COLUMBIUM (NIOBIUM) AND TANTALUM

By Larry D. Cunningham

Domestic survey data and tables were prepared by Robin C. Kaiser, statistical assistant, and the world production table was prepared by Regina R. Coleman, international data coordinator.

Columbium [Niobium (Nb)] is vital as an alloying element in steels and in superalloys for aircraft turbine engines and is in greatest demand in industrialized countries. It is critical to the United States because of its defense-related uses in the aerospace, energy, and transportation industries. Substitutes are available for some columbium applications, but, in most cases, they are less desirable.

Tantalum (Ta) is a refractory metal that is ductile, easily fabricated, highly resistant to corrosion by acids, a good conductor of heat and electricity, and has a high melting point. It is critical to the United States because of its defense-related applications in aircraft, missiles, and radio communications. Substitution for tantalum is made at either a performance or economic penalty in most applications. Neither columbium nor tantalum was mined domestically because U.S. resources are of low grade. Some resources are mineralogically complex, and most are not currently (2000) recoverable. The last significant mining of columbium and tantalum in the United States was during the Korean Conflict, when increased military demand resulted in columbium and tantalum ore shortages.

Pyrochlore was the principal columbium mineral mined worldwide. Brazil and Canada, which were the dominant pyrochlore producers, accounted for most of total estimated columbium mine production in 2000. The two countries, however, no longer export pyrochlore—only columbium in upgraded valued-added forms produced from pyrochlore.

Columbium (Niobium) and Tantalum in the 20th Century

Columbium.—Columbium (niobium) was discovered in 1801; prior to 1918, however, most U.S. interest in columbium was for experimental purposes. Commercial columbium usage began around 1925 when it was added to tool steel as a substitute for tungsten. In 1933, columbium (in the form of ferrocolumbium) was first used in stainless steel, and about 1935, columbium was added to superalloys for use in gas turbines. About 3.5 metric tons of columbium-bearing minerals valued at about $4,520 was reported shipped from domestic mines in 1935. Imports of columbium-bearing minerals were about 540 tons valued at about $107,000, with Nigeria accounting for most of the imports. Nigeria was the leading source for columbium-bearing minerals, and the country shipped its entire output to the United States.

In 2000, there was no domestic columbium mining, and the United States satisfied its columbium requirements primarily by importing ferrocolumbium and columbium oxide from Brazil, ferrocolumbium from Canada, and columbium-bearing mineral concentrates for processing mainly from Australia and Nigeria. U.S. columbium imports totaled about 6,500 tons of contained columbium valued at about $110 million. Brazil and Canada were the world's largest producers of columbium minerals, together accounting for more than 95% of the total. Ferrocolumbium and columbium metal, alloys, and compounds were produced in the United States by six companies located mostly in the eastern United States. Columbium consumption in the United States was mainly as ferrocolumbium by the steel industry and as high-purity columbium alloys and metal by the aerospace industry. Steelmaking accounted for more than 75% of reported columbium consumption, with the value of consumption estimated to be about $70 million.

Tantalum.—Tantalum was discovered in 1802. Commercial use of tantalum began in Germany in 1903 with the production of tantalum wire to replace carbon in incandescent light filaments. By 1909, tungsten began to replace tantalum in filaments, and by 1912, the substitution was complete. During this period, U.S. tantalum requirements were imported from Germany. By 1918, U.S. demand for tantalum for experimental purposes was large enough that about 2 metric tons of tantalum-bearing minerals valued at about $2,250 was marketed from material mined in South Dakota. Tantalum carbide was produced in the United States in 1929, and the tantalum capacitor was developed in 1940. There was no reported domestic tantalum mine production in 1940, and U.S. imports of tantalum minerals totaled about 222 tons valued at about $260,000. Australia was thought to be the major producer of tantalum minerals at that time.

In 2000, there was no domestic tantalum mining, and the United States satisfied its tantalum requirements by importing alloys, metal, and powder from China, Japan, and Thailand, and tantalum-bearing mineral concentrates for processing mainly from Australia, Canada, and Nigeria. U.S. tantalum imports totaled more than 900 tons of contained tantalum valued at more than $190 million. Australia was the world's largest producer of tantalum mineral concentrates and accounted for more than 60% of U.S. imports. Tantalum metal, alloys, and powders were produced in the United States by three companies located in the eastern part of the United States. The major use (more than 60%) for tantalum as tantalum metal powder was in the production of electronic components, mainly tantalum capacitors. Tantalum was also consumed in cemented carbides and in superalloys. The value of tantalum consumed in the United States in 2000 was estimated to be about $200 million.

Brazil exported mostly regular-grade ferrocolumbium and columbium oxide, and Canada exported regular-grade ferrocolumbium. The remaining columbium mineral supply came from the mining of columbite in Nigeria and tantalite-columbite, mostly in Australia, Brazil, and certain African countries. Tantalum mineral was produced mostly from tantalite-columbite mining operations in Australia, which was almost 60% of total estimated tantalum mine production in 2000, and from other tantalum mine operations in Brazil, Burundi, Canada, Congo (Kinshasa), Ethiopia, Nigeria, and Rwanda. The reliance on tantalum-containing tin slags as a source of tantalum supply remained low.

The United States remained dependent on imports of columbium and tantalum materials; Brazil was the major source for columbium, and Australia, the major source for tantalum. The Defense National Stockpile Center (DNSC) offered and sold selected columbium and tantalum materials from the National Defense Stockpile (NDS). The Generalized System of Preferences (GSP), a renewable preferential trade program, was extended to September 30, 2001. Columbium price quotations remained stable. Tantalum price quotations for tantalite ore escalated amidst concerns about the status of the world tantalum supply. Overall reported consumption of columbium in the form of ferrocolumbium and nickel columbium increased, with demand for columbium in superalloys up significantly. Tantalum consumption increased.

Legislation and Government Programs

Summaries of important columbium and tantalum statistics are listed in tables 1 and 2, respectively. To ensure supplies of columbium and tantalum during an emergency, various materials have been purchased for the NDS. The Stockpile goals, effective as of October 5, 1999, for tantalum metal powder and tantalum metal (contained tantalum) were about 16 metric tons (t) and about 55 t, respectively (table 3). The NDS had no goals for columbium materials. For fiscal year (FY) 2000 (October 1, 1999, through September 30, 2000), the DNSC sold about 182 t of columbium contained in ferrocolumbium valued at about $2.8 million, and about 9 t of columbium contained in columbium metal ingots valued at about $567,000 and disposed of about 80 t of columbium contained in tantalum minerals that were sold in FY 2000; no columbium value was obtained, as the columbium was contained within the tantalum minerals. Additionally, the DNSC sold about 2 t of tantalum contained in tantalum carbide powder valued at about $254,000, about 23 t of tantalum contained in tantalum metal powder valued at about $3.67 million, about 18 t of tantalum contained in tantalum metal ingots valued at about $3.84 million, about 134 t of tantalum contained in tantalum minerals valued at about $42.7 million, and about 9 t of tantalum contained in tantalum oxide valued at about $1.32 million. As of September 30, 2000, columbium and tantalum inventory sold but not shipped from the NDS included about 37 t of columbium contained in ferrocolumbium and about 106 t of tantalum contained in tantalum minerals (U.S. Department of Defense, 2001, p. 14, 15, 43, 45, 47, 48).

In its revised Annual Materials Plan (AMP) for FY 2001 (October 1, 2000, through September 30, 2001) and proposed AMP for FY 2002 (October 1, 2001, through September 30, 2002), the DNSC had authority to sell about 10 t of columbium contained in columbium carbide powder (actual quantity limited to the remaining sales authority or inventory), about 254 t of columbium contained in columbium concentrates, about 68 t of columbium contained in ferrocolumbium (actual quantity limited to the remaining sales authority or inventory), about 9 t of columbium contained in columbium metal ingots, about 2 t of tantalum contained in tantalum carbide powder, about 23 t of tantalum contained in tantalum metal powder (actual quantity limited to the remaining sales authority or inventory for FY 2002), about 18 t of tantalum contained in tantalum metal ingots (actual quantity limited to the remaining sales authority or inventory for FY 2002), about 227 t of tantalum contained in tantalum minerals, and about 9 t of tantalum contained in tantalum oxide (Defense National Stockpile Center, 2001a, b). For FY 2001, through June 30, 2001, the DNSC sold about 48 t of columbium contained in ferrocolumbium valued at about $1.29 million, about 9 t of columbium contained in columbium metal ingots valued at about $142,000, about 20 t of tantalum contained in tantalum capacitor-grade metal powder valued at about $14.3 million, about 18 t of tantalum contained in tantalum metal ingots valued at about $16.1 million, about 2 t of tantalum contained in tantalum carbide powder valued at about $1.34 million, and about 11 t of tantalum oxide valued at about $2.55 million.

Under the GSP, the United States grants duty-free access to eligible products from designated developing countries. In 2000, U.S. import duties for selected columbium and tantalum materials ranged from duty free to 8.5% ad valorem for normal-trade-relations (NTR) status and from duty free to 45% ad valorem for non-NTR status (U.S. International Trade Commission, 1999). In March, the GSP program, which expired on June 30, 1999, was renewed through September 30, 2001, retroactive to July 1, 1999, by a provision in the Ticket To Work and Work Incentives Improvement Act of 1999. Customs began processing refunds due to the renewal on January 7, 2000 (U.S. Customs Service, 2000). Categories of U.S. imports from developing countries affected by the GSP included all columbium and tantalum tariff articles except columbium and tantalum ores and concentrates, synthetic tantalum-columbium concentrates, and columbium and tantalum unwrought waste and scrap, for which the general rate of duty already was zero.

Production

Neither columbium nor tantalum was mined domestically in 2000. Domestic production data for ferrocolumbium are developed by the U.S. Geological Survey from the annual voluntary domestic survey for ferroalloys. Ferrocolumbium production data for 2000 were, however, incomplete at the time this report was prepared.

Cabot Performance Materials, Boyertown, PA, had production capability that ranged from raw material processing through the production of columbium and tantalum end products. In September, Cabot proceeded with the company’s decision to close its Revere, PA, plant, which had produced high-purity ferrocolumbium and nickel columbium. Shieldalloy Metallurgical Corp., Newfield, NJ, was a producer of ferrocolumbium. H.C. Starck Inc. was a major supplier of tantalum and columbium products. Reading Alloys Inc., Robesonia, PA, and Wah Chang, Albany, OR, were major producers of high-purity columbium products. Kennametal Inc., Latrobe, PA, was a major supplier of columbium and tantalum carbides (table 9).

In July, KEMET Corp., Greenville, SC, announced planned expansion of more than 7,900 square meters (m^2) of manufacturing floor space in South Carolina and Mexico dedicated to the production of solid tantalum and conductive polymer tantalum capacitors. With increasing customer demand for capacitors, KEMET, a major world maufacturer of tantalum capacitors, indicated that the capacity expansions would ensure the company's ability to provide high-value tantalum and high-frequency organic tantalum capacitors to meet its customers' needs. About 1,000 m^2 of manufacturing space would be created with additions in Mauldin and Greenwood, SC; relocation of support functions in Simpsonville, SC, would add 418 m^2; and construction of a new facility in Matamoros, Mexico, would add 6,500 m^2. The new capacity at each facility would be used to increase production rates for solid tantalum surface-mount capacitors. New capacity in Mauldin and Simpsonville would also increase production rates for KEMET's new high-performance conductive polymer tantalum capacitor. The expansions were expected to add approximately 1,100 new jobs (KEMET Corp., 2000b).

In November, KEMET announced a memorandum of understanding with Australasian Gold Mines NL (AGM) to establish a 50-50 joint venture, which would own and fund development of AGM's existing tantalum projects, including a pilot-processing plant at Dalgaranga, Australia. The feasibility of future mining and commissioning of full-scale plants would be determined. KEMET would purchase processed tantalum products from the pilot plant and any future processing development. The material would be toll converted into tantalum powder necessary for the production of capacitors. In February 2001, KEMET announced completion of the joint-venture agreement with AGM. KEMET's initial investment in the venture would be approximately \$5.5 million, and KEMET would acquire a 10% interest in AGM for approximately \$2.5 million. When full-scale mining operation is achieved, KEMET anticipates that the venture could ultimately provide up to 10% to 15% of its total annual tantalum requirements (KEMET Corp., 2000a; 2001).

Consumption

Overall U.S. reported consumption of columbium as ferrocolumbium and nickel columbium rose by almost 20% compared with that of 1999 (table 4). Consumption of columbium by the steelmaking industry increased by more than 10% as a result of an increase in raw steel production, with consumption up in all major reported steel end-use categories. Demand for columbium in superalloys increased significantly to more than 940 t, reflecting strong demand from the aerospace industry. That portion used in the form of nickel columbium increased to about 600 t. Overall U.S. apparent consumption of all columbium materials was estimated to be about 4,300 t, compared with about 4,100 t in 1999.

Estimated overall U.S. apparent consumption of all tantalum materials increased by more than 15% to about 650 t, owing to continued strong demand for tantalum powder for the production of tantalum capacitors. More than 60% of total tantalum consumed was in the electronics industry. Major end uses for tantalum capacitors included portable telephones, pagers, personal computers, and automotive electronics. Tantalum consumption was also affected by increased demand for tantalum-containing superalloys for jet engine and gas turbine components.

Columbium.—"Columbium" and "niobium" are synonymous names for the chemical element with atomic number 41; "columbium" was the name given in 1801, and "niobium" was the name officially designated by the International Union of Pure and Applied Chemistry in 1950. The metal conducts heat and electricity well and is characterized by a high melting point (about 2,470 °C), resistance to corrosion, and ease of fabrication.

Columbium in the form of ferrocolumbium is used worldwide, mostly as an alloying element in steels and in superalloys. Because of its refractory nature, appreciable amounts of columbium in the form of high-purity ferrocolumbium and nickel columbium are used in nickel-, cobalt-, and iron-base superalloys for such applications as jet engine components, rocket subassemblies, and heat-resisting and combustion equipment. Columbium carbide is used in cemented carbides to modify the properties of the cobalt-bonded tungsten carbide-based material. It is usually used with carbides of such metals as tantalum and titanium. Columbium oxide is the intermediate product used in the manufacture of high-purity ferrocolumbium, nickel columbium, columbium metal, and columbium carbide. Acceptable substitutes, such as molybdenum, tantalum, titanium, tungsten, and vanadium, are available for some columbium applications, but substitution may lower performance and/or cost effectiveness.

Tantalum.—The major use for tantalum as tantalum metal powder is in the production of electronic components, mainly tantalum capacitors. The tantalum capacitor exhibits reliable performance and combines compactness and high efficiency with good shelf life. Applications for tantalum capacitors include computers, communication systems, and instruments and controls for aircraft, missiles, ships, and weapon systems. 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. Because of tantalum's excellent corrosion-resistant properties, tantalum mill and fabricated products are used in the chemical industry in such applications as heat exchangers, evaporators, condensers, pumps, and liners for reactors and tanks. 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.

Prices

Published prices for pyrochlore concentrates produced in Brazil and Canada were not available because these concentrates were consumed internally by producers of regular-grade ferrocolumbium and are no longer being exported. A price for Brazilian pyrochlore has not been available since 1981, and the published price for pyrochlore produced in Canada was discontinued in early 1989. The columbium price is affected most by the availability of regular-grade ferrocolumbium produced from pyrochlore. The American Metal Market published price for regular-grade ferrocolumbium ranged from

$6.75 to $7 per pound of contained columbium and has not changed since September 1997.

The Metal Bulletin price for columbite ore, which is based on a minimum 65% contained columbium oxide (Nb_2O_5) and tantalum oxide (Ta_2O_5), quoted since February 1995 at a range of $2.80 to $3.20 per pound, rose to a range of $5.50 to $7 in late November, where it remained through December. The American Metal Market published price for high-purity (vacuum-grade) ferrocolumbium ranged from $17.50 to $18 per pound of contained columbium and has not changed since September 1997. Industry sources indicated in December 1999 that nickel columbium sold at about $18.50 per pound of contained columbium, columbium metal products sold in the range of about $24 to $100 per pound in ingot and special shape forms, and columbium oxide for master alloy production sold for about $8.80 per pound (Mining Journal, 1999a; Tantalum-Niobium International Study Center, 1999a, p. 5). Significant events affecting columbium prices since 1958 include the following: 1960-70, development of pyrochlore deposits in Brazil and Canada; 1970-79, increased demand and rising prices; 1980, columbium oxide produced from pyrochlore-based feed material; 1981, exports of Brazilian pyrochlore ceased; 1994, production of ferrocolumbium began in Canada; 1997-98, sales of ferrocolumbium from the NDS; and 1998, expansion of ferrocolumbium production capacity in Brazil (Cunningham, 1999a).

The price for tantalum products is affected most by events in the supply of and demand for tantalum minerals. During 2000, published prices for tantalite ore (per pound contained oxide) rose significantly: Platt's Metals Week, rose to a range of $145 to $175 from a range of $33 to $35; Metal Bulletin, rose to a range of $180 to $240 from a range of $28 to $31.50; and Ryan's Notes, rose to a range of $250 to $300 from a range of $45 to $48. Strong global demand and an apparent shortage of tantalum source materials for processing contributed to the price increase. In 2000, sales of tantalum minerals from the NDS averaged about $118 per pound contained tantalum oxide. In July 2001, published prices for tantalite ore (per pound contained oxide) were as follows: Platt's Metals Week, a range of $75 to $100; Metal Bulletin, a range of $55 to $75; Ryan's Notes, a range of $48 to $55. The decrease in price reportedly was due in part to excess tantalum inventories and a downturn in tantalum demand from the electronics sector. The Metal Bulletin published price for Greenbushes tantalite ore, Australia, was $40 per pound contained oxide and has not changed since April 1991. The most recent industry source (August 1999) on tantalum product prices indicated that the average selling prices per pound of contained tantalum 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, 1999b). Presumably these prices increased in 2000, based on the escalating price for tantalum ore, but public information on prices for these products was not available. Significant events affecting tantalum prices since 1958 include the following: 1979-80, tantalum price accelerates to record levels; 1982, industry's accumulation of large tantalum material inventories; 1988, drawdown of tantalum material inventories by processors; 1990, purchase of tantalum materials for the NDS; 1991, long-term tantalum supply contracts between major producer and processors; and 1998, sales of tantalum minerals from the NDS (Cunningham, 1999b).

Foreign Trade

Table 5 lists columbium and tantalum export and import data. Net trade for columbium and tantalum continued at a deficit. Overall trade value for exports increased significantly with total volume down slightly. In descending order, Israel, the United Kingdom, Japan, Germany, and China were the major recipients of the columbium and tantalum materials, on the basis of value, with more than 80% of the total. For imports, overall trade value was up by about 35%, with total volume up by more than 10%. In descending order, Brazil, Japan, Australia, China, Germany, and Canada were the major sources of columbium and tantalum imports, on the basis of value, with more than 70% of the total.

Imports for consumption of columbium ores and concentrates increased by about 60% (table 6); imports from China accounted for more than 20% of quantity and value. Imports at an average grade of approximately 30% Nb_2O_5 and 31% Ta_2O_5 were estimated to contain about 30 t of columbium and about 40 t of tantalum. Ferrocolumbium and columbium oxide imports were down slightly; Brazil accounted for more than 80% of U.S. ferrocolumbium imports and about 40% of columbium oxide imports.

Imports for consumption of tantalum ores and concentrates increased twofold (table 7); imports from Australia accounted for more than 60% of quantity and about 55% of value. Imports at an average grade of approximately 37% Ta_2O_5 and 18% Nb_2O_5 were estimated to contain about 610 t of tantalum and about 270 t of columbium.

The schedule of tariffs applied during 2000 to U.S. imports of selected columbium and tantalum materials is found in the Harmonized Tariff Schedule of the United States—2000 (U.S. International Trade Commission, 1999). Brazil, which was the major source for U.S. columbium imports, accounted for about 68% of total, in units of contained columbium (figure 1), and Australia, which was the major source for U.S. tantalum imports, accounted for about 48% of total, in units of contained tantalum (figure 2).

Net import reliance as a percent of apparent consumption is used to measure the adequacy of current domestic columbium and tantalum production to meet U.S. demand. For columbium in 2000, net import reliance as a percent of apparent consumption was 100%. For tantalum, net import reliance as a percent of apparent consumption was estimated to be about 80%.

World Review

Industry Structure.—Principal world columbium and tantalum raw material and product producers are listed in tables 8 and 9, respectively. Annual world production of columbium and tantalum mineral concentrates, by country, is listed in table 10. Brazil and Canada were the major producers of columbium mineral concentrates, and Australia, Brazil, Canada, and Congo (Kinshasa) were the major producers of tantalum mineral concentrates. The importance of tantalum-containing tin slags as a source of tantalum supply has decreased owing to structural changes in the tin industry. Tantalum-containing tin slags account for about 18% of tantalum supply compared with about 70% 20 years ago (Mining Journal, 2000b; Tantalum-Niobium International Study Center, 1998, p. 2-6).

Australia.—For its 1999-2000 financial year ending June 30, 2000, Sons of Gwalia Ltd., West Perth, Western Australia, reported that tantalum production (tantalum oxide contained in mineral concentrates) totaled about 505 t at its Greenbushes and Wodgina Mines and that tantalum sales totaled about 500 t. Greenbushes production was about 315 t, and sales, about 314 t. Production at Wodgina was about 190 t, and sales, about 186 t. Existing "main production" at Greenbushes will be exhausted in 1993. Annual production capacity at Greenbushes is planned to be expanded from about 320 t to about 590 t. The existing processing facility will be expanded from about 1.6 million metric tons (Mt) of ore to more than 2.75 Mt. Preproduction capital cost for underground development at the mine, and capital cost for expansion of the existing processing facilities, total about $65 million. At Wodgina, annual production capacity will be increased over the next 2 years to more than 450 t, with plant processing capacity increasing to at least 2 Mt of ore. Capital cost for the Wodgina expansion will be approximately $35 million. By 2003, total company annual sales of contained tantalum oxide were expected to build to at least about 1,040 t. Forecast production increases from development of an underground operation at Greenbushes and the plant expansions at Greenbushes and Wodgina were expected within 3 years, with construction activities scheduled to commence in early 2001. Greenbushes existing production and the increased production from the Wodgina expansion were committed to Cabot Corp. and H.C. Starck of Germany under long-term contracts through to calender year 2005 (Sons of Gwalia Ltd., 2000, p. 7, 22-26).

In its quarterly report for March 31, 2001, Sons of Gwalia reported that Greenbushes tantalum "resource base" was about 44,000 t of contained tantalum oxide, including about 20,400 t classified as tantalum reserves. As a result of a successful drilling program, Wodgina's tantalum "resource base" doubled to about 27,200 t of contained tantalum oxide, including about 24,000 t classified as tantalum reserves (Sons of Gwalia Ltd., 2001, p. 9, 10).

Brazil.—Cia. Brasileira de Metalurgia e Mineração (CBMM), which was the world's largest columbium producer, completed its $80 million expansion program that was initiated in 1998. Annual columbium ore concentration capacity was increased to about 84,000 t of concentrate, and annual ferrocolumbium capacity increased to about 45,000 t. The new concentration plant uses a pyrometallurgical process, which replaced a leaching plant. In 2000, CBMM was expected to produce about 51,000 t of concentrate, about 30,000 t of ferrocolumbium, and about 2,000 t of columbium oxide for use in the aerospace industry. In 1999, CBMM reportedly produced about 40,000 t of concentrate and about 25,000 t of ferrocolumbium. For 2001, CBMM planned to increase concentrate output to about 55,000 t and to increase ferrocolumbium output to about 33,000 t. CBMM was said to export 95% of its ferrocolumbium production, mostly to Europe and North America, 35% each, and to Japan, 16% (American Metal Market, 2000; TEX Report, 2000).

Canada.—Production of columbium oxide contained in pyrochlore concentrate at the Niobec Mine near Chicoutimi, Quebec, was about 3,270 t compared with about 3,370 t in 1999. Niobec was a 50-50 joint venture between Cambior Inc. (product marketing), and Teck Corp. (operator). Columbium contained in ferrocolumbium production was about 2,170 t compared with about 2,290 t in 1999. Pyrochlore-to-ferrocolumbium converter recovery was 96.2% compared with 97.1% in 1999. Ore milled increased to 907,000 t as the mill operated, on the average, at about 2,480 metric tons per day. Average recovery decreased to 54.6%, with the Nb_2O_5 grade of concentrate at 66%. Operating cost, dollars per metric ton of ore milled, was about $37.30 compared with about $36.10 in 1999. Capital expenditures were $9 million, including $7 million for expansion of mill and converter capacities. For 2001, capital costs were forecast at $3 million, including $2 million for underground development and equipment. Teck reported proven and probable ore reserves of 11.5 Mt grading 0.51% columbium. In November, Teck reached an agreement to sell its 50% interest in Niobec to Mazarin Inc., Quebec, for $47 million. The transaction was expected to be closed in the first half of 2001, with Teck expecting to record a pretax gain of $25 million on the sale (Cambior Inc., 2001, p. 11; Teck Corp., 2001, p. 24, 32, 58). As part of its financial restructuring, Cambior entered into an agreement with Jipangu Inc., a Japanese investment company, and a financial institution for a mortgage loan on its 50% interest in Niobec for $13 million. The term was for 4.5 years repayable in 16 consecutive quarterly installments commencing on March 30, 2001, with a maturity date of December 31, 2004. The mortgage was secured by Cambior's 50% interest in Niobec and its share of the cash flow generated by the mine. On January 18, 2001, Jipangu agreed to a $6.3 million private placement to subscribe to 15 million common shares of Cambior at a price of $0.42 per share, with proceeds from the private placement used to repay in part Jipangu's mortgage loan (Cambior Inc., 2001, p. 24, 25, 37).

In 2000, about 69 t of tantalum oxide contained in concentrate was produced at the Bernic Lake, Manitoba, tantalum operation, compared with about 66 t in 1999.

In October, it was reported that Avalon Ventures Ltd., Toronto, had finalized a joint-venture agreement with Global Canada Co., a private Nova Scotia company controlled by BSAV Inc., a private Delaware company. Global would have the right to earn up to 75% interest in any of Avalon's Canadian tantalum exploration properties, Lilypad Lakes, Raleigh Lake, and East Braintree. Global would have the right to earn an initial 50% interest in any of the properties by providing $5 million in exploration and development funding before December 31, 2002, or upon delivery of a feasibility study. The interest in any one property could be increased to 75% by Global arranging financing to bring a tantalum mine into production. Initial commitment by Global was to provide $1 million to fund work programs on the properties and to provide working capital. The program had a budget of $750,000 to be spent by December 31, 2000. Avalon would be the operator of the exploration programs, and Global would have the right to participate in any other tantalum exploration properties acquired by Avalon in Canada. Lilypad Lakes near Pickle Lake, Ontario, had top priority with a program budget of $580,000. A preliminary diamond drilling program completed in April intersected tantalum mineralization occurrences averaging 0.05 % Ta_2O_5 across 11.5 meters (m), 0.036% Ta_2O_5 across 24 m, and 0.076% Ta_2O_5 across 7 m. In addition, a surface program involving mapping, sampling, lithogeochemistry, and a gravity survey discovered a new high-grade tantalum occurrence. Assays of 10 random samples indicated tantalum ranging from 0.131% to 0.422% Ta_2O_5. A minimum 1,100-m diamond drilling program was scheduled to begin on the property in November (Avalon Ventures Ltd., 2000a, b;

Skillings Mining Review, 2000).

China.—China's Jiujiang Nonferrous Metals Smelter, eastern Jiangxi Province, completed an upgrade to its tantalum production line which increased annual production capacity to about 20 t from 2 t to 3 t. Existing production ceased in January and new production started in mid-August. However, owing to raw material shortages, output was expected to reach only about 4 t by January 2001. Jiujiang's annual columbium production capacity was about 20 t, with output in 2000 expected to be about 15 t. Annual production capacity for tantalum oxide and columbium oxide was about 100 t and 300 t, respectively, with tantalum oxide output in 2000 expected to be about 70 t and columbium oxide output about 100 t. In 1999, tantalum oxide output was about 60 t and columbium oxide output about 100 t (Platt's Metals Week, 2000).

Congo (Kinshasa).—In June, the President of the Security Council, United Nations, requested the Secretary-General to establish a panel of experts on the illegal exploitation of natural resources and other forms of wealth of the Democratic Republic of the Congo for a period of 6 months. The report of the panel was transmitted to the President on April 12, 2001. The panel's recommendations revolved around six broad themes: "(1) sanctions against countries and individuals involved in the illegal activities; (2) preventive measures to avoid a recurrence of the current situation; (3) reparations to the victims of the illegal exploitation of natural resources; (4) design of a framework for reconstruction; (5) improvement of international mechanisms and regulations governing some natural resources; and (6) security issues." Categories that were of primary consideration included coltan (columbium and tantalum). Some of the panel's recommendations for Security Council action included an immediate temporary embargo on the import or export of coltan and pyrochlore; the freezing of financial assets of the rebel movements and their leaders; the freezing of financial assets of the companies or individuals who continue to participate in the illegal exploitation of the natural resources of the Congo immediately after publication of the report; and the declaration of an immediate embargo on supply of weapons and all military material to rebel groups operating in Congo (United Nations, 2001).

Greenland.—Angus and Ross plc, a United Kingdom company with tantalum interest in Ireland, received a licence from the Greenland Government for rights to explore for tantalum in southern Greenland centered in an area 20 kilometers east of the southern capitol of Narsarsuaq. The area of interest is the Motzfeld Centre, an alkaline igneous ring complex, with pyrochlore the most important economic mineral phase. Data suggest that resources could be about 50 Mt of ore grading in the range of 0.03% to 0.1% Ta_2O_5, and about 130 Mt of ore grading in the range of 0.4% to 1% Nb_2O_5, with some zones in the range of 1% to 1.5% Nb_2O_5. Mineralogy of the area was said to be complex and mineral processing problems remain to be addressed (Mining Journal, 2000a).

Japan.—In 2000, Japan's demand for tantalum was about 552 t; powder, 269 t; compounds,157 t; and products, 126 t. Demand for tantalum powder was met by imports from China, Thailand, the United States, and domestic production from imported potassium fluotantalate. Imports of potassium fluotantalate totaled about 1,140 t, sufficient for the production of about 378 t of tantalum powder. Production of tantalum powder for the electronics sector was about 386 t. Demand for tantalum wire used in tantalum capacitors was met entirely by imports, about 68 t, mostly from the United States. Tantalum imports (powder, compounds, and products) in 2000 were about 139 t compared with about 98 t in 1999. In 2000, apparent consumption of tantalum powder, wire, and products was 269 t, 69 t, and 57 t, respectively. In 2001, tantalum demand is forecast to fall to about 462 t; powder, 225 t; compounds, 127 t; and products, 110 t (Roskill's Letter from Japan, 2001b). Tantalum scrap imported for the production of tantalum powder, compounds, and products was about 203 t; Portugal, the United Kingdom, and the United States accounted for about 75% of the imports. In 2000, Japan's production of tantalum capacitors totaled about 8.67 billion units compared with about 6.54 billion units in 1999. Tantalum capacitor exports in 2000 were about 3.24 billion units compared with about 2.56 billion units in 1999 (Roskill's Letter from Japan, 2001a).

Russia.—At yearend 1999, the Chita region made a decision to join a federal program named Libton for the creation of a scientific production center for rare metals, including tantalum, in the Trans-Baikal region. The Chita region and TVEL, a producer and supplier of nuclear fuel controlled by the Russian Ministry of Atomic Energy, signed an agreement on liaison with the Priargunsky Mining and Chemicals Production Association, a uranium producer controlled by TVEL, and the Zabaikalsky Mining and Beneficiation Plant, a rare metal producer. The Ministry was to finance the program and coordinate efforts by Priargunsky and Zabaikalsky to produce materials for the nuclear sector (Interfax International Ltd., 2000).

Outlook

Columbium.—The principal use for columbium will continue as an additive in steelmaking, mostly in the manufacture of microalloyed steels used for pipelines, bridges, automobiles, etc. The production of high-strength low-alloy steel is the leading use for columbium, and the trend for columbium demand, domestically and globally, will continue to follow closely that of steel production (see the "Outlook" section of the Iron and Steel chapter for a discussion of the future of the steel industry). The October 2000 medium-term forecast of the International Iron and Steel Institute projected an annual growth rate in steel consumption between 2000 and 2005 for the world of 2%; the North American Free Trade Agreement countries, 0.9%; European Union countries, 0.8%; China, 3.8%; and total Asian countries, 2.6%. Japan was the only major steel consumer where steel usage was expected to fall, by about 1% (International Iron and Steel Institute, October 3, 2000, IISI survey reveals renewed world steel consumption growth—Annual report of the Secretary General, accessed June 1, 2001, at URL http://www.worldsteel.org/trends_indicators/demand.html).

The outlook for columbium also will be dependent on the performance of the aerospace industry and the use of columbium-bearing alloys in it. Columbium consumption in the production of superalloys, which is the second largest end use for columbium, will be most dependent on the market for aircraft engines. Because nickel-base superalloys (such as alloy 718, which contains about 5% columbium) can account for about 40% to 50% of engine weight, they are expected to be the materials of choice for the future owing to their high temperature operating capability (Tantalum-Niobium International Study Center, 1999b). The Aerospace Industries Association (2001, p. 3) forecast that U.S. aerospace industry sales will rise to $145 billion in 2001 from $144 billion in 2000 owing to the strength of Department of Defense increases.

The majority of U.S. demand for columbium units will continue to be met by imports. Brazil will continue as the leading source for U.S. imports of columbium, and Canada will also be a major source of supply.

Tantalum.—U.S. apparent consumption of tantalum totaled about 650 t in 2000 compared with about 555 t in 1999. More than 60% of the tantalum consumed was used to produce electronic components, mainly tantalum capacitors. This market sector is expected to be stimulated by the growth in the use of cellular telephones; each phone may contain from 10 to 20 capacitors (Mining Journal, 2000b). Tantalum consumption in superalloys, mostly in the aircraft industry, is expected to grow by about 3% per year. Tantalum carbide in the metal cutting industry and tantalum in the chemical processing industry will be dependent on the growth of the general economy, and both are expected to grow at an estimated 2% per year (Tantalum-Niobium International Study Center, 1998).

In 2000, world tantalum supply was estimated to be about 1.8 Mt of contained tantalum. For 2001, world tantalum supply was projected to be about 2.1 Mt of contained tantalum. World tantalum supply will come mostly from Australia, Brazil, Canada, China, Southeast Asia, and certain African countries (including Burundi, Congo (Kinshasa), Ethiopia, Mozambique, Nigeria, Rwanda, Uganda, and Zimbabwe) (Tantalum-Niobium International Study Center, 2001). Another important component of world supply is the U.S. Government sales of tantalum materials from the NDS. As of June 30, 2001, tantalum materials authorized for disposal from the NDS totaled about 910 t of contained tantalum, including about 860 t contained in tantalum minerals.

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FIGURE 1

MAJOR SOURCES OF U.S. COLUMBIUM IMPORTS

(Columbium content)

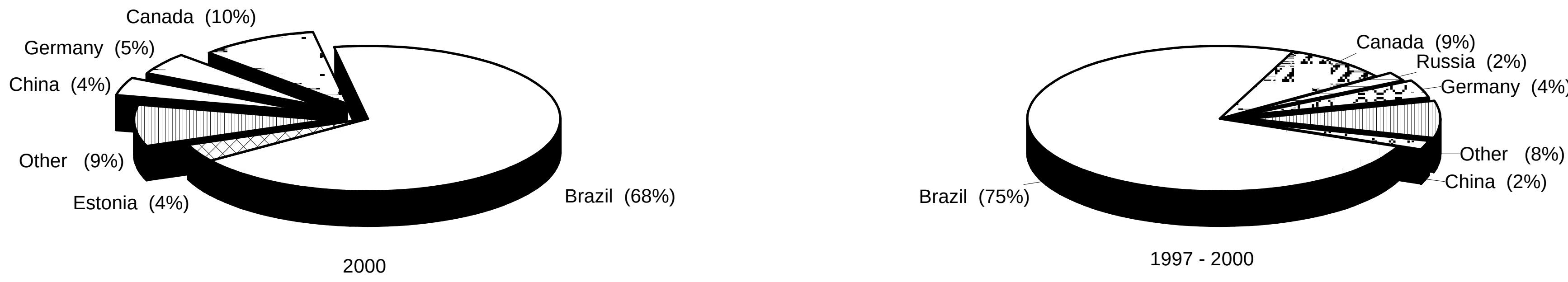

FIGURE 2

MAJOR SOURCES OF U.S. TANTALUM IMPORTS

(Tantalum content)