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 Dr 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).
6. Next General Assemblies:
   Twenty-fourth: Brussels, October 1985
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, Gostar, 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 tantalum 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/Neobium Division of the Gostar 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 valued materials and items 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.S.E.E. degree in 1964 from Rensselaer Polytechnic Institute, and a MSIE 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 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 capacity powders. NRC powders are known for lot-to-lot consistency and reliability. These factors, plus superior performance under a wide range of conditions and temperatures, contribute to the 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 powders 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 the other new facilities which include a scanning electron microscope, a physical properties laboratory and a new building dedicated to the marketing of tantalum and niobium.

As a specialist in tantalum metal, NRC is also a major source for metallic 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-based products which 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 high-speed engines, chemical vessels and superconducting 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 products and processes. Notable developments were frozen orange juice concentrate (a subsidiary was the former 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 processes, 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 tantalum 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 1976, 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 involved in metal refining 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 NFC.

NFC 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 NFC 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 5,000 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 products include:
- **Capacitors**
- **Semiconductors**
- **Specialties**

**Products**
- **Components**
- **Interchange Filters**
- **Power Supply Magnetics**

**Multilayer Ceramic**
- **Resistors**
- **Delay Lines**

**Tantallium**
- **Hall-Effect ICs**

**Aluminum**
- **CMOS ICs**
- **Pulse Transformers**

**Plastic Film**
- **Transistors**

**Oil-Paper**
- **CMOS ICs**
- **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 Digital Equipment Corp. The company also serves over 5,000 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-oxide electrolytic capacitors for power supplies. In an allied area, the company is one of the world’s largest suppliers of thin-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 controller for use with the radio set in his shop. 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 manufactur-
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 assay of oxygen in the weld zone could be made. Samples of the original wire were also analyzed, again without removal of the normal surface oxide layer. It is useful to note at this stage that tantalum readily oxidizes 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 when a material such as hydrofluoric acid, fluorides and fuming sulphuric acid which corrode tantalum. The results of the oxygen analysis are:

Oxygen Analysis of Spot Welds

<table>
<thead>
<tr>
<th>Wire Size</th>
<th>Original Wire O₂</th>
<th>Weld O₂</th>
</tr>
</thead>
<tbody>
<tr>
<td>0.105&quot;</td>
<td>110 p.m.p.</td>
<td>140 p.m.p.</td>
</tr>
<tr>
<td>0.192&quot;</td>
<td>120 p.m.p.</td>
<td>150 p.m.p.</td>
</tr>
</tbody>
</table>

Referring to ASTM B365/77, it will be noted that up to 250 p.p.m. of oxygen is acceptable in the wire. The second weld on 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 Ltd for permission to publish this report and the English Valve Company, New Cross, 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 be said that the methods of construction, i.e., spot welding in argon for the 0.105" wire meshes and spot welding plus 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>
<thead>
<tr>
<th>Wire Size</th>
<th>Weld Type</th>
<th>Start Weight (gm)</th>
<th>1 week Weight (gm)</th>
<th>% Loss or Gain</th>
<th>2 weeks Weight (gm)</th>
<th>% Loss or Gain</th>
<th>4 weeks Weight (gm)</th>
<th>% Loss or Gain</th>
<th>6 weeks Weight (gm)</th>
<th>% Loss or Gain</th>
</tr>
</thead>
<tbody>
<tr>
<td>0.105</td>
<td>Conventional Spot</td>
<td>7.2829</td>
<td>7.2814</td>
<td>-0.0200</td>
<td>7.2824</td>
<td>-0.0099</td>
<td>7.2821</td>
<td>-0.0110</td>
<td>7.2824</td>
<td>-0.0099</td>
</tr>
<tr>
<td>0.105</td>
<td>Spot in Argon</td>
<td>6.9362</td>
<td>6.9362</td>
<td>-0.0007</td>
<td>7.3410</td>
<td>-0.0027</td>
<td>7.3412</td>
<td>+0.0027</td>
<td>7.3412</td>
<td>0</td>
</tr>
<tr>
<td>0.105</td>
<td>Fusion in Argon</td>
<td>7.3410</td>
<td>7.3408</td>
<td>0</td>
<td>7.5092</td>
<td>0</td>
<td>7.5097</td>
<td>+0.0067</td>
<td>7.5097</td>
<td>+0.0067</td>
</tr>
<tr>
<td>0.105</td>
<td>Spot in Argon +</td>
<td>22.0429</td>
<td>22.0409</td>
<td>-0.0091</td>
<td>22.0430</td>
<td>+0.0005</td>
<td>22.0412</td>
<td>-0.0068</td>
<td>22.0411</td>
<td>-0.0082</td>
</tr>
<tr>
<td>0.105</td>
<td>Fusion in Argon</td>
<td>21.7389</td>
<td>21.7376</td>
<td>-0.0015</td>
<td>21.7382</td>
<td>-0.0032</td>
<td>21.7376</td>
<td>-0.0060</td>
<td>21.7377</td>
<td>-0.0055</td>
</tr>
<tr>
<td>0.192</td>
<td>Conventional Spot</td>
<td>17.0882</td>
<td>17.0897</td>
<td>+0.0008</td>
<td>17.0937</td>
<td>+0.0032</td>
<td>17.0899</td>
<td>+0.0047</td>
<td>17.0894</td>
<td>0</td>
</tr>
<tr>
<td>0.192</td>
<td>Spot in Argon</td>
<td>17.0882</td>
<td>17.0897</td>
<td>+0.0008</td>
<td>17.0937</td>
<td>+0.0032</td>
<td>17.0899</td>
<td>+0.0047</td>
<td>17.0894</td>
<td>0</td>
</tr>
<tr>
<td>0.192</td>
<td>Fusion in Argon</td>
<td>23.5767</td>
<td>23.5767</td>
<td>0</td>
<td>23.5708</td>
<td>+0.0138</td>
<td>23.5821</td>
<td>+0.0021</td>
<td>23.5688</td>
<td>+0.0088</td>
</tr>
</tbody>
</table>

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. It was 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 its future hold?

Niobium, atomic weight 41, is much lighter than tantalum, atomic weight 73. 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 Ross, 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%, a small 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 steels. 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 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 15 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 is currently, in the United States, in automobiles; the application which provides the current strength of the nickel market. The HSLA steels are used in bumpers, in wheels, wheel spindles and many other components such as doors, pillars, supports and various other parts of the cars. Trucks are also using HSLA steels for for aero-motor and for aero-motor. 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, the market in the United States probably represents about 20 to 25 % of the niobium consumption.

There are also other alloy 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 5 % 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 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 eyeglasses. 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, of course, 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.

**AIKEN SOURCES**

<table>
<thead>
<tr>
<th>Country</th>
<th>Capacity (lb/yr)</th>
<th>Ore Grade</th>
<th>Niobium (lb/yr)</th>
</tr>
</thead>
<tbody>
<tr>
<td>Araxa, Brazil</td>
<td>55</td>
<td>3.0</td>
<td>500 +</td>
</tr>
<tr>
<td>St. Ives, Quebec</td>
<td>7</td>
<td>0.7</td>
<td>11</td>
</tr>
<tr>
<td>Catalão, Brazil</td>
<td>13</td>
<td>1.3</td>
<td>20</td>
</tr>
<tr>
<td>Nigeria</td>
<td>7</td>
<td>0.7</td>
<td>11</td>
</tr>
</tbody>
</table>

**POTENTIAL SOURCES**

<table>
<thead>
<tr>
<th>Country</th>
<th>Description</th>
</tr>
</thead>
<tbody>
<tr>
<td>Canada</td>
<td>0.12% Nb₂O₅ - Significant Reserve</td>
</tr>
<tr>
<td>Quebec</td>
<td>0.12% Nb₂O₅ - Significant Reserve</td>
</tr>
<tr>
<td>Sweden</td>
<td>0.37% Nb₂O₅ - Significant Reserve</td>
</tr>
<tr>
<td>Japan</td>
<td>0.03% Nb₂O₅ - Significant Reserve</td>
</tr>
<tr>
<td>China</td>
<td>0.03% Nb₂O₅ - Significant Reserve</td>
</tr>
<tr>
<td>USSR</td>
<td>0.03% Nb₂O₅ - Significant Reserve</td>
</tr>
<tr>
<td>U.S.A.</td>
<td>0.03% Nb₂O₅ - Significant Reserve</td>
</tr>
</tbody>
</table>

The first deposit shown, in Aoxa, Brazil, is the CBMM operation with its vast reserves of very rich ore, 3 % Nb₂O₅ contained. Then comes Niobec in Quebec with much smaller reserves and a much leaner ore, followed by Catalão in Goleia 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 carbonate deposits which contain niobium. Canada has many, such as the James Bay and Okla deposits in Quebec. The Okla 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 Luoxia, 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 % Nb₂O₅ with significant reserves at Taipir; an incredible deposit at San Gabriel in the Amazon region at almost 3 % Nb₂O₅ 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 ferro niobium, 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. Those master alloys are produced either directly 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 1994. The distribution of consumption is equal between North America and Europe. North America consumes more vacuum-grade master alloy 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 ferro niobium 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 ferro niobium 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% 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 6% to 10% per year.

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

Niobium Consumption U.S.A. Lbs x 10^6

HSLA Steel Shipments % of Total Steel
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 high-strength 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 4% to 20% of the market. Niobium is replacing the more expensive 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 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 to 1980. When the data of the last three years is considered, the average rate for the past twenty years has been somewhat less, about 6.5% 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 North American Tantalum Corp. and one from Amalgamated. As a 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 niobiferous 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 is difficult to justify the development at this time.

- The high purity niobium product 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 interested in getting into the superconductivity business is used as a guide, that segment of the market will be very good for niobium.

**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 Muskegon, Michigan, facility, has been in operation continuously since acquisition but has been modified and updated substantially. There are presently two three-gun furnaces in operation, each gun with an independent 150 kW power supply. The twin 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-foot diameter by 5-foot high.

The vacuum system for each furnace comprises three, 32-inch diameter, oil diffusion pumps, each rated at 50,000 liter per second pumping rate. Back diffusion pumps are mounted 190 cm. 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 gages located at several positions. Vacuum pumping 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 as a dovetail or step, not 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 326 gpm of cooling water may be circulated to the furnaces for cooling the crucibles and magnetic deflection 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 dips 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 dipped melted. After striking the feed stock, the electron beam sweeps 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 process pressure (vacuum) and the rate of outgassing. Because the more volatile impurities are removed during the first melt, the outgassing frequency 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 2896 °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 contamination and for improving 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 500 °C on a temperature profile, an accompanying discoloration will occur. Such surface oxidation is not critical since complete skin removal is easily carried out subsequently by etching and scraping.

   (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. Ta₂O₅ contained

<table>
<thead>
<tr>
<th>1984 - 4th quarter</th>
<th>Production</th>
<th>Shipments</th>
</tr>
</thead>
<tbody>
<tr>
<td>Tin slag</td>
<td>384 332</td>
<td>387 915</td>
</tr>
<tr>
<td>Tantalite and other materials</td>
<td>175 991</td>
<td>47 009</td>
</tr>
<tr>
<td>Total</td>
<td>560 323</td>
<td>434 924</td>
</tr>
</tbody>
</table>

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

<table>
<thead>
<tr>
<th>1984 - 4th quarter</th>
<th>Shipments</th>
</tr>
</thead>
<tbody>
<tr>
<td>Tantalum oxide</td>
<td>31 195</td>
</tr>
<tr>
<td>Carbides</td>
<td>117 688</td>
</tr>
<tr>
<td>Powder/anodes</td>
<td>248 330</td>
</tr>
<tr>
<td>Mill products</td>
<td>94 969</td>
</tr>
<tr>
<td>Alloy additive</td>
<td>29 767</td>
</tr>
<tr>
<td>Scrap, ingot, unworked metal, other</td>
<td>120 447</td>
</tr>
<tr>
<td>Total</td>
<td>642 416</td>
</tr>
</tbody>
</table>

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. Ta₂O₅ contained

<table>
<thead>
<tr>
<th>Production</th>
<th>Shipments</th>
</tr>
</thead>
<tbody>
<tr>
<td>Tin slag</td>
<td>1 010 421</td>
</tr>
<tr>
<td>Concentrate</td>
<td>500 910</td>
</tr>
<tr>
<td>Total</td>
<td>1 520 334</td>
</tr>
</tbody>
</table>

Tantalum processors' shipments
Quoted in lb. tantalum contained

| Tantalum oxide | 115 398 |
| Carbides       | 590 899 |
| 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. Ta₂O₅ contained)

LMB quotation: $30 $40 $50
4th quarter 1984 511 610 530 560 642 960
1st quarter 1985 385 610 421 615 534 075
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)

<table>
<thead>
<tr>
<th>Type</th>
<th>Manufacturers</th>
<th>Distributors</th>
<th>Export</th>
<th>Total</th>
</tr>
</thead>
<tbody>
<tr>
<td>Foil</td>
<td>280</td>
<td>79</td>
<td>7</td>
<td>366</td>
</tr>
<tr>
<td>Metal cased solid</td>
<td>35 809</td>
<td>13 666</td>
<td>11 288</td>
<td>61 063</td>
</tr>
<tr>
<td>Non-metal cased solid</td>
<td>145 201</td>
<td>21 566</td>
<td>24 930</td>
<td>191 796</td>
</tr>
<tr>
<td>Chips</td>
<td>9 976</td>
<td>101</td>
<td>2 120</td>
<td>12 197</td>
</tr>
<tr>
<td>Wet slug</td>
<td>1 774</td>
<td>982</td>
<td>234</td>
<td>2 990</td>
</tr>
<tr>
<td>Total</td>
<td>193 040</td>
<td>36 784</td>
<td>33 588</td>
<td>268 412</td>
</tr>
</tbody>
</table>

Total for year, 1984

<table>
<thead>
<tr>
<th>Type</th>
<th>Manufacturers</th>
<th>Distributors</th>
<th>Export</th>
<th>Total</th>
</tr>
</thead>
<tbody>
<tr>
<td>Foil</td>
<td>1 006</td>
<td>345</td>
<td>55</td>
<td>1 367</td>
</tr>
<tr>
<td>Metal cased solid</td>
<td>187 678</td>
<td>57 806</td>
<td>59 716</td>
<td>305 200</td>
</tr>
<tr>
<td>Non-metal cased solid</td>
<td>596 804</td>
<td>103 313</td>
<td>96 703</td>
<td>796 820</td>
</tr>
<tr>
<td>Chips</td>
<td>33 942</td>
<td>358</td>
<td>10 860</td>
<td>45 160</td>
</tr>
<tr>
<td>Wet slug</td>
<td>8 397</td>
<td>3 552</td>
<td>1 267</td>
<td>13 216</td>
</tr>
<tr>
<td>Total</td>
<td>827 827</td>
<td>165 375</td>
<td>168 561</td>
<td>1 161 783</td>
</tr>
</tbody>
</table>

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

4th quarter 1984

<table>
<thead>
<tr>
<th></th>
<th>Production</th>
<th>Of this, export</th>
</tr>
</thead>
<tbody>
<tr>
<td>594 523</td>
<td>126 121</td>
<td></td>
</tr>
</tbody>
</table>

Total for year, 1984

<table>
<thead>
<tr>
<th></th>
<th>Production</th>
</tr>
</thead>
<tbody>
<tr>
<td>124 567</td>
<td>468 164</td>
</tr>
</tbody>
</table>

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