from these sources is collected and sorted by grade (i.e., chemical composition) in scrap yards. Scrap brokers play a role in moving material from where it is recovered to where it is consumed. The steel industry consumes stainless steel scrap as a source of chromium and nickel. Thus chromium units are recycled when stainless steel is reused. A study of domestic stainless steel found that its average chromium content is about 17% (Papp, 1991, p. 1). Chromium recycling in the United States was studied (Papp, 1999§[6]).

Cobalt[7]

Cobalt-bearing scrap is generated during manufacture and/or following use in these applications—catalysts used by the

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petroleum and chemical industries; cemented carbides used in cutting and wear-resistant applications; rechargeable batteries; and superalloys, magnetic and wear-resistant alloys, and tool steels. Depending on the type and quality of the scrap, it might be recycled within the industry sector that generated it, processed to reclaim the cobalt as a cobalt chemical or metal powder, downgraded by using it as a substitute for nickel or iron in an alloy with a lower cobalt content, or processed to an intermediate form that would then either be further refined or downgraded. The products of recycled cobalt scrap include alloys; mixed metal residues; pure cobalt metal, metal powder, or chemicals; and tungsten carbide-cobalt powders (Shedd, 2002, p. 5-12).

In 2001, scrap consumption reported by U.S. cobalt processors and consumers was 2,740 t of contained cobalt, an increase of 7% from the 2,550 t consumed in 2000. U.S. imports of cobalt waste and scrap increased by 6% to 583 t, gross weight, valued at $10.2 million. Six countries supplied nearly 90% of these materials—the United Kingdom (21%), Japan (20%), the Netherlands (18%), Australia (16%), and France and Germany (6% each). U.S. exports of cobalt waste and scrap are reported in combination with exports of unwrought cobalt metal and metal powders.

Copper[8]

The International Copper Study Group (2002, p. 16) estimated that world production of secondary refined copper declined by about 15% in 2001 to 1.8 Mt and accounted for only 11.8% of global world refined copper production. According to data compiled by the World Bureau of Metal Statistics (2002, p. 42) and adjusted by the U.S. Geological Survey, an additional 3.07 Mt of copper was recovered from the direct remelting of copper scrap, a decline of about 135,000 t from that of 2000 revised data. Secondary refined production in the United States continued its downward trend, declining by 36,000 t, 17%, in 2001. Secondary refined production has fallen by about 225,000 t (57%) since 1997 owing to contraction of the secondary smelting/refining industry. Following the 13% decline in reported refined copper consumption (primary plus secondary), copper recovered in alloys and chemicals from scrap (direct melt scrap) fell by about 125,000 t, 11%.

Copper scrap prices generally followed the trend in refined copper prices, though the discount for various grades of scrap tended to narrow with lower prices. The upward trend in refined copper prices that began in mid-1999 stalled during the fourth quarter of 2000, and prices began a 10-month descent in January 2001. The COMEX spot price, which averaged $0.87 in December 2000, averaged only $0.84 in January and by August had fallen to an average of only $0.67 per pound. The annual average COMEX price fell from $0.84 in 2000 to $0.73 in 2001. The annual average discount to COMEX prices for No. 1 (brass mill) scrap and No. 2 (refiners) scrap averaged 2.9 cents per pound and 13.6 cents per pound, respectively, down from 3.3 cents and 19 cents per pound, respectively, in 2000.

According to data compiled by the International Copper Study Group (2002, p. 40-43), global trade in copper scrap, based on reported exports, declined in 2001, principally owing to reduced shipments from Europe. Total scrap exports from the United States continued to rise, however, increasing to 534,000 t, up from 485,000 t in 2000 and 315,000 in 1999. The United States was the largest international source for copper scrap, accounting for about 21% of all reported scrap exports. Exports of scrap from Russia, which had averaged about 360,000 t in 1997 and 1998, continued to fall and amounted to less than 10,000 t in 2001. China (including Hong Kong), which reported copper scrap receipts of 3.4 Mt, up from 2.6 Mt in 2000, was the largest recipient of scrap. Note, however, that data on world scrap trade are incomplete, with reported imports generally exceeding reported exports. Chinese scrap receipts alone exceed total reported world exports of scrap in 2001 and probably contain very low-grade or misclassified material. In 2001, U.S. imports of copper scrap of 115,000 t were down from 144,000 t in 2000. Canada and Mexico were the leading sources for U.S. imports of copper and copper alloy scrap, accounting for 82% of imports in 2001.

During 2001, one secondary smelter and three fire refineries processed scrap to recover unalloyed copper products in the United States. Scrap was also consumed in relatively small quantities at several of the primary smelters. At the end of October, Chemetco Inc. abruptly closed its secondary copper smelter near Hartford, IL. Chemetco had been ordered to pay $3.8 million in fines for dumping hazardous wastes over a 10-year period, ending in 1996, through a pipe that ran from the plant to an area about 150 yards away. Six company employees and the company itself were charged in 1999 with discharging wastewater containing lead, cadmium, and zinc into a lake and wetland adjacent to the plant (Platts Metals Week, 2001a). Chemetco, with a capacity of about 135,000 metric tons per year (t/yr) of copper anode, was the last dedicated secondary copper smelter operating in the United States. It processed a variety of copper materials including radiators, No. 2 copper, and low-grade residues.

Direct melt scrap, principally alloy scrap, was consumed at about 35 brass mills, 20 alloy ingot makers, and 500 foundries, chemical plants, and miscellaneous consumers. Of the total copper recovered from copper-, aluminum-, nickel-, and zinc-base scrap, copper smelters and refiners recovered 15%; brass mills, 63%; brass and bronze ingot makers, 11%; and miscellaneous manufacturers (including aluminum and steel alloy producers), foundries, and chemical plants, 11%. Alloyed copper products accounted for about 84% of the total copper recovered from scrap.

In 2001, copper recovered from all refined or remelted scrap (about 28% from old scrap and 72% from new scrap) composed 34% of the total U.S. copper supply and had an equivalent refined value of $1.9 billion. The conversion of old scrap to alloys and refined copper declined for the fourth consecutive year, falling by 41,000 t (11%) to 316,000 t. Lower copper prices in 2001 and secondary copper smelter closures led to the continued downward trend in recovery. Copper recovered from new scrap, 833,000 t, declined by 13% owing to reduced industrial demand for copper products. Olin Brass Corp. idled its Indianapolis, IN, copper and copper-alloy sheet and strip mill in December. The plant was to be placed on care-and-maintenance status so that it could be reopened when demand for the plant's products increased. The plant primarily serves customers in the automotive, telecommunications, and computer sectors (Platts Metals Week, 2001c).

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Gallium[9]

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. Some GaAs also remains in the reactor after the ingot is produced, which can 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 there are crystal imperfections at the seed end. These ends represent up to 25% of the weight of the ingot. As the crystal is sliced into wafers, two types of wastes are generated—saw kerf, which is essentially GaAs sawdust, and broken wafers. When the wafers are polished with an abrasive lapping compound, a low-grade waste is generated. During the epitaxial growth process, various wastes are produced, depending on the growth method used. Because GaAs is a brittle material, wafers may break during the fabrication of electrical circuitry on their surfaces. These broken wafers also can be recycled. Gallium content of these waste materials varies from less than 1% to as much as 99.99%. In addition to metallic impurities, the scrap may be contaminated with other materials introduced during processing, such as water, silicone oils, waxes, plastics, and glass (Kramer, 1988, p. 15).

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

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

In 2001, Furukawa Co. Ltd. of Japan announced that it was developing technology to recover gallium and arsenic from the GaAs semiconductors that are used in cellular telephone applications. The company expected to use the recovered materials in its gallium phosphide (GaP) polycrystals, used in light-emitting diode applications (Compound Semiconductor, 2001).

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Gold[10]

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

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

Gold-bearing scrap is purchased on the basis of gold content, as determined by analytical testing and the market price for gold on the day that the refined product is available for sale. Processing charges and adjustments for processing losses are deducted from the total value in settling payments. Aside from dealer-processors and refiners, scrap gold has no market. The Federal Trade Commission requirement for karat identification of jewelry alloys requires gold refiners to identify the chemical analysis of the alloys they purchase and to separate the constituents of scrap to assure meeting karat standards [Public Law 226, an act forbidding the importation, exportation, or carriage in interstate commerce of falsely or spuriously stamped articles of merchandise made of gold or silver or their alloys, and for other purposes, 1906, 59th Congress, 1st Session, Revised Statute U.S. v. 34, part 1, June 13, p. 260].

Refiners throughout the world recover secondary gold from scrap. In the United States, about two-thirds of the scrap comes from manufacturing operations, and the remainder comes from old scrap in the form of such items as discarded jewelry and dental materials, used plating solutions, and junked electronic equipment. A few dozen companies, 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 New York, NY, and Providence, RI; refiners are also concentrated in areas of California, Florida, and Texas, although the current trend seems to be toward a less centralized industry. Scrap dealers may process the scrap and then ship the upgraded product to refiners and fabricators for further treatment and refining. The U.S. Department of Defense (DOD) recovers significant quantities of gold from military scrap (Laura Green, Precious Metals Specialist, Defense Logistics Agency, oral commun., 1998). Other Federal Government agencies either participate in the DOD recovery program or have one of their own. DOD awarded contracts to manage more than 11 million kilograms of electronic scrap anticipated to be collected through the middle of 2000

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(American Metal Market, 2000).

Domestic consumption of new and old gold scrap was 42,000 kg and 66,000 kg, respectively. These data were collected in 2001 by the U.S. Geological Survey (USGS), and include 26,000 kg of old imported scrap. In 2001, U.S. exports of gold scrap decreased by more than 37%, while imports decreased more than 11%. As it has been for many years, the United States was a net exporter of gold scrap in 2001. In 2001, the unit value of imported waste and scrap gold was $66 per troy ounce (oz); exported, $229 per oz; the average price was $272 per oz (Platts Metals Week, 2002b).

Indium[11]

Domestic recovery of secondary indium remained low for the 5th consecutive year since the unusually high price in 1996 encouraged the recycling of old scrap. Owing to that high price, several companies were interested in reclaiming the 37 t of indium contained in the flue dust located at the site of the former Bunker Hill smelter in Kellogg, ID. In 1996, however, the site was declared a Superfund site by the U.S. Environmental Protection Agency, and by the following year, all the flue dust that remained after 50 years of operation was stabilized and buried at the site (Platts Metals Week, 2001b).

In 2001, as in the past 5 years, only small amounts of indium were recovered and only from new scrap. The exact amount is not available because it was reused directly by the producers of indium-containing products.

Worldwide recycling of indium in 2001 increased to 202 t from 182 t in 2000 (Ryan's Notes, 2002). Nearly three-fourths of that amount was recycled by Japan, where about 45% of consumption is from indium scrap, most of it collected domestically (Roskill's Letter from Japan, 2002).

Iron and Steel[12]

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 appliances, bridges, buildings, containers, highways, machinery, tools, and vehicles. Because it is economically advantageous to recycle iron and steel by melting and recasting into semifinished forms for use in the manufacture of new steel products, a significant industry has developed to collect old scrap (used and obsolete iron and steel products), and new scrap (the ferrous scrap generated in steel mills and steel-product manufacturing plants). The North American steel industry's overall recycling rate is 68% (Rich Tavoletti, American Iron and Steel Institute, unpub. data, July 2002).

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

In the United States, the primary source of obsolete steel is the automobile (Rich Tavoletti, American Iron and Steel Institute, unpub. data, July 2002). Of the ferrous metals used to make a typical 2001 U.S. family vehicle, 45% was recycled metal. About 12,000 car dismantlers and 3,000 scrap processors produced about 13.9 Mt of iron and steel scrap for recycling in 2001—enough steel to produce over 14 million new cars. The recycling rate of automobile scrap steel was 102% in 2001 compared with 95% in 2000. A recycling rate greater than 100% is a result of the steel industry recycling more steel from automobiles than was used in the production of new vehicles.

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

Steel mills melt scrap in basic-oxygen furnaces (BOF), 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 that in an EAF can be as much as 100%. Steel and iron foundries use scrap in EAFs and cupola furnaces. In 2001, BOFs were used to produce 53% of total steel in the United States, while using only 28% of total scrap consumed (American Iron and Steel Institute, 2001, p. 86). During the same period, EAFs produced 47% of total steel while using 71% of total scrap consumed. Scrap was also melted in blast furnaces and other types of furnaces.

Iron and steel scrap is an additional resource for steelmakers that is more than just economically beneficial. Recycling conserves natural resources, energy, and landfill space. Recovery of 1 metric ton of steel from scrap conserves an estimated 1,030 kg of iron ore, 580 kg of coal, and 50 kg of limestone. Each year, steel recycling saves the energy equivalent to electrically power about one-fifth of the households in the United States (about 18 million homes) for 1 year (Steel Recycling Institute, 2000§).

During 2001, steel recycling rates were 102% for automobiles, 95% for construction structural beams and plates, 85% for appliances, 58% for steel cans, and nearly 68% overall (Rich Tavoletti, American Iron and Steel Institute, unpub. data, July 2002).

Ferrous scrap is an important raw material for the steel and foundry industries. Because scrap comes from such sources as old buildings, industrial machinery, discarded cars and consumer

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durables, and manufacturing operations, the mature industrialized economies are the main exporters of scrap. The main trade flows of scrap are from the heavily industrialized and developed countries of North America and Europe to lesser developed steelmaking countries. Germany was the leading exporting country of iron and steel scrap in 2000, as reported by the International Iron and Steel Institute (2001, p. 102), followed by Russia, the United States, Ukraine, France, the United Kingdom, the Netherlands, and Japan. The most significant importing nations were, in decreasing order of importance, Turkey, the Republic of Korea, Spain, Belgium-Luxembourg, China, and Italy (International Iron and Steel Institute, 2001, p. 104).

The U.S. trade surplus for all classes of ferrous scrap was 4.7 Mt in 2001 (Bureau of the Census, unpub. data, 2000). Total U.S. exports of carbon steel and cast-iron scrap went to 65 countries and totaled 6.4 Mt. The largest tonnages went to China, the Republic of Korea, Canada, Mexico, and Malaysia. Total U.S. exports of stainless steel scrap went to 43 countries and consisted of 443,000 t. The largest tonnages went to Taiwan, the Republic of Korea, Canada, China, and Japan. U.S. exports of alloy steel scrap (excluding stainless steel) were shipped to 47 countries and consisted of 611,000 t. The largest tonnages went to China, Canada, and Mexico.

Lead[13]

About 79% of the 1.39 Mt of refined lead produced in the United States in 2001 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 numerous applications such as uninterruptible power-supply equipment, load-leveling equipment for commercial electrical power systems, industrial forklifts, mining vehicles, golf cars and other human and materials transport vehicles, lawn equipment, airport ground-support equipment, floor sweepers and scrubbers, and bicycles. About 7% 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 was produced domestically by 17 companies operating 24 lead recovery plants. Of the 1.10 Mt of lead recycled in 2001, about 99% was produced by 7 companies operating 15 secondary smelter-refineries in Alabama, California, Florida, 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 87% of the reported consumption of lead in the United States in 2001.

During 2001, the United States exported about 125,000 t of lead-bearing scrap, which included whole spent lead-acid batteries as well as nonbattery forms (American Metal Market, 2002 a, b). Only minimal quantities of lead-bearing scrap were imported during the year.

The recovery of lead from spent lead-acid batteries and other lead scrap at secondary smelters in 2001 was sufficient to meet about 74% of the demand for lead in the manufacture of new batteries. The market price for undrained whole scrap batteries averaged about 3.8 cents per pound at the end of 2001, translating to a lead price of 7.6 cents per pound, assuming that lead accounted for about 50% of battery weight. Soft lead scrap averaged 6.3 cents per pound and mixed hard lead and wheel weights averaged 8.5 cents per pound at yearend 2001 (American Metal Market, 2001). The average price for refined lead produced at secondary smelters in 2001 was about 45 cents per pound (Platts Metals Week, 2002a). The failure rate of automotive batteries increased during the summer months as a result of sustained higher temperatures in some regions of the United States. However, a milder fall and early winter essentially slowed the battery failure rate to a more normal average level. Production of refined lead recycled from old scrap decreased by about 3% in 2001 compared with production in 2000. Stocks of refined secondary lead held by producers and battery manufacturers decreased slightly by yearend 2001 compared with yearend 2000.

A report issued by the Chicago-based Battery Council International (BCI) near the end of 2001 indicated that the U.S. battery industry recycled 93.3% of the available lead scrap from spent lead-acid batteries during the period 1995 through 1999. The report, "BCI 1995-1999 National Recycling Rate Study" tracks the lead recycling rate from spent automobile, truck, motorcycle, marine, garden tractor, and other lead-acid batteries. According to a BCI official, the high recycling rate is the result of a successful collaboration among members of the battery industry, retailers, and consumers. Laws are now in place in 42 States that prohibit the disposal of spent lead-acid batteries and require that these batteries be collected through a customer return procedure when a replacement battery is purchased (Advanced Battery Technology, 2001).

Magnesium[14]

New magnesium-base scrap typically is categorized into one of four types. Type I is high-grade scrap, generally material such as gates, runners, and drippings from diecasting operations that is uncontaminated with oils. Types II, III, and IV are lower graded materials. Type II is oil-contaminated scrap, type III is dross from magnesium-processing operations, and type IV is chips and fines. The most desirable type of scrap is type I. Most of the type I scrap is generated during diecasting magnesium alloys. This scrap is either reprocessed at the diecasting facility or sold to a scrap processor. The other types of scrap are either sold to a scrap processor or are used directly in steel desulfurization. Old magnesium-base scrap, or postconsumer scrap, consists of such material as automotive parts, helicopter parts, lawnmower decks, used tools, and the like. This scrap is sold to scrap processors.

In addition to magnesium-base scrap, significant quantities of magnesium are contained in aluminum alloys that also can be recycled. Although some magnesium is lost in scrap processing, a significant quantity of the magnesium is recycled with the aluminum alloy. New aluminum-base scrap that is recycled consists, in descending order of importance, primarily of solids, borings and turnings, dross and skimmings, and other material, which includes foil and can-stock clippings. Because the main aluminum product that contains magnesium is beverage cans,

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the principal magnesium-containing, aluminum-base scrap is can-scrap skeleton from lids and can sheet clippings. This represents about one-half of the overall magnesium-containing, aluminum-base scrap.

Old aluminum-base scrap consists of a variety of materials, but the most important magnesium-containing component is UBCs. Because of the high recycling rate, UBCs represent about three-quarters of the magnesium-containing, old aluminum-base scrap that is reprocessed. The magnesium in old and new aluminum-base scrap is not separated from the aluminum alloy when it is recycled; rather, it is retained as an alloying component.

Magnesium scrap arrives at the recycler either loose on a dump trailer or in boxes on a van-type trailer. Sorting the magnesium-base scrap correctly is crucial to producing a product that meets specifications. Because magnesium and aluminum closely resemble each other, a load of magnesium scrap may contain some aluminum scrap as well. The scrap is visually inspected, and one of the ways to separate the magnesium from the aluminum scrap is by scratching the metal with a knife. Magnesium tends to flake, whereas the softer aluminum tends to curl. After separating the aluminum-base scrap and any other foreign material, the magnesium scrap is sorted according to alloy. In melting, sorted scrap is charged to a steel crucible, which is 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 alloying elements, such as aluminum, manganese, or zinc, are added and melting is complete, molten magnesium is transferred to ingot molds by hand ladling, pumping, or tilt pouring (Wentz and Ganim, 1992).

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 (Dahm, 2000).

Xstrata Magnesium Corp. opened its new magnesium scrap recycling facility in Anderson, IN, in the third quarter of 2001. The plant has an initial capacity of 25,000 t/yr of magnesium alloy from two lines that can process class I and class II scrap generated during the die-casting process. The company began shipping products in December; however, only one of the two lines was operating at yearend. Xstrata hoped to have the second line operating by late 2002, if demand was sufficient (Platts Metals Week, 2002c).

Magnesium Elektron (a subsidiary of Luxfer Group) began production at its new magnesium recycling plant in the Czech Republic in mid-October. Enough equipment was available at the plant to produce at a level of 7,000 t/yr by January 2002. Additional equipment was expected to be installed to increase capacity to 10,000 t/yr by mid-2002. Magnesium Elektron also operates a 10,000-t/yr magnesium recycling plant in the United Kingdom (Metal Bulletin, 2001).

Manganese[15]

Scrap recovery specifically for manganese is insignificant. To a large extent, it is recycled incidentally as a minor component within scrap of another metal, particularly steel and, to a much lesser degree, aluminum. High-manganese (Hadfield) steel, which has a manganese content of about 12%, is recovered for its manganese content, but the quantity of such scrap is believed to be well below 1% of the total quantity of purchased steel scrap. Recycling of aluminum and steel are discussed in the respective sections of this chapter. Manganese is ubiquitous throughout the various grades of steel, which, on average, contains about 0.7% manganese (Jones, 1994, p. 10). Manganese that is recycled to steelmaking within steel scrap largely is lost because of its removal in the decarburization step of steelmaking, and needs to be added back. Manganese is recycled in the aluminum industry as a component of scrap of certain manganese-bearing aluminum alloys, principally as UBC in which the manganese content is about 1%. Melting and processing of aluminum is nonoxidizing toward manganese, so that most of the manganese is retained. The amount of manganese being recycled in the aluminum industry is estimated to be in the vicinity of 1% of manganese apparent consumption. In the future, small additional amounts of manganese could be recovered through widespread recycling of dry cell batteries (Watson, Andersen, and Holt, 1998).

Mercury[16]

Secondary mercury is recovered from a variety of source materials in response to Federal and State regulations to reduce the discharge and disposal of mercury-containing products. 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, Minnesota, and Pennsylvania, produce the bulk of secondary mercury in the United States. Mercury waste generated in the manufacturing of products (new scrap) is either reused internally or collected for reprocessing.

Molybdenum[17]

Molybdenum is recycled as a component of ferrous (alloy steel, stainless steel) and superalloy scrap and catalysts. Ferrous scrap consists of home, new, and old scrap. Home scrap is generated within the steel mill during production of iron and steel and is generally held captive. New scrap consists mainly of trimmings from fabrication processes, such as stamping, and recycled unusable fabricated items. New scrap also includes recycled catalysts and sludge from the production of tungsten filaments in light bulbs. Old scrap includes molybdenum-bearing alloys, carbon and stainless steel that have been used in a variety of applications. The steel grades with the highest percentage of molybdenum are alloy and stainless steels; however, the highest volume of production is in carbon steel. The amount of molybdenum consumed to produce new alloy and catalyst products is not recorded, but in 1998 the old scrap supply available to industry was estimated to be 26,700 t based

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on the life cycle of the products in which molybdenum is used. The ratio of new scrap to old scrap consumption has been estimated to be between 1 and 2, and recycling rates are not likely to change significantly in the near term.

Nickel[18]

Austenitic stainless steel scrap is the largest source of secondary nickel for the United States, accounting for about 87% of the 101,000 t of nickel reclaimed in 2001. An additional 2% came from the recycling of alloy steel scrap. The combined 89% 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).

Western World demand for austenitic scrap decreased substantially in the second half of 2001 because of lower prices for primary nickel. The decline in nickel prices reportedly occurred because nickel producers chose to increase output of cathode and briquets at a time when demand for stainless steel was temporarily weakening. In the second half of 2000, recessionary forces in the United States triggered a dropoff in domestic stainless steel production and a slackening of deliveries of austenitic scrap to U.S. steelworks. These forces worsened in 2001 and were magnified by the impact of the September 11 terrorist attacks on the U.S. economy. The U.S. steel industry produced 1.01 Mt, gross weight, of austenitic stainless steel in 2001, down 18% from a solid 1.24 Mt in 2000. Production of austenitic stainless steel in the European Union (EU) also was down in 2001—but only slightly—because of economic problems in Belgium, France, Germany, and Sweden. Austenitic stainless production in Japan, however, rose to a 4-year high of 2.14 Mt (International Nickel Study Group, 2002a, p. 18; 2002b, p. 14).

The monthly LME cash price for 99.8% pure nickel peaked at $7,061 per ton ($/t) in May and then gradually declined during the remainder of the year to finish at $5,264/t. Prices for austenitic scrap delivered to U.S. mills closely track the LME price and also gradually declined during the second half of 2001. The benchmark price for 18-8 stainless steel bundles delivered to mills in the Pittsburgh area rose from $637 per long ton ($/lt) (gross weight) in January to $753/lt (gross weight) in June, but then continuously declined over the next 6 months and ended at $548/lt (gross weight) in December, reducing profit margins for several scrap processors and brokers. The profit squeeze was attributed to the slowdown in the United States of overall industrial production, the concurrent decline in prompt scrap generation, and the increased availability of primary nickel. Collection of obsolete stainless scrap, the bulk of which comes from demolition work, also was down in some regions because shrinking profit margins discouraged processors from replacing stocks. By yearend, inventories of 18-8 scrap at some processing facilities were extremely low.

Inconsistency in the chemistry of scrap blends is becoming a serious concern for a number of U.S. foundries. Elements like boron and titanium can create major problems for cast iron producers if the scrap chemistry is not properly controlled. Scrap buyers for the foundries were complaining that increasing amounts of tramp elements were showing up in shipments from scrap processors and brokers. One problem is that producers of alloy steel have been adding greater amounts of niobium, titanium, and vanadium to their melts to improve the strength of their products. The three elements are recycled along with the iron and can easily contaminate ductile iron castings. Chromium is another alloying element that has to be carefully monitored (Marley, 2002§).

U.S. exports of stainless steel scrap declined from 35,100 t of contained nickel in 2000 to 32,900 t in 2001, a drop of 6%. Taiwan was the largest importing nation, purchasing 11,600 t of contained nickel in 2001. The Republic of Korea dropped to second place, with 8,950 t of contained nickel. Canada and China vied for third place, with 2,670 t and 2,200 t respectively. Although Chinese purchases of U.S. stainless scrap have grown dramatically since 1997, additional sales reportedly have been hampered because some Chinese ports are not equipped to handle the newer scrap-carrying vessels. The harbor channels and turning areas in some ports north of Shanghai also have serious draft limitations that prevent entry of vessels in excess of 25,000-dead weight tons (Marley, 2000§).

The Russian Federation and the United States were the two largest exporters of stainless steel scrap in 2001. In the United States, strong import penetration by foreign stainless steel and the post-September 11 decline in domestic production of stainless steel left more scrap available for future collection and export. Weak scrap prices and poor profit margins, though, kept significant amounts of both obsolete and prompt scrap from entering the U.S. collection pipeline. A slackening in orders from EU stainless steel producers for U.S. scrap also hurt collections (Marley, 2001§).

The huge influx into Western Europe of Russian stainless steel scrap and nickel alloy scrap, which began in 1995, slackened in 1999 after the Russian Government imposed new tariffs on scrap metal exports. Nickel and six other scrap metals were subject initially to a 30% export tariff (Interfax International Ltd., 2000a, b). A tariff equal to 15% of the customs value (but no less than 15 euros per metric ton) was imposed on ferrous scrap at the same time. Since 1999, the Russian scrap metal industry has lobbied for reduction or abolishment of the export duties. Novolipetsk Iron & Steel Corp., however, warned Russian officials that a proposal to lower the ferrous scrap export tariff from 15% to 10% would destabilize an already weakened Russian steel industry. Because of low prices for cathode in 2001 and the tariffs, Russian exports of stainless steel scrap fell 46% between 2000 and 2001, dropping from 417,000 t (gross weight) (revised) to 227,000 t (International Nickel Study Group, 2002b, p. 97; fig. 1).

In Russia, even though increased domestic consumption of scrap and new export restrictions left less scrap for export, Russia was still the world's largest exporter of stainless steel scrap. In past years, scrap metal could be exported via any customs checkpoint. Beginning in February 2001, however, only 66 seaports and 26 railway checkpoints were authorized to clear scrap exports. The checkpoints were listed in State Customs Committee Order No. 1219 of December 27, 2000.

In March, the Russian Government reduced the number of exit points in the Russian Far East, further restricting scrap exports. In August, similar restrictions were applied to border crossings into the Baltic States, Moldova, and Ukraine. Scrap shipments destined for Riga and Tallinn reportedly had to be redirected to

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St. Petersburg. Key scrap collection centers are located in Orlov, Rostov, St. Petersburg, Samara, and Voronezh. Federation requirements for a scrap export license also have been tightened. The Russian Government acted because significant amounts of pseudo-goods continued to be exported. Pseudo-goods are goods made from scrap with little or no value added in the process (Interfax International Ltd., 2002).

The Russian Government increased its 5% export tariff on refined nickel to 10%. The nonferrous scrap customs duty was hiked from 30% to 50%, causing exports of nonferrous scrap and waste to plummet 85%. These higher tariffs and stricter regulations left nonferrous scrap brokers in a more precarious position than the primary producers. Federation officials were evaluating new procedures for levying value-added taxes on exports. The entire policy of levying tariffs on exports continued to be debated in the State Duma—the lower house of the Russian Parliament.

Growing demand for scrap in China, Korea, and Taiwan helped keep international scrap trade in stainless steel in balance (Buchanan, 2002§). Imports of stainless steel scrap by Taiwan increased 29% between 2000 and 2001, rising to 317,000 t (gross weight). Imports by the Republic of Korea also increased significantly to 442,000 t (gross weight), but decreased slightly in the case of China to 88,600 t.

The world's largest supplier of stainless steel scrap is the German conglomerate ELG Haniel GmbH. ELG Haniel processes 1.4 million tons per year (Mt/yr) of stainless scrap in 12 countries and is owned in turn by Franz Haniel & Cie. GmbH of Duisburg, Germany. In 2000, ELG Haniel GmbH moved the scrap processing facilities of Jewometaal Stainless Processing B.V., its Dutch subsidiary, to a new location in the Port of Rotterdam. Jewometaal spent Eur 8 million, or about $7.7 million, on the new recycling and transhipment facilities. The Rotterdam operation now processes up to 30,000 t of stainless steel scrap each month (Franz Haniel & Cie. GmbH, 2002a, p. 44-45; b, p. 14-15).

Also in 2000, ELG Haniel Metals, Inc., a Pennsylvania-based subsidiary, took steps to enter the stainless steel scrap market in Japan. ELG Haniel Metals (ELG) has teamed up with several Japanese companies to process stainless steel scrap at a new facility in Osaka, Osaka Prefecture. The joint venture, JS Processing Co., Ltd. (JSP), is owned by ELG (40%), Mitsubishi Corp. (19%), Mitsui & Co., Ltd. (19%), Nippon Steel Trading Co., Ltd. (12%), Sangyo Shinko Co., Ltd. (5%), and Fujimoto Metal Co., Ltd. (5%). The last two companies—Japanese scrap dealers—jointly operated the Osaka facility. The Osaka operation has been producing about 36,000 t/yr of specially blended 18-8 scrap, select chromium scrap, and a variety of select nickel-bearing scrap. The blended scrap is designed to replace more expensive stainless steel turnings and clippings that historically have been the mainstay of Japanese stainless steel producers. The first shipments of blended scrap were delivered to the Hikari works of Nippon Steel Corp. in Yamaguchi Prefecture, replacing material previously imported from ELG's facility in Houston, TX (Furukawa, 2000§; Japan Economic Institute of America, 2000§). In April 2001, Sumitomo Metal Industries Ltd. halted stainless steel melting operations at its Wakayama works, 60 km southwest of Osaka, as part of an agreement with Nippon Steel. The scrap dealers that formerly supplied the Wakayama works now deliver their material to Hikari.

In July 2001, JSP opened a second scrap processing facility in Japan. This second facility, located at Oyama in Tochigi Prefecture, also has begun supplying scrap to Nippon Steel. Raw scrap for the Oyama facility comes mainly from industries in the Kanto area surrounding Tokyo (Japan Metal Bulletin, 2001§).

International Metals Reclamation Co. Inc. (Inmetco) converts a variety of nickel and chromium wastes at Ellwood City, PA, into a remelt alloy suitable for stainless steelmaking. The operation was set up in 1978 to reclaim chromium and nickel from emission control dusts, swarf, grindings, mill scale, and other wastes generated by the stainless steel industry. Over the past 23 years, Inmetco has made a number of improvements to its Pennsylvania facility and now also processes nickel- and/or chromium-bearing filter cakes, plating solutions and sludges, catalysts, refractory brick, and spent batteries.

U.S. industry recycles a broad spectrum of other nickel-bearing materials in addition to stainless steel. Copper-nickel alloy scrap and aluminum scrap accounted for about 6% of the nickel reclaimed in 2001. Scrap in this category comes from a myriad of sources and includes cupronickel (a series of copper alloys containing 2% to 45% Ni), the Monels (a group of alloys typically containing 65% Ni and 32% Cu), nickel-silver (a misnomer for a series of copper-zinc-nickel alloys), 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 aerospace industry uses 2218, 2618, 4032, 8280 and several other wrought aluminum alloys that contain 0.2% to 2.3% nickel.

The remaining 5% 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 INCONEL 718, WASPALOY, and similar aerospace-grade superalloys, much of the superalloy 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 three largest importers of U.S. nickel waste and scrap were Canada, Japan, and the Republic of Korea, taking 19,800 t; 2,490 t; and 2,532 t gross weight, respectively.

Demand for superalloy scrap remained at near-record levels in 2001. Three factors contributed to the tightness of supply. First, manufacturing of land-based gas turbines increased dramatically as power companies rushed to meet growing demand for electrical power, especially on the west coast of the United States. Second, orders for new jet aircraft engines and other aerospace components picked up in 2000 after a 2-year downturn. Third, several processors of superalloy scrap were operating at maximum capacity (Newman, 2001). Declining prices for primary nickel in 2001 discouraged the scrap industry from adding new processing capacity. A major problem was inadequate capacity to process turnings from machine shops. To help relieve the tightness in the superalloy scrap market, Keywell LLC set up a new processing facility in Los Angeles, CA, in 2000. The Los Angeles facility was consolidating shipments for forwarding to Keywell's Vac Air Alloys Division at Frewsburg, NY. The Frewsburg facility reportedly is the largest processor of vacuum-grade superalloy and titanium scrap in the world. Keywell also opened a new facility in Fairless Hills, PA, to process stainless steel scrap in bulk.

The U.S. collection and recycling program for NiCd and nickel-metal hydride (NiMH) 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 (RBRC), a nonprofit public service corporation funded by more than 285 manufacturers and marketers of portable rechargeable batteries and battery-operated products. The program is primarily designed to recycle the more than 75 million small, sealed, rechargeable NiCd batteries sold annually to U.S. and Canadian businesses and consumers for use in cordless products. RBRC licensees now account for four out of five NiCd sales in North America. Almost 25,000 retail outlets or community collection sites in the United States accept spent NiCd batteries. Some 4,500 collection sites in Canada also participate in the RBRC program. The bulk of the collected batteries are sent to Inmetco for reclamation.

In Western Europe, the portable battery market has grown substantially since 1985. However, environmental activists continued to oppose the manufacturing and sale of NiCd batteries. In March 2001, the European Commission drafted a directive that calls for the phaseout of cadmium in portable batteries by January 1, 2008. Special exemptions were proposed for batteries used in medical devices, emergency equipment, and special scientific instrumentation. The proposed directive also would establish a minimum recycling target of 55% for all collected batteries. More costly NiMH and lithium-ion batteries were to be substituted for the NiCds. Some 13,000 t of portable NiCd batteries averaging 15% cadmium (Cd) and 3,500 to 4,000 t of industrial NiCd batteries averaging 6% Cd are marketed annually in the EU. Industry studies show that only 11% of the portable NiCd batteries were being reclaimed compared with 53% of the industrial batteries (Commission of the European Communities, 2001).

Platinum-Group Metals[19]

Despite their limited availability, platinum-group metals (PGM), and chemical compounds containing them, are extremely useful as catalysts in the automotive and chemical industries, in the electrical and electronics industry, in dental and medical applications, and jewelry.

For most PGM applications, the actual loss of metal during use is small, and the ability to recover the metal efficiently contributes greatly to the economics of PGM use. For the most part, spent chemical process catalysts and used equipment containing PGM, e.g., from the glass industry, are toll refined and may not be considered as recycling. Spent automotive catalysts, however, are waste materials that have emerged as a leading source of secondary PGM. In 2001, 11,400 kg of platinum was recovered from scrap, most of which was imported; about 2,300 kg of palladium was recovered. The Stillwater Mining Company, Columbus, MT, reported the recovery of 2,100 kg of combined palladium and platinum from spent automotive catalyst in 2001 (Stillwater Mining Company, 2002, p. 16).

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Selenium[20]

Most selenium, except that applied to the surfaces of the photoreceptor drums in plain paper copiers, is dissipated as process waste or is eventually discarded as a minor constituent of products. The small quantities that are added to glass as a decolorant and to ferrous and nonferrous metal alloys to improve metalworking properties are not recovered 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. Additionally, current high processing costs have made it uneconomical to recover selenium scrapped rectifiers.

In 2001, very little secondary selenium was recovered in the United States. Wornout photoreceptor drums and scrap generated in the manufacture of new drums were exported for the recovery of the selenium content. An estimated 470 t of unwrought selenium waste and scrap was imported. Practically all the selenium used in photoreceptor drums is recovered through very efficient recycling programs (Hoffman and King, 1997, p. 704). Secondary selenium was recovered in Canada, Europe, Japan, and the Philippines. The photocopier market for selenium, still the main feed source for secondary selenium, continued its decline owing to competition from other technologies, mainly organic photoreceptors.

Hydromet Environmental Recovery Ltd. (2001) announced the completion of its metallurgical and waste recovery plant in Newman, IL. The plant will begin to receive selenium and tin waste products and process them into salable products for the market. Selenium wastes and residues are generated in the copper smelting and refining industry. The processed ore contains precious metals that become concentrated in the selenium waste dust. Hydromet removes the selenium content, which represents about 70% of the weight of the wastes. The recovered selenium is converted to a high-grade metal powder for resale. The 2001 value of the high-grade selenium powder was about $5,000 per ton. The remaining residue from this process contains upgraded contents of palladium, platinum, and rhodium that Hydromet will ship to a precious metals refiner for final processing (Hydromet Environmental Recovery.

Silver[21]

About 1,060 t of silver, valued at $150 million, was recovered from scrap in 2001. Photographic scrap was estimated to have generated 1,000 t of silver; the largest part was recovered from spent fixer solution, x-ray and graphic arts wastes, and a small quantity directly from color film wastes. The remainder was recovered from jewelers' sweepings, spent catalysts, electronic scrap, and other heterogeneous silver bearing materials. U.S. industrial demand for silver in 2001 was about 5,400 t; mine production was 1,740 t.

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Tantalum[22]

Tantalum (Ta) is ductile, easily fabricated, highly resistant to corrosion by acids, a good conductor of heat and electricity, and has a high-melting point. The major use for tantalum, as tantalum metal powder, is in the production of electronic components, mainly tantalum capacitors. More than 60% of total tantalum consumed is in the electronics industry. Major end uses for tantalum capacitors include portable telephones, pagers, personal computers, and automotive electronics. Alloyed with other metals, tantalum is also used in making carbide tools for metalworking equipment and in the production of superalloys for jet engine components. Substitutes such as aluminum, rhenium, titanium, tungsten, and zirconium, can be used in place of tantalum but are usually used at either a performance or economic penalty.

In 2001, U.S. apparent consumption of tantalum totaled about 550 t, with consumed scrap (from various sources) accounting for an estimated 20% of the total. Tantalum was mostly recycled from new scrap that was generated during the manufacture of tantalum-related electronic components and new and old scrap products of tantalum-containing cemented carbides and superalloys. The amount of tantalum recycled from finished electronic components (old scrap) is very small because this source has not yet been fully developed. New scrap materials reclaimed at manufacturing plants that produce tantalum-related electronic components are a major source of tantalum supply and are delivered back to tantalum processors for recycling (Cunningham, 2001, 2002b).

Tin[23]

In 2001, about 27% of the domestic apparent supply of tin metal was recovered from scrap (table 1). Old tin scrap is collected at hundreds of domestic scrap yards, three detinning plants, and most municipal collection-recycling centers. New tin scrap is generated mainly in the tin mills of six steel plants, scores of canmaking facilities, numerous brass and bronze plants, and many solder-making operations. Most tin-scrap-processing facilities are close to the tin-using industries and to densely populated markets in the midwest and the northeast.

Detinning facilities are unique to the tin scrap industry in that no other major metal industry has numerous large scale plants to remove plated metal. Detinning operations are performed on new tinplate scrap from tin mills or canmaking plants and on old tinplate scrap in the form of used tin cans. For most of the past century, the detinning process has been the only technique in the secondary tin industry by which free tin metal returns 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 this reappears in regenerated alloys.

The Steel Recycling Institute (SRI) (2002) continued to promote the recycling of used tin cans, which has been an important raw material for the nation’s steel industry during the past 20 years. The SRI announced that the domestic steel can recycling rate had remained about the same in 2001 as in 2000, at 58%, compared with 56% in 1995 and 15% in 1988.

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

Titanium[24]

Titanium scrap is generated during the melting, forging, casting, and fabrication of titanium components. “New scrap” is generated during the production and fabrication of titanium components, while “old scrap” is recovered from used components (old aircraft parts, heat exchangers, submarine hulls, etc.).

In the titanium metal industry, titanium scrap is used as an alternative to titanium sponge in the production of titanium ingot. Scrap is recycled into titanium ingot with or without virgin metal by using either traditional vacuum-arc-reduction or cold-hearth melting practices. Major sources of titanium ingot producers include France, Germany, Japan, Russia, the United Kingdom, and the United States. In the United States, titanium ingot producers (recyclers) included Allegheny Technologies Inc., Howmet Corp., Lawrence Aviation Industries Inc., RMI Titanium Co., and Titanium Metals Corp. Numerous companies were involved in the generation, segregation, and processing of scrap for recycling.

U.S. production of titanium ingot increased 13% in 2001 compared with that of 2000. Scrap supplied about 39% of the titanium required for ingot production, significantly less than the 50% supplied in 2000. Although no data are available as to the percentage breakdown of sources of titanium scrap, it is estimated that about 3% of titanium ingot production is derived from old scrap.

In addition to that recycled by ingot producers, titanium scrap is consumed by the steel and nonferrous alloy industries. Consumption by the steel industry is largely associated with the production of stainless steels. In steelmaking, titanium is used for deoxidation, grain-size control, and carbon and nitrogen control and stabilization. Titanium is introduced during steelmaking as a ladle addition often in the form of ferrotitanium because of its lower melting point and higher density when compared with titanium scrap. Ferrotitanium is produced from titanium and steel scrap by induction melting.

World ferrotitanium production capacity is led by, in descending capacity order, the United Kingdom, Russia, Japan, and the United States. In 2001, there were three domestic producers of ferrotitanium—Global Titanium, Inc., Detroit MI; Galt Alloys Inc., North Canton, OH; and ShieldAlloy Inc., Newfield, NJ. In addition to domestic producers, numerous companies were involved in the import and trade of ferrotitanium.

In the nonferrous metals industry, titanium scrap is primarily consumed to produce aluminum-titanium master alloys for the aluminum industry. When used in aluminum alloys, titanium improves casting and reduces cracking.

In 2001, the United States was a net importer of titanium scrap, with imports exceeding exports by 4,080 t. Imports and exports of titanium scrap increased 54% and 48%, respectively, compared with those of 2000. It should be noted that imports and exports of titanium scrap include material to be recycled back into titanium components as well as that consumed by steel and nonferrous alloys.

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Owing to a moderate drop in demand, prices for unprocessed titanium scrap turning (Ti-6AL-4V) decreased from $0.78 per pound at yearend 2000 to $0.69 per pound at yearend 2001. Yearend prices for ferrotitanium decreased from about $1.59 per pound in 2000 to $1.65 per pound in 2001.

Future consumption of titanium scrap is largely dependent on demand for titanium metal products by the aerospace industry. Over the next decade, the growth in titanium demand by the aerospace industry is expected to exceed 5%; however, growth in the aerospace industry is highly cyclical. Growth in the consumption of ultra low carbon steels for automotive applications and appliances is expected to increase demand for ferrotitanium. Given the long-term growth trend for ferrotitanium imports, imports are expected to meet much of the future domestic demand for ferrotitanium.

Tungsten[25]

In 2001, an estimated 25% to 30% of world tungsten supply was from recycled materials (Maby, 2000, p. 7). 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 or used as a source of tungsten by another consuming industry, or used as a substitute for tungsten concentrate by tungsten processors (Smith, 1994, p. 4-14).

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

In 2001, scrap consumption reported by U.S. tungsten processors and consumers was 5,390 t of contained tungsten, an increase of 3% from the revised 5,210 t consumed in 2000. The United States imported 1,080 t of tungsten contained in waste and scrap, valued at $7.5 million, 8% more than the tungsten content of waste and scrap imports in 2000. Five countries supplied nearly three-quarters of these imports—China, 37%; Germany, 14%; Japan, 10%; South Africa, 8%; and Russia, 5%. U.S. exports of tungsten waste and scrap were an estimated 972 t of contained tungsten valued at $6.4 million, which was 18% higher than the estimated tungsten content of waste and scrap exports in 2000. The leading destinations for these exports were Germany, 38%; the United Kingdom, 30%; Taiwan, 7%; Hong Kong, 5%; and Canada, China, and Mexico, 3% each.

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Vanadium[26]

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[27]

In 2001, about 30% of world zinc production was from secondary materials—brass, die casting scrap, flue dust, galvanizing residues, zinc sheet, etc. In the United States, more than one-fourth of the 1.4 Mt consumed by domestic industries is secondary zinc. About 85% of recycled zinc was derived from new scrap, generated mainly in galvanizing and die casting plants and brass mills. The remaining 15% was obtained from brass products, flue dust, old die casts, and old rolled zinc articles. Recycled zinc was used by 3 primary smelters and 12 large and medium (more than 1,000 t/yr) sized secondary smelters principally for production of zinc chemicals, mainly oxide, and zinc metal, including alloys. In addition, there is a changing number of smaller companies that usually produce pure zinc chemicals. IMCO Recycling Inc., Midwest Zinc Corp., and the Zinc Corporation of America are the largest users of secondary zinc.

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

In 2001, trade in zinc scrap was small—about 2% of total domestic consumption. About 95% of imported zinc scrap was supplied by Canada, and the major destination of U.S. exports was India (36%), followed by Taiwan (25%) and China (17%). Prices for scrap varied according to quality, presence of other components, geographic location, and environmental difficulties in handling, transporting, or treating. The price for a ton of zinc metal contained in scrap was about three-fourths of the London Metal Exchange price for refined zinc metal.

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Zirconium[28]

Zirconium scrap comprises about one-fourth to one-third of the feedstock for ingot production. New scrap is generated during the melting, forging, rolling, casting, and fabrication of zirconium components. In addition, some 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 (a subsidiary of Allegheny Technologies Inc.), Albany, OR, and Western Zirconium (a subsidiary of Westinghouse Electric Company), Ogden, UT, using vacuum-arc-reduction melting practices.

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

Year	Quantity of metal (metric tons)					Value of metal (thousands)			
	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/									
1997	2,020,000	1,530,000	3,550,000	8,740,000	41	$3,430,000	$2,590,000	$6,020,000	$14,800,000
1998	1,950,000	1,500,000	3,440,000	9,040,000	38	2,810,000	2,160,000	4,970,000	13,100,000
1999	2,120,000	1,570,000	3,700,000	9,890,000	37	3,070,000	2,280,000	5,350,000	14,300,000
2000	2,080,000	1,370,000	3,450,000	9,610,000	36	3,420,000	2,260,000	5,670,000	15,800,000
2001	1,770,000	1,210,000	2,980,000	8,000,000	37	2,680,000	1,840,000	4,530,000	12,100,000
Chromium: 8/									
1997	NA	NA	120,000	489,000	25 r/	NA	NA	122,000	716,000
1998	NA	NA	104,000	524,000	20 r/	NA	NA	91,500	551,000 r/
1999	NA	NA	118,000	558,000	21	NA	NA	77,700	501,000 r/
2000	NA	NA	139,000	589,000	24	NA	NA	98,600	454,000 r/
2001	NA	NA	122,000	332,000	37	NA	NA	70,800	160,000
Copper: 9/									
1997	967,000	498,000	1,460,000	3,900,000	37.5	2,380,000	1,170,000	3,450,000	9,210,000
1998	956,000	466,000	1,420,000	3,980,000	35.7	1,660,000	808,000	2,470,000	6,900,000
1999	949,000	381,000	1,330,000	4,080,000	32.5 r/	1,590,000	637,000	2,220,000	6,820,000
2000	955,000 r/	357,000 r/	1,310,000	4,080,000 r/	32.1 r/	1,860,000 r/	693,000 r/	2,550,000	7,930,000 r/
2001	833,000	316,000	1,150,000	3,340,000	34.5	1,410,000	535,000	1,950,000	5,650,000
Iron and steel: 10/									
1997	NA	NA	73,000,000	127,000,000	58	NA	NA	9,520,000	16,500,000
1998	NA	NA	73,000,000	133,000,000	55	NA	NA	7,910,000	17,400,000
1999	NA	NA	71,000,000	130,000,000	55	NA	NA	6,680,000	12,300,000
2000	NA	NA	74,000,000	134,000,000	55	NA	NA	7,100,000	12,800,000
2001	NA	NA	71,000,000	119,000,000	60	NA	NA	5,320,000	8,880,000
Lead: 11/									
1997	54,000	1,030,000	1,090,000	1,660,000	65.4	55,400	1,060,000	1,120,000	1,700,000
1998	45,800	1,050,000	1,100,000	1,740,000	63.1	45,700	1,050,000	1,100,000	1,740,000
1999	42,700	1,050,000	1,090,000	1,790,000	60.9	41,200	1,010,000	1,050,000	1,730,000
2000	35,500 r/	1,080,000	1,120,000	1,790,000	62.6	34,100 r/	1,040,000	1,080,000	1,720,000
2001	47,300	1,050,000	1,100,000	1,700,000	65.0	45,500	1,010,000	1,060,000	1,640,000
Magnesium: 12/									
1997	47,000	30,500	77,600	233,000	33	172,000	112,000	284,000	851,000
1998	45,200	31,800	77,100	226,000	34	158,000	111,000	284,000	788,000
1999	52,000	34,200	86,100	231,000	37	178,000	117,000	294,000	789,000
2000	52,200	30,100	82,300	209,000	39	158,000	90,800	248,000	630,000
2001	38,600	27,200	65,800	162,000	41	106,000	75,000	181,000	446,000
Nickel: 13/									
1997	NA	NA	68,400	222,000	31	NA	NA	474,000	1,540,000
1998	NA	NA	63,100	212,000	30	NA	NA	292,000	983,000
1999	NA	NA	71,000	211,000	34	NA	NA	427,000	1,270,000
2000	NA	NA	84,000	231,000	36	NA	NA	726,000 r/	2,000,000 r/
2001	NA	NA	101,000	230,000	44	NA	NA	600,000	1,370,000
Tin: 14/									
1997	4,540	7,830	12,400	48,600	25	38,200	65,600	104,000	409,000
1998 15/	8,470	7,790	16,300	54,600	30	69,600	64,000	134,000	449,000
1999 15/	8,650	7,720	16,400	57,300	29	70,400	62,800	133,000	466,000
2000 15/	9,140 r/	6,560 r/	15,700 r/	54,500 r/	29	74,400 r/	53,500 r/	128,000 r/	443,000 r/
2001 15/	7,190	6,700	13,900	50,600	27	49,800	46,500	96,300	351,000
Titanium: 16/									
1997	NA	NA	28,200	W	46	NA	NA	37,600 e/	NA
1998	NA	NA	28,600	W	50	NA	NA	22,100 e/	NA
1999	NA	NA	21,900	W	55	NA	NA	28,900 e/	NA
2000	NA	NA	18,500	W	50	NA	NA	38,200 e/	NA
2001	NA	NA	17,000	W	39	NA	NA	35,200 e/	NA
Zinc: 17/									
1997	286,000	89,700	376,000	1,490,000	25.2	376,000	118,000	495,000	1,960,000
1998	344,000	89,900	434,000	1,580,000	27.5	352,000	92,100	444,000	1,620,000
1999	321,000	78,100	399,000	1,610,000	24.8	379,000	92,200	471,000	1,900,000
2000	369,000	70,300	439,000 r/	1,630,000 r/	26.9 r/	454,000	90,000 r/	544,000 r/	2,020,000 r/
2001	316,000	52,100	368,000	1,400,000	16.3	306,000	53,800	360,000	1,360,000

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 no more than three significant digits; may not add to totals shown.

2/ Scrap that results from the manufacturing process, including metal and alloy production. New scrap of aluminum, copper, lead, tin, and zinc excludes home scrap, which is scrap generated and recycled in the metal producing plant.

3/ Scrap that results from consumer products.

4/ Metal recovered from new plus old scrap.

5/ Apparent supply is production plus net imports plus stock changes. Production is primary production plus recycled metal. Net imports are imports minus exports. Apparent supply is calculated on a contained-weight basis.

6/ Same as apparent supply defined in footnote 5 above but calculated on a monetary value basis.

7/ Quantity of metal is the calculated metallic recovery from purchased new and old aluminum-base scrap, estimated for full industry coverage. Monetary value is estimated based on average U.S. market price for primary aluminum metal ingot.

8/ Chromium scrap includes estimated chromium content of stainless steel scrap receipts (reported by the iron and steel and pig iron industries) where chromium content was estimated to be 17%. Trade includes reported or estimated chromium content of chromite ore, ferrochromium, chromium metal and scrap, and a variety of chromium-containing chemicals. Stocks include estimated chromium content of reported and estimated producer, consumer, and Government stocks. Recycled value calculated from quantity using the average annual import value of high-carbon ferrochromium. Apparent supply value calculated from quantity using average annual trade value.

9/ Includes copper recovered from unalloyed and alloyed copper-base scrap, as refined copper or in alloy forms, as well as copper recovered from aluminum-, nickel-, and zinc-base scrap. Monetary value based on annual average refined copper prices.

10/ Iron production measured as shipments of iron and steel products plus castings corrected for imported ingots and blooms. Secondary production measured as reported consumption. Apparent supply includes production of raw steel. Monetary value based on U.S. annual average composite price for No. 1 heavy melting steel calculated from prices published in American Metal Market.

11/ Lead processors are segregated by primary and secondary producers. This segregation permits inclusion of stock changes for secondary producers. Monetary value of scrap and apparent supply estimated based upon average quoted price of common lead. Excludes copper-based scrap.

12/ Includes magnesium content of aluminum-base scrap. Monetary value based on the annual average Platts Metals Week's U.S. spot Western price.

13/ Nickel statistics were derived from the following:

Canvass data

- Reported nickel content of products made from reclaimed stainless steel dust, spent nickel-cadmium batteries, plating solutions, etc.
- Estimated nickel content of reported net receipts of alloy and stainless steel scrap.
- Reported nickel content of recovered copper-base scrap.
- Reported nickel content of obsolete and prompt purchased nickel-base scrap.
- Estimated nickel content of various types of reported obsolete and prompt aluminum scrap.

Trade data

- Reported nickel content of International Nickel Study Group (INSG) Class I primary products, including cathode, pellets, briquets, powder, and flake.
- Reported or estimated nickel content of INSG Class II primary products, including ferronickel, metallurgical-grade nickel oxide, and a variety of nickel-containing chemicals.
- Estimated nickel content of secondary products, including nickel waste and scrap and stainless steel scrap.

Stock data

- Reported or estimated nickel content of all scrap stocks, except copper.
- Reported nickel content of primary products held by world producers in U.S. warehouses.
- Reported nickel content of primary products held by U.S. consumers.
- Reported nickel content of U.S. Government stocks.

Monetary value based on annual average cash price for cathode, as reported by the London Metal Exchange.

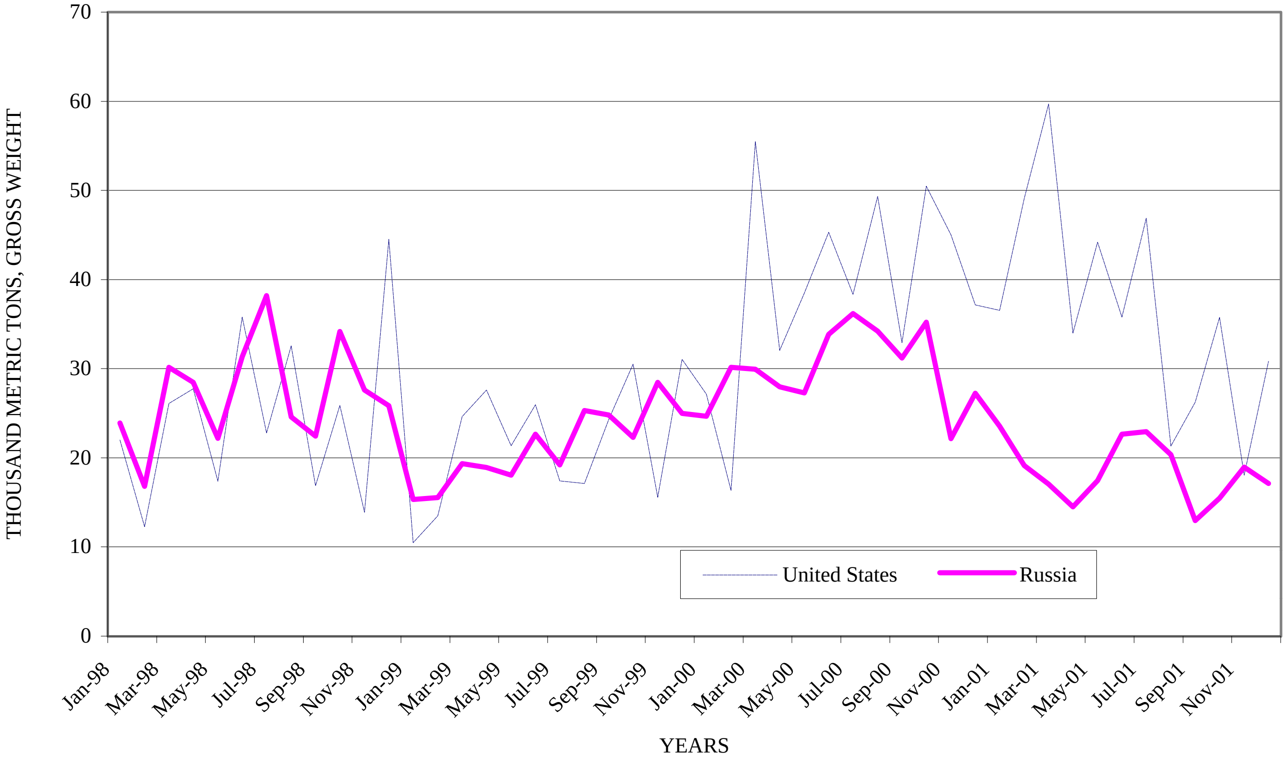
14/ Monetary value based on Platts Metals Week Composite price for tin.

15/ 1998 to 2001 new scrap data include data unavailable for 1997.

16/ Percentage recycled based on titanium scrap consumed divided by primary sponge and scrap consumption.

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

FIGURE 1
EXPORTS OF STAINLESS STEEL SCRAP--RUSSIA AND UNITED STATES



Source: International Nickel Study Group. Russian export data as reported by importing countries.