

COLUMBIUM (NIOBIUM) AND TANTALUM

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Columbium [Niobium (Nb)] is vital as an alloying element in steels and 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. Acceptable 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, and 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 domestic resources are of low grade. Some resources are mineralogically complex, and most are not currently commercially recoverable. The last significant mining of columbium and tantalum 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 were the dominant pyrochlore producers, accounting for about 98% of total columbium mine production in 1998. The two countries, however, no longer export pyrochlore—only columbium in upgraded valued-added forms produced from pyrochlore, regular-grade ferrocolumbium and columbium oxide mostly exported from Brazil, and regular-grade ferrocolumbium exported from Canada. The remaining columbium mineral supply came from the mining of columbite in Nigeria and the mining of tantalite-columbite, mostly in Australia, Brazil, and certain African countries. Tantalum mineral production came mostly from tantalite-columbite mining operations in Australia and Brazil, about 85% of total tantalum mine production in 1998, and from other tantalum mine operations in Canada and certain African countries.

The United States remained dependent on imports of columbium and tantalum materials; Brazil was the major source for columbium imports, and Australia, the major source for tantalum imports. 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), which expired on June 30, 1998, was renewed on October 21, 1998 (retroactive to July 1, 1998), and extended to June 30, 1999. Industry

structure changed owing to mergers and acquisitions.

Columbium and tantalum price quotations remained stable. Overall reported consumption of columbium in the form of ferrocolumbium and nickel columbium decreased; demand for columbium in superalloys was down significantly. Tantalum consumption decreased.

Legislation and Government Programs

Summaries of important columbium and tantalum statistics are listed in tables 1 and 2, respectively. To ensure a supply of columbium and tantalum during an emergency, various materials have been purchased for the NDS. (See table 3.) As of November 17, 1998, the NDS goal for tantalum metal powder was about 16 metric tons (t), and that for tantalum metal was about 55 t (U.S. Department of Defense, 1999, p. 37 and 39). The NDS had no goals for columbium materials.

During the year, the U.S. Government sold columbium and tantalum materials from the NDS. According to the DNSC Annual Materials Plan (AMP) for fiscal years (FY) 1998 (October 1, 1997, through September 30, 1998) and FY 1999 (October 1, 1998, through September 30, 1999), the maximum amount of ferrocolumbium that could be sold from the NDS would be about 91 and about 181 t, respectively, of columbium contained in ferrocolumbium (Defense National Stockpile Center, 1999b; U.S. Department of Defense, 1999, p. 8). For FY 1998, the DNSC sold about 90 t of columbium contained in ferrocolumbium valued at about \$1.27 million to Considar, Inc., New York, NY, and H.C. Starck, Inc., Newton, MA. From October 1 through December 31, 1998, the DNSC sold about 84 t of columbium contained in ferrocolumbium valued at about \$1.19 million to Considar and ABS Alloys, Inc., Mexborough, United Kingdom (Defense National Stockpile Center, 1997a, b, c, 1998a, b). From March 1997, when sales of ferrocolumbium from the NDS were initiated, through December 1998, the DNSC sold about 212 t of columbium contained in ferrocolumbium valued at about \$3 million. For FY 2000, the DNSC proposed to dispose of an additional 181 t of columbium contained in ferrocolumbium from the NDS. The DNSC also proposed maximum disposal levels of about 10 t of columbium contained in columbium carbide powder, about 91 t of columbium contained in columbium concentrates, and about 9 t of columbium contained in columbium metal ingots in each of FY 1999 and FY 2000 (Defense National Stockpile Center, 1999a, b).

For FY 1998, the DNSC had the authority under the AMP to

sell about 1 t of tantalum contained in tantalum carbide, about 9 t of tantalum contained in tantalum oxide, and about 45 t of tantalum contained in tantalum minerals. For FY 1999, the DNSC had the authority to sell about 2 t of tantalum contained in tantalum carbide, about 9 t of tantalum contained in tantalum oxide, about 91 t of tantalum contained in tantalum minerals, about 11 t of tantalum contained in tantalum metal ingots, and about 11 t of tantalum contained in tantalum metal powder (Defense National Stockpile Center, 1999b; U.S. Department of Defense, 1999, p. 9). For FY 1998 and FY 1999, the DNSC sold a total of about 2 t of tantalum contained in tantalum carbide valued at about \$269,000 to H.C. Starck. From April 1997, when sales of tantalum carbide from the NDS were initiated, through November 1998, the DNSC sold a total of about 3 t of tantalum contained in tantalum carbide valued at about \$404,000 to H.C. Starck (Defense National Stockpile Center, 1997d, e, 1998c). In October 1997, the DNSC sold about 9 t of tantalum contained in tantalum oxide valued at about \$1.3 million to Kennametal, Inc., Latrobe, PA. In April 1997, the DNSC sold about 9 t of tantalum contained in tantalum oxide valued at about \$1.1 million to H.C. Starck (Defense National Stockpile Center, 1997f, g). No tantalum oxide, however, was sold in calendar year 1998. For FY 1998 and FY 1999 (October 1, 1997, through December 30, 1998), the DNSC sold a total of about 90 t of tantalum contained in tantalum minerals valued at about \$11.6 million to Cabot Performance Materials, Boyertown, PA, and Amlon Metals, Inc., New York, NY (Defense National Stockpile Center, 1998d, e). The DNSC also proposed maximum disposal levels of about 2 t of tantalum contained in tantalum carbide, about 9 t of tantalum contained in tantalum oxide, about 91 t of tantalum contained in tantalum minerals, about 18 t of tantalum contained in tantalum metal ingots, and about 23 t of tantalum contained in tantalum metal powder for FY 2000 (Defense National Stockpile Center, 1999a).

Under the GSP, a renewable preference trade program, the United States grants duty-free access to eligible products from designated developing countries. In 1998, U.S. imports for selected columbium and tantalum materials ranged from duty free to 5% ad valorem for most-favored-nation (MFN) status and from duty free to 45% ad valorem for non-MFN status.

The GSP expired on June 30, 1998, but was renewed effective October 21, 1998, by a provision in the Omnibus Consolidated and Emergency Supplemental Appropriations Act, 1999 (Public Law 105-277); extension was retroactive to July 1, 1998, when the program was allowed to lapse. The provision "provides notice to importers that Customs will begin processing refunds on all duties paid, with interest from the date the duties were deposited, on GSP-eligible merchandise that was entered on July 1, 1998, through October 20, 1998, and that customs will accept claims for GSP duty-free treatment for merchandise entered, or withdrawn from a warehouse, for consumption on or after October 21, 1998, through June 30, 1999, the provision's current sunset date" (U.S. Customs Service, 1998, p. 67169).

Oremet-Wah Chang, Albany, OR, and Cabot Performance Materials, Boyertown, PA, were awarded contracts totaling \$31.9 million to supply the U.S. Department of Energy with

about 363 t of columbium-titanium alloy and 23 t of pure columbium metal sheet. The material will be used in the production of superconducting magnets for a particle accelerator being constructed near Geneva, Switzerland (Platt's Metals Week, 1998).

Production

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 1998 were, however, incomplete at the time this report was prepared.

Neither columbium nor tantalum was mined domestically in 1998. Cabot Performance Materials was integrated, with capability ranging from raw material processing through to the production of columbium and tantalum end products. Shieldalloy Metallurgical Corp., Newfield, NJ, was a producer of ferrocolumbium. H.C. Starck was a major supplier of tantalum and columbium products. Reading Alloys, Inc., Robeson, PA, and Oremet-Wah Chang were major producers of high-purity columbium products. Kennametal was a major supplier of columbium and tantalum carbides. (See table 9.)

In March, Allegheny Teledyne, Inc., headquartered in Pittsburgh, PA, completed the acquisition of Oregon Metallurgical Corp. (OREMET), a fully integrated domestic titanium producer. Under the terms of the merger, OREMET shareholders received about 1.3 shares of Allegheny Teledyne common stock in a tax-free exchange for each share of OREMET common stock. Subsequently, OREMET was combined with Allegheny Teledyne's subsidiary Wah Chang to form Oremet-Wah Chang, which became a part of Allegheny Teledyne's High Performance Metals Group (Allegheny Teledyne, Inc., 1999, p. 5 and 20).

In June, Metallurg, Inc., New York, NY, announced that the company was being acquired by a group of institutional investors led by Safeguard International Fund, L.P., an international private equity fund based in Wayne, PA. The group would pay \$30 per share, in cash, to acquire Metallurg's outstanding common stock and to assume Metallurg's outstanding indebtedness. The merger, valued at approximately \$300 million, was unanimously approved by Metallurg's Board of Directors, and the transaction was finalized in July. Metallurg, founded in 1911, was an international producer and seller of high-quality metal alloys and speciality metals used by manufacturers of steel, aluminum, superalloys, titanium, and other metal products (American Metal Market, 1998a, b; Tantalum-Niobium International Study Center, 1998b). In April 1997, Metallurg and Shieldalloy Metallurgical, its subsidiary, had emerged from court protection under Chapter 11 of the U.S. Bankruptcy Code, following completion of an operational and financial restructuring.

In late September, KB Alloys, Inc., headquartered in Reading, PA, announced that the company had completed the purchase of Reading Alloys. Terms of the purchase were not disclosed. KB Alloys was owned by Code, Hennessy & Simmons, a Chicago, IL-based financial limited partnership.

The company was a leading supplier of master alloys to the aluminum industry, with production plants in Wenatchee, WA, and Henderson, KY. The company employed about 250 people worldwide. Reading Alloys, family owned since its inception in 1953, produced master and other special alloys and employed about 100 people. KB Alloys indicated that management of Reading Alloys would remain substantially intact (KB Alloys, Inc., 1998).

Consumption

Overall reported consumption of columbium as ferrocolumbium and nickel columbium was down by about 3% compared with that of 1997 (table 4). Consumption of columbium by the steelmaking industry was little changed; the percentage of columbium usage per ton of steel produced was basically unchanged. Columbium consumption in carbon and stainless and heat-resisting steels increased, and columbium consumption in high-strength low-alloy steel decreased by about 9%. Demand for columbium in superalloys was down significantly from that of 1997. That portion used in the form of nickel columbium decreased to about 400 t. The consumption of columbium in superalloys was affected most by a soft superalloy market, less columbium being required in the superalloy production mix, and the availability-use of more superalloy scrap.

Overall consumption of tantalum was about 525 t; about 60% of the total was consumed in the electronics industry. Industry sources indicated that factory sales of tantalum capacitors increased by about 4%, to about 3.4 billion units, a more-than 200% increase since 1990. Demand for tantalum capacitors in electronic products, such as portable telecommunications devices, personal computers, and automotive electronics, remained strong.

Columbium.—Columbium and niobium are synonymous names for the chemical element with atomic number 41; columbium was the first name given, 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 shelflife. 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, 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 made at either a performance or economic penalty.

Prices

A published price for pyrochlore concentrates produced in Brazil and Canada was not available, because these concentrates are no longer being exported from Brazil and Canada. 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 throughout the year.

The Metal Bulletin price for columbite ore, based on a minimum 65% contained columbium oxide (Nb_2O_5) and tantalum oxide (Ta_2O_5), ranged from \$2.80 to \$3.20 per pound. For the year, the American Metal Market published price for high-purity (vacuum-grade) ferrocolumbium ranged from \$17.50 to \$18 per pound of contained columbium. Industry sources indicated that nickel columbium sold at about \$19 per pound of contained columbium, and that columbium metal ingots sold in the range of about \$25 to \$35 per pound (Mining Journal, 1998b). The Platt's Metal Week published price for columbium oxide, \$8.17 per pound of oxide, was discontinued at yearend 1996.

The price for tantalum products is affected most by events in the supply and demand of tantalum minerals. The Platt's Metals Week spot price for tantalite ore, based on contained Ta_2O_5 , f.o.b. U.S. ports, which 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 to \$31.50 per pound of contained Ta_2O_5 , and that for Greenbushes tantalite, Australia, based on 40% contained

Ta₂O₅, was \$40 per pound. The most recent industry source on tantalum prices indicated that the average selling prices for some tantalum products (per pound of contained tantalum) were as follows: capacitor-grade powder, \$135 to \$240; capacitor wire, \$180 to \$250; and vacuum-grade metal for superalloys, \$75 to \$95 (Mining Journal, 1998c).

Foreign Trade

Data for exports and imports are summarized in table 5. Net trade for columbium and tantalum continued at a deficit. Overall trade value for exports decreased slightly with total volume up significantly. For imports, overall trade value was up by more than 15% with total volume up by more than 10%.

Imports for consumption of columbium ores and concentrates continued to decrease. (See table 6.) Columbium ores and concentrates were not imported from Canada. Imports at an average grade of approximately 52% Nb₂O₅ and 15% Ta₂O₅ were estimated to contain about 26 t of columbium and about 10 t of tantalum. Ferrocolumbium imports increased by about 15%; Brazil accounted for about 85% of quantity and value.

Imports for consumption of tantalum ores and concentrates were up by about 35% (table 7); imports from Australia accounted for almost 60% of quantity and value. Imports at an average grade of approximately 37% Ta₂O₅ and 20% Nb₂O₅ were estimated to contain about 370 t of tantalum and about 174 t of columbium.

In 1998, synthetic tantalum-columbium concentrates were not imported into the United States; in 1997, 27 t valued at \$908,000 had been imported. These figures are not included in the salient statistics data (table 1).

The schedule of tariffs applied during 1998 to U.S. imports of selected columbium and tantalum materials is found in the U.S. International Trade Commission's Publication 3066, 1998 Harmonized Tariff Schedule of the United States (U.S. International Trade Commission, 1997). Brazil continued as the major source for U.S. columbium imports, contained columbium, accounting for about 79% of the total (figure 1), and Australia continued as the major source for U.S. tantalum imports, contained tantalum, accounting for about 45% of the total (figure 2).

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 tantalum mineral concentrates were produced mainly in Australia, Brazil, and Canada.

Australia.—In May 1998, Sons of Gwalia, Ltd., West Perth, Western Australia, merged with its associate, Gwalia Consolidated, Ltd., acquiring Gwalia Consolidated's Minerals Division. It included the Greenbushes Mine, southwest Western Australia, and the Wodgina Mine, northwest Western Australia. As part of the transaction, Sons of Gwalia also

issued 7.5 million shares to Cabot Corp., the Minerals Division's largest customer for tantalite, at \$4 per share. For its 1997-1998 financial year ending June 30, 1998, Sons of Gwalia reported that tantalum produced at the Greenbushes and the Wodgina Mines totaled almost 400 t and that sales of tantalum totaled about 390 t. Greenbushes tantalum production of about 330 t was a record level owing to expanded ore-milling capacity and access to better quality ore. Tantalum production at Wodgina, a smaller and lower cost operation than Greenbushes, totaled about 68 t. Based on encouraging exploration results, approval was given to increase ore-milling capacity at Wodgina, which will double annual tantalum production capacity to about 140 t in 1999-2000. The \$14 million expansion was expected to be completed by the end of June 1999. Greenbushes and Wodgina reportedly produced about 25% of the world's annual requirements for tantalum. All production from Greenbushes and Wodgina was presold to the world's two largest tantalum processors, Cabot Corp. and H.C. Starck GmbH & Co. KG of Germany, at fixed prices and quantities through 2003. Tantalum reserves at Greenbushes totaled about 6,900 t of contained tantalum oxide, and reserves at Wodgina totaled about 1,400 t of contained tantalum oxide (Sons of Gwalia, Ltd., 1998, p. 3-4, 8-10, 24-25, 27, and 34).

Brazil.—Cia. Brasileira de Metalurgia e Mineração (CBMM), the world's largest columbium producer, announced the signing of a letter of intent with Mannesmann Demag do Brasil for the supply of a 10.5-megavolt-ampere electric furnace to treat columbium concentrates. The furnace will be capable of producing about 40,000 metric tons per year of ferrocolumbium beginning in December 1999. The furnace will allow CBMM to replace the current leach method, will result in reduced production costs, and will be more environmentally friendly. CBMM reportedly sold some 6% of its ferrocolumbium production to domestic steelmakers, some 40% to North America, about 36% to Europe, and about 14% to Japan and Southeast Asia. CBMM also began operation at its new \$1.4 million high-purity columbium oxide plant. Output from the 150-t plant was intended for the Japanese optical industry (Metal Bulletin, 1998a; Tantalum-Niobium International Study Center, 1998a).

The Paranapanema Group, Brazil's largest tin producer, began preliminary talks with a number of local and international mining companies to sell a stake in the Group. The sale would generate needed working capital to implement the planned \$100 million expansion program at Paranapanema's Pitinga tin mine, in Amazonas. The plans included annual production of 500 t of tantalum oxide and 4,000 t of columbium oxide and alloys (American Metal Market, 1998c; Metal Bulletin, 1998b).

Canada.—Production of columbium oxide contained in pyrochlore concentrate at the Niobec Mine near Chicoutimi, Quebec, was about 3,290 t compared with about 3,280 t in 1997. Niobec was a 50-50 joint venture between Cambior, Inc. (product marketing), and Teck Corp. (operator). Columbium contained in ferrocolumbium production was about 2,180 t compared with about 2,190 t in 1997. Pyrochlore-to-ferrocolumbium converter recovery was 96.8%. Ore milled decreased to 819,000 t because the mill operated on the average

of about 2,240 metric tons per day (t/d) of ore compared with about 2,280 t/d in 1997. Average recovery increased to 58.2% from 57.8% with the Nb₂O₅ grade of concentrate at 69%. Teck reported that Niobec reserves were sufficient for another 13 years of mine life. In 1999, Niobec was expected to produce about 2,180 t of columbium contained in ferrocolumbium. In 1998, capital expenditures totaled \$8.6 million and were used to deepen the mine shaft and for initial development of a lower ore block. Total capital expenditures for 1999 were budgeted at \$4.7 million (Cambior, Inc., 1999, p. 2, 9, 11, and 22; Teck Corp., 1999, p. 22, 30, and 39).

Since midyear 1992, tantalum mining at the Bernic Lake, Manitoba, tantalum operation has remained suspended. About 74 t of tantalum oxide contained in concentrate, however, was produced at the mine from tailings retreatment in 1998 compared with about 60 t in 1997.

Niocan Inc. reportedly will proceed with development of an underground mine and processing plant at its columbium property in the OKA carbonatite complex west of Montreal, on the basis of a favorable feasibility study. Ore reserves have been estimated at 13.3 million metric tons (Mt) grading 0.63% Nb₂O₅. Niocan anticipated that future underground drilling will indicate additional reserves that could extend the mine life from 15 years to at least 25 years. The mine will be developed in two phases. The first phase will consist of sinking a three-compartment shaft and construction of a decline from the surface down to a depth of 300 meters (m). The second phase, to begin during the fifth year of mining, will extend the shaft and decline down to a depth of 530 m. Annual production was expected to be about 9,000 t of pyrochlore concentrate yielding about 4,500 t of ferrocolumbium containing 65% columbium. Total capital cost for development of the project has been estimated to be \$89.8 million for the first phase and \$11.2 million for the second phase. The total operating cost for the project was estimated to be \$5.57 per pound of columbium. The operation was expected to employ about 155 jobs when in full production (Northern Miner, 1998).

Avalon Ventures, Ltd., Toronto, commissioned a prefeasibility study to outline a development plan for its Separation Rapids rare metals property, 60 kilometers (km) north of Kenora, Ontario. The study was undertaken on the basis of the completion of a positive market study, successful development of a selective flotation process, and completion of a second-phase drilling program at the property. Assuming an initial annual mining rate of 200,000 t of ore, annual sales of 58,000 t of petalite, 65,000 t of feldspar, and 10 t of tantalum concentrates were estimated. Mining costs for an open-pit operation were expected to begin at \$1 per metric ton and rise to \$3 per metric ton during a 3- to 5-year period after the near-surface reserves have been exploited. Processing costs were estimated to be \$25 per metric ton, and capital costs could total \$20 million (Avalon Ventures, Ltd., 1998; Skillings Mining Review, 1998a).

China.—A joint venture, Ninning Tantalum-Niobium Mining Co., was established by Fujian Minbei Geological Prospecting Party, Nanping Mining Development Corp., and Ningxia Nonferrous Metals Smelter to oversee the development of the Nanping tantalum-niobium deposit in Fujian Province.

About \$6.7 million will be invested for initial development of the deposit, which, reportedly has proven reserves of 4,250 t of contained tantalum oxide. Production was anticipated to begin the second half of 1999. Initial annual production capacity was expected to be about 116 t of tantalum and niobium concentrates. The concentrates will be shipped to Ningxia, Ningxia Huizu Autonomous Region, for processing and the production of tantalum powder (Mining Journal, 1998a, d).

Gabon.—Reunion Mining Plc, United Kingdom, NMC, the Netherlands, and Treibacher Industrie AG, Austria, entered into a joint-venture agreement to develop the columbium-enriched portion of the Mabounié carbonatite complex in Gabon. Niobium Resources, controlled by these companies, will have a 70% interest in the Gabonese company Société Minière de la Mabounié, which will hold the mineral rights to the deposit. A group of Gabonese private investors will hold the remaining 30%. The Mabounié deposit is located about 200 km southeast of Libreville and has a near-surface resource amounting to about 41 Mt grading about 1.9% Nb₂O₅. Reunion will be responsible for a feasibility study investigating the annual production of pyrochlore concentrate and converting the concentrate to ferrocolumbium containing about 4,000 t of columbium, NMC will design the flow sheet for recovery-processing of the concentrate, and Treibacher will convert the concentrate to ferrocolumbium and have responsibility for marketing. The first phase of the feasibility study, pyrochlore concentrate production, was expected to be completed by midyear 1999 at a cost of \$1.42 million. The deposit was discovered by the Gabonese Government in 1986 and later explored by Bureau de Recherches Géologiques et Minières, the French State mineral-exploration company (Metal Bulletin, 1998c; Skillings Mining Review, 1998b).

Japan.—Domestic production of ferrocolumbium remained essentially idle. Ferrocolumbium imports totaled about 6,520 t compared with about 4,980 t in 1997. Brazil remained the major source for ferrocolumbium, supplying more than 90% of total imports (TEX Report, 1999). Japan's production of tantalum capacitors for the first half of the year was about 2.9 billion units compared with about 2.6 billion units for the same period in 1997. Japan's exports of tantalum capacitors totaled about 1.5 billion units from January through August 1998 compared with about 1.4 billion units for the same period in 1997 (Roskill's Letter from Japan, 1998).

Outlook

Columbium.—The principal use for columbium will continue as an additive in steelmaking, which accounted for about 80% of reported domestic consumption in 1998. The trend of columbium demand, domestically and globally, will continue to follow closely that of steel production; the reader is referred to the outlook section of the Iron and Steel Annual Mineral Industry Surveys for discussion of the outlook for the steel industry. The International Iron and Steel Institute estimate for overall world steel demand in 2005 is projected to be 10% higher than that of 1998. Most growth will be in China, which, along with other Asian countries, will account for about 45% of the total (Iron & Steelmaker, 1998). 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 has increased by more than 50% since 1990 and peaked at 838 t in 1997. Industry sources forecast that U.S. aerospace sales will grow from about \$141 billion in 1998 to about \$145 billion in 1999. The majority of U.S. demand for columbium units will continue to be met by imports.

Tantalum.—In 1998, U.S. apparent consumption of tantalum totaled about 525 t compared with about 550 t in 1997. About 60% of the tantalum consumed was used to produce electronic components, mainly tantalum capacitors. Worldwide consumption of tantalum capacitors is expected to increase to about 25 billion units by 2000, an annual growth rate of about 14%, with tantalum consumption at around 950 t. The annual per-unit requirement of tantalum powder for tantalum capacitors is, however, expected to decline. Tantalum powder usage is forecast to decrease to about 32 kilograms per million units in 2000 from about 45 kilograms per million units in 1995. 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, 1998c). The overall trend is for moderate increased tantalum consumption.

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TABLE 1
SALIENT COLUMBIUM STATISTICS 1/

(Metric tons of columbium content unless otherwise specified)

	1994	1995	1996	1997	1998
United States:					
Releases from Government excesses	--	--	--	--	--
Production of ferrocolumbium	NA	NA	NA	NA	NA
Exports: Columbium metal, compounds, alloys (gross weight)	NA	NA	NA	NA	NA
Imports for consumption:					
Mineral concentrates e/	1,480	615	285	220	200
Columbium metal and columbium-bearing alloys e/	171	257	322	423	563
Ferrocolumbium e/	2,590	3,580	2,970	4,260	4,900
Tin slag	NA	NA	NA	NA	NA
Consumption:					
Raw materials	NA	NA	NA	NA	NA
Ferrocolumbium and nickel columbium e/	2,750	2,900	3,370	3,770 r/	3,640
Apparent e/	3,700	3,800	3,800	3,900	4,000
Prices:					
Columbite, dollars per pound 2/	2.60	2.97	3.00	3.00	3.00
Pyrochlore, dollars per pound 3/	NA	NA	NA	NA	NA
World: Production of columbium-tantalum concentrates e/	15,700	15,600 r/	15,500 r/	18,100 r/	18,500

e/ Estimated. r/ Revised. NA Not available.

1/ Data are rounded to three significant digits, except prices.

2/ Average value, contained pentoxides for material having a columbium pentoxide to tantalum pentoxide ratio of 10 to 1.

3/ Average value, contained pentoxide.

TABLE 2
SALIENT TANTALUM STATISTICS

(Metric tons of tantalum content unless otherwise specified)

	1994	1995	1996	1997	1998
United States:					
Releases from Government excesses	--	--	--	--	--
Exports:					
Tantalum ores and concentrates (gross weight) 1/	23	1	53	91	389
Tantalum metal, compounds, alloys (gross weight)	242	281	342	396	423
Tantalum and tantalum alloy powder (gross weight)	46	41	26	58	61
Imports for consumption:					
Mineral concentrates e/	310	300	360	280	380
Tantalum metal and tantalum-bearing alloys 2/	73	181	203	187	208
Tin slag	NA	NA	NA	NA	NA
Consumption:					
Raw materials	NA	NA	NA	NA	NA
Apparent e/	430	515	490	550 r/	525
Prices:					
Tantalite, dollars per pound 3/	26.24	26.98	27.75	28.76	33.79
World: Production of columbium-tantalum concentrates e/	333	361 r/	389 r/	409 r/	454

e/ Estimated. r/ Revised. NA Not available.

1/ Includes reexports.

2/ Exclusive of waste and scrap.

3/ Average value, contained tantalum pentoxides.

TABLE 3
COLUMBIUM AND TANTALUM MATERIALS IN GOVERNMENT
INVENTORIES AS OF DECEMBER 31, 1998 1/

(Metric tons of columbium or tantalum content)

Material	Stockpile goals	Disposal authority	National Defense Stockpile inventory			
			Uncommitted		Total	Committed
			Stockpile-grade	Nonstockpile-grade		
Columbium:						
Concentrates	--	726	384	343	726	60
Carbide powder	--	10	10	--	10	--
Ferrocolumbium	--	324	203	121	324	90
Metal ingots	--	73	73	--	73	--
Total	--	1,130	669	464	1,130	150
Tantalum:						
Minerals	--	923	469	454	923	90
Carbide powder	--	10	10	--	10	--
Metal:						
Capacitor grade	(2/)	57	73	(3/)	73	--
Ingots	(2/)	57	111	--	111	--
Oxide	--	56	56	--	56	--
Total	71 2/	1,100	719	454	1,170	90

1/ Data are rounded to three significant digits; may not add to totals shown.

2/ Goals as of November 17, 1998; about 16 tons for tantalum metal powder, and about 55 tons for tantalum metal.

3/ About 60 kilograms.

Source: Defense Logistics Agency, Defense National Stockpile Center.

TABLE 4
REPORTED CONSUMPTION, BY END USE, AND INDUSTRY STOCKS OF
FERROCOLUMBIUM AND NICKEL COLUMBIUM
IN THE UNITED STATES 1/

(Metric tons of contained columbium)

End use	1997	1998
Steel:		
Carbon	1,360	1,410
Stainless and heat-resisting	473	522
Full alloy	(2/)	(2/)
High-strength low-alloy	1,080	980
Electric	(3/)	(4/)
Tool	(4/)	(4/)
Unspecified	21	17
Total	2,930	2,930
Superalloys	838	694
Alloys (excluding alloy steels and superalloys)	(5/)	(5/)
Miscellaneous and unspecified	9	13
Total consumption	3,770 r/	3,640
Stocks, December 31:		
Consumer	NA	NA
Producer 6/	NA	NA
Total stocks	NA	NA

r/ Revised. NA Not available.

1/ Data are rounded to three significant digits; may not add to totals shown.

2/ Included with "Steel: High-strength low alloy."

3/ Revised from zero; included with "Steel: Unspecified."

4/ Included with "Steel: Unspecified."

5/ Included with "Miscellaneous and unspecified."

6/ Ferrocolumbium only.

TABLE 5
U.S. FOREIGN TRADE IN COLUMBIUM AND TANTALUM METAL AND ALLOYS, BY CLASS 1/

Class	1997		1998		Principal destinations and sources, 1998 (Gross weight, metric tons, thousand dollars)
	Gross weight (metric tons)	Value (thousand dollars)	Gross weight (metric tons)	Value (thousand dollars)	
Exports: 2/					
Columbium:					
Ores and concentrates	32	349	20	181	Netherlands 17, \$154; Italy 2, \$14; Japan 1, \$10; Taiwan (3/), \$3.
Ferrocolumbium	59	588	23	206	Germany 16, \$159; Mexico 6, \$41; Canada 1, \$6.
Tantalum:					
Synthetic concentrates	14	126	1	5	All to French Polynesia.
Ores and concentrates	91	842	389 4/	3,050	Brazil 257, \$1,530; Netherlands 90, \$1,170; China 41, \$308; France 2, \$39; Japan (3/), \$5.
Unwrought and waste and scrap	208	8,220	230	9,710	Hong Kong 151, \$3,650; Germany 38, \$2,910; United Kingdom 14, \$2,380; Taiwan 25, \$504; Japan 1, \$165; Mexico 1, \$51.
Unwrought powders	58	17,100	61	18,400	Israel 38, \$13,900; Germany 7, \$2,020; Australia 10, \$1,230; Japan 2, \$640; Thailand 3, \$312; France 1, \$199.
Unwrought alloys and metal	112	29,200	110	24,800	Israel 47, \$12,000; United Kingdom 20, \$7,520; France 24, \$2,080; Germany 4, \$1,490; Barbados 2, \$557; Taiwan 1, \$429.
Wrought	76	31,700	83	28,600	Japan 30, \$11,800; Germany 17, \$6,850; United Kingdom 10, \$3,150; France 2, \$1,210; Singapore 2, \$906; Sweden 6, \$955.
Total	XX	88,200	XX	85,000	Israel \$26,300; Germany \$13,400; United Kingdom \$13,100; Japan \$12,600; Hong Kong \$3,720; France \$3,530; Brazil \$1,570; Netherlands \$1,340.
Imports for consumption:					
Columbium:					
Ores and concentrates	129	884	72	729	Nigeria 51, \$416; China 21, \$283; Switzerland (3/), \$29; United Kingdom (3/), \$1.
Oxide	1,750	30,700	1,230	23,200	Brazil 876, \$15,000; Germany 124, \$4,820; China 116, \$1,780; Russia 113, \$1,420; Estonia 5, \$94; United Kingdom (3/), \$4.
Ferrocolumbium	6,550	59,600	7,530	68,400	Brazil 6,400; \$57,500; Canada 753, \$7,670; France 376, \$3,190; Belgium 5, \$38; United Kingdom 1, \$11.
Unwrought alloys, metal, powder	423	10,400	563	14,600	Brazil 344, \$8,680; Germany 106, \$2,330; Estonia 58, \$2,270; Belgium 25, \$618; Ukraine 7, \$250; China 9, \$196.
Tantalum:					
Synthetic concentrates	27	908	--	--	
Ores and concentrates	907	21,600	1,220	35,000	Australia 703, \$21,000; Ethiopia 77, \$5,140; Congo (Kinshasa), 5/ 186, \$3,380; Rwanda 71, \$1,610; Burundi 36, \$1,130; Brazil 43, \$583.
Unwrought waste and scrap	213	17,000	481	21,400	China 44, \$3,500; Japan 32, \$3,170; United Kingdom 38, \$2,570; Lithuania 20, \$2,240; Germany 13, \$2,070; Austria 23, \$2,000; Russia 14, \$1,630.
Unwrought powders	117	32,700	122	37,100	Japan 48, \$20,900; Thailand 42, \$9,800; China 22, \$5,270; Germany 6, \$811; Hong Kong 1, \$135; Lithuania 1, \$107.
Unwrought alloys and metal	46	8,320	43	9,490	Kazakhstan 16, \$3,820; China 13, \$3,140; Russia 9, \$1,570; United Kingdom 1, \$291; Germany 2, \$258; Israel (3/), \$162.
Wrought	24	6,190	43	9,200	China 26, \$5,380; Kazakhstan 10, \$1,540; Japan 1, \$715; Canada 3, \$536; Austria 2, \$433; United Kingdom 1, \$225.
Total	XX	188,000	XX	219,000	Brazil \$81,700; Japan \$24,900; Australia \$21,000; China \$19,500; Germany \$10,600; Thailand \$10,400; Canada \$8,220; Kazakhstan \$6,020.

XX Not applicable.

1/ Data are rounded to three significant digits; may not add to totals shown.

2/ For columbium, data on exports of metal and alloys in unwrought and wrought form, including waste and scrap, are not available; included in nonspecific tariff classification.

3/ Less than 1/2 unit.

4/ All or part of these data have been referred to the Bureau of Census for verification.

5/ Formerly Zaire.

Sources: Bureau of the Census and U.S. Geological Survey.

TABLE 6
U.S. IMPORTS FOR CONSUMPTION OF COLUMBIUM ORES AND CONCENTRATES, BY COUNTRY 1/

Country	1997		1998	
	Gross weight (metric tons)	Value (thousand dollars)	Gross weight (metric tons)	Value (thousand dollars)
Canada	11	68	--	--
China	2	31	21	283
Nigeria	82	451	51	416
Russia	33	335	--	--
Switzerland 2/	--	--	(3/)	29
United Kingdom 2/	--	--	(3/)	1
Total	129	884	72	729

1/ Data are rounded to three significant digits; may not add to totals shown.

2/ Presumably country of transshipment rather than original source.

3/ Less than 1/2 unit.

Sources: Bureau of the Census and U.S. Geological Survey.

TABLE 7
U.S. IMPORTS FOR CONSUMPTION OF TANTALUM ORES AND CONCENTRATES, BY COUNTRY 1/

Country	1997		1998	
	Gross weight (metric tons)	Value (thousand dollars)	Gross weight (metric tons)	Value (thousand dollars)
Australia	570	14,600	703	21,000
Austria 2/	1	103	--	--
Bolivia	2	83	15	401
Brazil	115	1,470	43	583
Burundi	--	--	36	1,130
Canada	--	--	(3/)	3
Congo (Kinshasa) 4/	51	600	186	3,380
Ethiopia	25	1,520	77	5,140
France 2/	6	124	(3/)	5
French Guiana	(3/)	6	--	--
Ivory Coast 2/	1	42	2	150
Japan 2/	(3/)	4	(3/)	11
Nigeria	21	776	9	500
Russia	--	--	(3/)	2
Rwanda	58	984	71	1,610
Sweden 2/	1	8	--	--
Thailand	56	1,270	51	524
Uganda	--	--	18	429
Zimbabwe	--	--	8	48
Total	907	21,600	1,220	35,000

1/ Data are rounded to three significant digits; may not add to totals shown.

2/ Presumably country of transshipment rather than original source.

3/ Less than 1/2 unit.

4/ Formerly Zaire.

Sources: Bureau of the Census and U.S. Geological Survey.

TABLE 8
PRINCIPAL WORLD COLUMBIUM AND TANTALUM RAW MATERIAL PRODUCERS

Country	Company and/or mine	Material type
Mining of columbium- and tantalum-bearing ores:		
Australia	Sons of Gwalia, Ltd. (Greenbushes)	Columbium-tantalum.
	Sons of Gwalia, Ltd. (Wodgina)	Tantalum.
Brazil	Cia. Brasileira de Metalurgia e Mineracao (CBMM) (Araxa)	Columbium.
	Cia. de Estanho Minas Brasil (MIBRA) 1/	Columbium-tantalum.
	Parapanema S.A. Mineracao Indústria e Construcao (Pitinga)	Columbium-tantalum.
	Mineracao Catalao de Goias S.A. (Catalao)	Columbium.
Canada	Cambior Inc., and Teck Corp. (Niobec)	Columbium.
	Tantalum Mining Corp. of Canada, Ltd. (Tanco) 2/	Tantalum.
China	Government-owned	Columbium-tantalum.
Production of columbium- and tantalum-bearing tin slags:		
Australia	Sons of Gwalia, Ltd. (Greenbushes)	
Brazil	Cia. Industrial Fluminense 1/ Mamoré Mineracao e Metalurgia 3/	
Thailand	Thailand Smelting and Refining Co. Ltd. (Thaisarco)	
Production of columbium- and tantalum-bearing synthetic concentrates: Germany: Western states		
	Gesellschaft Für Elektrometallurgie mbH (GFE) 1/ H.C. Starck GmbH & Co. KG	

1/ A wholly owned subsidiary of Metallurg, Inc., New York, NY.

2/ A wholly owned subsidiary of Cabot Corp.

3/ A subsidiary of Parapanema S.A. Mineracao Indústria e Construcao.

TABLE 9
PRINCIPAL WORLD PRODUCERS OF COLUMBIUM AND TANTALUM PRODUCTS

Country	Company	Products 1/
Austria	Treibacher Industrie AG	Nb and Ta oxide/carbide, FeNb, NiNb.
Brazil	Cia. Brasileira de Metalurgia e Mineracao (CBMM)	Nb oxide/metal, FeNb, NiNb.
	Cia. Industrial Fluminense 2/	Nb and Ta oxide.
	Mineracao Catalao de Goias S.A. (Catalao)	FeNb.
Canada	Cambior, Inc., and Teck Corp. (Niobec)	FeNb.
Estonia	Silmet	Nb oxide/metal.
Germany: Western states	Gesellschaft Für Elektrometallurgie mbH (GFE) 2/ H.C. Starck GmbH & Co. KG	FeNb, NiNb. Nb and Ta oxide/metal/carbide, K-salt, FeNb, NiNb, Ta capacitor powder.
Japan	Mitsui Mining & Smelting Co. Showa Cabot Supermetals 3/ H.C. Starck-V Tech Ltd. 4/	Nb and Ta oxide/metal/carbide. Ta capacitor powder. Ta capacitor powder.
Kazakhstan	Ulba Metallurgical Irtysk Chemical & Metallurgical Works	Ta oxide/metal. Nb oxide/metal.
Russia	Solikamsk Magnesium Works	Nb and Ta oxide.
Thailand	H.C. Starck (Thailand) Co. Ltd. 4/	K-salt, Ta metal.
United States	Cabot Performance Materials	Nb and Ta oxide/metal, K-Salt, FeNb, NiNb, Ta capacitor powder.
	H.C. Starck, Inc. 5/	Nb and Ta metal, Ta capacitor powder.
	Kennametal, Inc.	Nb and Ta carbide.
	Reading Alloys, Inc.	FeNb, NiNb.
	Shieldalloy Metallurgical Corp. 2/	FeNb, NiNb.
	Oremet-Wah Chang 6/	Nb oxide/metal, FeNb, NiNb.

1/ Nb, columbium; Ta, tantalum; FeNb, ferrocolumbium; NiNb, nickel columbium; K-salt, potassium fluotantalate; oxide, pentoxide.

2/ A wholly owned subsidiary of Metallurg, Inc., New York.

3/ A joint venture between Showa Denko and Cabot Corp.

4/ A subsidiary of H.C. Starck GmbH & Co. KG.

5/ Jointly owned by Bayer Corp. and H.C. Starck GmbH & Co. KG.

6/ A subsidiary of Allegheny Teledyne, Inc.

TABLE 10
COLUMBIUM AND TANTALUM: ESTIMATED WORLD PRODUCTION OF MINERAL CONCENTRATES, BY COUNTRY 1/ 2/

(Metric tons)

Country 5/	Gross weight 3/					Columbium content 4/					Tantalum content 4/				
	1994	1995	1996	1997	1998	1994	1995	1996	1997	1998	1994	1995	1996	1997	1998
Australia: Columbite-tantalite	700	900	920	1,010	1,150	81	109	112	125	140	238	274	276	302	330
Brazil:															
Columbite-tantalite	175	175	190	190	220	40	40	45	45	50	50	50	55	55	60
Pyrochlore	31,400	31,200 r/	31,000 r/	37,100 r/	38,000	13,200	13,100 r/	13,000 r/	15,600 r/	16,000	--	--	--	--	--
Canada:															
Pyrochlore	5,130	5,230	5,160	5,090	5,110	2,310	2,350	2,320	2,290	2,300	--	--	--	--	--
Tantalite	144	130	220	196 r/	244	7	7	11	10 r/	12	36	33	55	49 r/	61
Congo (Kinshasa): 6/															
Columbite-tantalite	4	4	--	--	--	1	1	--	--	--	1	1	--	--	--
Namibia: Tantalite	--	(7/)	--	--	--	--	NA	--	--	--	--	(7/)	--	--	--
Nigeria: Columbite	30	65 r/ 8/	57 r/ 8/	60 r/	60	13	26 r/	23 r/	23 r/	23	2	3 r/	3 r/	3 r/	3
Rwanda: Columbite-tantalite	10	--	--	--	--	3	--	--	--	--	2	--	--	--	--
Spain: Tantalite	6	--	--	--	--	NA	--	--	--	--	2	--	--	--	--
Zimbabwe: Columbite-tantalite	7	1	--	--	--	1	(7/)	--	--	--	2	(7/)	--	--	--
Total	37,600	37,700 r/	37,500 r/	43,600 r/	44,800	15,700	15,600 r/	15,500 r/	18,100 r/	18,500	333	361 r/	389 r/	409 r/	454

r/ Revised. NA Not available.

1/ Data are rounded to three significant digits; may not add to totals shown.

2/ Excludes columbium- and tantalum-bearing tin ores and slags. Production of tantalum contained in tin slags was, in metric tons: 1994--NA; 1995--126; 1996--82; 1997--40; and 1998--NA according to data from the Tantalum-Niobium International Study Center. Table includes data available through July 9, 1999.

3/ Data on gross weight generally have been presented as reported in official sources of the respective countries, divided into concentrates of columbite, tantalite, and pyrochlore where information is available to do so, and reported in groups, such as columbite and tantalite, where it is not.

4/ Unless otherwise specified, data presented for metal content are estimates based on, for the most part, reported gross weight and/or pentoxide content.

5/ In addition to the countries listed, Bolivia, China, Russia, and Zambia also produce or are believed to produce columbium and tantalum mineral concentrates, but available information is inadequate to make reliable estimates of output levels.

6/ Formerly Zaire.

7/ Less than 1/2 unit.

8/ Reported figure.

FIGURE 1
 MAJOR SOURCES OF U.S. COLUMBIUM IMPORTS
 (Columbium content)

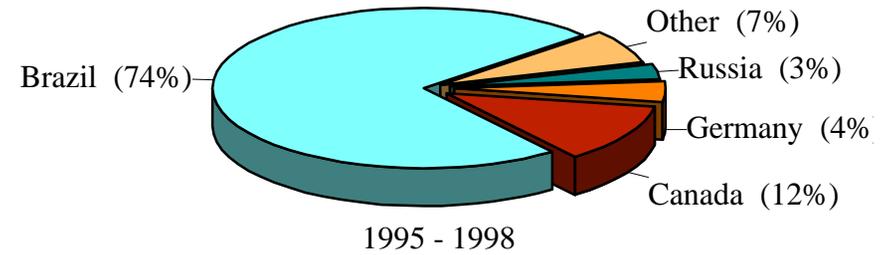
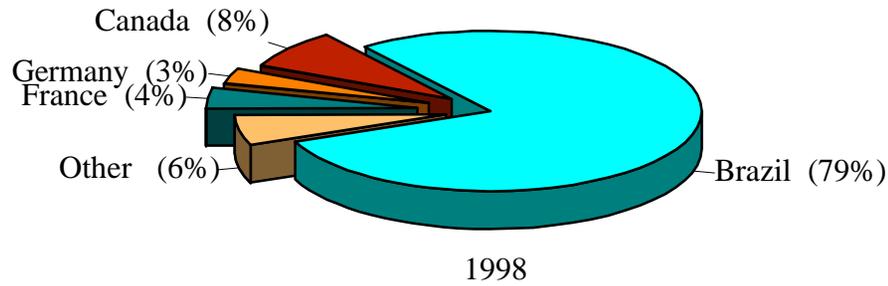


FIGURE 2
 MAJOR SOURCES OF U.S. TANTALUM IMPORTS
 (Tantalum content)

