TANTALUM-NIOBIUM INTERNATIONAL STUDY CENTER

BULLETIN N° 58 JUNE 1989 SECOND QUARTER

Thirtieth General Assembly and associated meeting

The Thirtieth General Assembly will be held on Thursday October 19th 1989 at the Frankfurt Kempinski Hotel, Neu-Isenburg, Federal Republic of Germany.

On Wednesday October 18th delegates will be able to register at the T.I.C. desk at the hotel, and in the evening there will be a cocktail party to open the meeting.

On October 19th the General Assembly (with attendance restricted to delegates of member companies) will be followed by a programme of technical presentations for the rest of the morning and afternoon sessions, with a break for lunch. The technical programme will close with a panel discussion. In the evening there will be a banquet dinner, also in the hotel.

The participants will go to nearby Hanau on Friday October 20th for a tour of the metallurgical plant of W.C. Heraeus GmbH, where they will also be the guests of Heraeus for lunch. The meeting will close at about 15.30.

The formal sessions of the meeting, and the social events, on October 18th and 19th, will be held at the Frankfurt Kempinski Hotel, where delegates will also stay — a large number of rooms has been reserved for the group. The hotel is at Neu-Isenburg, about fifteen minutes' drive from Frankfurt International Airport and some thirty minutes from Hanau. It has the atmosphere of a country house, and is set in a park of 37 acres (15 hectares) with woodland and a lake, but it also has the facilities of a modern luxury hotel, with several restaurants in various styles, indoor and outdoor swimming pools, fitness room, tennis courts and beauty farm. There is a golf course nearby.

Tours of some of the interesting and historic places in the surrounding area will be arranged during the meeting for ladies accompanying delegates, and the ladies will be most welcome at the cocktail party and the banquet dinner.

A varied technical programme with presentations of interest to all sections of the industries involving both niobium and tantalum is being arranged by the Executive Committee.

Heraeus is well-known as a company in the forefront of metallurgical technology concerned with both tantalum and niobium, and it also works with gold, silver, platinum, titanium, zirconium and beryllium. Participants are assured of a most interesting and informative plant tour when they visit the Hanau works of this company which has been a member of the T.I.C. since 1976.

Invitations will be sent to the nominated delegates of member companies by August 15th 1989. Others interested in attending the meeting should contact the Secretary General of the T.I.C.

President's letter

All the participants in the International Symposium on Tantalum and Niobium, held in November 1988, have by now been sent their copies of the book of the Proceedings. This is a publication which will be most useful to many interested in tantalum and niobium, copies are selling well and we are sure that other readers of the *Bulletin* will wish to order them.

Now the Executive Committee, with the help of W.C. Heraeus GmbH, is arranging the programme for the autumn meeting of the T.I.C. I believe this will be another successful event for the association and I hope to see you there.

Harry Stuart
President

SYMPOSIUM PROCEEDINGS : The Proceedings are now available in the form of a hard-cover book. The price is US $ 100 per copy, including postage and packing. Payment may be sent with the order, or a pro forma invoice may be requested. Inquiries or orders should be sent to the Secretary General, T.I.C., 40 rue Washington, 1050 Brussels, Belgium.

Pancontinental Mining to produce tantalite in the Pilbara

This article is based on company information

Pancontinental Mining Ltd. is an Australian company involved in the production and marketing of coal and gold, as either mine operator, joint-venture partner or holder of interests. Its sales during the year 1987-88 were A$ 134.2 million (US$ 110.9 million, approximately). The company has also been active in the exploration for a number of other minerals, including tantalum, as part of a policy of becoming a diversified mining house.

In 1983, Pancontinental set itself the objective of discovering high-grade tantalum reserves which could be mined by open-pit methods. Exploration has continued since 1983 despite the low tantalum prices immediately after that time, and last year the discovery and proving were announced of tantalum mineralisations at four locations in Australia.

In a joint venture with Goldrim Mining Australia Ltd., Pancontinental has earned a 50 % interest in tenements at Wodgina, Wodgina West and Tabba Tabba in the Pilbara region of Western Australia. A further resource has been identified at Mount Farmer in the Murchison region of Western Australia.

At Wodgina, exploration drilling has demonstrated that the main lode deposit has a geological resource of 310 000 tonnes at 0.2 % Ta_2O_5. A preliminary feasibility study suggested a production estimate of 340 000 tonnes at 0.16 % Ta_2O_5. In the same region, drilling indicated resources at Wodgina West and Tabba Tabba. These are not of sufficient size to sustain a "stand-alone" operation, but could, if proven by further drilling, be used as supplementary feed to the Wodgina main lode operation.

A production estimate of 15 000 tonnes at 0.29 % Ta_2O_5 has been determined for Mount Farmer. Additional evaluation by bulk sampling, process testing and a preliminary economic study indicated that, while the grade is high, the economics would be significantly improved by the discovery of further ore reserves. To achieve this, further exploration is planned in the area.

The pegmatite bodies at Wodgina and their resultant alluvial and eluvial deposits have been mined for tin, tantalum and beryl since their discovery in 1902 until 1985. From 1905 to 1985, a total of 231 tonnes of tantalite concentrate was produced from the alluvial and eluvial deposits. The lode deposit was also worked by small-scale, open-cut and underground methods to produce a total of 112 tonnes of concentrate.

The main pegmatite lies in the heart of the Wodgina greenstone belt approximately 110 km south of Port Hedland or 1600 km north of Perth. The pegmatite outcrops at surface and has a strike length of approximately 1000 metres. It pinches and swells from 5 metres to 40 metres in thickness and dips variously from 30° to 40° east, and is ultimately a truncated downdip by north-south normal faulting. The principal component minerals of the host rock are quartz, albite, K-feldspar and muscovite/sericite. The main tantalum minerals are wodginite and microlite which occur as coarse and fine-grained disseminations in the albite host rock.

Early in 1989, Pancontinental Mining announced that Wodgina would start producing tantalite in the last quarter of the year. The ore will be extracted by open-pit mining to a depth of 45 metres. An on-site milling and concentrating facility is being built which will be able to process 100 000 tonnes of ore a year. Annual production is estimated at around 150 000 lb Ta_2O_5. A new wholly-owned subsidiary, Pan West Tantalum Pty. Ltd., will hold all of Pancontinental's tantalum mining and exploration assets.

Pancontinental's tantalum resources and reserves in the Pilbara and Murchison regions

	Tonnes	*Grade (% Ta_2O_5)*	*Content (lb Ta_2O_5)*	*% Interest*
Geological in-situ resources				
Wodgina main lode (proved/probable)	310 000	0.20	1 360 000	50
Wodgina-West (probable)	44 000	0.10	97 000	50
Tabba Tabba (probable)	53 000	0.28	326 000	50
Wodgina-Pancon (probable)	250 000	0.07	385 000	100
Mount Farmer (proved)	14 200	0.29	91 000	100
Mining reserves				
Wodgina main lode (proved/probable)	271 000	0.21	1 250 000	50

Tantalite production in China

An update of "The Chinese tantalum and niobium industry", Bulletin no. 54, April 1988

The two known Chinese sources of tantalite concentrates are the Limu mine, Guangxi province, and Yichun mine, Jiangxi province. A test programme has been performed to upgrade the ore from a tantalum deposit at Guangning, Guangdong province.

Limu has been in production for at least ten years. There are three separate mines, of which only one, known as "Tiger Head", is currently operating. Grades established are 0.15-0.20 % Sn, 0.15-0.17 % Ta_2O_5 and 0.02-0.04 % W; reserves amount to 12 million tonnes. Tiger Head is worked by open-cast methods, whereas the two other mines at Limu ("Water Stream Temple" and "Golden Bamboo Garden") are underground. In 1980, production was equivalent to about 50 tonnes Ta_2O_5 a year.

The deposit at Yichun has been identified as an apogranite. These mineralisations are typified by their large ore tonnages and fine-grained minerals. Apogranites occur close to the surface and so can be exploited by open-cast mining at a low cost. A number of these deposits has been brought into production elsewhere in the world, an example being the Pitinga tin-niobium-tantalum deposit in Amazonas state, Brazil.

Yichun was discovered as a result of a five-year exploration programme to find such a deposit. Due to the steep terrain and fine grain size of the minerals, no surrounding placers have been formed. The average grain size of the columbite-tantalite and microlite is less than 0.1 mm.

Reserves in one of the ore bodies exceed 100 million tonnes; the grades are 0.017 % Ta_2O_5, 0.009 % Nb_2O_5 and 0.012 % Sn. Close to this ore body are located two others which are of an equivalent size. It was reported in 1987 that 1500 tonnes of ore a day were being treated at Yichun, suggesting a production of about 50 tonnes Ta_2O_5 a year. The mine also produces mica and feldspar.

In 1986, a prospecting and exploration programme was concluded by the Ministry for Geology and Raw Materials, Guangdong province, and the Federal Institute of Geosciences and Natural Resources, West Germany. The venture was successful in identifying tantalum occurrences in pegmatites near Guangning, Guangdong province. Concentrations of 0.023 % Ta_2O_5 and 0.008 % Nb_2O_5 in the ore were reported, as well as significant zircon and cassiterite values. An ore processing flowsheet was developed, consisting of two milling, four sieving and nine sorting stages followed by magnetic separation. The basic process was grinding, high-intensity magnetic separation, table grading and flotation of middlings. Tests demonstrated a recovery of 70-75 % and an attainable concentrate grade of 30 % Ta_2O_5. In 1987, a local dressing plant was using the developed route to process 32 tonnes of ore daily.

Besides the processing plants at Jiujiang, Limu, Ningxia and Zhuzhou which were identified in the *Bulletin* article of April 1988, another tantalum plant exists in Guangdong province, south-east China. The Conghua Tantalum and Niobium Smelter produces potassium fluotantalate, tantalum and niobium oxides, tantalum powder and ferro-niobium, using tantalum-niobium ore concentrates as feedstock. The plant's annual capacity is five tonnes of tantalum powder and 50 tonnes of ferro-niobium. Conghua was originally built as a concentrating mill in 1960, but was converted into a tantalum/niobium smelter in 1970. It is located north-east of Guangzhou city, Guangdong province.

Almost no Chinese exports of tantalite are expected this year. Mine production is probably declining due to internal difficulties, and China is even having to import some material to meet its own demand for tantalum. Rising prices for tantalite led to a high level of exports in 1988, but these were probably supplied by stockpiled material, accumulated during the poor tantalite market of the mid-1980s. Until China can develop further tantalum sources, exports are likely to remain at a low level.

LITERATURE

R. Gaines; "Geology of tantalum and niobium deposits"; International Symposium on Tantalum and Niobium, November 1988.

O. Burghardt, E. Martins; "A contribution to the beneficiation of a tantalum-niobium ore from China"; Mineral Processing 1987.

Some newer uses for niobium

This article is based on "Outlook", a Teledyne Wah Chang Albany publication, and other company literature

Past issues of the *Bulletin* have discussed many developing applications for niobium. The metal has a number of useful properties, and its range of uses is expanding constantly. This article presents an update rather than a complete survey of niobium's newer applications. The reader is invited to refer back to past *Bulletin* articles such as that in issue no. 50, April 1987, for a full discussion of applications for niobium.

WATER PURIFICATION SYSTEMS

A new type of water purification system uses anodes made from niobium. The system, developed by a company in California, USA, could revolutionize water purification for the consumer market.

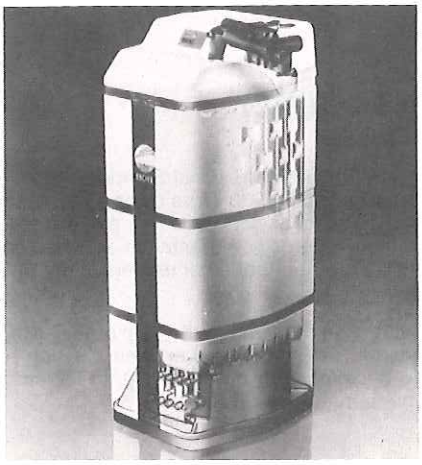
The electrochemical-based system effectively and automatically combines seven different, proven water treatment processes in a self-contained unit. Most water treatment devices combine only two or three processes; the new system, with seven process steps, bears a close resemblance to a large-scale, municipal water treatment plant.

Niobium was selected for use in the anodes because it provided superior operating performance with less maintenance than was possible with previously used materials.

A major benefit of the system (known as the *Watergizer*) is that it does not use chemicals for cleaning or regeneration. These chemicals add contamination to the sewage environment and consequently their use is often prohibited. The system offers a viable alternative that does not leave salt deposits in waste water.

The initial household model is approximately 50 inches high, 17 inches wide and 18 inches deep, and weighs about 250 lb.

(continued on page 4)



The Watergizer water treatment system.

T.I.C. statistics

TANTALUM

PRODUCTION AND SHIPMENTS 1988

(quoted in lb Ta_2O_5 contained)

Production	*1st quarter*	*2nd quarter*	*3rd quarter*	*4th quarter*	*Total*
Tin slag (2 % and over)	240 063	390 765	401 102	366 598	1 398 528
Tantalite (all grades), other materials	66 495	52 357	63 760	112 112	294 724
Total	306 558	443 122	464 862	478 710	1 693 252
Response	16/16	16/16	16/16	16/17	

Shipments	*1st quarter*	*2nd quarter*	*3rd quarter*	*4th quarter*	*Total*
Tin slag (2 % and over)	220 096	408 847	154 689	274 049	1 057 681
Tantalite (all grades), other materials	24 392	90 657	40 574	103 894	259 517
Total	244 488	499 504	195 263	377 943	1 317 198
Response	16/16	16/16	16/16	16/17	

Notes :

1. The response from companies asked to report included these producers, whose reports are essential before the data may be released :
   Datuk Keramat Smelting
   Greenbushes
   Malaysia Smelting
   Mamoré Mineração e Metalurgia
   Metallurg Group
   Tantalum Mining Corporation of Canada
   Thailand Smelting and Refining
2. The figures are subject to review and final confirmation. An adjustment has already been made to the figures previously circulated for the first two quarters, in the light of information subsequently received.

PROCESSORS' SHIPMENTS 1988

(quoted in lb Ta contained)

Material	*1st quarter*	*2nd quarter*	*3rd quarter*	*4th quarter*	*Total*
Ta_2O_5, K_2TaF_7	19 959	27 442	23 574	10 588	81 563
Alloy additive	41 863	37 811	31 388	33 313	144 375
Carbides	144 266	167 768	163 592	152 565	628 191
Powder/anodes	275 253	269 567	289 853	302 458	1 119 131
Mill products	98 823	102 001	103 158	107 010	410 992
Scrap, ingot, unworked metal, other	16 310	14 125	22 906	23 480	76 821
Total	578 474	618 714	634 471	629 414	2 461 073
Ta_2O_5 equivalent	780 941	835 264	856 536	849 709	3 322 450
Response	17/18	17/18	16/16	14/16	

Notes :

1. The response from companies asked to report included these processors, whose reports are essential before the data may be released :
   Cabot Corporation - Electronic Materials and Refractory Metals
   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
   V-Tech
2. Reports were made in lb tantalum contained.

QUARTERLY PRODUCTION ESTIMATES

(quoted in lb Ta_2O_5 contained)

In the *fourth* quarter of 1988, the following estimates of production were made :

LMB quotation	*$ 30*	*$ 40*	*$ 50*
1st quarter 1989	232 000	358 500	416 500
2nd quarter 1989	277 000	361 500	416 500
3rd quarter 1989	220 000	353 500	421 500
4th quarter 1989	220 000	343 500	451 500
1st quarter 1990	215 000	333 500	415 500

Capacitor statistics : see page 4.

Capacitor statistics

EUROPEAN TANTALUM CAPACITOR SHIPMENTS

(thousands of units)

4th quarter 1988	151 933
Total for 1988	676 436

(Data from ECTSP)

JAPANESE TANTALUM CAPACITOR PRODUCTION AND EXPORTS

(thousands of units)

	Production	*Of this, exports*
4th quarter 1988	944 647	253 105
Total for 1988	3 515 879	991 164

(Data from JEIDA)

U.S. TANTALUM CAPACITOR SALES

(thousands of units)

4th quarter 1988

	U.S. shipments	*Exports*	*Total*
Foil	256	0	256
Metal-cased	25 792	7 412	33 204
Moulded	66 828	11 298	78 126
Dipped	87 817	15 854	103 671
Chips	42 532	6 689	49 221
Wet slug	2 037	168	2 205
Total	225 262	41 421	266 683

(Data from EIA)

Production of the system began in 1988 and was the culmination of nearly 10 years of design and research efforts. There are also plans to manufacture other types of unit in the future for different applications, such as the desalination of seawater.

SHAPE MEMORY ALLOYS

A "shape memory" material can be transformed from a heat-unstable condition (the martensite phase) to its original, stable condition (the austenite phase) by the application of a small amount of heat. Articles made from these materials in effect "remember" their original shape.

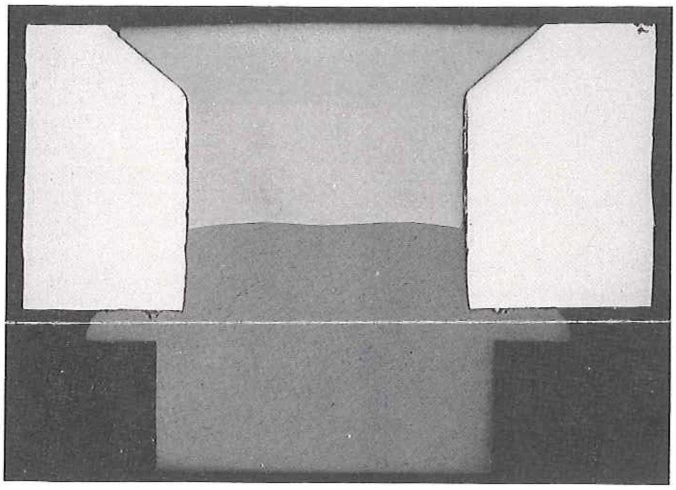
The main shape memory alloy being used commercially is nickel-titanium. To expand the temperature range over which the alloy remains austenitic so that it includes room temperature, niobium is being added in contents of up to 30 at . %. However, the most usual contents are 5-20 at . % niobium. The new alloy is also easier to machine.

Applications for shape memory alloys have included pipe couplings, electrical connectors and switches, but the improved properties of the niobium-containing alloy are leading to many more uses being actively developed.

AEROSPACE FASTENERS

Materials for the aerospace industry need both lightness and strength. An alloy of niobium and titanium has both these characteristics and so has been used to manufacture aerospace fasteners since 1972.

The bimetallic, one-piece fastener combines a 95 ksi shear strength shank with a tail made from titanium-niobium alloy (55 Ti-45 Nb). A major advantage of these fasteners is the 10-40 % weight saving over comparable two-piece ones.



Photomicrograph of the bimetallic fastener installed in an aluminium frame (the lower part is TiNb alloy).

The upper shear part of the fastener is made from a titanium-based alloy, while the lower part is titanium-niobium alloy, which is ideal because of its ductility, lightness and heat resistance. The shear part and the tail are joined by inertial welding.

These fasteners are installed in airframe structures by an automated process and provide excellent blind side clearance. Over 30 million have been produced by a company in California, USA, in the last 15 years.

LIGHTING COMPONENTS

Niobium's hot strength and superior formability has led to its use in small tubular parts in sodium gas discharge lamps. The niobium component holds the sodium, which is vaporized and channelled through the quartz tube to create light. Road lighting is the most common application of these systems.

Niobium can be reduced from 0.75 inch diameter by 0.065 inch wall tubing to dimensions of only 0.12 inch diameter by 0.01 inch wall. These tubes can be fabricated into components by a variety of processes. They can be bent and coiled, slotted, dimpled, punched, lanced, notched, shaped and cut precisely to size.

CATALYSIS

Niobic acid, a solid niobium-based compound, has been found to be an effective catalyst for a number of reactions, including : pollution abatement; selective oxidation; hydrocarbon conversion; hydrogenation and dehydrogenation; hydrotreating; carbon monoxide hydrogenation; polymerization; dehydration and hydration; and photochemistry and electrochemistry.

The niobium component in these catalytic applications is present as a compound/complex, mixed bulk oxide, oxide support or surface niobium oxide phase. Current research focussing on the development of new niobium-based catalytic materials will expand the available application.

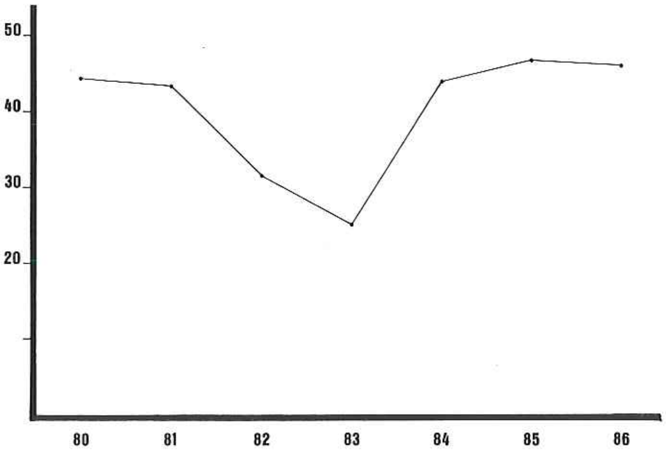
(Readers are referred to an article in issue no. 56 of the "Bulletin" published in December 1988, "Niobic acid as an unusual acidic solid material", K. Tanabe.)

Niobium industry statistics

Statistical data on niobium production and shipments for the years 1980-86 have been compiled and published by the T.I.C. These data, which are summarised here, will be updated quarterly and published in the *Bulletin* when available.

RAW MATERIAL PRODUCTION

Between 85 % and 90 % of niobium is added to micro-alloyed, stainless and heat-resisting steels. Since niobium supply and demand have approximately been in balance over the past few years, raw material production more or less reflects the movements of the steels market : a downturn from 1980 to 1983, followed by a recovery in the years since then.

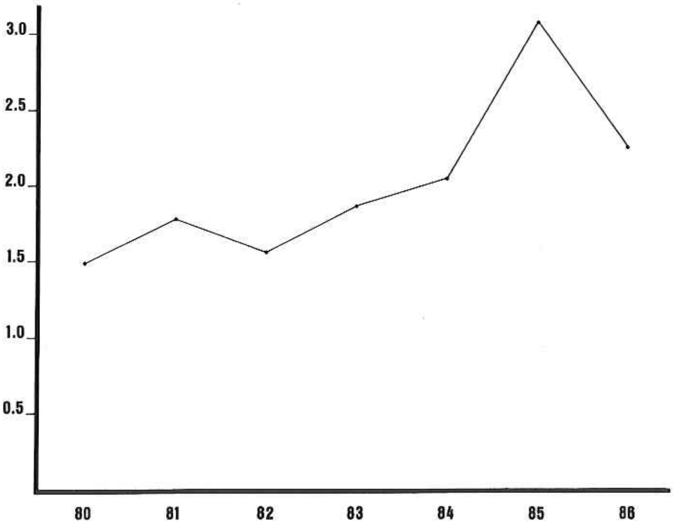


Raw material production (million lb Nb_2O_5)

The portion of total niobium demand supplied as a tantalum by-product has remained below 5 % during the years in question. The bulk of niobium production is centred at just three mines.

COMPOUNDS AND ALLOY ADDITIVE

Most of the material reported in this category consists of vacuum-grade superalloy additive, namely nickel-niobium and ferro-niobium. The remainder is in the form of carbide, for cutting tools, and extra-purity oxide, for the optical and ceramic markets. T.I.C. data only cover the years 1980-86 so far, but from other available data it can be estimated that approximately 2.5 million lb Nb were shipped in 1987 and 2.7 million lb Nb in 1988.



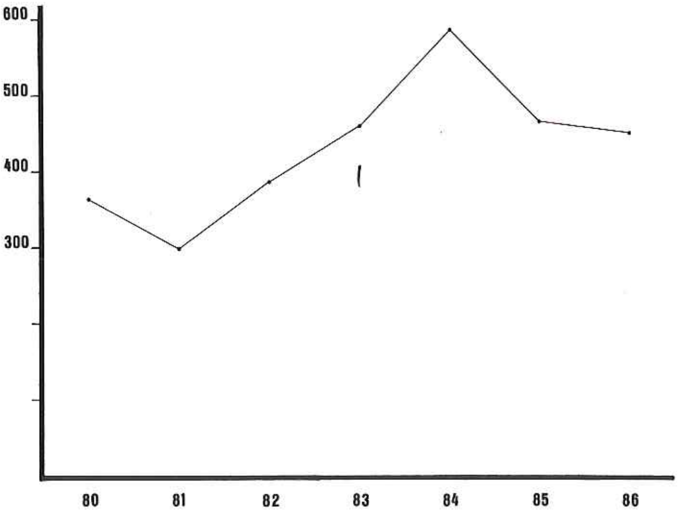
Compound/alloy additive shipments (million lb Nb)

Superalloys are nickel-, cobalt- and iron-nickel-based alloys applied extensively in manufacturing components for turbines, mostly jet engines, because of their high-temperature properties. Over 90 % of the category "compounds/alloy additive" consists of vacuum-grade additives so the increase in shipments during the 1980s has been driven by the superalloy market.

High prices for cobalt during the late 1970s resulted in its substitution out of superalloy components favouring IN718, an iron-nickel-based composition containing 5.3 % Nb. Today, this alloy accounts for 35 % of all wrought superalloy production. Because of its ease of fabrication and welding and its adequate strength up to 650°C, IN718 has been adopted for all kinds of jet engine components. Its growth in popularity accounts for much of the increase in demand for niobium alloy additive in the 1980s. The downturn in 1986 is explained by the release on to the market of a large quantity of stockpiled 718 scrap by a jet engine manufacturer.

NIOBIUM-BASED ALLOYS

Applications for niobium alloys lie in aerospace, corrosion protection and superconductivity. From other available data, it can be estimated that about 470 000 lb Nb in metal and alloys were shipped in 1987 and about 500 000 lb Nb in 1988.



Metal/alloy shipments (thousand lb Nb)

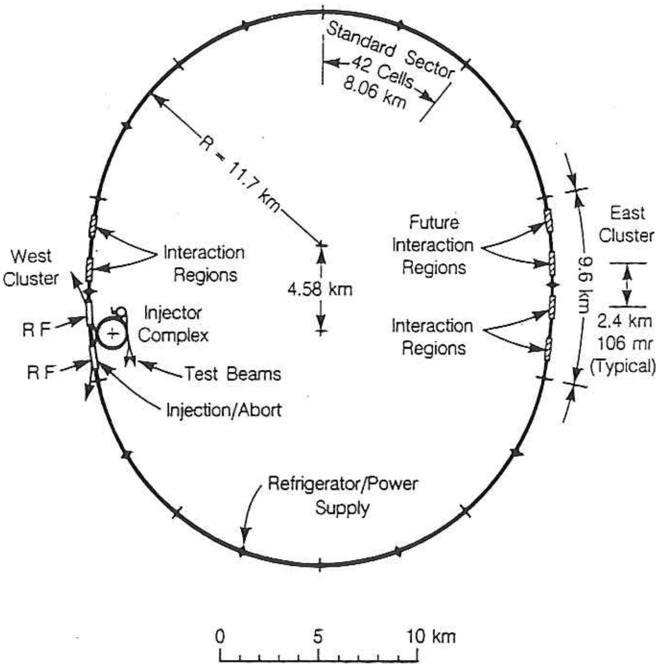
The increase in shipments after 1981 is largely accounted for by growth of the superconductor market. A major particle physics installation completed in 1984, together with the development of the market for magnetic resonance imaging equipment in the 1980s, increased demand for the superconductor alloy, niobium-titanium.

Andrew Jones
formerly Technical Officer

Niobium requirements for the Superconducting Super Collider

This article is based on a presentation made by Dr Rae Stiening, SSC Central Design Group, at the International Symposium on Tantalum and Niobium, Orlando, November 7th-9th 1988.

The Superconducting Super Collider (SSC) is a proposed, but not yet approved, project for elementary particle physics research that would use about a million pounds of niobium-titanium alloy in the many thousand bending, focusing and trim magnets needed for its one trillion electron-volt (1 TeV = 10^{12} electron-volt) injector and its two 82 km circumference main rings.



Schematic concept of the SSC's proposed layout

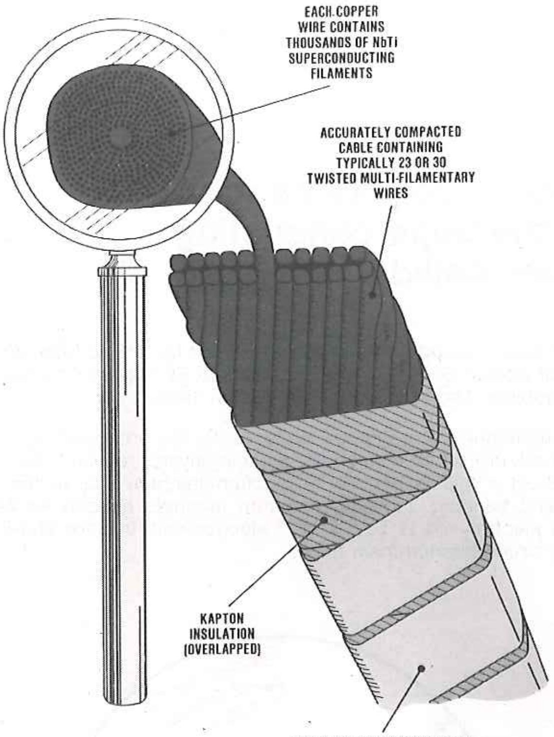
PARTICLE PHYSICS

In the SSC's main rings, contra-rotating beams of protons, about 1 mm in diameter, will be accelerated to 20 TeV each before being guided into collisions at interaction regions where the beams will be further reduced in diameter to about 5 microns.

This collision energy will be distributed between the various quarks and gluons making up the proton constituents. At 20 TeV, the effective mass of the proton is increased 20 000 times and in the collisions this energy is converted to mass in the form of other particles. These are to be studied in detectors surrounding the interaction region and containing an array of suitable analytic instrumentation. It is hoped that the information generated will enhance our understanding of the underlying physical laws governing the interaction of matter, energy and gravitation in our universe, and of their nature.

THE SUPERCONDUCTING SUPER COLLIDER

Detectors for the SSC might weigh 50 000 tonnes or more. Many collider detectors will contain large magnets for analysing the charge and momenta of the emitted particles; in some — but not all — cases, these magnets will be superconducting. The recently commissioned 4500 tonne, $65 million detector for the Tevatron at the Fermi National Accelerator Laboratory in Batavia, Illinois, USA, contains a superconducting magnet. This machine is the highest energy collider in operation and the first very high energy machine to use superconducting magnets in its main ring.

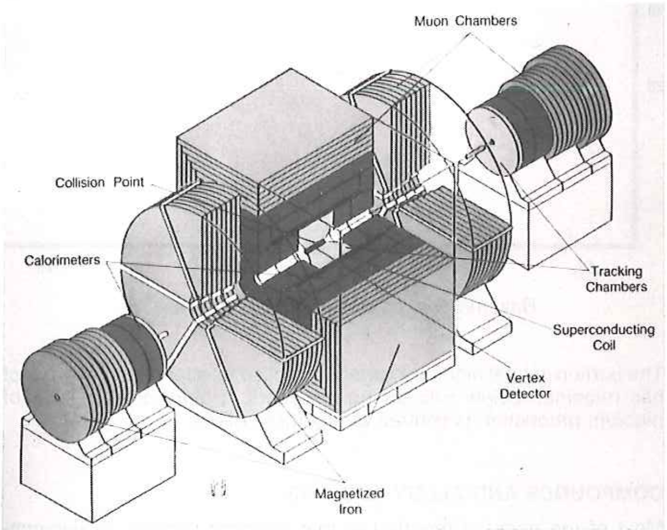


Artist's impression of an SSC detector

Successful operation of the Tevatron has demonstrated that superconducting magnet technology is reliable and economic. This forms the basis for confidence that the SSC can be built. The circumference and projected energy of the Tevatron approximate to those of the High Energy Booster (HEB) which is planned as the final injector for the main-ring proton beams of the SSC.

The Superconducting Super Collider is the largest of the big machines so far proposed using superconducting magnet technology. If built, it will be sited near Dallas in Texas, USA. The 82 km tunnel is a race-track shape with two semi-circular 11.7 km radius ends joined by two slightly curving 5 km segments containing the interaction halls and injector complex to be buried 60 m below the land surface. This tunnel will be a concrete tube about 2.5 m in diameter with a wall thickness of about 250 mm and will contain the main-ring components. The protons will be accelerated in opposing directions in each tube from 1 TeV to 20 TeV in a beam whose highest energy intensity is then maintained for 24 hours.

The main rings will contain 7680 horizontal dipoles and about ten thousand dipoles, 1776 quadrupoles in total, together with a large number of trim coils. The 40 mm bore, 17 m long, 6.6 T dipole magnets operate at a nominal current of 6504 amperes and a temperature of 4.35 K and have an equivalent magnetic length of 16.6 m. The effective magnetic length of a complete dipole is somewhat less, being around 16.5 m. The windings consist of two layers of multifilamentary, keystoned, transposed, niobium-titanium cable containing 23 strands in the inner layer and 30 strands in the outer layer.



Schematic drawing of cable for SSC dipole

Each strand contains 7250 six-micron diameter filaments. Such fine filaments are essential to minimize magnetization effects which, at low injection fields, could produce unacceptable distortion in the dipole guide field. In magnets of this type, thermal transients, which occur as the conductors move when the coil is energized, are an important cause of instability. These are minimized by the use of kapton round the cable to reduce friction when slippage occurs and by the thermal diffusivity of the stabilizing copper.

MATERIAL REQUIREMENTS

Specified copper to superconductor ratios for the inner- and outer-layer magnet conductors are 1.3 : 1 and 1.8 : 1, respectively. Consideration is being given to increasing the inner-layer ratio to 1.5 : 1. These ratios, filament numbers and diameters may be changed as magnet development continues.

The current conductor specification calls for a superconductor current density of 2750 A/mm^2 at 5 T measured at an effective conductor resistivity of 10^{-14} ohm-m with a strain tolerance of 0.5 %. The peak operating field at the conductor is around 7 T. The improvement in current-carrying capacity of conductors since 1984 is one reason why the SSC is considered economically feasible, since much less of the expensive conductor and alloy is now needed.

Copper-stabilized, NbTi multifilamentary wire manufacture is now a well-established process. The alloy is produced in ingot form by vacuum-arc melting niobium and titanium. The resulting material is reduced to rods, typically 3-6 mm diameter, and these rods are inserted into rods of copper with circular bore and hexagonal outer periphery or directly into holes in a copper billet. In the former case, the hexagonal elements are packed in a cylindrical container to obtain the highest possible density. In these ways, billets containing several thousand NbTi tubes in a matrix of copper, chosen to give the desired copper to superconductor ratio and filament size, are formed. The billets are then drawn down until multifilamentary wire of the necessary dimensions is obtained.

CURRENT STATUS OF THE SSC

Funding for the machine has not yet received the approval of the US Congress, but about $180 million has already been spent on conceptual design and prototype magnet construction. A decision as to when construction could proceed is expected in 1989. The complex would be built with massive industrial participation, including magnet fabrication, and an active programme of technology transfer to industry has begun. International participation may also be encouraged. The machine, if approved, could be in operation by the mid-1990s and be expected to be operating for as long as 20 years.

In late January 1989, the Department of Energy nominated a director and a management organization for the project. Based on a decision to start construction in fiscal year 1990 (which begins in October 1989), a feasible construction funding plan has been developed by the SSC Central Design Group. From the order schedule for magnet cable, the consequent niobium metal and alloy demand has been estimated.

Nb metal and NbTi alloy requirements for the SSC
(assumes 75 % yield — for contained alloy, reduce by 25 %)

	Weight, tonnes		*Cumulative weight,*
	NbTi	*Nb*	*tonnes Nb*
1989	4.84	2.59	2.59
1990	2.07	1.11	3.70
1991	4.57	2.45	6.14
1992	49.39	26.42	32.56
1993	104.32	55.81	88.37
1994	233.61	124.98	213.36
1995	233.61	124.98	338.34
1996	154.16	82.48	420.82

Recycling of tantalum

This paper was presented by Dr Meinhard Aits, Gesellschaft für Elektrometallurgie mbH, at the International Symposium on Tantalum and Niobium, Orlando, November 7th-9th 1988.

A remarkable amount of the world's total consumption of tantalum is covered by scrap recycling. The most important sources for this tantalum-containing scrap are the hard-metal, glass and ceramic industries, and tantalum equipment and capacitor manufacturing.

The composition of scrap materials varies widely, some examples being : nearly pure metal, such as turnings and grey anodes; complex systems where tantalum occurs as carbide or oxide; and heterogeneous systems of metal partially oxidised together with plastic, other oxides and metals in electronics scrap. To recover the tantalum from these different sources, individually adapted techniques had to be established, not only to extract the tantalum content but to do it in the most economical way with adequate recoveries.

The amount of tantalum being recycled in the industry is estimated to cover between 10 % and 20 % of total raw material requirements. These recycling activities reflect a general trend in the industry towards improving the usage of limited natural resources and were accelerated in the late 1970s by increasing raw material costs. Due to tantalum's high value, the industry has reached a high standard of integration, comparable to that of the precious metals industry.

RECYCLING DURING TANTALUM PROCESSING

In each step of tantalum processing, from the chemical digestion of ore concentrates to the manufacture of the final products, tailings, off-grade materials and scrap arise.

Wastes from the production of oxides, carbides and metals are recycled in the system itself as far as technically possible. If not — and the tantalum content is high enough — these materials can be fed into the chemical line again. Tailings, leaching residues, grinding sludges and wastes with low tantalum contents can be processed via the block-metal process together with tin slags.

Technically it is possible to treat materials with contents as low as one percent Ta with some exceptions, e.g. materials with high levels of radio-active components. The economic limits depend on the tantalum raw material price. Obviously, the value which can be placed on such materials is very low, but in times of tight raw material supply, substantial quantities of tantalum could be recovered via the chemical and metallurgical process.

All efforts should be made to recover tantalum from every possible source, to recycle this valuable material in the most economic way, and to avoid additional recovery losses. That means keeping the stage of refinement as high as possible.

The following possibilities for recycling tantalum should be considered as examples, as it is impossible to mention every possible alternative in this short review.

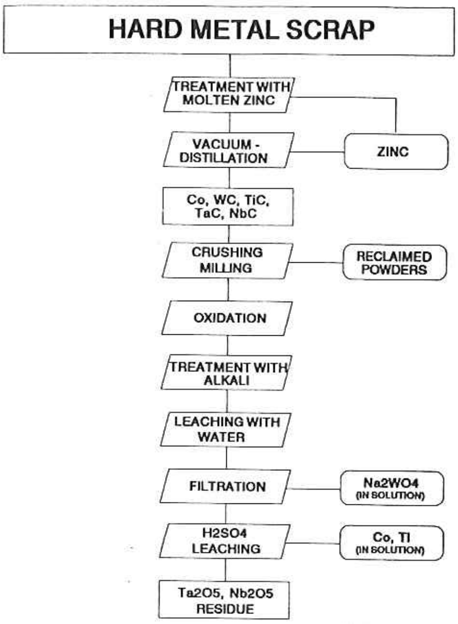
TANTALUM IN GLASSES AND CERAMICS

Up to now, no special technical method is known for treating glass and ceramic scrap. If the material is separated in a pure form during the production process, it is normally recycled directly into the glass melt. But if tantalum is present as oxide, the glass or ceramic scraps are fed back into the chemical tantalum line if the Ta_2O_5 content is high enough, or they can be processed like tin slags. The laboratory-scale recovery of high-purity tantalum oxide from lithium tantalate single crystals using an ion exchanger has already been described in the literature.

During the last decade, an enormous variety of glasses and ceramics with exotic compositions was developed using other valuable elements, such as lanthanum and yttrium. Special techniques have to be developed to recover those rare elements too. During these operations, a sludge containing tantalum will normally arise, suitable for standard chemical treatment.

RECOVERY OF TANTALUM FROM HARD METALS

Recycling operations on hard-metal scrap are mainly used to recover the combined carbides as powder, or the tungsten as ammonium paratungstate and the remaining elements as oxides.



Tantalum recovery from hard metals

For this purpose, the zinc process is commonly used as the first step to disintegrate the sintered parts. Liquid zinc at temperatures of about 800°C breaks the linkage between the carbide particles and the cobalt metal. The zinc is recycled via vacuum distillation, and grinding the residue produces a powder with the original composition of carbides and cobalt. This powder can be used in the as-produced condition or blended with virgin powders.

In the zinc process, no purification of the material takes place. Therefore, contaminated or not well defined compositions must be treated in a way that allows the recovery of nearly all components in a chemically pure condition.

For this reason, the zinc-treated hard-metal powder, grinding sludges, etc. are oxidised under alkaline conditions to form sodium tungstate. During the following leaching operation, the soluble tungstate is filtered off with the mother liquor, then purified by precipitation and transformed into ammonium paratungstate, better known as APT. The remaining residue contains cobalt, tantalum, niobium and titanium as insoluble hydroxides from which the cobalt and the titanium are extracted by leaching with sulfuric acid. These elements can be separated easily from each other by the selective precipitation of titanium hydroxide and cobalt oxalate. The final residue containing the tantalum and niobium is used as feedstock for chemical processing.

RECYCLING OF CAPACITOR SCRAP

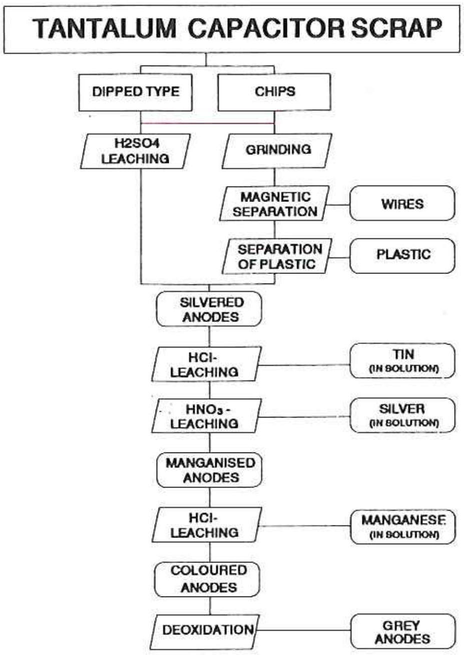
Different types of capacitor scrap need specially adapted techniques for the recovery of the tantalum content as pure metal if possible.

During capacitor manufacturing, scrap arises as powder, grey and coloured anodes, foil, manganised or silvered items, as well as pins from the connecting wires. All the materials from these sources can be fed into the various steps of the recovery process.

Recovery of tantalum from plastic-encapsulated capacitors

The removal of the cover is done by treatment with hot sulfuric acid, which cracks the material, chemically yielding undetermined organic compounds and carbon. The waste acid is normally neutralised with lime and discarded. This technique may lead to environmental problems because of the uncontrolled formation of secondary organic compounds.

In most instances, the chemical destruction of the case can be avoided by using mechanical techniques. The scrap is ground to a size of about 1 mm to produce isolated particles of plastic, wire and metal from the original capacitor. The lead wires can normally be separated magnetically leaving a mixture of light plastics and heavy metal. This mixture is separated in a second step using the differences in the density, either by classical ore dressing methods or by using a high-density liquid.



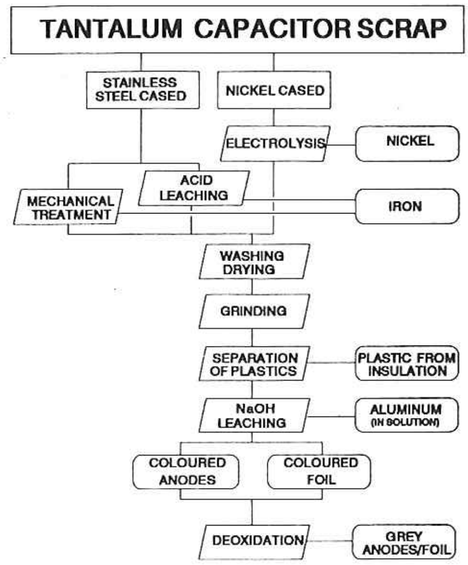
Tantalum recovery from plastic-encapsulated capacitors

As the core of the capacitor also contains tin, silver and manganese dioxide, additional chemical leaching steps have to be applied. Tin is soluble in sodium hydroxide solution, silver in nitric acid, and manganese dioxide in hydrochloric acid, so at least three leaching steps have to be carried out, combined with careful intermediate washing with de-ionised water. The remaining solutions can be treated individually in order to recover tin and silver. Manganese compounds are not normally recovered due to their relatively low price.

The coloured anode is de-oxidised using base metals like sodium at temperatures up to 900°C. The formed oxide of the base metal is leached out with acid, yielding either grey anodes, a granulate or coarse powder : these materials can be refined either by electron-beam melting, compacting into sintered bars or conversion into tantalum carbide.

Recovery of tantalum from metal-cased wet capacitors

If the case is made from nickel or copper, an electrolysis using the capacitor as anode and a stainless steel cathode is a suitable method to remove and recover the metal. The problem using electrolysis is the complete removal of the metal, therefore additional acid leaching is normally required.



Tantalum recovery from metal-cased wet capacitors

Aluminium cases can be dissolved in sodium hydroxide solution, copper cases in nitric acid, stainless steel cases in hot hydrochloric acid. But the chemical removal of the outer cases always requires a relatively large amount of chemicals and leads to a waste water problem, because all the dissolved metals have to be neutralised and precipitated to avoid environmental pollution.

In certain cases, especially if larger amounts of a single size of capacitor scrap are available, mechanical removal of the case is possible and more economical. That means using mechanical equipment which is able to separate the metal from the core.

In any case, the liquid electrolyte has to be leached out afterwards and neutralised. Aluminium or other metals can be dissolved by additional leaching. To separate the metal content from plastic or glass insulations, the material can be ground to a size below 1 mm and separated by gravity as described before. The final step is a de-oxidation to reduce the oxygen content and prepare the material for EB refining or other uses.

It is shown that a ready-for-use recipe cannot be given as the structure of the capacitor scrap varies widely and a lot of adaptation work has to be done to find a technically suitable and economical method of treatment.

If the capacitor scrap contains another refractory metal besides tantalum in sizeable amounts, e.g. molybdenum from doped tantalum wire, the resulting metal may be out of specification. In this case, the material has to be chemically processed, with the corresponding economic disadvantage.

TANTALUM IN SUPERALLOYS AND COATINGS

Direct recycling of superalloy scrap requires careful attention and is mostly done by the superalloy producers themselves. Collected scrap, such as turnings, etc., is very seldom available to the tantalum industry and only of interest at a high tantalum price level. In this case, the scrap materials are normally recycled via the block-metal process as the tantalum content is usually low.

Coatings normally contain only small amounts of tantalum metal, therefore recycling is not economic. More frequently, off-grade powders, used targets, etc. are collected and recycled as described before. If coatings have to be recycled, they can be dissolved in hydrofluoric acid and chemically recovered.

SUMMARY

The recycling of tantalum has become an important factor in the total market, but is up to now only used for materials with a relatively high tantalum content. Whether or not certain materials can be recycled depends directly on the price level for raw materials.

In this sense, the design and production of devices containing a costly material like tantalum should involve a number of considerations :

- the production process should be optimised to keep losses to a minimum;
- if the occurrence of scrap or other tantalum-containing wastes cannot be avoided, it should be collected where it arises in order not to devalue it by dilution with other wastes;
- pure materials are preferable to complex compounds as recycling is easier and thus more economic;
- during the design of new products, experts in recycling should be contacted as early as possible to avoid losses in the scrap's value, thus keeping the tantalum-containing product more competitive.

Although tantalum recycling has already reached high standards compared to other industries, more development work is still needed to use the limited sources in the most economic way. It is a question of availability, the total amounts and the economics whether tantalum will be recovered from other sources, but recycling has become an important factor in judging a process or a product's overall economy and environmental compatibility.

TANTALUM-NIOBIUM INTERNATIONAL STUDY CENTER — Rue Washington 40, 1050 Brussels - Tel. (02) 649 51 58 - Telex 65080 INAC B
PRINTED BY PUVREZ, avenue Fonsny 59, 1060 Brussels.