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U.S. GEOLOGICAL SURVEY

TANTALUM RECYCLING IN THE UNITED STATES IN 1998

by Larry D. Cunningham

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ABSTRACT

This report describes the flow of tantalum in the United States in 1998 with emphasis on the extent to which tantalum was recycled/reused. 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. In 1998, about 210 metric tons of tantalum was recycled/reused, with about 43% derived from old scrap. The tantalum recycling rate was calculated to be 21%, and tantalum scrap recycling efficiency, 35%.

INTRODUCTION

This materials flow study of tantalum, as shown in figure 1, includes a description of tantalum supply and demand factors for the United States in 1998 to illustrate the extent of tantalum recycling and to identify recycling trends.

Tantalum (Ta) was discovered in 1802. Tantalum is a refractory metal that is ductile, easily fabricated, highly resistant to corrosion by acids and a good conductor of heat and electricity and has a high melting point (about 3,000 °C). 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 cemented carbide tools for metalworking equipment and in the production of superalloys for jet engine components.

Salient tantalum statistics are based mostly on the tantalum content of old cemented carbide and superalloy scrap (table 1). In 1998, about 300 metric tons (t) of tantalum contained in old scrap was generated, with about 90 t of tantalum valued at about $8 million recycled/reused. The old scrap recycling efficiency was calculated to be about 35%, and the recycling rate was about 21%. Tantalum contained in new scrap consumed was about 120 t. (See Appendix for definitions.)

GLOBAL GEOLOGIC OCCURRENCE OF TANTALUM

The principal source of tantalum is an isomorphous series of minerals that contain columbium (niobium), iron, manganese, and tantalum oxides. Tantalum and columbium have strong geochemical affinity and are found together in most rocks and minerals in which they occur. Tantalite-columbite, which is the major source for tantalum, occurs mainly as accessory minerals disseminated in granitic rocks or in pegmatites associated with granites. The proper name for the mineral is tantalite when tantalum predominates over columbium; when the reverse is true, the proper name is columbite. Economic mineral concentrations occur where, as in Nigeria or Southeast Asia, weathering has led to residual or placer deposits or where, as in the Bernic Lake deposit in Canada, the pegmatites contain a high concentration of these minerals. The microlite-pyrochlore mineral series is also a source of tantalum. These minerals consist essentially of complex oxides of calcium, columbium, sodium, and tantalum in combination with hydroxyl ions and fluoride(s). Microlite may contain as much as 70% tantalum oxide, and pyrochlore generally contains less than 10% tantalum oxide. Microlite occurs mainly in the albitized zones of granite pegmatites, often associated with tantalite or columbite. Struverite, which is a titanium-bearing oxide, is a low-grade source of tantalum that is recovered from tin-mining wastes in Southeast Asia. Struverite typically contains about 12% each of tantalum and columbium oxides (Cunningham, 1985; Crockett and Sutphin, 1993, p. 6-7).

Tantalum resources and reserves occur mainly in pegmatite deposits in Australia, Canada, Brazil, and several African countries. The largest tantalum reserves and resources are located in Australia where reserves are estimated to be about 25,000 t of contained tantalum. Canadian tantalum reserves are estimated to contain more than 3,000 t of contained tantalum. U.S. tantalum resources are of low grade, and none were considered economically minable in 1998.

PRODUCTION AND PRODUCTION PROCESSES

The United States, which has no tantalum mining industry, must import all its tantalum source materials for processing. Tantalum mineral production comes mostly from tantalite and columbite mining operations in Australia, Brazil and Canada, and from smaller mining operations in certain African countries. Australia, which is the largest producer, accounts for about 25% of the world's annual tantalum requirements. Also, Australia's Sons of Gwalia Ltd. has initiated expansion programs at its Greenbushes and Wodgina Mines to increase total tantalum production capacity to about 850 t of contained tantalum in mineral concentrate by 2003. Tantalum is also obtained from low- and high-grade tantalum-bearing tin slags, which is a byproduct from tin smelting, principally from Australia, Brazil, and Asia. Low-grade tin slags, however, must first be treated by a pyrometallurgical technique to upgrade them to a synthetic concentrate before delivery

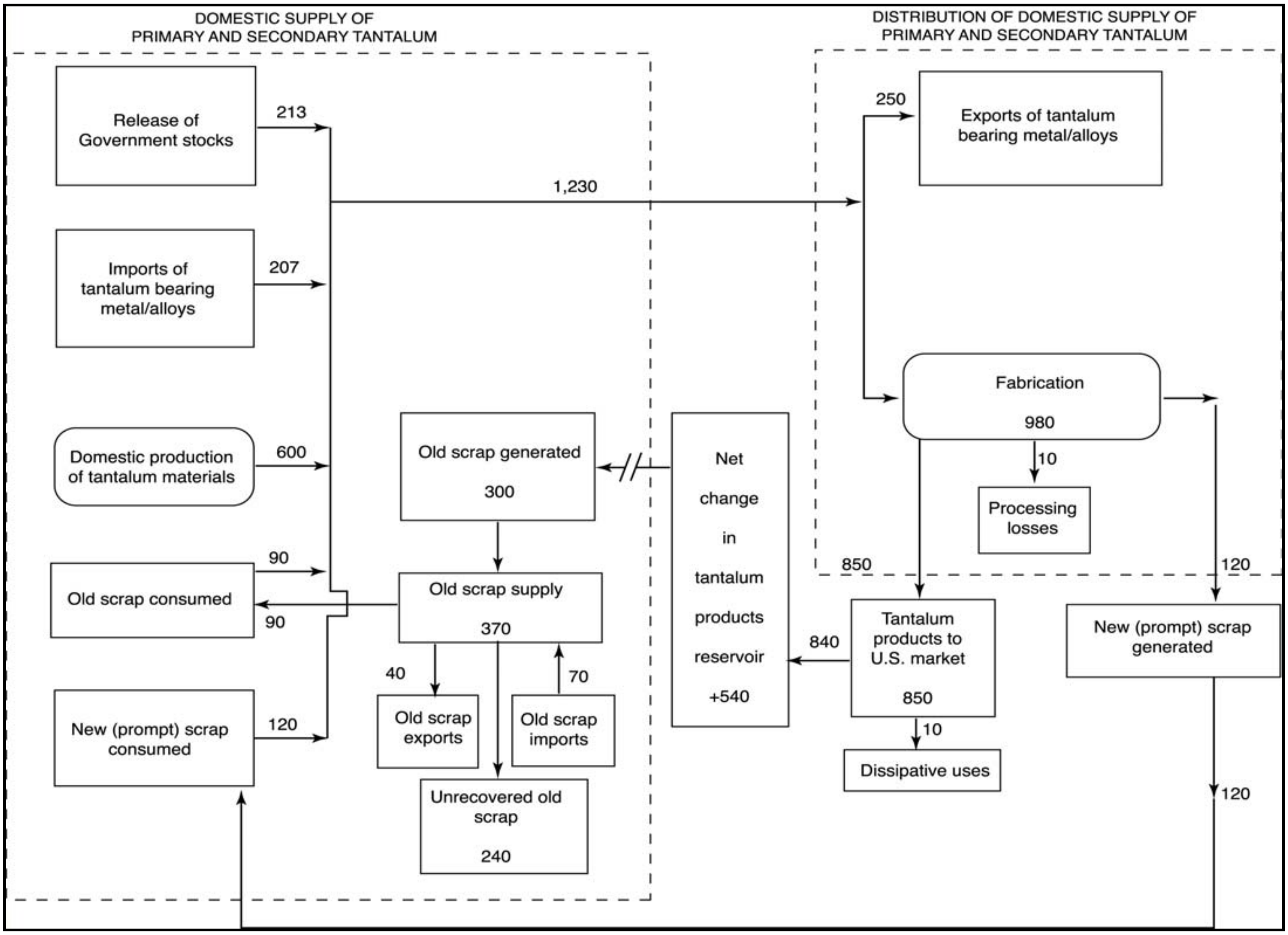

Figure 1. U.S. tantalum recycling flow, 1998, in metric tons contained tantalum.

to the tantalum extraction plant. The low-grade tin slag upgrading operation is performed in Germany. In past years, tantalum-containing tin slags were an important source of tantalum supply. Owing to structural changes in the tin industry, however, their importance has decreased with the exception of accumulated inventory. Thus, future tantalum supply will have a greater dependence on natural sources, such as tantalite-columbite.

Most tantalum-related mining operations in the past generally were small, relatively high-cost intermittent operations that depended on the recovery of byproduct or coproduct minerals for economic viability. Current mine development, however, has shifted more to primary tantalum sources, notably operations in Australia. Alluvial and residual tantalum and tantalum-containing tin deposits are normally mined by hand, hydraulic monitors, dredges, or mechanized open pit mining. The mining of pegmatite deposits, which may be either open pit or underground, is carried out by blasting, transporting, and crushing the rock to free the tantalum and associated coproduct minerals. The materials are then concentrated by wet gravity methods (sluices, jigs, spirals, and tables) and finally separated from associated minerals by gravity and electrostatic and electromagnetic processes. The extraction of tantalum from tantalum source materials involves dissolution with hydrofluoric acid followed by liquid-liquid extraction with methyl isobutyl ketone (MIBK). This procedure efficiently recovers tantalum in a form that then can be further processed into tantalum oxide and potassium fluotantalate. Potassium fluotantalate is reduced with metallic sodium to produce tantalum metal powder. The tantalum metal powder produced by the sodium reduction process is treated to convert the metal to a form suitable for use as capacitor-grade powder and as feedstock for tantalum wire and sheet. A solid-state reaction between tantalum oxide and carbon under vacuum conditions produces tantalum carbide (Cunningham, 1985; Tripp, 1997, p. 660-669).

Table 1. U.S. salient tantalum scrap statistics, 1998
[Metric tons tantalum content, unless otherwise specified]

Old scrap:	
Generated[1]	300
Consumed[2]	90
Value consumed (million dollars)	8
Recycling efficiency[3] (percent)	35
Supply[4]	370
Unrecovered[5]	240
New scrap consumed[6]	120
New-to-old scrap ratio[7] (percent)	57:43
Recycling rate[8] (percent)	21
U.S. net imports of scrap[9]	30
Value of U.S. net imports of scrap (million dollars)	2.7

[1]Tantalum content of products theoretically becoming obsolete in the United States in 1998. It excludes dissipative uses.
[2]Tantalum content of products that were recycled in 1998.
[3](Old scrap consumed plus old scrap exported) divided by (old scrap generated plus old scrap imports).
[4]Old scrap generated plus old scrap imports.
[5]Old scrap generated plus old scrap imports minus old scrap consumed minus old scrap exports.
[6]Prompt industrial scrap (excluding home scrap).
[7]Ratio of quantities consumed, in percent.
[8]This is the fraction of supply that is scrap on an annual basis. It is defined as old plus new scrap consumed divided by apparent supply [primary plus secondary production (old plus new scrap) plus imports minus exports plus adjustment for Government stock changes], in percent.
[9]Trade in scrap is assumed to be principally in old scrap.

USES

The principal end use for tantalum is in the production of electronic components, mainly in tantalum capacitors. In 1998, estimated end-uses for tantalum in the United States were electronic components, 65%; machinery, 21%; transportation, 9%; and other, 5%. U.S. tantalum consumption during the past 20 years is shown in figure 2.

Faced with runaway tantalum source material prices during the late 1970's and early 1980's, processors were forced to pass along a large part of the price increases to end users, which had the effect of a decrease in the use of tantalum. Because of escalating tantalum prices, consumers began to substitute alternate products, to decrease tantalum content in products, and to increase recycling to substitute for virgin tantalum products. In the consumer electronics sector, tantalum was designed out of some circuits and replaced primarily with aluminum-bearing electronic components.

A significant spike in tantalum demand occurred in 1984. U.S. factory sales of tantalum capacitors were at an alltime high. The computer and automotive markets were experiencing steady growth that fostered a need for greater miniaturization without sacrificing tantalum capacitor performance. In 1985, demand for tantalum capacitors from computer manufacturers declined significantly. Tantalum for cemented carbides also decreased owing to the growing popularity of coated cutting tools and the automotive industry's emphasis on producing smaller vehicles that require less metal cutting.

During the 1990's, the demand for tantalum was strong with increased consumption in most years. Demand was robust in the electronics sector for tantalum capacitors in such products as portable telephones, pagers, video cameras, personal computers, and automotive electronics. Overall growth in this sector, however, was slowed owing to the industry's continued emphasis on the miniaturization of electronic components, which results in less tantalum used per unit. The tantalum capacitor exhibits reliable performance and combines compactness and high efficiency with good shelf life.

Because of its high melting point (about 3,000 °C), good strength at elevated temperatures, and good corrosion resistance, tantalum is combined with cobalt, iron, and nickel to produce superalloys that are used in aerospace structures and jet engine components. Tantalum carbide, which is used mostly in mixtures with carbides of such metals as columbium, titanium, and tungsten is used in cemented-carbide cutting tools, wear-resistant parts, farm tools, and turning and boring tools. Owing to tantalum's excellent corrosion-resistant properties, tantalum mill and fabricated products are used for corrosion and heat-resistant chemical plant equipment, such as heat exchangers, heating elements, evaporators, condensers, and liners for reactors and pumps.

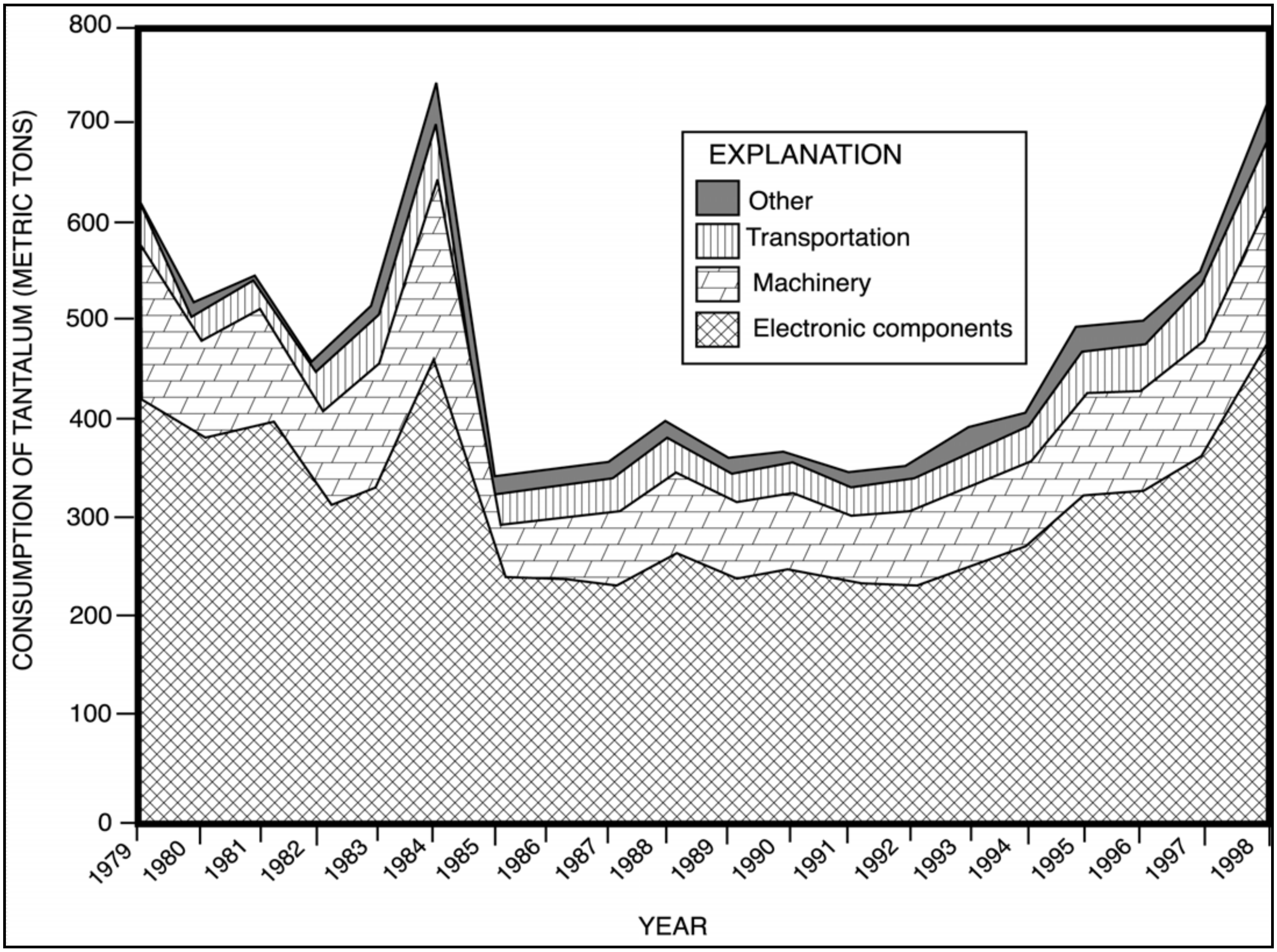

Figure 2. U.S. tantalum end-use patterns, 1979-98, in metric tons contained tantalum.

PRICES

Tantalum mineral concentrates (tantalite) are the main primary source of tantalum, and the price for tantalum products is affected most by events in the supply of and demand for tantalite. The price for tantalum metal products generally follows the pattern for that of tantalum concentrates. The price for tantalum metal products is also affected by the size of the order/contract and material specification. Events that had some impact on the tantalum price during the 1990's include robust demand for tantalum capacitors in the electronics sector, long-term tantalum mineral supply contracts between major producer and processors, and initiation of sales of tantalum materials from the National Defense Stockpile (Cunningham, 1999).

Figure 3 shows trends in the yearend average tantalum concentrate price from 1979 to 1998. In 1979-80, the price for tantalum source materials exploded. Tantalum source material production could not meet market demand, which resulted in sustained inventory reduction. With optimistic forecasts of market growth, processors found themselves locked into a bidding contest for available tantalum source materials. By yearend 1982, large high-cost inventories of tantalum source materials were accumulated as a hedge against perceived future shortages. By 1988, price increases for tantalum source materials were again of major concern in the tantalum industry. The yearend 1988 price for tantalite ore nearly doubled the yearend 1987 price. The price escalation was attributed to increased demand for tantalum source materials following a drawdown of the tantalum inventories that had been built up. The price for tantalum ore continued its cyclic pattern through 1993; thereafter, the price was steady with some moderate increases.

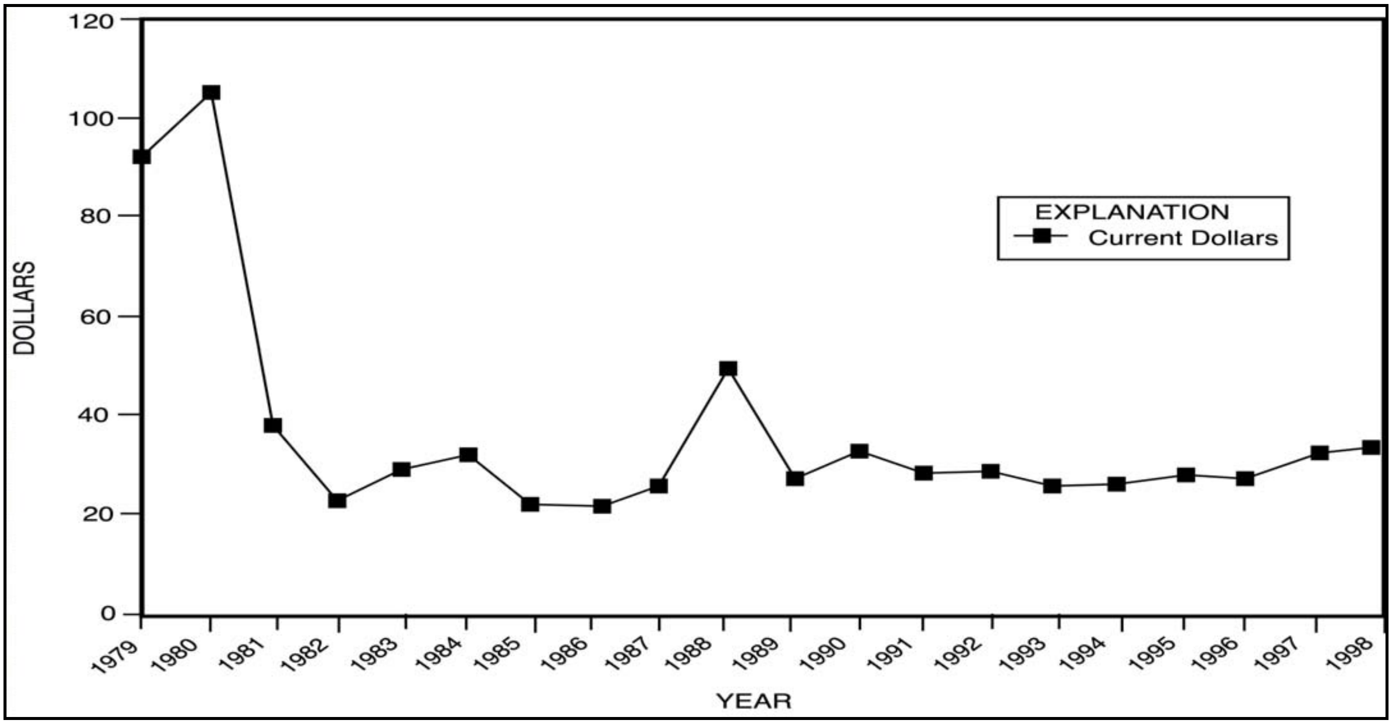

Figure 3. Yearend average tantalum concentrate price, 1979-98, in dollars per pound contained pentoxide. (Source: Metals Week, 1979-92, and Platt's Metals Week, 1993-98.)

In 1998, the Platt's Metals Week spot price for tantalite ore, which was based on contained Ta_2O_5, f.o.b. U.S. ports, began the year at a range of $32 to $34 per pound, rose to a range of $33 to $35 per pound in March, and remained at that level through December. For the year, the Metal Bulletin published price for tantalite ranged from $28.00 to $31.50 per pound of contained Ta_2O_5, and that for Greenbushes tantalite, Australia, which was based on 40% contained Ta_2O_5, was $40 per pound.

Industry sources indicated that the average selling prices per pound tantalum content for some tantalum products were as follows: capacitor-grade powder, $135 to $260; capacitor wire, $180 to $270; and vacuum-grade metal for superalloys, $75 to $100 (Mining Journal, 1999). In 1998, no public price for tantalum scrap was published. For this report, the price for tantalum contained in tantalum-bearing scrap was taken to be the average published price for tantalite ore (about $33.80 per pound of contained Ta_2O_5).

SOURCES OF TANTALUM SCRAP

The value of tantalum is a driving force for its recycling. The major end use, which is more than 60% in the production of electronic components, is mainly in tantalum capacitors. The amount of tantalum recycled from finished electronic components (old scrap), however, 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 (Tantalum-Niobium International Study Center, 1996).

Tantalum carbide is used mostly in the manufacture of cemented carbide inserts and tools for metal cutting and metalworking applications. Tools for metal cutting (estimated 1-year or less lifetime) account for an estimated 30% of total demand for cemented carbides. Cutting tool insert demand is dependent on the demand for and sales of durable goods, such as automobiles, which accounts for an estimated 40% of total cutting tool consumption. The cemented carbide inserts typically contain about 3% tantalum. Events that affect the use of cutting tools include the use of coatings, such as titanium carbide, which increases cutting tool efficiency; increased use of ceramic tools; and net shape metal forming processes that reduce the need for metal cutting (Santhanam, 1992; Roskill Information Services Ltd., 1999).

Superalloys are nickel- and cobalt-base materials used to make heat-resistant gas-turbine engine parts. Nickel-base superalloys are more widely used than cobalt-base superalloys. Tantalum is added to nickel-base superalloys to increase overall strength and to improve oxidation resistance of the alloy. The first major use for tantalum in superalloys was in alloys that contained up to 4% tantalum for use in jet-engine turbine blades in the early 1970's. In the 1980's, single crystal casting techniques led to the commercialization of Pratt & Whitney's nickel-based single crystal alloy, PWA 1480, which contains about 12% tantalum. Although tantalum is not recovered from the superalloy scrap that contains it, recycling of superalloy scrap is significant, and tantalum content, where applicable, can be reutilized. New tantalum-bearing scrap is generated from fabricators of parts made from superalloys. This type of scrap is usually quickly returned to superalloy melters for remelting. Some major sources for old tantalum-bearing scrap are discarded or obsolete parts made from superalloys, mostly jet engine components (estimated 20 year lifetime). Of the total superalloy scrap processed worldwide in 1996, about 70% was recycled into the same alloy; about 20%, downgraded; and the remaining 10%, sold to nickel refineries (Tantalum-Niobium International Study Center, 1982; ASM International, 1998).

DISPOSITION OF TANTALUM SCRAP

In 1998, the quantity of tantalum recycled/reused from old scrap represented about 7% of domestic tantalum supply. Because the United States has no tantalum mining industry, tantalum-bearing old scrap is a welcome addition to the tantalum supply chain. Of the estimated 370 t of tantalum contained in old scrap that was available for recycling in 1998, about 24% was used for domestic tantalum supply; about 65%, unrecovered; and the remainder, exported. Most of the unrecovered material was in the form of finished electronic equipment. Recycling of tantalum from old/discarded tantalum-containing electronic equipment has not been developed/used to any significant degree.

RECYCLING EFFICIENCY

Recycling efficiency shows the relation between what is theoretically available for recycling and what was recovered and not recovered. By definition, this relation was the amount of old scrap consumed plus exports divided by the sum of old scrap generated and scrap imports plus or minus scrap stock changes, as applicable. Most tantalum is recycled/reused in the form of tantalum-bearing cemented carbide and superalloy scrap. A tantalum recycling efficiency of about 35% was estimated to have been reached in 1998. The recycling efficiency would have been higher if not for the lack of a concerted program to reuse tantalum from its major end use, electronic components.

INFRASTRUCTURE

No tantalum was mined in the United States in 1998. Metal, alloys, and compounds, however, were produced mostly by three companies by using tantalum units obtained from imported tantalum-bearing concentrates and metal and from domestic and foreign scrap. Cabot Performance Materials, Boyertown, PA, had a production capability that ranged from raw material processing through to the production of tantalum end products; H.C. Starck Inc., Newton, MA, was a major supplier of tantalum products; and Kennametal Inc., Latrobe, PA, was a supplier of tantalum carbide. Tantalum consumption was mainly in the form of metal, powder, ingot, fabricated forms, compounds, and alloys in the electronics, superalloy, and cemented carbide sectors.

PM Recovery Inc. of Harrison, NY, which has been in operation since 1978, sorted, cleaned, and repackaged tungsten carbide and tantalum scrap at its Belfast, TN, facility. Hard-metal scrap, turnings, and sludges processed at the plant total about 900 metric tons per year (t/yr) (Cassidy, 2001). High-Temp Specialty Metals Inc., Willingboro, NJ, which was founded in 1983, was involved in the physical and chemical cleaning of molybdenum, tungsten, and tantalum scrap. Scrap was deoiled with water, soap, and orange oil. Leachates were evaporated, and salts were treated by E. I. du Pont de Nemours & Co. at its Deepwater, NJ, plant. Hi-Temp also leached tantalum capacitors to remove manganese and processed them to Ta_2O_5. Amlon Metals Inc. recycles about 200,000 t/yr of metal-bearing materials, which include tantalum. The company, which was founded about 1950, maintains offices in Australia, Brazil, China, India, Mexico, South Africa, Spain, Tanzania, the United States, and the United Kingdom (Cassidy, 2001). ECS Refining of Terrell, TX, was active in the recycling of electronic scrap, including integrated circuits and circuit boards. Components were either reused or processed for their metal content (Mossholder, 2001).

The U.S. International Trade Commission's Harmonized Tariff Schedule System categorizes some selected tantalum materials. The United States imports a significant amount of its tantalum requirements. In 1998, imports of tantalum metal and alloys totaled about 207 t of contained tantalum valued at about $56 million. Imports came mostly from China, Japan, and Thailand. Imports that were categorized as "waste and scrap" contained an estimated 70 t of tantalum scrap. China, Japan, and the United Kingdom were the major suppliers. Exports of tantalum metal and alloys totaled about 250 t of contained tantalum valued at about $72 million. Israel, Germany, Japan, and the United Kingdom were the major recipients of the materials. Exports of tantalum waste and scrap contained an estimated 40 t of tantalum scrap, with most of the material going to Germany, Hong Kong, Taiwan, and the United Kingdom.

PROCESSING OF TANTALUM-BEARING SCRAP

CEMENTED CARBIDES

The emphasis for recycling most cemented carbide scrap is to recover the contained tungsten. There is value, however, in the recovery of other metals, such as, tantalum. The choice of the process for recycling cemented carbide scrap depends on the concentration of tungsten, other metals, and the purity of the scrap. Recycling is mostly accomplished by using chemical or zinc processing methods. In the chemical process, carbide scrap with different contents of various metals, such as tantalum, are treated chemically to extract the tungsten and cobalt values first. The contained tantalum is collected in an oxide sludge, which is suitable as source material for the tantalum extraction plant (see section on "Production and Production Processes"). The advantage to this process is that almost any type of cemented carbide scrap can be reused and that the resultant product is equivalent to virgin material (Tantalum-Niobium International Study Center, 1984; Stjernberg and Johnson, 1998).

The zinc process uses hard scrap, such as used tool inserts, as the source material. This process is not a purification process, and careful sorting and pretreatment to remove oil, solder, and refractory coatings is essential for satisfactory reclamation. Zinc treatment dissolves the binder phase of the cemented carbide without changing the composition phase of the material. The composition of the carbide is conserved, and the treated carbide can be reused in a new batch of cemented carbides that requires the same or similar composition. At elevated temperatures, zinc metal is added to the scrap source material in a vacuum furnace, which results in a breakdown of the hard metal structure, thus allowing conversion into a powder form. Zinc is removed from the powder by distillation, and the powder can then be used directly in a blend with virgin carbides to manufacture cemented carbide parts (Tantalum-Niobium International Study Center, 1984, 1996).

The zinc process is less expensive than the chemical process, generates no waste products, and produces a powder essentially ready for use. That the chemical and the zinc processes complement each other results in better use of tantalum source materials. Excluding some special applications, cemented carbide scrap is recycled either by the chemical process (about 35%) or the zinc process (about 25%); the remaining material is not recycled (Tantalum-Niobium International Study Center, 1984; Stjernberg and Johnson, 1998).

SUPERALLOYS

The processing of superalloy scrap can be difficult and complicated. There are hundreds of superalloys that contain more than 20 alloying elements, and each element must be considered when designing and evaluating processes for separating and recovering the valuable metals. Each piece of superalloy scrap must be identified and its composition certified before it is sold. Turnings are degreased, fragmented, and compressed for remelting. Balers are used to compress superalloy scrap; shredders are rarely used. Superalloys are usually air melted or vacuum melted. Recycled scrap is acceptable for most air-melted alloys. Product specifications, however, usually prohibit the use of recycled scrap in vacuum-melted alloys to reduce the chance that detrimental impurities may be included in the final product, such as in critical components for jet engines. Owing to the high cost and/or periodic scarcity of superalloys, scrap recycling is used extensively (Gupta and Suri, 1994, p. 139-140; ASM International, 1998). Scrap is a preferred furnace charge for superalloy melters and can provide about 50% of a superalloy furnace charge. Scrap is prerefined, prealloyed, and easy to handle. New or home scrap turnings are the largest form of superalloy scrap. Vacuum-quality turnings are collected to produce a furnace-ready charge that can be easily melted. The first step is a qualitative verification of chemical purity to isolate severely contaminated material from chemically clean material. Turnings are crushed into chips, which are then cleaned of residual cutting fluids and dirt. Lot homogenization and certification follows; processed scrap is required to meet the same chemical requirements as the finished heat (Lane, 1998).

ELECTRONIC COMPONENTS

Although more than 60% of the tantalum that is consumed in the United States is in the electronics sector, the amount of tantalum recovered from obsolete electronic equipment is small. The trend toward higher capacitance tantalum powders and capacitor miniaturization promotes the use of less tantalum in products. Miniaturization, however, increases the amount of labor involved in recovery and provides less tantalum to be recovered when tantalum-bearing products are disassembled/recycled. One company processed capacitors by first leaching to remove manganese. The capacitors were then disintegrated by hydriding in a retort and calcined to Ta_2O_5 (Cassidy, 2001). Computers, which are a major end use for tantalum, have a life span, which includes reuse, of up to 7 years at which time their materials must be recycled or disposed. By 2005, about 64 million computers will have reached the end of their usefulness. Recycling of computers, however, can be difficult, because they contain a number of recyclable materials, some of which present environmental problems on disposal. Such materials as lead solder and mercury are common in most electronics. Computer and electronic equipment account for only about 1% of the total waste generated in the United States, but an estimated 70% of heavy metals that go to landfills results from this 1% (Resource Recycling, 2000a, b, 2001).

A small amount of workable used computers will be sold/reused through the resale market, and some will be donated to schools and nonprofit organizations. Demanufacturing, which is the disassembly of obsolete products, is one method to recycle electronic equipment, such as computers. In North America, more than 300 facilities harvest computer components, such as hard drives and circuit boards for resale value. Demanufacturing can be profitable, but barriers, such as the lack of an adequate collection infrastructure, limited and cyclical markets for recovered materials, and products that are not designed to be disassembled and recycled, exist. A major source of material for demanufacturing is institutions that frequently update equipment owing to software updates and technology requirements. Shredding is another option that can be used to recycle computer equipment. Components ranging from laptops to mainframes can be shredded and the materials separated. This is an efficient way to recycle large volumes of computers, such as units formerly leased to businesses (Recycling Today, 2000; Resource Recycling, 2000a, b; Mossholder, 2001; U.S. Geological Survey, 2001).

OUTLOOK

A 20-year pattern of U.S. tantalum consumption is shown in figure 2. The principal use for tantalum (more than 60%) as tantalum metal powder and wire in the production of electronic components, mainly tantalum capacitors, is expected to continue. This market sector is expected to be stimulated by the growth in the use of mobile telephones, which have a lifecycle of less than 2 years (Metal Bulletin Monthly, 2001). Each phone may contain from 10 to 20 capacitors. Development of tantalum recycling (old scrap) in the electronics sector, however, is very limited and represents a major potential for future tantalum recycling. Tantalum recycling in this area will have to be part of a total recycling concept for electronic equipment, requiring time and major effort/cooperation between the tantalum industry and the electronics equipment recyclers.

Concerns, factors, and issues that relate to disposal of obsolete/discarded electronic equipment include the need for a plan for disposition of stored surplus equipment and the disposition of the increasing volume of equipment being sold; State government initiatives that affect electronic equipment disposition; loss of offshore processing/recycling capacity; and the logistics for the collection/transport of used equipment to scrap processors/recyclers (Resource Recycling, 2000a). Although the United States has no mandatory electronic take back/recycling program, certain U.S. computer manufacturers have voluntary internal recycling programs to handle some leased and purchased equipment. Legislation in the European Union (EU), however, set new standards for sale of electronic equipment in Europe, including equipment manufactured outside the region. EU directives require companies to take back and recycle their electronic equipment and to phase out the use of various heavy metals, such as lead, in new equipment by 2008 (Metal Bulletin Monthly, 2001; Recycling Today, 2001)

Tantalum carbide in the metal-cutting industry will be dependent on the growth of the general economy and is expected to grow at an estimated 2% per year. Tantalum consumption in superalloys, mostly in the aircraft industry, is expected to grow by about 3% per year (Tantalum-Niobium International Study Center, 1996, 1998; Mining Journal, 2000). The rate at which tantalum is recycled in the carbide and superalloy sectors will depend on the rate at which tantalum-containing cemented carbides and superalloys are recycled.

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APPENDIX—DEFINITIONS

apparent consumption (AC). Primary plus secondary production (old scrap) plus imports minus exports plus adjustments for Government and industry stock changes.

apparent supply (AS). AC plus consumption of new scrap (CNS).

dissipative use. A use in which the metal is dispersed or scattered, such as paints or fertilizer, making it exceptionally difficult and costly to recycle.

home scrap. Scrap generated as process scrap and consumed in the same plant where generated.

new scrap. Scrap produced during the manufacture of metals and articles for both intermediate and ultimate consumption; it includes all defective finished or semifinished articles that must be reworked. Examples of new scrap are borings, castings, clippings, drosses, skims, and turnings. This includes scrap generated at facilities consuming old scrap. Included as new scrap is prompt industrial scrap obtained from a facility separate from the recycling refiner, smelter, or processor. Excluded from new scrap is home scrap that is generated as process scrap and used in the same plant.

new-to-old-scrap ratio. New scrap consumption compared with old scrap consumption measured in weight and expressed as a percentage of new plus old scrap consumed; for example 40:60.

old scrap. Scrap that includes, but is not limited to, metal articles that have been discarded after serving a useful purpose. Typical examples of old scrap are electrical wiring, lead-acid batteries, metals from shredded cars and appliances, silver from photographic materials, spent catalysts, tool bits, and used aluminum beverage cans. This is also referred to as "postconsumer scrap" and may originate from industry or the general public. Expended or obsolete material used dissipatively, such as paints and fertilizer, are not included.

old scrap generated. Metal content of products theoretically becoming obsolete in the United States in the year of consideration; this excludes dissipative uses.

old scrap recycling efficiency. Amount of old scrap recovered and reused relative to the amount available to be recovered and reused. Defined as [consumption of old scrap (COS) plus exports of old scrap (OSE)] divided by [old scrap generated (OSG) plus imports of old scrap (OSI), plus a decrease in old scrap stocks (OSS) or minus an increase in old scrap stocks], measured in weight and expressed as a percentage; that is,

$$\frac{\text{COS + OSE}}{\text{OSG + OSI + decrease in OSS or - increase in OSS}} \times 100.$$

old scrap supply. Old scrap generated plus old scrap imports plus old scrap stock decrease; that is,

$$\text{OSG + OSI + OSS decrease.}$$

old scrap unrecovered. Old scrap supply minus old scrap consumed minus old scrap exports minus old scrap stock increase; that is,

$$\text{OSS - COS - OSE - OSS increase.}$$

price. Unit value of contained tantalum in materials used in calculating total value of contained metal in scrap.

recycling. Reclamation of a metal in useable form from scrap or waste. This includes recovery as the refined metal or as alloys, mixtures, or compounds that are useful. Examples of reclamation are recovery of alloying (or base metals) in steel; recovery of antimony in battery lead; recovery of copper in copper sulfate; and even the recovery of a metal where it is not desired, but can be tolerated—such as tin from tinplate scrap that is incorporated in small quantities (and accepted) in some steels, only because the cost of removing it from tinplate scrap is too high and/or tin stripping plants are too few. In all cases, what is consumed is the recoverable metal content of scrap.

recycling rate. Fraction of the metal apparent supply that is scrap, on an annual basis. It is defined as consumption of old scrap plus consumption of new scrap divided by apparent supply measured in weight and expressed as a percentage; that is,

$$[(\text{COS + CNS})/\text{AS}] \times 100.$$

scrap consumption. Scrap added to the production flow of a metal or metal product.