TANTALUM-NIOBIUM INTERNATIONAL STUDY CENTER

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The Chinese tantalum and niobium industry

The People's Republic of China has been self-sufficient in tantalum and niobium over the last two decades or so, even exporting some products to the West from time to time. However, these sales have been sporadic, and Chinese production seems to be directed towards satisfying domestic demand — China has never been regarded as a stable supplier of tantalite concentrates. The government intends to expand and modernise some sectors of the country's non-ferrous metals industry and apparently has some interest in tantalum/niobium production.

In China's centrally planned economy, mines and smelters do not market their own products; various quasi-governmental organisations have this responsibility. Minmetals, the state-owned corporation, have traditionally been the principal outlet for Chinese metallic products. They have now been joined by the China National Non-ferrous Metals Industry Corporation (CNNC) which is divided into subsidiaries operating at provincial level. Each of these provincial organisations is responsible for its own area's non-ferrous metals output.

A large part of China's marketing effort in non-ferrous metals has been directed towards tungsten in recent years, and China is today the world's largest producer of tungsten products. Chinese tantalum/niobium production has a strong tungsten association; but there do not appear to be any plans to capture a share of the world's market in the way that China has gained a large share of the tungsten market. Previously, exports of tantalite concentrates have only increased significantly when the market conditions have been favourable. China is attempting to increase and modernise its production to meet domestic requirements which are said to be rising in such areas as electronics, aerospace and nuclear energy. Western expertise is being sought for some of these projects.

MINE PRODUCTION

Chinese tantalite production appears to be centred at two distinct sources : Limu, Guangxi province; and Yichun, Jiangxi province.

In 1980 it was reported that three separate mines existed at Limu, one open-cast and two underground. The open-cast mine had ore reserves of four million tonnes at 0.1 % Sn, 0.015 % Ta_2O_5 and 0.015 % Nb_2O_5. One underground mine had ore reserves of 30 million tonnes at 0.006 % Ta_2O_5/Nb_2O_5 combined; the other had 30-100 million tonnes at 0.015 % Ta_2O_5. Mineral dressing was by milling and separating with wet tables and spirals. The low concentrate obtained was further upgraded pyrometallurgically. The total production was around 50 tonnes of oxide content in 1980, most of this from the open-cast mine. The mine is also a significant producer of tin and tungsten.

There is a processing plant at Limu to produce various tantalum and niobium products : oxides, carbides, potassium fluotantalate, mill products and powders (capacitor-grade and metallurgical-grade). Processing was based on hydrofluoric acid digestion and alcohol (not MIBK) separation in 1980. A two-stage development plan was announced in 1986 to increase tantalum and niobium production and improve the standard of products to an international level. The Chinese were seeking a joint venture with a foreign company to supply the appropriate technology. The expansion was due to take place over three years.

Development plan at Limu — anticipated future outputs (tonnes/year)

Product	*Short-term*	*Long-term*
Tantalum oxide	5	10
Niobium oxide	10	10
Tantalum and niobium strip	3	5
Metallurgical-grade tantalum powder	5	10
Capacitor-grade tantalum powder	10	25

Tantalite concentrate production at Yichun, China's second significant source, has recently been increased, and the mine now treats 1500 tonnes of ore a day. The mine also produces tungsten, and the ore is thought to have a large radio-active content. The Yichun deposit is China's largest potential production base for tantalum and niobium.

In addition to the large-scale productions, there seem to be smaller quantities of tantalite coming as a by-product from other mining operations, such as for tungsten. The Xinjiang Research Institute of Metallurgy has developed a small-scale rotary spiral chute which is recommended for heavy minerals such as tantalite.

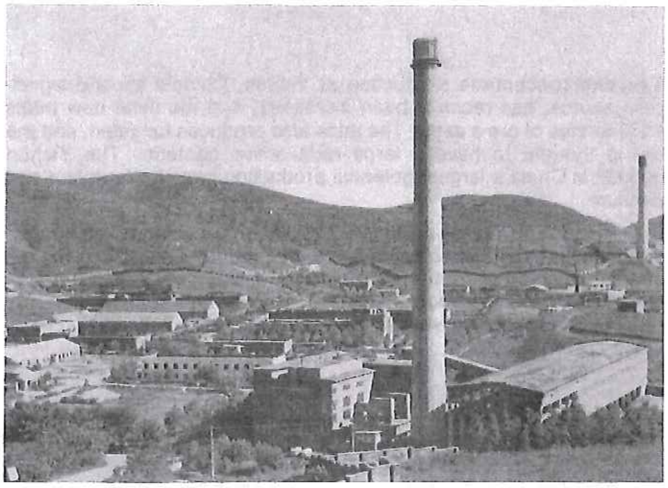
PROCESSING PLANTS

Apart from the facility at the Limu mine, Guangxi province, three other tantalum/niobium processing plants are known to exist in China : Jiujiang Nonferrous Metallurgical Factory, Jiangxi province; Ningxia Nonferrous Metals Smelter, Ningxia province; and Zhuzhou Cemented Carbide Works, Hunan province. These plants produce the full range of tantalum/niobium metallic and compound products, some of which, it is claimed, are exported, though Chinese capacitor-grade powder is essentially unusable in Western capacitor plants as it does not conform to the necessary chemical and electrical parameters.

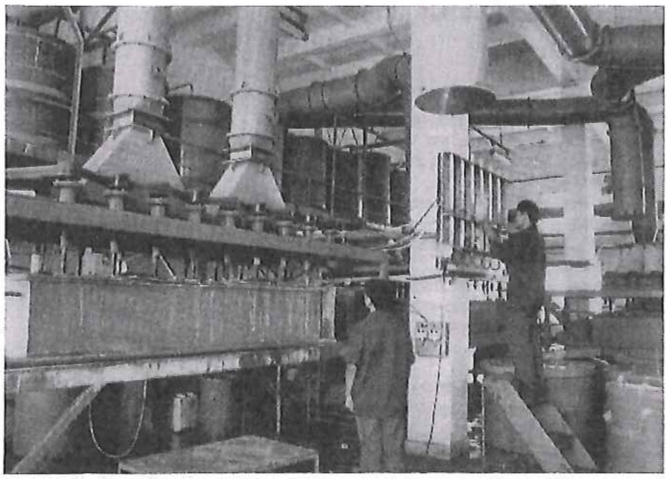
The Jiujiang plant is China's largest producer of tantalum and niobium, as well as rare earths. The plant began operating in 1981, and over 150 technicians are currently employed there.

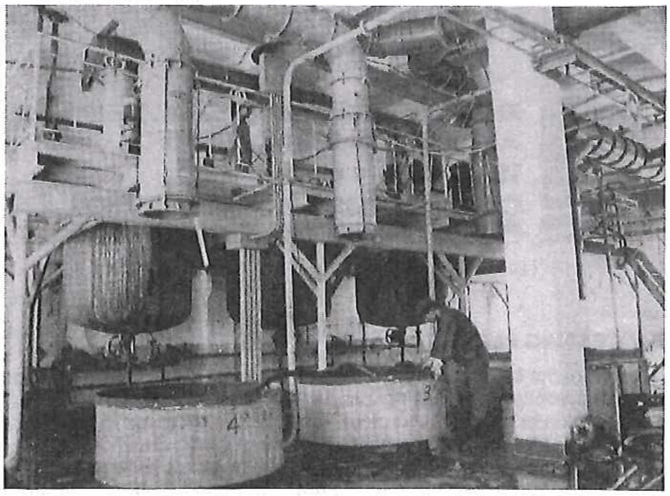
Products of the plant include : capacitor-grade and metallurgical-grade powders; capacitor-grade wire; billet, sheet and rod; carbides (single and mixed); oxides (standard-grade and high-grade); potassium fluotantalate; ferro-niobium; lithium niobate; and ceramic crucibles. The annual output of Jiujiang is around 50 tonnes of tantalum and niobium metal and 50 tonnes of oxide.

Jiujiang Nonferrous Metallurgical Factory



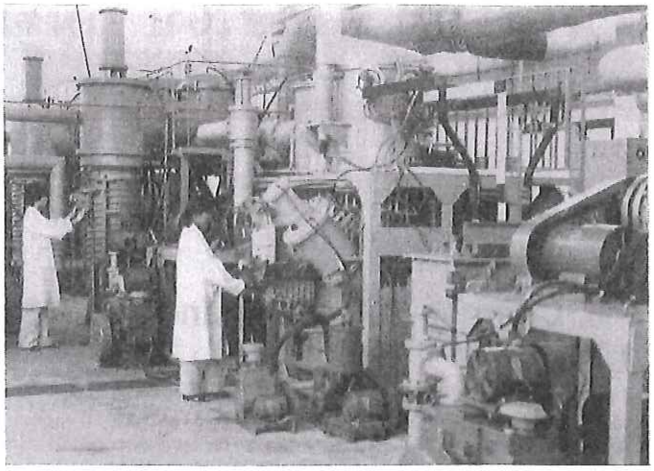
Potassium fluotantalate production





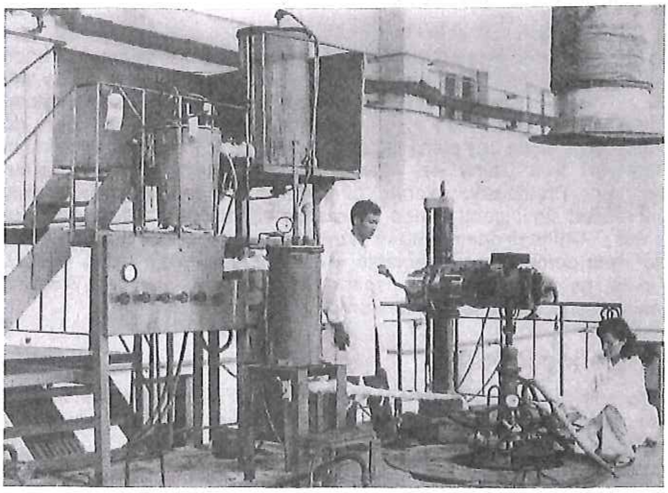
Tantalum powder CV ratings go from 500 to 10 000 μFV/g (in the West, CV ratings exceed 22 000 μFV/g). These powders are produced by the sodium reduction of molten salt.

Tantalum powder production



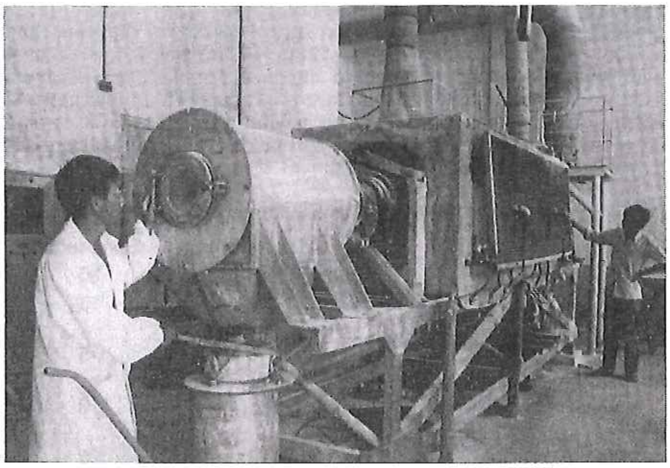
Metallurgical-grade powder obtained from oxide is pressed into bars and then sintered to produce billets. The maximum cross section is 14 × 14 mm for niobium and 10 × 10 mm for tantalum; this limits the sheet dimensions which can be produced to 500 × 200 mm. The Jiujiang plant does not appear to be capable of electron-beam melting on a commercial scale, so the powder-metallurgical route seems to be the main production method for sheet, wire, etc. Capacitor-grade tantalum wire seems to be the principal mill product with diameters between 0.25 and 1.00 mm. Niobium is used to manufacture components for sodium-vapour lamps, as well as for superconducting and high-temperature alloys.

Tantalum capacitor wire production



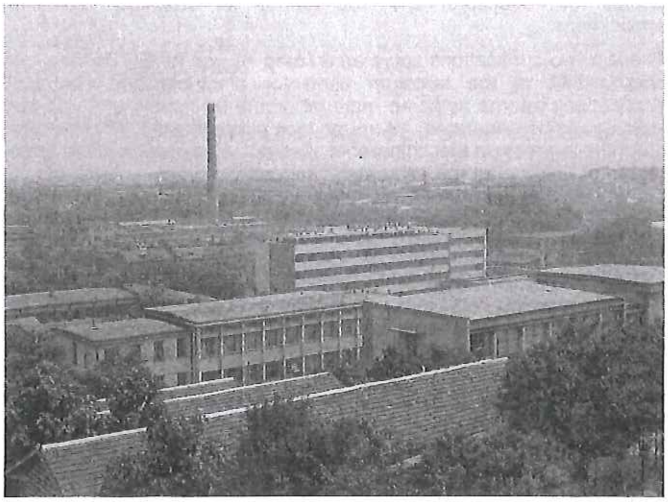
The main compound product is carbide, both single and binary (tantalum-niobium) forms; this is consumed by the Chinese cemented carbide industry. Some oxide is further refined for use as an additive to optical glasses and ceramic capacitors. The Jiujiang plant also produces lithium niobate single crystals from high-purity oxide; this material is used for the manufacture of surface acoustic wave devices. The plant also makes ceramic crucibles from tantalum and niobium oxides, apparently for internal use to sinter high-purity oxides.

Production of niobium oxide



The Zhuzhou Cemented Carbide Works was China's first large producer of cemented carbides and refractory metals, being built during 1954-58 with the assistance of Soviet technology.

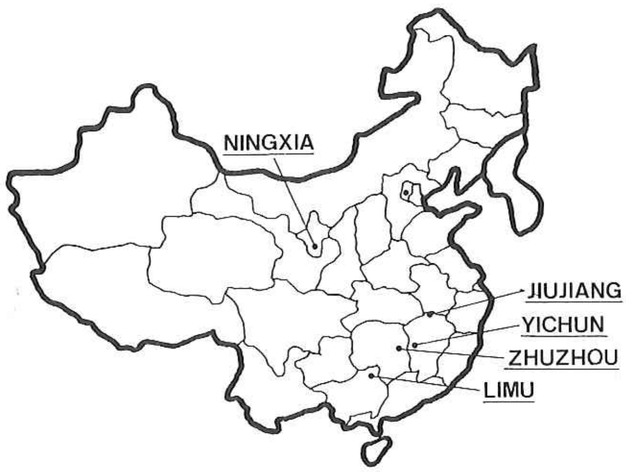
Zhuzhou Cemented Carbide Works



The Tantalum and Niobium Smelting and Processing Division Factory produces annually around 10 tonnes of tantalum and niobium powder, 40 tonnes of niobium oxide, and 3 tonnes of tantalum mill products (mainly capacitor wire). Various grades of tantalum/niobium carbides are also produced for use in the cemented carbide plant, the main business of the Zhuzhou enterprise. The tantalum capacitor-grade powder has a CV rating up to 10 000 μFV/g. One-third of the niobium oxide is used to make lithium niobate single crystals, the remainder for ceramic capacitors.

Recently, the China National Nonferrous Metals Industry Corporation (CNNC) has been seeking co-operation from foreign companies to improve the tantalum powder production plant at Ningxia Nonferrous Metals Smelter.

Chinese production centres



RESEARCH ACTIVITIES

The General Research Institute for Non-ferrous Metals, Beijing, recently claimed to have developed capacitor-grade tantalum powder with a CV rating of 18 000 μFV/g which approaches Western standards. And the Central South University of Technology, Hunan province, is investigating the influence of sintering temperatures on the anode performance of tantalum capacitors.

SUMMARY

China has a long-established tantalum and niobium industry which is directed towards satisfying domestic demand rather than exporting products to the West. The non-ferrous metals industry is currently undergoing a programme of modernisation; some of these projects involve tantalum/niobium production.

Andrew Jones
Technical Officer

President's letter

It is now half a year since we held the last General Assembly in Brussels.

The expectations mentioned there — based to a large extent on the T.I.C. statistical work — seem to be materialising now. This shows once more the importance of good communication, which is the chief target of our organisation.

This is also the main purpose of the International Symposium on Tantalum and Niobium which the T.I.C. is organising. In this issue of our Bulletin you will find an invitation to co-operate in this event, either by sponsoring it or by presenting a paper.

In any case, please be sure to come to Orlando in November !

H.J. Heinrich
President

Metallurgie Hoboken-Overpelt and their present activities in the field of tantalum and niobium

This paper was presented by Mr Theo De Cleyn, Metallurgie Hoboken-Overpelt (MHO), at the T.I.C. meeting on October 20th 1987.

MHO are a 56 % subsidiary of Union Minière which in turn is 100 % owned by the Société Générale de Belgique Group.

Société Générale de Belgique (SGB) are the largest private holding in Belgium and active in many different sectors : mining, industry, distribution, finance, engineering, shipping and trading. SGB control 1261 companies in 67 countries, of which 487 companies are located in Belgium, 468 companies in other countries of the European Economic Community (EEC), 30 in European countries outside EEC and 276 companies outside Europe. The most important mining and industrial investments concern the sector of non-ferrous metals and represent 16 % of the estimated value of the total shareholdings of SGB.

Union Minière are the key company as regards the activities in the non-ferrous metals sector of the SGB Group. UM have been 100 % controlled by SGB since 1981.

The origins of **Metallurgie Hoboken-Overpelt** (MHO) go back to the early 1900's with the establishment of the copper smelter and refiner 'Cie Industrielle Union' in 1908 and the acquisition of the site on which MHO's Olen works now stand. This company, which was later to become Metallurgie Hoboken-Overpelt, acquired a desilvering and lead refining plant at Hoboken in 1919. The origins of the second strand of MHO, 'Cie des Métaux d'Overpelt-Lommel et de Corphalie', date back to 1913 with the acquisition of a lead and zinc refining plant at Overpelt.

MHO are the result of the integration of three plants with several smelting and refining facilities, located at Hoboken, Olen and Overpelt. The processing of feed material relies on the production circuits of three base metals — lead, copper and zinc — with major interflow of products containing several secondary metals.

Without any privileged access to sources of raw materials, Metallurgie Hoboken-Overpelt, today one of the largest and most diversified European producers of non-ferrous metals, specialize in the treatment of secondary products. Scrap and recycling in general are becoming more and more important for the supply of the smelting and refining facilities of Metallurgie Hoboken-Overpelt. Secondary materials represent 66 % of the feed of the Hoboken plant and supply more than 80 % of precious metals.

MHO's capital and reserves total 10.8 billion Belgian francs (about $ 285 million); business volume is 76.5 billion Belgian francs (about $ 2 billion). The number of employees is 6850.

PRODUCTION AT MHO OF METALS OTHER THAN TANTALUM AND NIOBIUM

MHO produce pure metals, alloys and compounds as well as chemical products of about 26 elements of the Periodic Table. These activities are centred at three sites : Olen, Overpelt and Hoboken.

Olen

The copper refinery at Olen ranks first in Europe and fourth in the world. The electrolysis facility covers more than five acres and has a capacity of 330 000 tonnes of electrolytic copper per year. Its main sources of supply consist of blister copper, black copper and scrap with high copper content. The most up-to-date technology for continuous and semi-continuous casting are employed. An original process developed at Olen is now in use for continuous casting and rolling cathodes straight into 'Contirod' copper rod.

MHO are the most important supplier of special cobalt products in the world. The total capacity of the plant is 8400 tonnes cobalt content per year. The special cobalt products can be divided into three categories : powder (the extra-fine grade ensures a worldwide reputation for the plant), oxides and salts. MHO's U.S. subsidiary, Carolmet, produces extra-fine powder at Laurinburg, North Carolina.

The germanium production facility at Olen is not only the largest but also the most diversified in the world, delivering products for advanced applications, e.g. electronic-grade tetrachloride for optical fibres, lens blanks for infrared optics, and 'Intrinsic' metal for radiation detectors.

Sophisticated equipment at Olen treats very complex secondary products, the advanced technology used having been developed in the company's laboratories. Nickel salts and concentrates with high precious metal contents are produced.

Overpelt

Zinc and cadmium are the main products of this division. The zinc electrolysis has an annual capacity of 120 000 tonnes of cathodes; these zinc cathodes are melted and cast into many marketable shapes or converted into various alloys, 'Zamac' being the best known. A new installation produces remelted zinc from shredder residues; high-grade thermic zinc is yielded by refining in distillation columns. Other workshops produce powder for alkaline batteries and slugs and cans for dry-cell batteries.

Further activities of this division include the production of aluminium sulphate and the transformation of lead into sheet, strip, tube, wire and shields against ionizing rays.

The moulds and tools workshop is internationally known for the quality and reliability of its moulds for the die-casting of alloys and injection of plastics.

Hoboken

The Hoboken division specializes mainly in the treatment of complex lead, copper and precious-metal concentrates and secondary products. Processing methods rely on a combination of the known processes used in lead and copper extraction. Precious metals, concentrated in various by-products of the lead and copper refineries, are separated in a refinery operating a nitric acid cycle. Several refinery plants produce special metals such as selenium, tellurium, arsenic, antimony, bismuth and indium, either in elemental form, as salts or various intermediate products.

TANTALUM AND NIOBIUM PRODUCTION AT MHO

MHO's tantalum-niobium plant, located at the Hoboken site, has a capacity of 50 tonnes Ta per year, plus the associated niobium output.

When the tin market was more rewarding than today, MHO produced an average of 900 tonnes per year of tin, the slags of which were tantalum-bearing. MHO stopped tin production at the beginning of this decade and learned to work with tantalum concentrates as well. Throughout the feedstock variations, MHO maintained capacity at 50 tonnes Ta per year.

The integrated production line is sub-divided into three stages that lead subsequently to the production of : potassium fluotantalate and niobium hydroxide; sodium-reduced tantalum powder; and tantalum ingot, sheet, bar and melt pieces. Each of these products is commercialized.

The chemical processing of tantalum-niobium concentrates is based on solubility differences of salts in aqueous solution and in organic solution. The concentrates are leached with hydrofluoric acid. Aqueous solution is separated by liquid-liquid extraction with an organic solvent (MIBK) in mixer-settlers. After distillation, the pure tantalum fluoride solution is treated with potassium fluoride to obtain potassium fluotantalate, and the niobium fluoride solution is treated with ammonia to obtain niobium hydroxide.

Since MHO's chemical section has changed to producing potassium fluotantalate instead of tantalum hydroxide, reduction by electrolysis has been replaced by sodium reduction in appropriate reactors. After milling, washing, chemical treatment and drying, tantalum melting powder (metallurgical-grade) is obtained.

Before melting, the tantalum powder is degassed and then isostatically pressed into bars under a pressure of several tonnes per cm^2; the same is done with tantalum scrap delivered by customers, in the form of anodes, clippings, foil, wire, powder, etc. The bars are suitable for electron-beam melting in the 500 kW four-gun furnace under high vacuum (7×10^{-8} bar) at about 3000 °C.

The unscarfed ingots have a 6-inch nominal diameter and weigh about 500 kg. They can also be delivered scarfed, with a $5\frac{1}{2}$-inch nominal diameter, or can be further processed to forged sheet-bars or to 'melt pieces' suitable as additive to superalloys.

Due to the liquidation of large stocks of tantalum scrap over the last few years, refining of scrap to high-purity ingots has become economically very attractive today compared to production of ingots from primary sources. MHO further developed their electron-beam melting know-how to refine impure tantalum scrap to high-purity ingots.

To see where tantalum scrap is generated, it is helpful to recall that the present world consumption of about 1000 tonnes Ta per year can be split up into : 300 tonnes for carbides; 100 tonnes for superalloys; 450 tonnes for capacitors; and 150 tonnes for chemical corrosion applications.

The last two applications serve as a scrap source for EB melting. If about 15 % of the tantalum used for electrical and chemical applications returns as scrap material, about 90 tonnes of scrap per year should be generated. A rough look at the latest T.I.C. statistics gives the impression that shipments of scrap could now be in the same region of volume as the estimated production volume. This should then mean that the offered quantities would be in the neighbourhood of the generated quantities which confirms the now prevailing feeling of a certain scrap shortage.

Tantalum scrap is available on the market in the following forms :

- Powder which has been rejected by the capacitor producers as being too fine, too coarse or containing too many impurities, or has been produced through hydrogenation, grinding and degassing of clippings, wire, plate or any other shape;
- Anodes rejected by the capacitor industry for lack of purity or poor electrical properties;
- Pins (wire) are short pieces of wire recycled from the production of anodes;
- Clippings, plate, sintered ends, turnings are generated by sheet, wire or equipment production.

Scrap presents its own problems during refining : some powder has a high impurity content; oxygen and sometimes manganese are high in coloured anodes; and sintered ends, clippings, wire and plate can be contaminated by refractory metals (W, Nb, Mo and Ti). To avoid any contamination MHO do not mix scrap of different origin and execute for every scrap lot a complete sampling and weighing procedure which has three steps : each lot is separated by shape; each part is then weighed and sampled by an automatic rotary splitter; each sample is crushed under inert gas to a fine powder, mixed and further divided into the final samples by a second rotary splitter. The samples are then analysed and the results transmitted to the scrap supplier.

The scrap preparation prior to electron-beam refining depends on the scrap's origin as :

- clippings, foil, plate and turnings are normally soiled with oil and so need to be degreased;
- material containing high levels of hydrogen, sodium or potassium needs to be degassed under vacuum at a medium temperature;
- anodes too highly contaminated need special treatment such as degassing or chemical refining.

All these scrap types are then compacted into bars in order to feed them into the melting furnace. For this purpose a cold isostatic press is used to compact the anodes, powder or other pieces at 200 MPa.

The refining of scrap is achieved in a high-vacuum electron-beam furnace, as mentioned before. Impurities such as oxygen, carbon, nitrogen, hydrogen and non-refractory metals are reduced to very low values. Oxygen will evaporate mainly under the Ta-O form and can be reduced from an initial 2.5 %, the maximum allowed content in scrap, to less then 100 ppm. Nitrogen is limited to 500 ppm in scrap as it is removed at a very slow rate. Hydrogen is driven off far below tantalum's melting point (2996 °C), but the content in the feed is limited to 100 ppm to avoid too much pumping. As a general rule, one may say that the melting yield is basically determined by melting technique and by the impurity content of the molten scrap, mainly the oxygen content.

It is hoped that this short presentation will give an idea of Metallurgie Hoboken-Overpelt and their activities in the field of tantalum and niobium.

Tantalum production at Greenbushes

The information for this article was obtained from the "Greenbushes Annual Report 1987" and "An overview of the operations (Greenbushes)".

In response to the improving market for tantalite concentrates, Greenbushes increased production significantly during the second half of 1987. Further increases can be expected this year if the current upward trend in the tantalite market continues. In February 1988, Greenbushes re-instated their producer price for tantalite (40 % basis) after a six-year suspension.

In the financial year ending June 30th 1987, the Western Australian mine produced around 120 tonnes of tantalite concentrates at 30 % Ta_2O_5, equivalent to 36 000 kg Ta_2O_5 contained. The mine site operated at approximately 40 % of capacity for both tantalum and tin with emphasis on mining of high-grade tin alluvial deposits.

Mine operating summary
(year ending June 30th)

Year	Ore treated (million tonnes)	kg/tonne Ta_2O_5	kg/tonne Sn
1983	1.02	0.029	0.42
1984	1.54	0.031	0.28
1985	1.88	0.033	0.27
1986	1.50	0.027	0.29
1987	1.27	0.027	0.35

In the half-year (28 weeks) following the end of the 1987 financial year, ore throughput was 0.71m tonnes to produce 39 300 kg Ta_2O_5 and 144 tonnes of tin metal.

The two-stage, electric-arc tin smelter ran on a five-days-a-month basis during the year. Besides tin metal, the smelter produces a high-grade Ta_2O_5-containing slag marketed under the name of "tantalum glass". This product contains 30 % Ta_2O_5 and 13 % Nb_2O_5.

Tin smelter outputs

Year	Tin metal (tonnes)	Tantalum glass (kg Ta_2O_5)
1983	*520*	*17 000*
1984	*515*	*22 000*
1985	*690*	*33 620*
1986	*551*	*29 010*
1987	*495*	*25 430*

Slag being tapped from the smelter

Over the last three years, the company has responded to the low market for tantalite by entering the market for "downstream" products. The mine-site solvent extraction plant was restarted in February 1987 and has been expanded to allow the production of 50 tonnes of tantalum oxide and 30 tonnes of niobium oxide a year. Almost half of the mine production has been sold in upgraded forms : oxides have been toll-converted into carbides in the U.S.A. and into metallurgical-grade powder and ingot in Europe.

Oxide plant outputs

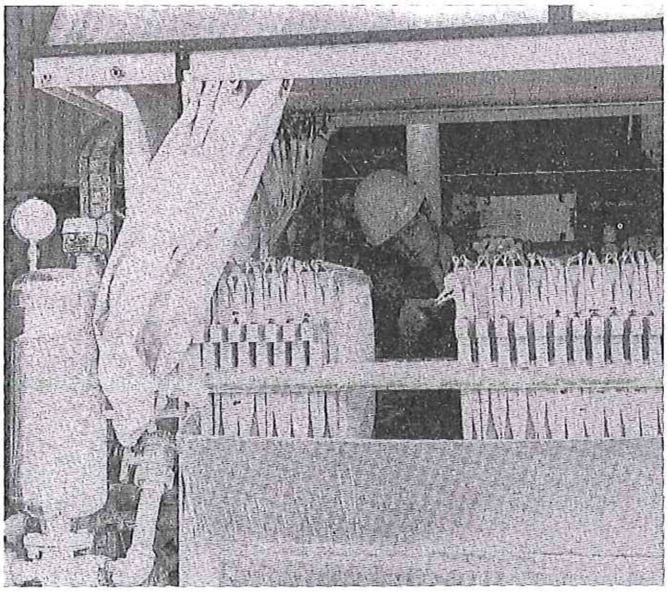
Year	Tantalum oxide (kg)	Niobium oxide (kg)
1983	2 300	nil
1984	10 100	1 000
1985	18 200	2 000
1986	9 250	2 300
1987	7 420	5 740

Greenbushes' policy is to increase the proportion of future production sold as refined products so as to be less dependent on the raw material market. The company is also committed to increasing its market share to 25 % of world demand.

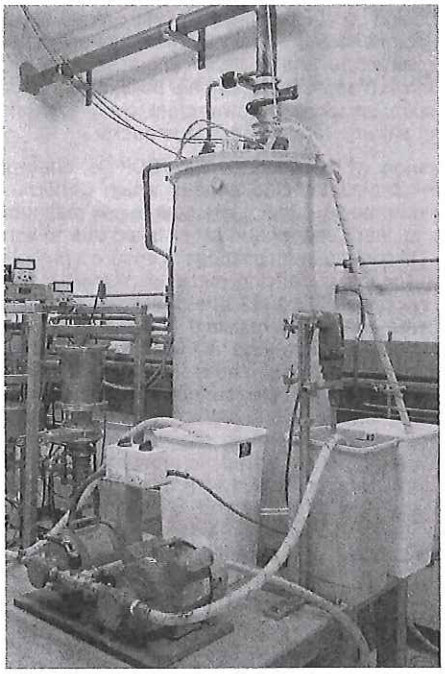
A collaborative research project was completed during the year with the Commonwealth Scientific and Industrial Research Organisation (CSIRO) into high-gradient magnetic separation using superconductivity. A prototype facility demonstrated the feasibility of extracting fine particles of tantalite which are lost with conventional technology. Greenbushes estimate that a production-scale plant could increase recovery of tantalite by 6-7 %.

Current tantalite production is entirely from open-pit mining of weathered (soft rock) pegmatites. The ore is first treated in the clay plant to achieve primary separation. The concentrate obtained is sent for secondary separation which is a two-step process : the first is wet gravity concentration, and the second is dry gravity concentration. Magnetic separation is used to obtain cassiterite (tin) and tantalite concentrates. A mineral called stibio-tantalite is also produced by the secondary separation which contains 20 % antimony and

Tantalum/niobium oxide production



Superconducting high-gradient magnetic separator at CSIRO laboratories



so is not a preferred raw material for tantalum processing; specially developed techniques, such as leaching and high-temperature roasting, are required to remove the antimony content.

A tailings treatment plant was built in 1981 to reprocess waste material from the ore concentration. During 1987, the plant was not in operation, but much of this year's expected increase in tantalite production will come from this secondary source.

Tailings treatment plant

The underground tin-tantalite mine is currently on care and maintenance, but mining is ready to commence at short notice. This year, it is intended to complete the planning and engineering designs of a hard-rock, open-cut mine and a primary concentration plant.

Greenbushes, located 250 km south-west of Perth, Western Australia, is celebrating its centenary as a tin-mining town. Tin was first mined in Greenbushes in 1888 and production has been continuous ever since. Greenbushes Ltd. will join the townspeople in celebrating the event.

Miniaturised impressed-current corrosion protection systems : an application for platinum-clad niobium

This article was first published in the April 1986 issue of 'Platinum Metals Review'. The author is Dr Robert Baboian, Texas Instruments Inc.

The need for corrosion protection of metals in aggressive environments is well recognised; one of the important ways of providing this corrosion resistance is by cathodic protection. With impressed-current corrosion protection (ICCP), the metal structure to be protected is polarised cathodically by means of an impressed current between the structure and a stable anode. Today, ICCP is used extensively in such applications as ship hulls, oil and gas rigs, marine structures such as docks, power-plant heat exchangers, buried pipelines and storage tanks, and bridge decks.

The wide range of applications for ICCP is due mainly to the development of platinum-clad anodes which perform efficiently in corrosive environments. Initial attempts to use platinum coatings on metals such as lead, copper and silver failed due to corrosion of the substrate. Thicker platinum coatings to ensure a pinhole-free protective covering for the underlying metal were tried but these anodes were not economical. In 1913, the possibility of using platinum in conjunction with chemically resistant 'valve metals' was first recognised. Tantalum, niobium and titanium have rectifying characteristics in that when anodised in aqueous environments, an insulating oxide film is formed on the surface. Thus, when coated with platinum, these metals will form protective oxide films where exposed, and the anodic electrochemical reaction will occur on the platinum. The development of economic processes for the production of these rectifier metals, combined with the development of ingenious methods of applying thin layers of platinum on them — such as electro-deposition and cladding — led to the development of the stable platinum-clad anode. The potential of this anode for ICCP was first recognised in 1958. Since that time, the performance and development of various platinum-surfaced anodes have been widely covered in the literature.

MINIATURISED SYSTEMS

To date, impressed-current corrosion protection has been used almost exclusively for the protection of relatively large structures. However, the need for small, economical systems has increased through the years. In the case of hot-water storage tanks, potable waters have become more corrosive in recent years due to increased acidity and aggressive ions. Another example involves the more stringent requirements for reliability in water pumps, valves and other plant equipment which have required the use of more expensive materials. An economic miniaturised impressed-current corrosion protection system (mini-ICCP) can now be used in these applications, as well as in a wide range of others.

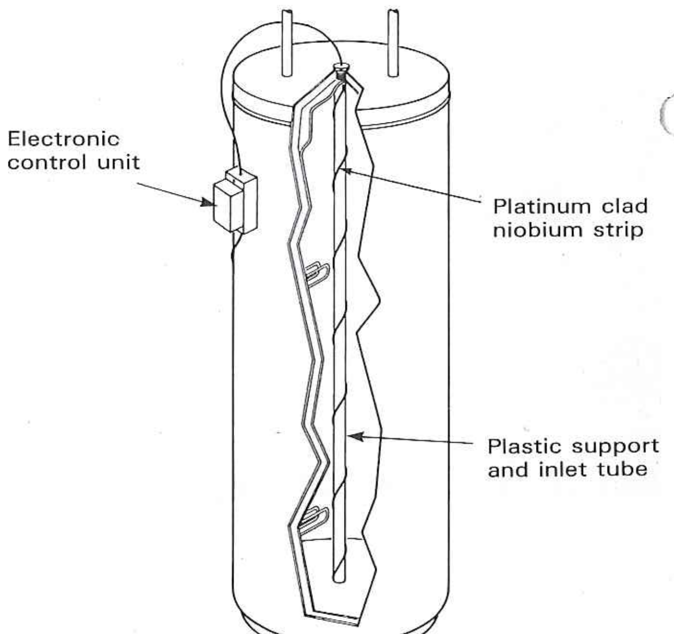
Recent developments in electronics technology for corrosion engineering, along with the development of platinum-clad anodes, have allowed the miniaturisation of ICCP systems. These mini-ICCP systems can now be used in applications where small, controlled currents are required. The miniaturised circuitry has been made possible through the development of sophisticated integrated circuits. The cost of these devices has been reduced so that small controllable power sources can be produced at competitive prices.

HOT-WATER STORAGE TANKS

Use of the best available technology has resulted in a hot-water storage tank constructed of glass-lined, welded steel shell. However, the glass coating is not always free from imperfections, especially in the weld areas. Thus, additional corrosion protection is necessary, normally through the use of magnesium sacrificial anodes. In recent years, premature failure of magnesium anodes has led to an increased failure rate of hot-water storage tanks. Manufacturers have searched for a universal cathodic protection system that is effective regardless of the corrosivity of the water. This has led to the development of a mini-ICCP system for hot-water storage tanks, as well as for a wide range of equipment requiring small protection currents and miniaturised components.

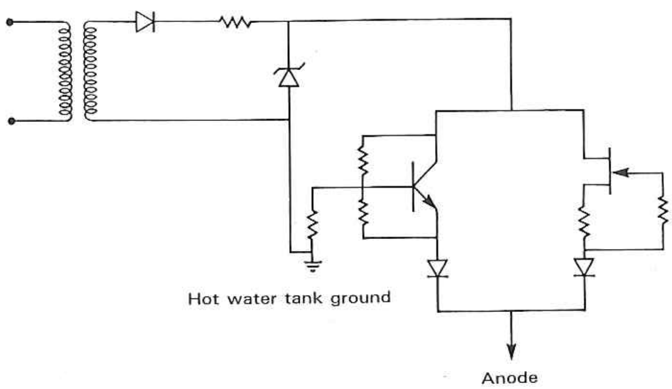
In order to protect the interior surface of a glass-lined steel tank, the system must be capable of providing uniform protection over the entire surface. Crevices formed by welds at the top and bottom of the shell are the most likely areas for defects in the glass lining, although such holidays may occur in other areas of the tank wall. In electrically heated tanks, the through-wall heating elements may also need protection. These factors require that the anode extends over the full length of the tank to provide uniform cathodic protection. The tank wall (cathode) and the platinum-clad niobium anode are connected through a control circuit to an AC power source.

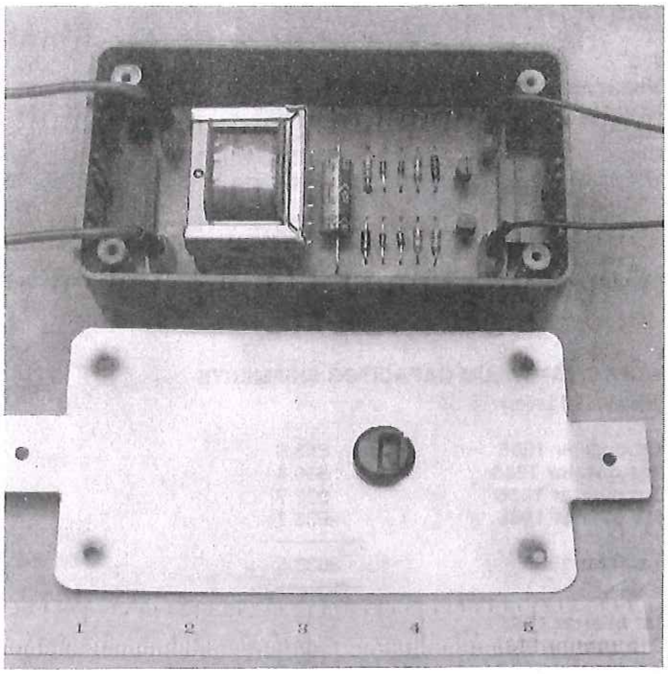
Hot-water storage tank protected by mini-ICCP system



The anode must be designed to have a long predictable life in the hot-water storage tank environment. Platinum-clad niobium has suitable properties for this environment, including high breakdown potential for the niobium substrate, a uniform platinum cladding, a sound metallurgical bond that prevents platinum spalling, and ease of fabrication. The platinum consumption rate is extremely low and predictable in this environment, so that the design of the platinum-clad

ICCP control circuit



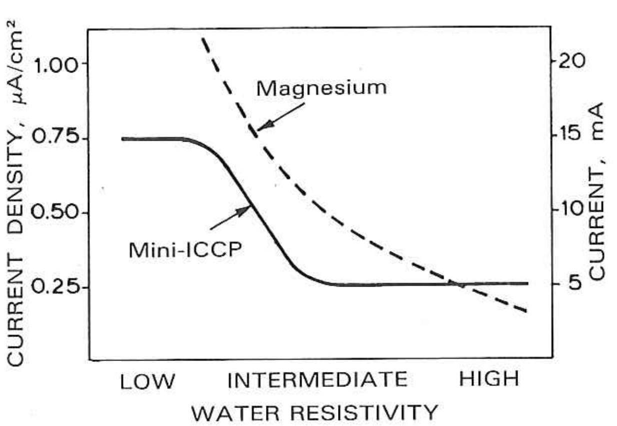


niobium anode is very reliable. The anode consists of a strip of platinum-clad niobium, spirally wound on a plastic support tube which extends from the top to the bottom of the tank. The support tube also serves as the water inlet tube.

In order to be universally effective, the mini-ICCP system must be capable of providing the necessary protection current in corrosive waters while not impressing too much current in less corrosive waters. In addition, an adequate protection current must be maintained regardless of the water resistivity. The key to this is the development of a control circuit which provides the protection current as a function of water resistivity.

For a state-of-the-art mini-ICCP system in a commercial hot-water storage tank, the curve of protection current versus water resistivity has three regions : the region of low resistivity and high corrosivity requires maximum protection current; the region of intermediate resistivity exists whereby the current decreases with increasing resistivity; and the third region of high resistivity and low corrosivity requires minimum protection current. At low resistivities (high corrosivity) the protection current is extremely high, possibly leading to rapid corrosion and premature failure rate of the magnesium anode. At high resistivities, the current is very low which could lead to under protection.

Tank protection current versus water resistivity



The regulating nature of the control circuit provides the output which conforms to a curve of current density versus water resistivity. The circuit consists of a constant voltage section, a constant current section, and appropriate switching circuitry.

(To be continued in Bulletin no. 55)

T.I.C. statistics

QUARTERLY PRODUCTION ESTIMATES

(quoted in lb Ta_2O_5 contained)

MB quotation :	*US \$ 30*	*US \$ 40*	*US \$ 50*
1st quarter 1988	274 550	304 000	480 900
2nd quarter 1988	274 550	314 000	500 900
3rd quarter 1988	274 550	334 000	510 900
4th quarter 1988	274 550	384 000	520 900
1st quarter 1989	274 550	394 000	560 900

PRODUCTION AND SHIPMENTS

(quoted in lb Ta_2O_5 contained)

4th quarter 1987

All materials :	*Production*	*Shipments*
tin slag (over 2 % Ta_2O_5), tantalite, other	350 206	310 968

(The combination of the categories is under investigation)

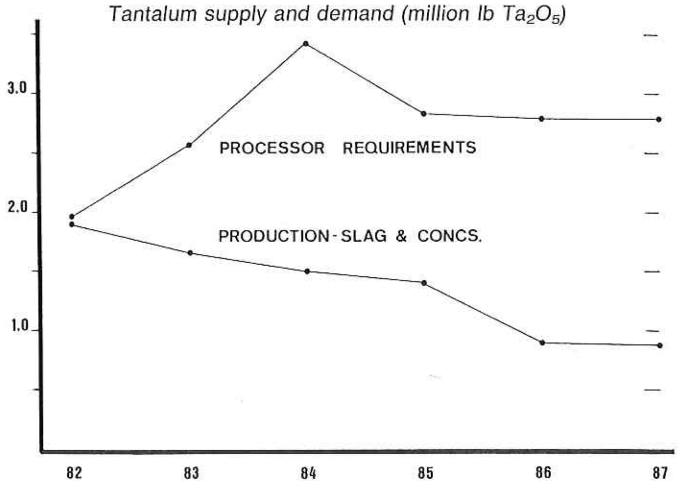
Note : The response from the companies asked to report was 15/16 and included these producers :

Datuk Keramat Smelting
Greenbushes
Malaysia Smelting
Metallurg Group
Tantalum Mining Corporation of Canada
Thailand Smelting and Refining

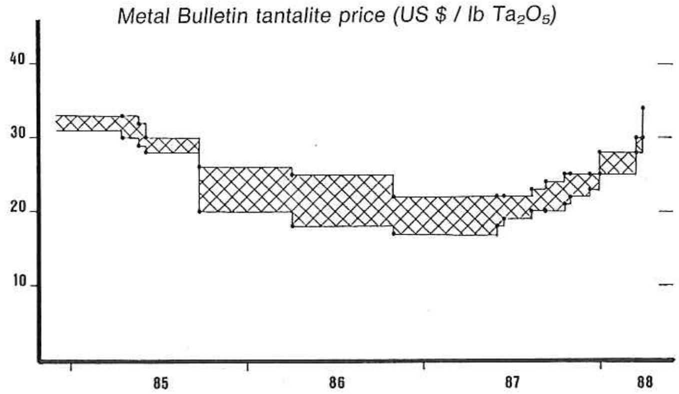
Total for 1987

All materials :	*Production*	*Shipments*
tin slag (over 2 % Ta_2O_5), tantalite, other	885 624	763 004

Tantalum supply and demand (million lb Ta_2O_5)



Metal Bulletin tantalite price (US \$ / lb Ta_2O_5)



PROCESSORS' SHIPMENTS

4th quarter 1987

Product category	*lb Ta contained*	*lb Ta_2O_5 equivalent*
Tantalum oxide/K_2TaF_7	27 021	36 478
Carbide	153 139	206 738
Powder/anodes	222 049	299 766
Mill products	94 970	128 210
Alloy additive, scrap, ingot, unworked metal, other	98 206	132 578
Total	595 385	803 770

Notes :

1. The response from the companies asked to report was 16/17 and included these processors :
   - Cabot Specialty Metals - Electronics
   - Fansteel
   - W.C. Heraeus
   - Kennametal
   - Metallurg Group
   - Mitsui Mining and Smelting
   - NRC
   - Showa Cabot Supermetals
   - Hermann C. Starck Berlin
   - Treibacher Chemische Werke
   - Vacuum Metallurgical Company
2. Reports were made in lb tantalum contained.

Total for 1987

Product category	*lb Ta contained*	*lb Ta_2O_5 equivalent*
Tantalum oxide/K_2TaF_7	105 966	143 054
Carbide	519 791	701 718
Powder/anodes	859 003	1 159 654
Mill products	322 058	434 778
Alloy additive, scrap, ingot, unworked metal, other	257 908	348 176
Total	2 064 726	2 787 380

Capacitor statistics

EUROPEAN TANTALUM CAPACITOR SHIPMENTS
(thousands of units)

4th quarter 1987	138 019
Total for 1987	544 228

(Data from ECTSP)

JAPANESE TANTALUM CAPACITOR PRODUCTION AND EXPORTS
(thousands of units)

	Production	*Of this exports*
4th quarter 1987	807 300	232 228
Total for 1987	2 891 750	777 541

(Data from JEIDA)

U.S. TANTALUM CAPACITOR SALES
(thousands of units)

3rd quarter 1987

	U.S. shipments	*Exports*	*Total*
Foil/wet slug	2 559	299	2 858
Metal-cased	34 754	9 170	43 924
Nonmetal-cased	165 698	28 846	194 544
Chips	21 297	2 286	23 583
Total	224 308	40 601	264 909

4th quarter 1987

	U.S. shipments	*Exports*	*Total*
Foil/wet slug	2 354	266	2 620
Metal-cased	30 980	8 626	39 606
Nonmetal-cased	158 253	27 587	185 840
Chips	24 992	6 040	31 032
Total	216 579	42 519	259 098

Total for 1987

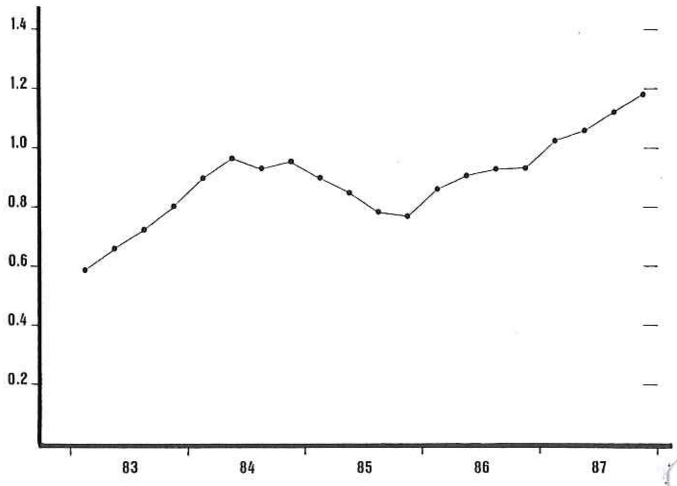
	U.S. shipments	*Exports*	*Total*
Foil	1 051	41	1 092
Metal-cased	123 348	36 790	160 138
Molded	315 061	57 267	372 328
Dipped	317 628	57 848	375 476
Chips	96 284	12 014	108 298
Wet slug	8 953	1 056	10 009
Total	862 325	165 016	1 027 341

(Data from EIA)

WORLD TANTALUM CAPACITOR SHIPMENTS
(millions of units)

1st quarter 1986	863.8
2nd quarter 1986	906.4
3rd quarter 1986	932.7
4th quarter 1986	935.7
Total for 1986	3638.6
1st quarter 1987	1027.5
2nd quarter 1987	1062.6
3rd quarter 1987	1125.5
4th quarter 1987	1183.0
Total for 1987	4398.6

World tantalum capacitor shipments 1983-87
(billion units/quarter)



Data for previous years :

Year	*Shipments*
1978	2066.1
1979	2446.9
1980	2642.6
1981	2557.9
1982	2381.5
1983	2795.9
1984	3754.2
1985	3321.4

Note : The above data, representing world shipments of tantalum capacitors, were compiled by the T.I.C. Statistics Committee by combining regional and export data. They will be updated on a regular basis.

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