TANTALUM INTERNATIONAL STUDY CENTER

QUARTERLY BULLETIN | ISSUE N° 42 | APRIL 1985 | SECOND QUARTER

Boston Meeting

The T.I.C. will hold a meeting from June 12th to 14th 1985 in Boston, Massachusetts, U.S.A., including the Twenty-third General Assembly of the members on June 13th. A particularly varied and interesting programme is being arranged in this attractive city. Delegates will stay at the Boston Marriott Long Wharf Hotel, where the formal meeting will take place.
Two member companies will host the meeting, NRC Inc. and Sprague Electric Company.

Wednesday June 12th 1985 :

Registration with the T.I.C.
The hosts' hospitality suite will be open, and the T.I.C. registration desk will be in this suite.
Cocktail Party in the Grand Ballroom, 6-8 p.m.
Dinner at leisure.

Thursday June 13th 1985 :

9 a.m. Twenty-third General Assembly : attendance limited to delegates of member companies.
10 a.m. Coffee break : guests from non-member companies join the meeting.
10.30 a.m. Presidential Address by Mr Carroll G. Killen, President of the T.I.C.
Welcome address on behalf of the host companies.
Presentation of technical papers : speakers will be Mr Kent N. Knowles, Office of Stockpile Transactions, General Services Administration
Dr Wolf-Wigand Albrecht, Hermann C. Starck Berlin
Mr David E. Maguire, Union Carbide Corporation.
12.30 p.m. Buffet luncheon : all delegates and guests are invited by the T.I.C.
2 p.m. Further presentations : speakers will be :
Mr Dennis J. Eagan, International Business Machines
Dr Robert B. Costello, General Motors.
3.30 p.m. Panel discussion.

Abstracts of the technical papers are given below.
In the evening all the participants, with their spouses, will be the guests of the host companies for Cocktails and Dinner at the John F. Kennedy Library, and there will be a tour of the museum dedicated to the memory of President Kennedy.
For the ladies and accompanying persons a tour has been arranged to include historic Boston, Harvard University, the Museum of Fine Arts and the Isabella Gardner Museum, followed by lunch at Hampshire House on Beacon Hill and a chance to shop on the way back to the hotel.

Friday June 14th 1985 :

A choice of two plant visits is offered, and each trip will include a tour for spouses while the delegates visit the plant, followed by luncheon for the two groups together.
Sprague : Delegates will see the Sprague Solid Tantalum Capacitor facility at Sanford, Maine, while the ladies go to the quaint seaside resort village of Kennebunkport and look also at the estate of Vice President George Bush. Lunch for both parties will be a "Downeast" lobster bake on spectacular Bald Head Cliff in Ogunquit.
NRC : A tour of the NRC processing facility in Newton, Massachusetts, will be provided for the delegates, and their spouses will tour the north coast of Massachusetts, stopping for an organ concert at Hammond Castle and to browse round shops at Rockport. A "clambake" luncheon will be ready for both groups in Gloucester, a fishing town.
The weather is generally fair, with temperatures from 15 to 25 °C, but the hosts remind everyone of the old New England saying "If you don't like our weather, wait a minute" !
Invitations have already been sent to member companies. Further information on the meeting may be obtained from the Secretary of the T.I.C., 40 rue Washington, 1050 Brussels, Belgium. Telex no. 65080 (INAC B). Telephone no. (02) 649.51.58.

TWENTY-THIRD GENERAL ASSEMBLY

The Assembly will be held at the Boston Marriott Long Wharf Hotel at 9 a.m. on Thursday June 13th 1985.

AGENDA

1. **Voting proxies.**
2. **Minutes of the Twenty-second General Assembly (held in Brussels on October 30th 1984).**
3. **Membership : applications, resignations.**
4. **Report of the Executive Committee.**
5. **Statistics :**
   production
   processing
   capacitors
   general.
6. **Next General Assemblies :**
   Twenty-fourth : Brussels, October 1985
   Twenty-fifth : Japan, May 1986.
7. **Other business.**

NEW MEMBERS

Do you know any companies which would be eligible for membership but have not yet become members ?
The T.I.C. would be happy to contact them : please send their names and addresses to the Secretary.

TECHNICAL OFFICER

The T.I.C. has pleasure in introducing its newly-appointed Technical Officer, Mr Andrew Jones, a recent graduate in metallurgy from Sheffield University, in England. We hope that companies in the tantalum and niobium industries will welcome visits from Mr Jones so that a useful and beneficial relationship will soon be built up.

PRESENTATIONS

The abstracts of the presentations to be made, with a biographical note on each author, are given below.

Improvement in quality control of high capacitance tantalum powders

by Dr Wolf-Wigand Albrecht and Mr A. Hoppe, Hermann C. Starck, Goslar, West Germany

Upgrading quality control and increasing productivity has become an interesting challenge in the production of electronic components. These trends are also reflected in the production of intermediate materials. In this context it will be discussed how tantalum powder producers can assist the capacitor industry by improving the quality of the powders used. Production of high capacitance tantalum powders, being used ever more widely in tantalum capacitors, will be taken as an example to demonstrate these activities.

The application of quality circles in general and examples of such diagrams, describing chemical, physical and electrical data, will be discussed. The role of computer assistance to minimize changes in the production of tantalum powders will be explained.

Dr Albrecht studied physics at the Technical University of Berlin, his native city. He joined the Hermann C. Starck company in 1971, where he was manager of the tantalum-metal plant for some years. Since 1980 he has been the General Manager of the Tantalum/Niobium Division of the Goslar plant.

Tantalum in the automotive industry

by Dr Robert B. Costello, General Motors, Detroit, Michigan, U.S.A.

Tantalum possesses unique, state-of-the-art properties that are conducive to the electronic requirements in the automotive industry. Some of the areas for potential future applications will be explored.

Pricing is a key issue in the automotive industry, and tantalum prices have been less than predictable. One way to establish price stability is through cost-based pricing, which means justifying prices on legitimate cost elements. From the ground level to the finished product, all value added to an item must be considered in establishing a base cost. This approach requires mutual cooperation with the tantalum/supplier family.

It is imperative that certain goals are met or aluminium and other substitute materials will continue to penetrate the tantalum market share.

Dr Robert B. Costello was named executive director of Purchasing Activities for General Motors Materials Management Staff in September 1982. He holds degrees in civil engineering and a doctorate in transportation engineering, and joined General Motors in 1960.

Component design for computer/electronic applications

by Mr Dennis J. Eagan, International Business Machines, Poughkeepsie, N.Y., U.S.A.

The computer/electronics industry is a major market for IBM's products. This market is dynamic, competitive, and operates on the leading edge of many technologies. In designing products for this market, engineers face the multiple challenges of specifying components that best fit application requirements (e.g. function, cost, quality, reliability) and also meet broad corporate goals (e.g. manufacturing cost, profit, customer satisfaction, continued growth).

This paper will discuss this design process with respect to tantalum capacitors. The key points examined include : IBM's overall goals; the effect of competition on designers; historical performance of our products; customer requirements; relationships between component, end product and corporate criteria; component design considerations.

The major component design considerations examined include function, cost, quality, reliability and substitute technologies.

In summary, this paper illustrates the broad scope of criteria applied to component selection, and the impact on tantalum capacitors.

Mr Eagan is a Senior Engineer Manager in Corporate Component Procurement (CCP) at IBM. He has engineering responsibility for passive electrical components purchased by CCP, including all capacitors. Mr Eagan has been at IBM for nineteen years, with experience in quality engineering, semiconductor reliability, product qualification and field performance measurement. He earned a B.Ch.E. degree in 1964 from Rensselaer Polytechnic Institute, and a MSIA degree in 1973 from Union College.

The economics and future outlook for solid tantalum capacitors

by Mr David E. Maguire, Union Carbide Corporation, Greenville, South Carolina, U.S.A.

The paper details the historical interrelationships of dielectrics, materials technology, materials costs, electrical characteristics, physical characteristics and ultimate capacitor function-in-place costs on the usage growth rate of solid tantalum capacitors. Changing electronics technology and assembly techniques are rapidly modifying the industry requirements for capacitors. The impact of these changes on the demand growth rate for solid tantalum capacitors is examined and forecast into the future. A concurrent forecast of the tantalum materials requirements for use in solid tantalum capacitors is provided.

Mr Maguire joined Union Carbide in 1957 and was appointed vice-president of the newly formed Electronics Division in 1977, the position he still holds. He has degrees in both mathematics and industrial engineering.

NRC Inc.

NRC Inc., one of the largest processors of tantalum, will be co-host to the Twenty-third General Assembly of the T.I.C. to be held in Boston, Massachusetts, U.S.A. from June 12th to 14th, 1985.

As one of the world's leading manufacturers of capacitor-grade tantalum for the electronics industry, NRC Inc. offers a complete line of both sodium-reduced and melt-purified, high surface area tantalum powders. These powders range from among the highest capacitance versions of both sodium-reduced and melted powder to the highest voltage capability powders. NRC powders are known for lot-to-lot consistency and reliability. These factors, plus superior performance under a broad range of conditions and temperatures, contribute to making tantalum capacitors the preferred type in high reliability applications.

NRC Inc., as one of the largest producers of tantalum in the western world, is a major supplier of mill products including ingot, rod, wire, tubing, foil and powder in all mesh sizes. NRC's 1982 expansion includes the most modern electron beam furnace in the world, a complete rolling facility, laboratory facilities and additional office space. These complement other new facilities which include a scanning electron microscope, complete forming and fabricating systems, and drawing equipment for all-tantalum capacitor cases.

As a specialist in tantalum metal, NRC is also a major source for metallurgical products for the chemical processing, aerospace and nuclear industries, as well as the electronics industry. Customers depend on NRC for a wide range of custom fabricated tantalum and tantalum-clad products. These include heat exchangers, pressure vessels, tanks, heat and radiation shields, vacuum furnace parts, fasteners, cups, crucibles, custom assemblies and many other products. Tantalum and niobium are preferred materials in many applications due to their extreme resistance to corrosion and excellent high temperature performance characteristics.

NRC has recently expanded its production of niobium and niobium oxide. Niobium, an element which almost always occurs naturally with tantalum, is contained along with tantalum in the raw materials used by NRC. It has applications in the electronics, chemical processing, aerospace and nuclear industries, just as tantalum does. NRC's extensive experience in melting and working with tantalum applies directly to the production and fabrication of niobium products such as rod, wire, foil, alloys and fabricated items.

Niobium oxide is used primarily to make niobium (columbium) alloys used in the manufacture of jet engines, chemical process equipment, and super-conducting materials for nuclear energy and power generation research. High purity niobium oxide is used in ceramic capacitors, piezoelectric devices, enamels and optical glass formulations.

Today, NRC Inc. operates out of a modern complex in Newton, Massachusetts, which has 100,000 sq. ft. of manufacturing and laboratory space and 20,000 sq.ft. of administration space. Recent expansions have included both a major addition to production facilities and new corporate offices. The company employs more than 200 people.

HISTORY

National Research Corporation — later to become NRC Inc. — was founded in 1940. The company specialized in the research and development of vacuum technology and its use to generate new processes and products. Notable developments were frozen orange juice concentrate (a subsidiary was the forerunner of Minute Maid Corporation, now part of Coca-Cola Company), and freeze-dried instant coffee. Once created new businesses were sold to provide added cash flow for the growth of the company.

The specialized expertise in vacuum melting of high temperature metals developed by the company in these early stages led directly to NRC Inc.'s present advanced melting technology for tantalum and niobium (columbium). Another landmark in the company's history was the creation of a process for producing titanium. Like NRC's present process for making tantalum, nearly all the processes studied by National Research involved the reduction of a metal compound with sodium. This work was funded in part by the U.S. Government.

Interest in titanium led to work on other reactive and refractory metals such as zirconium, niobium and tantalum. National Research found a market for capacitor-grade tantalum powder, which was just beginning to be used in commercial quantities. The company also started making mill products. The tantalum operation had grown large enough by 1959 to be a separate metals division.

In 1963, National Research Corporation was merged into Norton Company, and became the central research laboratory for new projects at Norton, and the Metals Division became a separate operating division of Norton specializing in refractory metals.

During 1975, Norton Company decided that the metals business did not fit their management experience and business strategy. Norton reached an agreement in 1976 to sell the Metals Division to Hermann C. Starck, a West German company, and South American Consolidated Enterprises, a company headquartered in South America. Hermann C. Starck is a major European processor of refractory metals with a broad line that includes tungsten, molybdenum, cobalt, tantalum and many others. South American Consolidated Enterprises is engaged in mining, manufacturing and trading in many parts of the world. The strong raw materials position and familiarity with the metals business of the two companies was of great benefit to NRC.

NRC is jointly owned by the two partners, who bought the assets and business of the Metals Division of Norton Company. In order to retain continuity and its reputation in the marketplace, the NRC name was chosen — but it no longer stands for National Research Corporation.

Sprague Electric Company

The Sprague Electric Company, a pioneer in the development of the tantalum capacitor and currently the world's largest manufacturer of it, will be a co-host to the Twenty-third General Assembly of the T.I.C. to be held in Boston, Massachusetts, U.S.A. from June 12th to 14th, 1985.

Sprague Electric Company is a multi-national company with worldwide sales and manufacturing operations. The Company supplies close to 1,000 different component type numbers with almost 100,000 different parts listed as standard catalogue items. The Company employs approximately 7,900 persons in plants in the United States and 3,250 in plants in Canada, Europe and the Far East. Sprague also owns substantial interests in electronic parts manufacturers in the United States and in Japan.

Sprague product lines include :

Capacitor Products	*Semiconductor Products*	*Speciality Components*
Multilayer Ceramic	Interface ICs	Thick Film Resistors
Tantalum	Linear ICs	Interference Filters
Aluminium	Hall-Effect ICs	Power Supply Magnetics
Plastic Film	Transistors	Delay Lines
Oil-Paper	CMOS ICs	Pulse Transformers
	Zener Diodes	

Sprague sells its products worldwide to over 5,000 original equipment manufacturers. Major customers include IBM, General Motors Delco, AT&T Technologies, Hewlett-Packard, Honeywell, Zenith, Olivetti, NCR, GTE, Magnavox and Digital Equipment Corp. The company also serves over 1,000 distributors in the United States who, in turn, sell to approximately 100,000 customers. Sprague annually ships more than 1.4 billion units of its various product lines.

Sprague was a pioneer in the development of the tantalum capacitor and is the world's largest supplier. Sprague is also the largest producer in the United States of aluminum electrolytic capacitors for power supplies. In an allied area, the company is one of the world's largest suppliers of thick-film circuits.

Sprague continues to expand its commitment to the rapidly growing high-technology semiconductor business. Sprague is a major supplier of integrated circuit drivers and controllers for data processing, telecommunications and display applications; discrete semiconductors for radio, TV and audio circuits; and Hall-Effect integrated circuits for industrial and automotive applications.

Sprague also furnishes EMI/RFI filters, pulse transformers, magnetic assemblies of various types, pulse forming networks, a variety of plastic-film capacitors, power factor correction equipment, and electrical interference locators.

HISTORY

The Sprague Electric Company was founded as Sprague Specialties Company in June 1926 by Robert C. Sprague at Quincy, Massachusetts. Mr Sprague pursued a personal interest in "wireless", and invented a tone control for use with the radio sets and speakers of the time. He organized the company to manufacture and sell this device.

Sprague Specialties Company began to manufacture and sell "condensers", used in the tone control circuits, to radio manufacturers who incorporated these circuits in their own sets. The "condenser/capacitor" business grew and by 1930 the Company had secured additional plant space in North Adams, Massachusetts. Sprague consolidated all of its operations in North Adams during the 1930's. With a new name as the Sprague Electric Company, it continued as a major supplier of paper capacitors and the newly developed electrolytic capacitors used by the growing radio industry.

With the onset of World War II, the company's marketing emphasis shifted from commercial to military electronics. This period saw the development of "high-reliability" parts programs, and Sprague added a wider range of component types.

During the post-war period the company expanded its operations to include manufacturing plants throughout the world - its product lines now cover virtually every area of application in electronics. The Sprague "Mark of Reliability" has become one of the most familiar trademarks in modern electronics.

In December 1976, 50 years after its founding, Sprague was acquired by the General Cable Corporation, later renamed GK Technologies, Inc. GK Technologies in turn was acquired by the Penn Central Corporation in May 1981. Sprague Electric is now a unit of the Penn Central Corporation, part of its Electronics Defense and Telecommunications Group headquartered in Greenwich Connecticut.

Sprague officially dedicated its new World Headquarters at Lexington, Massachusetts, on the outskirts of Boston, on December 6, 1984.

President's Letter

The Twenty-third General Assembly will be held in Boston June 12 through June 14, and will include visits to plants of NRC and Sprague.

If you have not already done so, please mark these dates on your calendar and begin to consider your travel plans.

Boston — considered by many historians to have been the "cradle of liberty" of the thirteen colonies which, in 1776, became the United States of America — offers an excellent opportunity for you to visit some of America's best known monuments. Our Twenty-third General Assembly offers our members a fine chance to meet and exchange ideas.

We have a first-rate program in store for you. The speakers will be :

Dr W.W. Albrecht of Hermann C. Starck
Dr Robert Costello of General Motors
Mr Dennis Eagan of IBM
Mr Kent N. Knowles, Assistant Commissioner, Office of Stockpile Transactions
Mr David Maguire of Union Carbide.

I hope that each of you will be able to attend. However, should you be unable to do so and you are your company's voting delegate to the T.I.C., please give your proxy to another delegate so that our member companies will be well represented during the business sessions.

The T.I.C. is continuing to grow in membership. We now have seventy-five members — an impressive group who make up a large part of the world tantalum industry. Even so, there are many companies which are eligible to become members but either do not know of the T.I.C. and its programs or who need to have "an arm twisted". I want to encourage each of you to bring in a new member.

Mrs Judy Wickens, the efficient Secretary of the Tantalum International Study Center, Rue Washington 40, 1050 Brussels, Belgium, will be pleased to send to you or to a potential member — as you may request — literature regarding the T.I.C. and a membership application. Please do not forget that our Charter includes niobium producers.

I look forward to seeing each of you in Boston.

Carroll G. Killen
President

The fabrication of a tantalum mesh construction for use in a chemical plant

The following paper, written by Mr. C.E.D.Rowe who is the Technical Manager of the Refractory Metals Department at Murex, Ltd. in Rainham, Essex, England, was first published in the February 1984 issue of "Metal Construction". It is reproduced here with permission for the benefit of the readers of the T.I.C. "Bulletin", modified only to the extent necessary to conform to the format of the "Bulletin".

(continuing the article in Bulletin 41)

CHEMICAL ANALYSIS

Sample spot welds in the argon shield on the 0.105" and 0.192" wires were carefully cut from the rod using a hacksaw so as to leave the minimum amount of rod adjacent to the weld zone. Oxygen analysis was carried out by vacuum fusion. Surface tarnishing was not removed prior to testing so that an accurate assessment of oxygen in the weld zone could be made. Samples of the original wire were also analysed, again without removal of the normal surface oxide layer. It is useful to note at this stage that tantalum readily oxidises in air at room temperature to produce a very thin oxide layer which prevents further oxidation and is responsible for the excellent corrosion resistance of the material. It is in fact only reagents which attack this layer such as hydrofluoric acid, fluorides and fuming sulphuric acid which corrode tantalum. The results of the oxygen analysis are :

Oxygen Analysis of Spot Welds

Wire Size	*Original Wire O_2*	*Weld O_2*
0.105"	110 p.p.m.	120, 200, 140 p.p.m.
0.192"	100 p.p.m.	140, 150, 120 p.p.m.

Referring to ASTM B365/77, it will be noted that up to 250 p.p.m. oxygen is acceptable in the wire. The second weld in the 0.105" wire was considered to be the worst weld showing most tarnishing, yet this still meets the ASTM standard. Oxygen is mainly detrimental to the tensile strength of the material and has no effect on corrosion resistance except when very large quantities are present. In fact, as mentioned above, it is the oxide which is responsible for the corrosion resistance. As the meshes are to be in contact with hydrochloric acid which does not attack the oxide layer, no problems are envisaged with oxygen content even above the 250 p.p.m. level.

CORROSION TESTING

Samples of all types of welds on both wire sizes were accurately weighed, immersed in concentrated hydrochloric acid and heated under reflux to 90 °C. The samples were kept immersed for one week, hot by day, cold by night and then removed, washed, dried and weighed. The process was repeated for a further week, then for two further two week periods, making six weeks in all. The results were variable, some samples gaining weight one week, then losing it again the next week. The results obtained are given in Table 1.

ACKNOWLEDGEMENTS

The author wishes to thank Murex Limited for permission to publish this report and the English Valve Company, Chelmsford, for the use of their electron microscope.

After the final testing, the fusion welds were unchanged whilst the spot welds showed some tarnishing in the weld region. However, the spot welds in argon on the 0.105" wire showed no corrosion after six weeks and all of the fusion welds in argon on the 0.192" wire showed a gain in weight possibly due to impurities deposited from the acid. Thus, it may safely be concluded that the methods of construction, i.e., spot welding in argon for the 0.105" wire meshes and spot welding plus fusion or fusion alone for the 0.192" wire, are suitable methods of construction, providing the environment for which the devices are intended remain free from fluoride ions. A virtually unlimited life for the construction is forecast.

TABLE 1

Corrosion Testing of Welded Tantalum Wires

Wire Size (in)	Weld Type	Start Weight (gm)	1 week Weight (gm)	% Loss or Gain	2 weeks Weight (gm)	% Loss or Gain	4 weeks Weight (gm)	% Loss or Gain	6 weeks Weight (gm)	% Loss or Gain
0.105	Conventional Spot	7.2829	7.2814	—0.0200	7.2824	—0.0069	7.2821	—0.0110	7.2824	—0.0069
0.105	Spot in Argon	6.9362	6.9362	0	6.9368	+0.0069	6.9362	0	6.9362	0
0.105	Fusion in Argon	7.3410	7.3408	—0.0027	7.3426	0	7.3412	+0.0027	7.3412	0
0.105	Spot in Argon + Fusion in Argon	7.5092	7.5085	—0.0093	7.5092	0	7.5089	—0.0040	7.5097	+0.0067
0.192	Conventional Spot	22.0429	22.0409	—0.0091	22.0430	+0.0005	22.0412	—0.0068	22.0411	—0.0082
0.192	Spot in Argon	21.7389	21.7378	—0.0051	21.7382	—0.0032	21.7376	—0.0060	21.7377	—0.0055
0.192	Fusion in Argon	17.0882	17.0897	+0.0088	17.0937	+0.0322	17.0890	+0.0047	17.0894	+0.0070
0.192	Spot in Argon + Fusion in Argon	23.5676	23.5676	0	23.5708	+0.0136	23.5681	+0.0021	23.5688	+0.0068

The Nature of the Niobium Industry

The following article has been extracted from a presentation made by Dr. Harry Stuart, Niobium Products Company Limited, Pittsburgh, Penn., U.S.A. at the Twenty-second General Assembly of the Tantalum International Study Center in Brussels on October 30, 1984.

Niobium Products Company is a subsidiary of CBMM which is the principal Brazilian producer of niobium. I have called my paper "The Nature of the Niobium Industry" as a general talk, not too detailed, but answering several questions :

— What is niobium ?
— What is it used for ?
— What are its product forms ?
— Who are the producers ?
— What does the future hold ?

Niobium, atomic weight 41, is much lighter than tantalum, atomic weight 93. It was discovered by Charles Hatchett, an Englishman, in 1801 and he called it columbium because the source of the material with which he was working was in the United States. It was first isolated by a German, Heinrich Rose, in 1844, who changed the name to niobium which is the most popular name today.

Niobium is very versatile, has many applications and is very cost-effective, particularly in steels. It is very plentiful. CBMM's deposit alone, with reserves of the order of 500 million tons, is sufficient to last hundreds of years.

Niobium has been determined in the United States to be a "strategic and critical" material, but this is questionable. Although there are many important uses for niobium, there is a usable substitute for every application. Using niobium is simply the best way to do things, not the only way. As a consequence of this determination, however, the United States government is currently in the process of buying six million pounds of niobium for its strategic stockpile. Other countries are considering doing the same thing.

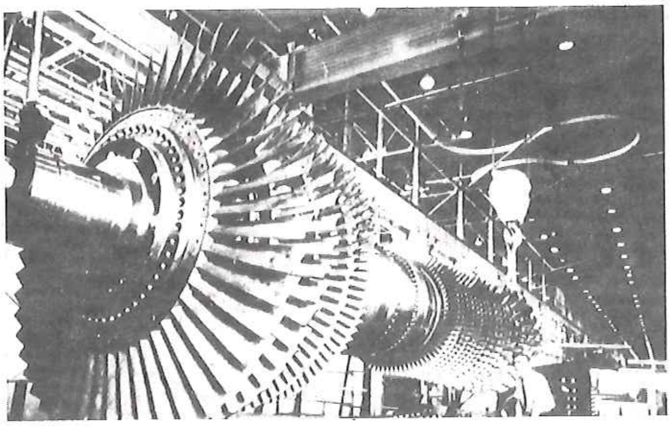
USES OF NIOBIUM

The principal use of niobium is in high strength, low alloy (HSLA) steels. HSLA steels are simple steels which are used for structural purposes. They have low carbon content at about 0.1 %, simple addition of manganese in the range of 1 % and a few hundred parts per million of niobium. Sometimes vanadium is also used. The use of niobium is to make the steel stronger and tougher so that less can be used in application.

Line pipe is probably the biggest consumer of niobium in HSLA steel. The economics of transporting gas are a function of the amount of steel used to build the line. If a stronger steel is used, less of it is needed. One of the most active projects for pipeline building these days is in the line running from north-central Siberia, through Russia and Czechoslovakia connecting with a distribution network in western Europe serving France, Belgium, Germany, Italy and Austria. The line often consists of as many as four parallel pipes and thousands of miles are being used. And the advantage of tougher steel is evident when the extreme climates through which the pipeline travels are considered.

HSLA steels are also used in reinforcing bar for concrete structures such as the Itaipu Dam in Brazil. The steels are used in bridges, railway cars and earth-moving equipment. Probably the biggest use of niobium HSLA steels currently, certainly in the United States, is in automobiles, the application which provides the current strength of the niobium market. The HSLA steels are used in bumpers, in wheels, wheel spiders and many other components such as doors, pillars, supports and various other parts of the cars. Trucks are also using HSLA steels for frames and for cross-members. They are used in electrical transmission towers and off-shore platforms where they offer a saving in weight and an improvement in the toughness and safety of the structures.

These HSLA steels use niobium in parts per million, but superalloys for aircraft engines use niobium at the 5 % level, plus or minus. Niobium in superalloys strengthens the alloy at the high service temperatures of many hundreds of degrees. The niobium superalloys go into the rotors, the discs and the turbine blades.

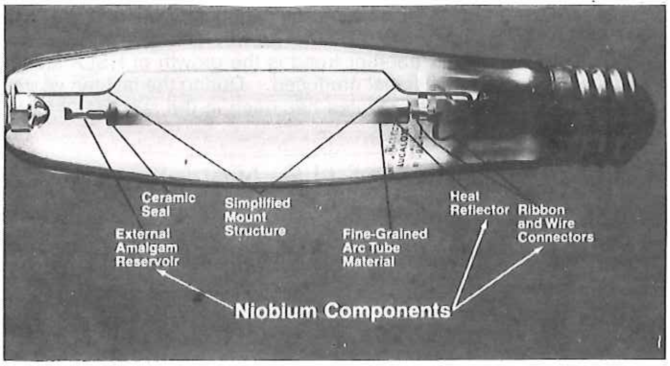


This is a smaller market than the HSLA steels but, because there is a much larger quantity of niobium used in the alloy, this market in the United States probably represents about 20 to 25 % of the niobium consumption.

There are also some other alloys coming along in the aircraft industry, the so-called titanium aluminides which can contain up to 25 % niobium. We are anxiously awaiting the commercialization of these alloys. But there are also niobium-based alloys containing 95 % or more niobium.

Superconductors containing niobium and titanium (50 % each) or the niobium-tin alloy are predicted to be a big growth market for niobium even though this has been an unfulfilled prediction for at least twenty years.

There are other niobium-base alloys used for high temperature applications. These are niobium-zirconium alloys used for lamp filaments and various small parts in high-intensity sodium vapor lamps.



There are also nuclear applications such as niobium-zirconium tubing, and niobium-base alloys are beginning to be used in corrosion resistant applications. A niobium-tantalum alloy recently commercialized that has 40 % tantalum and the balance niobium is cheaper than tantalum and approaches the corrosion resistance of pure tantalum metal.

Other applications of niobium include tool steels in which case niobium can be used to replace tungsten, vanadium and molybdenum. It is not now a very big market but it has potential to become quite large. Stainless steels are also using significant quantities of niobium, particularly the newer ferritic stainless steels used in automobiles and corrosion resistant applications.

Although all of the applications covered so far have been metals, there are also non-metal applications. Niobium oxide is used as an addition to certain glasses, lenses for cameras, lenses for eye-glasses. The niobium oxide raises the index of refraction of the glass so that lenses can be produced that are smaller and thinner. Niobium is being used instead of tantalum in these applications, the advantage being that the niobium is lighter.

Electronics has become a new area of use for niobium. Lithium niobate is used in SAW devices and Q-switches for lasers. These are very specialized applications. The niobium oxide used has to have a purity of at least 99.9 % which, for CBMM, is a new direction. CBMM is used to producing the oxide with several percent of impurity and now we are faced with only a few parts per million.

One development which could provide a very significant use for niobium is the application of niobium oxide as a catalyst and as a catalyst support. There are many patents in this field and research, supported by CBMM, shows that niobium can be used as a catalyst in many, many reactions. So far, the market has not developed but the possibilities are great.

In summary, the applications of niobium range from the use of a few parts per million in steels to almost 100 % in niobium-base alloys. The diversity of the applications is great and probably niobium is much more diverse in application than tantalum.

SOURCE MATERIAL

Currently, the niobium source material business is dominated by a few people.

NIOBIUM SOURCES

LOCATION	CAPACITY (lbs. Nb_2O_5 x10[6])	ORE GRADE (% Nb_2O_5)	RESERVES (tons Nb_2O_5 x10[6])
Araxa, Brazil	55	3.0	500 +
St. Honore, Quebec	7	0.7	11
Catalao, Brazil	5	1.5	50
Nigeria	2	-	Limited

POTENTIAL SOURCES

CANADA
James Bay: 0.52% Nb_2O_5 - Significant Reserves
Oka, Quebec: 0.4 - 0.6% Nb_2O_5 - Significant Reserves
AFRICA
Luesha, Zaire: 2.9% Nb_2O_5 - Abundant Reserves
Mrima Hil, Kenya: 0.7% Nb_2O_5 - Significant Reserves
BRAZIL
Tapira, M.G.: 0.5% Nb_2O_5 - Significant Reserves
Sao Gabriel, Amazonas: 2.8% Nb_2O_5 - Abundant Reserves
OTHERS
U.S.A., USSR, China

The first deposit shown, in Araxa, Brazil, is the CBMM operation with its vast reserves of very rich ore, 3 % Nb_2O_5 contained. Then comes Niobec in Quebec with much smaller reserves and a much leaner ore, followed by Catalao de Goias in Brazil, also with smaller reserves and leaner ore, and then the columbite producers in Nigeria. There are many potential sources around the world in the carbonatite deposits which contain niobium. Canada has many, such as the James Bay and Oka deposits in Quebec. The Oka deposit has been mined commercially during the past ten years but is now idle. There are a number of deposits in Africa, particularly the rich deposit in Luesha, Zaire, which is as rich as the CBMM deposit and with large reserves.

There are other significant properties in Brazil : a lean deposit, only 0.5 % Nb_2O_5, with significant reserves at Tapir; an incredible deposit at San Gabriel in the Amazon region at almost 3 % Nb_2O_5 and reserves of almost three billion tons but with a very complex mineralization.

There are many other deposits around the world, in the U.S.A., the U.S.S.R. and in China. China is producing as a by-product of iron ore mining, but it is unclear what is being done in the Soviet Union.

How is niobium mined ? CBMM has an open pit mine.

The over-burden is light, in some cases only a few meters thick. Thus mining is a relatively simple operation requiring only removal of the over-burden to have direct surface availability to the ore. It is a simple process. The other producer in Brazil has a similar mine, but the operation at Niobec is an underground mine.

PRODUCT FORMS

There are three common product forms of niobium :

- Master alloys, produced aluminothermically, available with a range of purity depending on the application,
- Niobium oxide, a white powder used as the starting-point for high-purity master alloys and as an additive to glass, and
- Niobium metal produced by electron-beam refining.

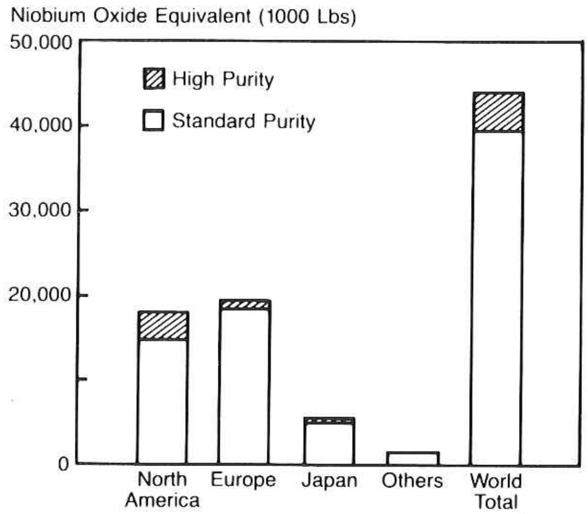
Standard-grade ferroniobium, as used by the steel industry, contains about 3 % impurities since these are not too important in the production of HSLA steel. Vacuum-grade master alloy, with about 0.75 % impurity, is used for making superalloys. Air-melt grade is an intermediate containing about 1.5 % impurities. These master alloys are produced either direct from ore concentrates in the case of the standard grade or from high-purity oxide in the case of the vacuum grade.

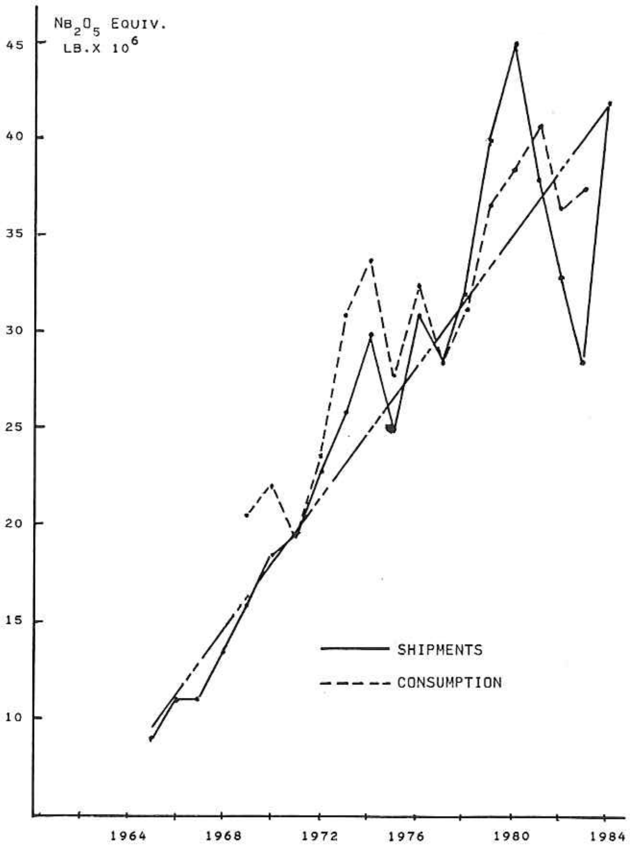
There are two grades of niobium oxide : superalloy grade, about 99 % pure, and optical grade at 99.9 % pure. The oxides are produced from either the ore concentrates or from columbite.

Niobium metal is produced from oxide, aluminothermically reduced to impure metal and then refined by electron-beam melting, alloyed by vacuum-arc melting and then worked into plate, sheet, bar, wire, etc.

PRODUCTION AND CONSUMPTION

How much niobium is produced ? This chart offers the data for 1980 but also reflects the consumption for 1984.





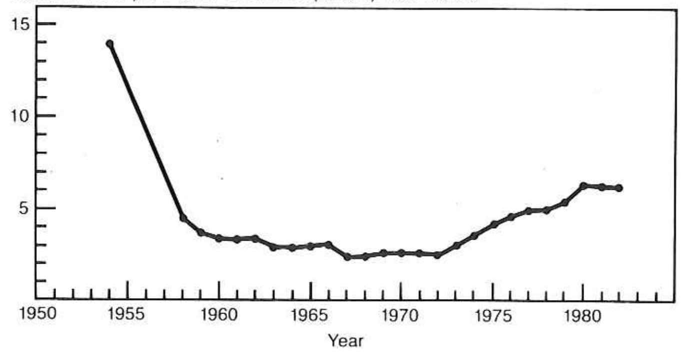
The total world consumption, excluding China and the U.S.S.R., is about 40 million pounds. In 1982 and 1983 it was significantly less but will be back to the 40 million pounds in 1984. The distribution of consumption is equal between North America and Europe. North America consumes more vacuum-grade masteralloy and niobium metal but Europe consumes more standard-grade ferro-niobium in making steel. Japan is the third largest consumer and the rest of the world is a very distant fourth.

The world niobium shipments from the early 1960's to the present time show the very strong increase in business from 1977 to 1980 and the equally drastic reduction from 1980 to 1983. However, with the strong reversal in 1984, the straight line trend is continued. Consumption has usually been in fairly close agreement with shipments although there has been some out-of-balance in the last few years.

COST OF NIOBIUM

How much does niobium cost ? The price of ferroniobium standard-grade in Swiss francs, a stable currency, is still at the same level today as it was in 1970. The price in U.S. dollars, however, declined drastically in the early 1960's after the CBMM deposit was discovered.

Niobium Price per Pound Contained (U.S.A.) U.S. Dollars



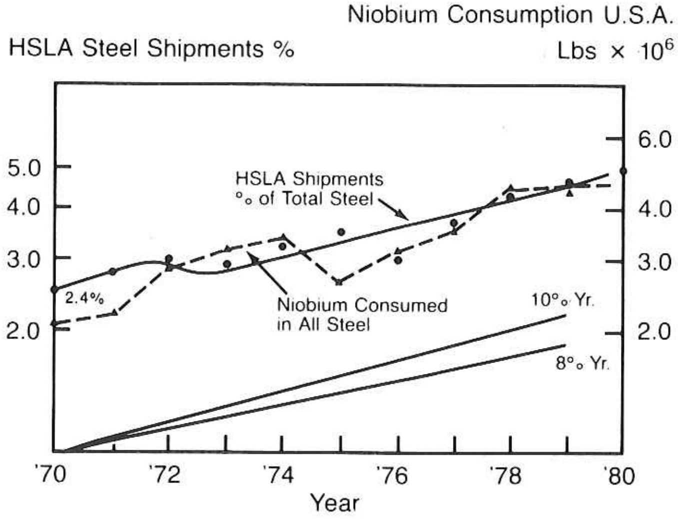
The price of niobium plummeted because it was no longer an exotic, rare metal. During the late 1960's and the 1970's it jogged up and down but started rising in the early 1970's as inflation became a factor. Since 1980, the price has gone down slightly each year.

As a comparison, a kilo of niobium contained in ore concentrate costs about $ 10, in standard-grade ferroniobium about $ 13 and in vacuum-grade master alloys between $ 30 and $ 40. A kilo in 99 % oxide costs $ 20 to $ 25 and in 99.9 % oxide the price goes up to the range of $ 90 to $ 115. Electron-beam ingots cost between $ 60 and $ 80 per kilo and the price of alloy rod or tube ranges from $ 100 to $ 150.

THE FUTURE

There is a direct correlation between the production of steel and the consumption of niobium. Since growth in world steel production in the foreseeable future is expected to be slight, only about 1 ½ % per year, there would appear to be little growth potential in niobium consumption. However, another trend is the growth of HSLA steels as a proportion of the total steel produced. During the last ten years, this proportion in the United States has been in the range of 8 % to 10 % per year.

Relationship Between U.S. Niobium Consumption in Steel and HSLA Steel Production



Will this growth rate continue ? A somewhat lower growth rate is predicted as there is a transference of steel production from North America and Europe to Asia where the degree of sophistication is much lower. The specific niobium consumption (total niobium consumed divided by the total steel production) in the industrial countries is much higher than it is in the developing nations. As these countries become more sophisticated, however, and begin to produce more HSLA steel, the consumption of niobium will increase.

In other niobium consuming areas, superalloys are very strong. The strength of the jet-engine market for both military use and for commercial airlines is improving and the next five years should provide a good market for niobium superalloys at a rate probably from 5 % to 20 % per year. Consumption is increasing in the ferritic stainless steels as they are consuming more niobium, particularly in Japan. The growth potential in niobium-base alloys is less certain but it appears that there is a significant potential. Many authorities have predicted that superconductor applications are going to increase rapidly and there are favorable factors apparent. Superconducting magnets finally have found a commercial application in NMR body scanners, expected to replace the x-ray CAT scanners. Although significant growth over the next twenty years is forecast, there is still uncertainty as to how many of these machines will be actually purchased. We predict that in the next fifteen years the consumption of niobium in superconductors will be about 2,000 tons but this is possibly on the low side.

In summary, there is a good potential for growth for the niobium business.

Dr. Stuart offered the following additional information about various aspects of the niobium industry in response to questions from the floor after the completion of his presentation :

— The overall growth rate of niobium consumption has been about 10 % per year up 1980. When the data of the last three years is considered, the average rate for the past twenty years has been somewhat less, about 8.5 % per year.

— About 95 % of the niobium consumed comes from pyrochlore as the source material and the remaining 5 % from the niobium produced as a by-product of tantalum processing.

— In the recent tender by the G.S.A. to buy niobium, the tender was for columbite and did not include concentrates derived from pyrochlore, even though Niobium Products tried to obtain a change which would have permitted the supply of pyrochlore concentrates. The G.S.A. received two offers for columbite, one from Norore and one from Amalgamet. As the result of Niobium Products offering, on the behalf of CBMM, to supply technical grade niobium oxide, the G.S.A. discovered that they could buy this product at a lower price than columbite. As a result, they rejected all of the bids. It is expected that a new tender will be made which will include pyrochlore concentrate and oxide, either or both.

— The San Gabriel deposit in Brazil is of a different mineralization from the deposit at Araxa. It is a niobiferrous rutile. There is probably no technology extant for the separation of the niobium content from the mineral and a new technology must be developed. In view of the presently available capacity from existing mines, it may be difficult to justify the development expense to attain the needed technology.

— The high purity niobium product market will grow at a substantially higher rate than the "bread-and-butter" products. Although there will be some growth in steel, the use of niobium will come from the increased use of HSLA steels in this market segment. But the growth in the high purity segment will be at a much greater rate as a result of the increasing demand for the niobium containing superalloys and niobium-base alloys. If the number of companies who are interested in getting into the superconductivity business is used as a guide, that segment of the market will be very good for niobium.

Operation of electron beam furnace for melting refractory metals

The following article has been extracted from a paper prepared by Dr. John Lambert, Vice President, and Mr. James Pierret, Plant Manager, of Fansteel Inc. It was presented at the Electron Beam Melting and Refining State of the Art 1984 Conference held in Reno, Nevada, U.S.A. on November 9 and 10, 1984.

ABSTRACT

A production facility for E-Beam melting of tantalum, columbium and their alloys is described.

Melt conditions, capacities and ingot chemistry and properties for three melts, pure tantalum, pure columbium (niobium) and a columbium-base alloy are described. Factors relating to operation of the equipment are disclosed. Based on experience, the effects of melt interruptions on ingot quality are discussed, and the importance of preventive maintenance in minimizing downtime is particularly emphasized.

HISTORY AND EQUIPMENT

In 1963, Fansteel acquired the electron beam melting technology and equipment for melting tantalum and columbium and alloys from the Stauffer Chemical Company. The equipment, now installed at Fansteel's Muskogee, Oklahoma, facility, has been in operation continuously since acquisition but has been modified and updated subsequently. There are presently two three-gun furnaces in operation, each gun with an independent 150 kw power supply. The transverse guns were made by Temescal and are mounted in the vacuum chamber at 120 degrees separation, with the electron beams undergoing 120 degree magnetic deflection. The mild steel vacuum furnace chambers are about 12-feet diameter by 5-feet high.

The vacuum system for each furnace comprises three, 32-inch diameter, oil diffusion pumps, each rated at 50,000 liter per second pumping capacity. Each diffusion pump is backed by a 1900 cfm Roots blower and 300 cfm mechanical roughing pump. The chamber is evacuated to less than one micron absolute pressure prior to initiation of melting. Chamber pressure is monitored by ionization gauges located at several positions. All vacuum valving is pneumatically controlled from the operator's control station.

The melt receptacles are open-ended, cylindrical, copper crucibles ranging in diameter from 5 to 11 inches by about 12 inches long. The crucibles are jacketed for water cooling. The bottom of the crucible is formed by a dove tail or stub ingot which is progressively withdrawn as melting proceeds and product accumulates in the crucible. The withdrawal rate is controlled to maintain a molten pool approximately three inches deep with the liquid level near the top of the crucible. Ingots as long as 120 inches have been cast.

A total of 325 gpm of cooling water may be circulated to the furnaces for cooling the crucibles, magnetic deflectors, vacuum seals, and other components. Heat removal is accomplished by pumping the water to a forced air cooling tower with a capacity of 30 million Btu per hour. Chemically treated and continuously filtered make-up water is supplied.

The equipment is capable of feeding melt stock, pressed compact bar pieces, or dense scrap, either through a side port or by suspending vertically in a tower. From the side port a push-rod mechanism moves the material across a ramp into the focused electron beam, whereupon the material drip melts into the molten pool in the crucible. Alternatively, a bar or previously melted ingot may be suspended in the tower and slowly fed into the electron beam path, whereupon metal is drip melted. After striking the feed stock, the electron beams sweep across the molten pool, with each electron gun focusing on one-third of the melt surface. The entire melting process may be viewed by either an indirect optical viewing system using leaded glass sign ports or by a video camera monitor.

Normally, the melt rate is limited by the system pressure (vacuum) and the rate of outgassing. Because the more volatile impurities are removed during the first melt, outgassing frequently limits melt rate in this step. For subsequent remelts, E-beam power is usually increased to permit faster melting.

TYPICAL REFRACTORY METAL MELT-CYCLES

1. **Pure Tantalum**

The melting point of tantalum is 2996 °C, the highest of any of the more common elements other than tungsten. Because of the high melting point, heat losses by conduction and radiation are large, thereby limiting the maximum ingot diameter which can be melted. In our furnaces, we routinely cast eight-inch diameter ingots at a feed rate of 140 to 160 lb. per hour. However, two melts are usually necessary since our starting material consists of bars isostatically pressed from sodium-reduced powders. Considerable degassing occurs during the first melt so that melt rates are reduced, typically to 90-100 lb. per hour, with total input power to the guns in the range of 300-400 kw. In the second melt (i.e., remelt of first melt ingot) power is increased to 350-400 kw. While the purpose of the first melt is primarily for consolidation, succeeding melts aim at improving ingot soundness and sidewall quality as well as obtaining required final purity. Ingots are vacuum cooled for at least 90 minutes before removal from the chamber. Unless ingot surface temperature is below 250 °C., on exposure to atmosphere oxidation and accompanying discoloration will occur. Such surface oxidation is not critical since complete skin removal is easily carried out subsequently by etching and scarfing.

(This article will be completed in Bulletin 43.)

Statistics

T.I.C. member companies report their production and processing during the fourth quarter of 1984 as follows :

TANTALUM PRODUCTION AND SHIPMENTS

Quoted in lb. Ta_2O_5 contained

1984 - 4th quarter	*Production*	*Shipments*
Tin slag	384 332	387 915
Tantalite and other materials	175 991	47 009
Total	560 323	434 924

Note : 22 companies out of 25 replied.

In accordance with the rules to protect the confidentiality of members, the categories "Tantalite under 25 %", "Tantalite over 25 %" and "Other materials" have been combined.

TANTALUM PROCESSORS' SHIPMENTS

Quoted in lb. tantalum contained

1984 - 4th quarter	*Shipments*
Tantalum oxide	31 195
Carbides	117 688
Powder/anodes	248 330
Mill products	94 969
Alloy additive	29 787
Scrap, ingot, unworked metal, other	120 447
Total	642 416

Note : 17 companies out of 19 replied.

In accordance with the rules to protect the confidentiality of members, the categories "Scrap" and "Ingot, unworked metal and other" have been combined.

ANNUAL TOTALS FOR 1984

Tantalum production and shipments

Quoted in lb. Ta_2O_5 contained

	Production	*Shipments*
Tin slag	1 010 421	1 014 073
Concentrates	509 913	375 456
Total	1 520 334	1 389 529

Tantalum processors' shipments

Quoted in lb. tantalum contained

Tantalum oxide	115 398
Carbides	590 889
Powder/anodes	1 031 767
Mill products	366 370
Alloy additive	102 270
Scrap, ingot, unworked metal, other	341 310
Total	2 548 004

PRODUCTION FORECASTS

The T.I.C. has decided to make projections of possible tantalum production on a world-wide basis, and below is the first attempt at these forecasts. Three price scenarios have been postulated : London Metal Bulletin quotations of $ US 30, $ US 40 and $ US 50; production has been estimated for each of these price levels if it were in force. It must be noted that the statistics are based on information relating to production received to date, and do not reflect total world production.

(Production estimates are quoted in lb. Ta_2O_5 contained)

LMB quotation :	*$ 30*	*$ 40*	*$ 50*
4th quarter 1984	511 610	530 560	642 960
1st quarter 1985	389 610	421 515	534 075
2nd quarter 1985	402 810	434 715	550 275
3rd quarter 1985	391 750	453 655	574 725
4th quarter 1985	399 950	461 855	587 725
1st quarter 1986	379 610	441 515	567 775

Capacitor statistics

The statistics of capacitor sales in the U.S.A. and Japan are given below. For the U.S.A. data "Manufacturers" covers U.S. capacitor manufacturers' products sold in the U.S.A. "Distributors" covers products imported by those manufacturers for resale. Other imports are not included.

The "Export" data in the Japanese manufacturers' statistics cover sales to eight main overseas countries only.

U.S. TANTALUM CAPACITOR SALES (THOUSANDS OF UNITS)

(Data from Electronic Industries Association)

4th quarter 1984

Type	*Manufacturers*	*Distributors*	*Export*	*Total*
Foil	280	79	7	366
Metal cased solid	35 809	13 966	11 288	61 063
Non-metal cased solid	145 201	21 656	24 939	191 796
Chips	9 976	101	2 120	12 197
Wet slug	1 774	982	234	2 990
Total	193 040	36 784	38 588	268 412

Total for year, 1984

Foil	1 006	346	35	1 387
Metal cased solid	187 678	57 806	59 716	305 200
Non-metal cased solid	596 804	103 313	96 703	796 820
Chips	33 942	358	10 860	45 160
Wet slug	8 397	3 552	1 267	13 216
Total	827 827	165 375	168 581	1 161 783

JAPANESE TANTALUM CAPACITOR SALES (THOUSANDS OF UNITS) (Data from Japanese Electronic Industry Development Association)

4th quarter 1984	*Production*	594 523	*Of this, export*	126 121
Total for year, 1984	*Production*	2 121 567	*Of this, export*	468 164

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