NIOBIUM

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Niobium was identified in 1801 by Charles Hatchett, an English chemist, in a mineral specimen from Connecticut that was sent to the British Museum in 1753. This year therefore marks the 200th anniversary of the discovery of this element.

Niobium (formerly known as columbium) is used in a wide variety of applications, ranging from the production of superconducting alloys to its use for the strengthening of HSLA steels. The consumption of niobium in 2000 has shown a 4.4% increase over 1999 levels, resulting in a total consumption of 52.9 Mlb. Approximately 85% of the total demand for niobium is for the high strength low alloy (HSLA) steel applications where the niobium-containing product additive is ferro-niobium that is produced directly from pyrochlore concentrates mined in either Brazil or Canada.

Niobium and tantalum are Group Vb elements that exhibit similar properties and are related mineralogically, physically, and chemically. They always occur together in nature. The economically significant minerals containing niobium are pyrochlore and columbite, with small quantities (relatively speaking) obtained as a by-product from the processing of tantalite, tin slag and struverite. Pyrochlore is a niobium-rich mineral, low in tantalum content, that is processed directly into ferro-niobium. Columbite can be processed directly into a ferro-niobium-tantalum alloy with a 10:1 to 12:1 ratio of niobium to tantalum. Columbite is also processed via solvent extraction chemistry to separate the niobium from the tantalum prior to conversion into finished products ranging from vacuum-grade ferro- and nickel-niobium, to various niobium chemicals, pure metal, and various alloys.

There are important properties of niobium that lead to its use in selected applications, namely, its high melting point (2,477°C), the high resistance to corrosion of the pure metal and specific alloys, the magnetic properties of specific alloys, and the grain refining attributes and increased strength imparted to steel and super-alloys. Useful properties of niobium compounds include the hardness of niobium carbide, and the electronic and optical properties of niobium oxide and other specific compounds, for example the lead perovskite formulations and lithium niobate.

Production

The world's largest deposit of pyrochlore is located at Araxá, Brazil. This open-pit mine is operated by Companhia Brasileira de Metalurgia e Mineração (CBMM), which supplies about 70% of the world demand for niobium products. This mine contains 460 Mt of ore at 2.5% niobium oxide. An investment of US$78 million in 2000 increased capacity in the pyrochlore concentration facilities from 50,000 to 84,000 t/y. The barium pyrochlore mineral is upgraded to a 65% concentrate that is converted via aluminothermic reduction to HSLA grade ferro-niobium. In 2000, the capacity for ferro-niobium was increased from 30,000 to 45,000 t/y.

These facilities also produce high purity niobium oxide (150 t/y) which is the feedstock for the production of vacuum grade (VG) ferro- and nickel-niobium and high purity niobium metal, the latter being produced via the direct aluminothermic reduction of the oxide followed by electron beam melting of the resultant ingots.

The world's second largest producer is Mineração Catalão de Goiás (MCG), at the Catalão mine in Brazil. This deposit is similar in geology to the Araxá deposit with a niobium oxide content of 1.34% in run-of-

mine ore. Physical processing coupled with flotation is used to upgrade the pyrochlore mineral to a nominal 57% niobium oxide concentrate. Conversion results in a production of about 3,600 t/y of HSLA grade ferro-niobium.

The third significant pyrochlore operation, is the Niobec mine in Quebec, Canada. The mine was operated in a 50:50 joint venture with Cambior, which is responsible for the marketing activities of the joint venture. However, in November 2000, Cambior's partner changed from Teck Corp. to Mazarin Mining Corp.

The pyrochlore mineral concentrate is produced from a hard-rock mine with run-of-mine ore at 0.6% niobium oxide being upgraded to a nominal 60%+ niobium oxide before conversion to HSLA grade ferro-niobium. The sale of Teck Corp.'s interests to Mazarin Mining Corp. also included the potential for the sale of Teck's interest in Niocan, a pyrochlore deposit in the Oka area of Quebec. Production of ferro-niobium totals about 1,100 t/y of contained niobium. However, completion of a two-phase expansion in 2001 is expected to increase total ferro-niobium production to reach an annual rate of 4,000 t/y.

Niobium is the primary element in columbite, with tantalum as an impurity, usually in a 10 to 12:1 Nb:Ta ratio, on a contained oxide basis. Processors of this mineral either accept the tantalum values in their ferro-niobium alloy or process the mineral concentrate through solvent extraction to separate the niobium and tantalum values prior to conversion to the ferro alloy or other purified niobium chemicals.

Metallurg has been processing niobium and tantalum minerals and slags from its MIBRA mine near São João del Rei in Rondonia State in Brazil and from mineral concentrates acquired from local producers as well as sources external to Brazil. A solvent extraction system at the Fluminense subsidiary is used to achieve separation of the niobium and tantalum that are processed and sold as oxides.

The Pitinga tin mine in the Amazonas region of Brazil is operated by Mamoré Mineração e Metalurgia of the Paranapanema Group. The ore is processed into a cassiterite concentrate (tin recovery) and a cassiterite-columbite concentrate from which a ferro-niobium-tantalum alloy is produced for sale to the industry with an assay of 50% niobium and 5% tantalum content. Production is estimated at about 2 Mlb/y of niobium.

Other large potential mining operations being evaluated currently are the Mabounié deposit in Gabon (Cluff Mining), the Mt. Weld deposit in Australia (Anaconda), and the Dubbo zirconia project, also in Australia (Alkane Exploration).

The largest processors of tantalite, columbite and other niobium source materials are companies like H.C. Starck, Cabot Performance Materials, Mitsui Mining and Smelting, and Ningxia Non-ferrous Metals Co. The niobium in these mineral sources requires that a solvent extraction circuit be employed to separate and purify the tantalum and niobium constituents prior to the production of various niobium compounds, metal, and alloys. These companies generally manufacture a niobium product line where chemical impurity levels are measured at well below 50 ppm with some products being of optical quality. Niobium metal or vacuum-grade ferro- or nickel-niobium purity requirements demand exceedingly small percentages of low-temperature melting point elements, such as lead, tin, zinc, etc., when used as an additive for the manufacture of certain alloys used in aircraft applications. This segment of the industry generally focuses on niche applications requiring high-value products.

Other companies involved with the processing of niobium raw materials and production of chemicals, niobium metal and

various alloys are A.S. Silmet, Wah Chang, and Osram Sylvania.

A summary of niobium raw material production from 1997 through 2000 is shown below.

Consumption

The growth of the superconducting alloy segment, primarily NbTi and NbZr, has increased by about 15% over 1999 shipments to 1.18 Mlb of contained niobium. A major application for NbTi is the construction of the magnetic coils for the Large Hadron Collider (LHC) project at Cern, near Geneva, Switzerland. This project will consume about 400 t of niobium-titanium alloy and 23 t of pure niobium. Niobium-titanium is the primary material used in the construction of the magnetic coils for the Magnetic Resonance Imagery (MRI) equipment utilized in medicine for the detection of anomalies in soft tissue.

The highest growth area for niobium during 2000 has been the segment composed of chemicals and vacuum-grade ferro- and nickel-niobium. Niobium chemicals, primarily niobium oxide, are used in a wide variety of applications including lenses with high refractive index; high dielectric, multilayer ceramic capacitor formulations; and in the manufacture of lithium niobate for Surface Acoustic Wave (SAW) filters, commonly used in electronic circuitry. Niobium carbide is used in the manufacture of cutting tools and in wear resistant applications. The vacuum-grade ferro- and nickel-niobium are used in the production of nickel-based superalloys where compositions range from 1 to 5% niobium. These alloys are used in aerospace and aircraft turbines, with land-based turbines also consuming significant quantities of niobium. The total amount of niobium consumed by this segment was 6.3 Mlb, which represents a growth rate of almost 29% over 1999 levels.

The last group of niobium products are the pure metal and wrought forms of the pure metal, such as sheet, rod, and tubing that are utilized in applications such as corrosion resistant equipment, sputtering targets, and cathodic protection systems. This segment consumed about 0.5 Mlb in 2000, which is less than 1% of the total worldwide demand for this element.

Another potential application on the horizon is the use of niobium in solid-state capacitors as a replacement for tantalum in specific designs and electronic circuitry requirements. The development of the use of niobium powders is in its early stages. Technical papers presented during 2000 on this topic suggest that the major obstacles of performance and reliability are being carefully studied and solutions found to offset, at least partially, the difficulties posed by the breakdown of the niobium oxide dielectric film. It is not yet clear whether the amount of penetration of niobium into tantalum requirements for capacitors will have any serious impact on the demands and growth rate observed for tantalum.

Pricing

There are no published prices for pyrochlore concentrates since this ore is consumed internally by the company that mines and upgrades this mineral. Niobium-bearing minerals and products are not traded on the London Metal Exchange. References to niobium-bearing mineral concentrates are found in the Metal Bulletin but the Tantalum-Niobium International Study Center has no knowledge or comment concerning the accuracy of this information.

Niobium Raw Material Production, 1997 – 2000 (Mlb contained niobium oxide)

	1997	1998	1999	2000
Pyrochlore and columbite concentrates	63.98	76.53	70.60	72.52
Tantalite, struverite, tin slag	0.58	0.92	2.57	1.20
Total	**64.56**	**77.45**	**73.17**	**73.72**

Source: Tantalum-Niobium International Study Center

HSLA-grade ferro-niobium reportedly has had stable pricing over the past twenty years, broadly with a range of US$6.50-7.50/lb. of contained niobium. Prices for niobium oxide, other niobium chemicals, niobium metal and various alloys derived from either pyrochlore or other niobium-bearing sources are highly variable depending on product specifications, volume, and processing considerations.

Niobium Product Shipments, 1997 – 2000 (Mlb contained niobium)			
	1998	**1999**	**2000**
Chemicals, VG FeNb, NiNb	4.87	4.91	6.32
Wrought Nb, Nb alloys as mill products, powder, ingot, and scrap			
Pure niobium	0.38	0.33	0.48
Alloys as NbTi, NbZr, NbCu	0.85	1.02	1.18
HSLA-grade FeNb	53.06	44.36	44.91
Total	**59.16**	**50.62**	**52.89**

Source: Tantalum-Niobium International Study Center