TANTALUM INTERNATIONAL STUDY CENTER

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Twenty-third General Assembly

The Twenty-third General Assembly of the T.I.C. was convened on Thursday, June 13th 1985 in the Marriott Long Wharf Hotel in Boston, Massachusetts, U.S.A. The meeting was chaired by Mr Carroll G. Killen, President of the T.I.C.

The following three companies were elected to membership of the T.I.C., bringing the total membership to seventy-seven :

— Kamativi Tin Mines Ltd., a producer of tantalite/columbite sold as a by-product of tin production in the form of a furnace slag, located in Zimbabwe;

— Nichicon-Sprague Corporation, a Japanese manufacturer of solid electrolyte tantalum capacitors;

— Sassoon Metals and Chemicals AG, an independent marketing company which, in tantalite, provides marketing support for many miners, financing production and promoting sales to end users, with offices in Brussels and New York.

The T.I.C. accepted, with regret, the resignation of Charter Consolidated Metals and Ores. The General Assembly recognised the transfer of the membership of Northbrook Metals to Derek Raphael and Company, within the same group, following internal reorganisation.

In order to finance the increase of services offered by the T.I.C., including the recent appointment of the Technical Officer, the Executive Committee would recommend to the Twenty-fourth General Assembly an increase in the annual membership fee from $ 750 to $ 1250, with effect from July 1st 1986.

The Executive Committee was reviewing carefully the means by which the interests of the niobium producers, the newest segment of T.I.C. membership, could be best served.

In the area of statistical reporting, the Executive Committee was making arrangements to obtain the capacitor production data from Europe to complete the world-wide data when combined with that now being received from Japan and the United States. The Committee was setting out to tackle the problems in relating capacitor production data to equivalent tantalum demand. Production and processing data collection was continuing and the best presentation and use of these data were under constant review. Steps were being taken towards collecting statistics on niobium.

The Twenty-fifth General Assembly will be held on May 19th, 20th and 21st 1986 in the Kobe Convention Center in Kobe, Japan. The programme was actively being prepared and it was hoped to include three or four speakers from Japan and one from the People's Republic of China.

The Twenty-fourth General Assembly will be held in Brussels on October 21st and 22nd 1985. It is hoped to include a plant visit on the afternoon of the 22nd, following the formal General Assembly and the presentation of technical papers.

When the Twenty-third General Assembly of the association had been formally closed, presentations were made by invited speakers, and a panel of speakers and member-company delegates discussed topics of current interest. Abstracts of the presented papers were published in issue number 42 of the Bulletin; extracts from the papers will be published in this issue and in issue number 44.

The local organisation of the conference, held from June 12th to 14th, was carried out most admirably by the joint hosts, NRC and Sprague Electric Company.

To complete a full and interesting day's activities on June 13th, the delegates and guests enjoyed an evening visit to the John F. Kennedy Library and Museum. After a conducted tour, the participants were the guests of the host companies — NRC and Sprague Electric Company — for cocktails and an excellent dinner served in the beautiful Kennedy Library.

The final day of the meeting included tours of the NRC plant at Newton, Massachusetts, and the Sprague Solid Tantalum Capacitor Facility at Sanford, Maine. During the plant visits, the ladies were guided on tours of the adjoining country and met together with the men for typical New England seafood lunches. The ladies also enjoyed tours of Boston and the surrounding area on June 13th.

Presidential Address to the Twenty-third General Assembly of the T.I.C.

It is my pleasure to welcome you to Boston and to the Twenty-third General Assembly of the T.I.C. and, in particular, I am pleased to welcome our new members and our various guests and observers as well. This is our largest General Assembly. There are 234 registered delegates and guests. I hope you are here because of our program and not because of our location.

Our General Assemblies have all been held in places which are rich in history. Our present one is no exception. Although the Boston area was first surveyed by Captain John Smith in 1614 and the city was established in 1630, it is probable that the Norsemen sailed the Boston Harbor 400 years earlier. The Boston Tea Party took place in 1773 and the seeds of the American Revolution were sown. Faneuil Hall, which was built in 1762 and which is near here, provided a place for public forums and is called the Cradle of American Liberty. I hope that while you are here you will not only visit Faneuil Hall, but that you will walk the "Freedom Trail" as well.

Our host companies, NRC and Sprague, have been superb. They, through the efforts of NRC's David Nocella and Sprague's Bob Arena, have spent many hours in planning and organizing the events and facilities in order that our Twenty-third General Assembly might be a success. Let us thank our hosts with a round of applause.

The T.I.C. has continued to grow both in membership and in usefulness to its members. Our three new member companies bring our total membership to 77. The publication of statistics is fundamental to the services provided by the T.I.C. Data for the production and shipments of tantalum-bearing concentrates and tin slags and processor statistics have been published on a regular basis. Capacitor statistics from Japan and the United States were first published in our June 1984 Bulletin and are now made available on a regular basis. The European capacitor community has agreed that their data, which is collated by Price Waterhouse in Zurich, will now be made available to us. We are asking the Japanese Electronic Industry Development Association to supply their data in a more detailed form so that it will be of greater use to our members.

A full-time Technical Officer, Andrew Jones, has been employed, is in training and is here. If you have not already met him, please introduce yourself to him. Andrew has already begun to familiarize himself with the various T.I.C. publications and reports and has begun a program of coordinated visits to the facilities of several of our member companies. The addition of a Technical Officer to our staff will allow the T.I.C. to expand the services that are offered to our members. If any of you have clearly defined assignments which you believe could be profitably undertaken, please communicate your ideas to any member of the Executive Committee or to Judy Wickens, our very efficient Secretary in Brussels.

The President's message which appeared in the January 1985 issue of the T.I.C. quarterly Bulletin, stated that "the tantalum industry to a large extent — has recovered from the difficult period which began in the early 1980's — that the decline of tantalum usage was abruptly halted by the spectacular recovery of the world-wide electronic market — with the result that the tantalum capacitor industry achieved record shipments during both 1983 and 1984".

The data published in our quarterly Bulletin suggests that 1984 was a good year for most of the tantalum industry. Capacitor shipments in both the United States and Japan, in units, were up approximately 36 % over the previous year. In fact, in real terms during 1984, this part of the industry enjoyed a rate of growth that was twice its annual average, or a two years' growth rate in one year. Capacitor data just received from Europe indicates that shipments there were up 26.6 % over 1983. This performance is not as good as was experienced in Japan or the United States but certainly made for a good year.

The tantalum processors' shipments of all products were up 26.3 %, powder and anodes were up 32.1 % and carbides were up 12.7 %.

The demand for tin slag and tantalite recovered from their low year of 1983. They were up approximately 30 % but were still 85 % below their 1980 banner year. Barring substantial new uses for tantalum, it is probable that this part of our industry will not recover fully until the beginning of the next decade.

My forecast of last January suggested that "the recovery process has run its course with the result that the industry, in 1985, will experience only a modest growth above that achieved during 1984 — that coping with the slower rate of growth during this period will be a major challenge to our industry — but there is a bright side : all forecasts indicate that the adjustment period will not last very long, perhaps no longer than four or five quarters".

The modest growth for 1985 over 1984 did not materialize. It now appears that the capacitor industry growth rate for this period will be a negative 7 - 8 %. In spite of this drop, I continue to believe that this adjustment period will last no longer than four or five quarters which will bring us into the first or possibly the second quarter of 1986.

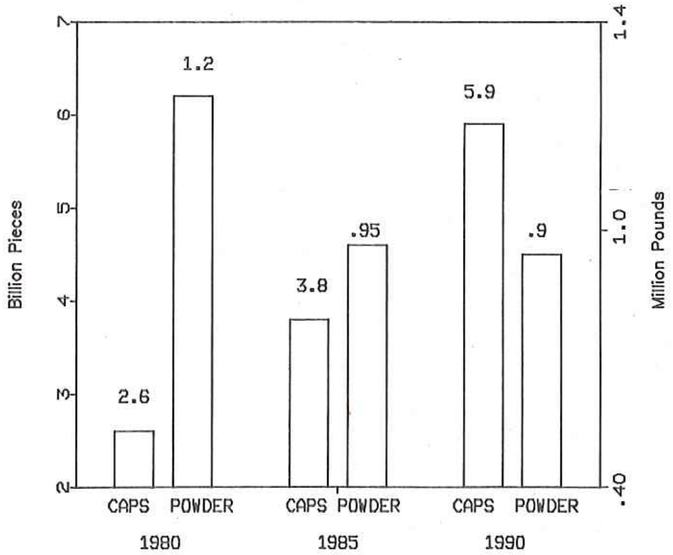
Many forecasters claim that the economy is about to go into a recession and, if that happens, all optimistic forecasts can be forgotten. U.S. Census Department data of key seasonally adjusted growth rates through the February-March period suggested a positive near term improvement in the electronic industry and as this industry accounts for approximately 60 % of the processors' total output, this improvement should be felt all the way back to the mine. April data dashed all hopes for an early recovery; however, the Federal Reserve Board's recent "technical adjustment" of the discount rate, which Chairman Volker testified before Congress, was designed to achieve a growth rate of around 8 % (4 % real growth, 4 % adjustment for inflation) for 1985 and should stimulate the demand for durable goods. An improvement in the market for durable goods will increase the demand for all types of goods which affect our industry including aircraft and engines, automobiles and trucks, all types of electronic equipment and other products which use the various materials and devices which our industry produces. On balance, 1986 should be a good year for most of our industry.

One of our former presidents, John Linden, in his message which was published in the December 1982 Bulletin stated, "The direction of research and development needs to be changed from the orientation of reduced usage in existing applications to one of new uses for the metal. Every member of the tantalum industry would benefit by a growth in the market for tantalum products. The metal has unique properties and lends itself to new uses and applications. The T.I.C. and its members can assist by providing the forum where some of the results from these new developments can be discussed".

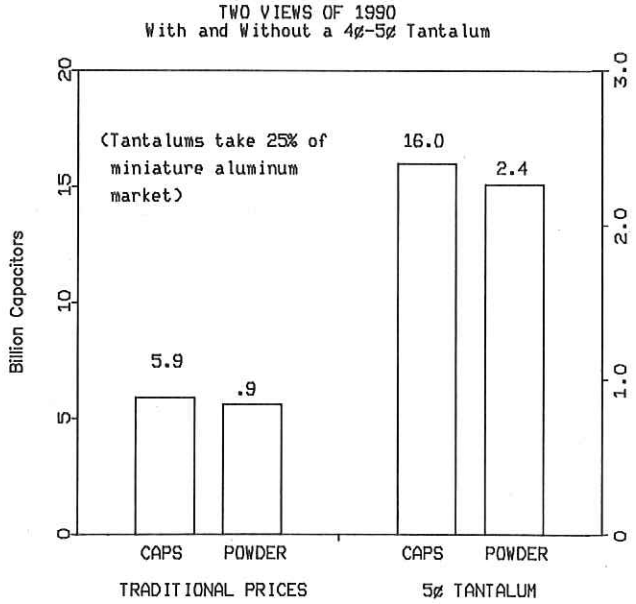
Regarding the development of new uses for the metal, John went on to say, "It is difficult to see how this can be achieved as those members of the industry that have sophisticated research and development facilities generally have an interest in only a small section of the tantalum industry as a whole".

Perhaps there is a way. The processors in response to the perceived shortage of tantalum developed a series of high charge powders and the capacitor manufacturers undertook development programs to learn how to use these new powders. As a result of some old-fashioned cost cutting and through the use of these new powders, capacitors were produced at a lower cost. This development slowed and in many cases stopped the efforts of design engineers to substitute capacitors which used other dielectrics for the tantalum units that were in their circuits or were already in or about to be designed in their new equipment.

The development and use of high charge powders was necessary if the tantalum capacitor industry was to remain a potent factor in the tantalum industry. As a result, the capacitor industry, on a world-wide basis, in 1985 will use 20.8 % less powder than it used in 1980 and by 1990 will use 5.3 % less than it used in 1985, or 25 % less than it used in 1980. The production of capacitors and the demand for powder reflect this.



The reduction in the total use of powder can be reversed if the tantalum capacitor manufacturers can find a way to produce a $ 0.04 or $ 0.05 tantalum capacitor. Such a development would allow design engineers to replace miniature aluminium electrolytic capacitors, particularly in surface mount applications, in many applications with tantalum. World-wide usage of miniature aluminium electrolytic capacitors in 1985 is estimated to be 25.0 billion units and by 1990 will exceed 40 billion units. If the tantalum capacitor manufacturers invaded this market with a low cost tantalum unit and succeeded in capturing an additional 10 billion units in 1990, they would more than double their requirement for tantalum powder over that which I just forecast. The two views for 1990 are compared in the table.



The processors have done their part. Now, it is up to the capacitor manufacturers to do theirs and I am confident that they will do so.

Former President, Dr George Korinek, in his address to the Fifteenth General Assembly stated "What we need most is stability of price, a reflection that the industry has matured". Former President Conrad Brown, speaking to the Seventeenth General Assembly, stated "We must assure our customers that adequate supplies of tantalum do exist at reasonable prices and, at the same time, we must assure an adequate financial return for our investments".
John Linden in his President's address to the Nineteenth General Assembly in May 1983 discussed the cost of producing tantalum metal from the various world-wide sources. He pointed out "that cost of production has nothing to do with the price of the commodity in question. Price is determined by market forces independent of the cost of production. In the long term, however, cost of production will have a relationship to price". Tantalum prices compared to production costs were further explored in the June 1984 Bulletin.

In concluding, we have achieved the stability of price, and our industry has matured. We have assured our customers that adequate supplies of tantalum do exist at reasonable prices and the free market will assure a fair price to the processors and, we hope, an adequate financial return to all concerned.

Component Design for Computer/Electronic Applications

(This article has been taken from a paper presented to the Twenty-third General Assembly by Mr Dennis J. Eagan, Senior Engineer Manager, Corporate Component Procurement, International Business Machines, Poughkeepsie, New York.)

COMPONENT DESIGN FOR COMPUTER/ ELECTRONIC APPLICATIONS

Circuit design is a complex blend of science, business, and intuition. These ingredients are blended to achieve the overall requirements faced by a designer - to provide a function that will meet the demands of the marketplace, and to match the competitive demands of cost, quality and availability. This paper will describe how IBM responds to this variety of requirements in specifying components for its products. In particular, the discussion will focus on the selection criteria for capacitors.

BUSINESS ENVIRONMENT

All technical decisions are made within the broad context of the company's business goals. For example, IBM's goals have been defined as the following :

1. to grow with the industry;
2. to exhibit product leadership across our entire product line — to excel in technology, value and quality;
3. to be the most efficient in everything we do — to be the low-cost producer, the low-cost seller, the low-cost servicer, the low-cost administrator;
4. to sustain our profitability, which funds our growth.

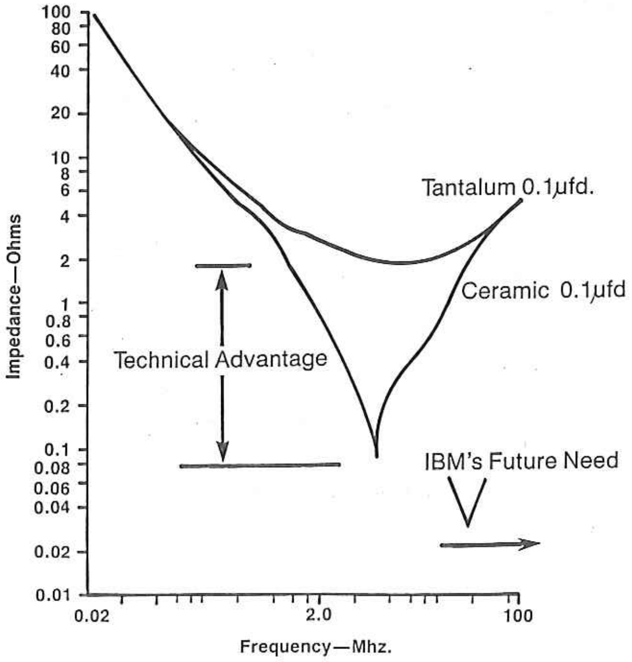
Component selection decisions must be compatible with these goals. Let's look at how these goals affect decisions made by individual designers.

TECHNICAL REQUIREMENTS

Capacitors are used in our whole product line for noise isolation and energy storage applications. Circuits are continually becoming faster to provide a competitive edge to the end product. As circuits become faster the technical criteria for capacitors increase. This chart shows the intrinsic frequency response comparison for tantalum capacitors and ceramic capacitors. The gap between the two curves shows the basic technical advantage of ceramic capacitors at higher switching speeds.

Major Technical Criteria Capacitor Impedance

(Impedance vs Frequency)



This advantage for ceramic capacitors represents an inherent competitive edge for ceramic over tantalum. Future circuit demands will require even further improvements in capacitor performance to give our end product a competitive performance in the marketplace.

Reliability is an important design criterion, especially the various costs associated with failure. Tantalum capacitors have a well known tendency to fail short, draw large currents, and flame, burn or explode. This is especially true if a device is mounted backwards in a circuit. This failure mode frequently damages the circuit board carrying the capacitors and eliminates the possibility of repairing and reusing the board. The capacitor's failure can also cause damage to other boards or hardware near the failure, causing additional costs. It should be obvious that a customer can become very upset when smoke pours out of his machine, so this type of failure is very damaging to customer satisfaction and to IBM's reputation. While fuses have been added to tantalum devices to mask this shorting failure mode, this solution carries penalties of extra cost, inductance and space. The elimination of the shorted failure mode is a challenge for the tantalum capacitor industry.

Manufacturability is also an important technical consideration. High volume manufacturing depends on automated pick and place equipment to mount components on boards. The pick and place machinery keys on a physical characteristic of the device being mounted to put accurately the device in place on the board. Precise package dimensional tolerances are required to pick and place accurately. Molded packages offer good dimensional characteristics but are costly. Conformally coated packages are lower in cost but cannot be handled with the required accuracy and defect levels. Capacitor manufacturers have a great opportunity to enhance their mechanical tolerance versus cost offerings to capture future applications. In contrast, ceramic capacitors offer a high degree of good dimensional characteristics due to their construction method.

Product cost is always a prime consideration in circuit design. Over the last 20 years there has been a seven-fold improvement in the cost of computing and an improvement of 5.5 times in the cost of tantalum capacitors. While these ratios may seem to be close, the result is that tantalum capacitors have become relatively more expensive in our products. I am sure that you realize the cost/performance curve for computer/electronic products will continue to be under sharp pressure to improve even further. Consequently, we will be depending on cost improvements in our components.

Naturally, technology makes advances. IBM is interested in exploiting the characteristics of Surface Mount Technology (SMT), a new packaging technique for components. These characteristics include savings in space, manufacturing costs savings, and faster circuit speeds. Our experience has shown that surface mounting is not a simple extension of pin in hole mounting by wave soldering.

SMT pick and place requirements are very demanding due to the small pad dimensions on the boards. If components are not placed accurately, they can "drawbridge", "tombstone" or move off the pads. These defects require additional cost and delay in order to rework the faulty component.

The thermal and chemical characteristics of the vapor phase process are also different from wave soldering. The vapor phase thermal gradient is very steep, resulting in mechanical stresses on the components. Components must be able to survive these stresses in order to pass through the soldering process without damage. The chemicals and cleansing agents used in the vapor phase process have the potential to damage the component packaging materials, particularly at the high temperatures seen in the process. Devices that are attacked during the process are unusable and need to be improved.

We have experienced component damage in vapor phase processing, and we are working with our suppliers to develop products that will stand up to the thermal and chemical stresses in the vapor phase process. We have also experienced problems mounting devices on cards with our pick and place equipment. These problems must be solved before tantalum capacitors can be considered reliable SMT components for vapor phase process.

QUALITY

Component quality, the ability of a component to meet its functional, mechanical, and electrical requirements, is an increasingly important consideration in component selection. Trade journals, the popular press, and TV all discuss industry's efforts to meet ever more demanding requirements from customers. It is difficult to miss the message that "Quality is the battlefield for the future" — particularly, with regard to competition from the Far East.

Demands for improved product quality naturally drive a need for better quality components. Quality levels today are normally in the range of 50 parts per million. Although quality levels have been improved, there will be strong pressure to reduce these levels even further.

Delivery performance and service are also important criteria. We need rapid delivery of new engineering designs and improvements because our product development cycles are becoming shorter. We also need on-time delivery to meet very precise schedules for our manufacturing lines. Poor delivery contributes to extra expense and quality defects caused by the scramble required to recover. Service has two major components : communications and response to problems. We want to work closely with all of our vendors to achieve outstanding delivery and service.

Sourcing decisions will continue to be made on the basis of quality, price, delivery and service. All of these criteria are important. Weakness in one area cannot be made up by strength in another area.

SUMMARY

I have outlined the criteria that are considered in the selection of an electronic component, particularly tantalum capacitors, for an IBM product. While not all these criteria are strictly technical criteria, it is important to know that the engineering community considers all these criteria in their design decisions. IBM's technical decisions are consistent with our corporate goals of growth, product leadership, efficiency, and profitability. My recommendations to the tantalum capacitor industry are to set and achieve the following objectives :

- improve frequency response for higher speed circuits;
- eliminate the shorted failure mode;
- enhance dimensional characteristics;
- continue cost improvements;
- improve SMT components, particularly dimensional characteristics, thermal shock resistance, and chemical resistance;
- improve product quality;
- on-time delivery performance;
- high level of service.

I hope that my thoughts will help the tantalum capacitor industry make advances in their product offerings, because this will help IBM produce better products for our customers.

ACKNOWLEDGEMENT

I want to thank Mr. Richard Horstmann for his very valuable help and guidance, and Mr. Lynn Pelton, Mr. Richard Duffee and Ms. Barbara Moore for their assistance in preparing this paper.

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.

(Concluding the article from issue no. 42 of the "Bulletin".)

A comparison of the chemistry of the powder feed and a tantalum ingot slice (mid-radius) after the first and second melts follows :

COMPARISON OF CHEMICAL COMPOSITION DURING PROCESSING OF E-BEAM MELTED TANTALUM (ppm)

Element	Feed Stock (Na Reduced)	1st Melt (mid-radius)	2nd Melt (mid-radius)
Na	180	10	10
Ca	280	10	10
Fe	70	10	<10
Ni	50	12	<10
W	<25	<25	<25
Si	130	21	<10
Ti	10	<10	<10
Cb	<10	<10	<10
C	50	10	<10
O	2070	110	64
N	50	20	16
H	386	21	<5
Ta	Bal.	Bal.	Bal.

Note: All Analyses except C, O, N and H by emission spectrograph.

2. Pure Columbium (Niobium) and FS-85 Alloy (Cb – 27 % Ta – 10 % W – 1 % Zr)

At Muskogee, we produce columbium by aluminothermic reduction. Because the separation of metal and slag in this process is never complete, considerable purification must be achieved during the first electron beam melt. (Columbium melts at 2468 °C.) Normally at least three melts are needed to obtain low oxygen, low nitrogen, high purity metal. It has been shown that, if minimal interstitial element concentrations are required, further purification occurs with continued remelting, but an asymptotic purity level is approached rather quickly. The vacuum quality, both as regards furnace cleanliness and leak rate, determines the final purity level. Typical melts, power requirements, and chemistries are compared for each of the three successive melts for the aluminothermic reduced columbium.

TYPICAL OPERATING DATA FOR BEAM MELTING OF ALUMINOTHERMIC REDUCED COLUMBIUM

	Thermite Feed	1st Melt	2nd Melt	3rd Melt
Melt Rate, lb./hr.	--	40	100	100
Gun power, kw	--	380	420	460

CHEMICAL COMPOSITION: (Analysis by Emission Spectrograph Except C, O, N: mid-radius sample.)

All values in ppm unless indicated as %

Element	Thermite Feed	1st Melt	2nd Melt	3rd Melt
Fe	730	30	<20	<20
Ni	120	35	<20	<20
W	50	50	50	50
Ti	<20	<20	<20	<20
Zr	<20	<20	<20	<20
Ca	450	50	30	20
Si	400	50	<20	<20
Mo	<20	<20	<20	<20
Al	2.5%	250	50	<20
Mn	<20	<20	<20	<20
C	1320	50	15	12
O	1.0%	1500	330	90
N	1500	170	79	45
Cb	Bal.	Bal.	Bal.	Bal.

In regard to alloys, several alternate starting materials are possible. A convenient procedure is to melt compacts pressed from blended powders. Columbium powder is commonly made by hydriding, crushing, and dehydriding previously melted pure metal and/or recycled scrap (e.g., ingot tail stock, cuttings, sheet trimmings). The compact for E-beam melting FS-85 alloy usually contains only the columbium, tantalum, and tungsten materials since zirconium is added by tack welding strips of sheet metal to the ingot prior to consumable arc remelting to produce the final alloy. Because the volatilities of the elements differ, compensation must be made in the starting powder chemistry to account for differences in evaporation losses. That is, evaporation losses increase in the order : tungsten < tantalum < columbium. The evaporated metal condenses on cooled surfaces, such as the heat shields (i.e., splatter deflectors), which must be cleaned frequently.

Melt inclusions, particularly of elements such as tungsten, are a further problem. Because of its high density and high melting point tungsten, for example, tends to settle to the bottom of the melt in the crucible. If the melting point difference between the inclusion and the matrix metals is large, the inclusion may be slow to dissolve. Often these defects go undetected until the alloy is examined by X-radiography after rolling the ingot to sheet.

Tungsten is often introduced in turnings from contaminated scrap used as feed stock. Screening feed material to pass 80 mesh and using only alloy materials of qualified chemistry are satisfactory means of avoiding these difficulties.

At least two melts are needed, the first for powder consolidation and removal of interstitials, subsequent melts for homogenization and further purification. Rates are typically 50 lb. per hour and 80 lb. per hour for the first two such melts. The final E-beam crucible diameter should match the electrode size required for arc remelt. Consequently, this size limitation may restrict the E-beam melt rate. Next, the surface of the E-beam alloy ingot is cleaned. Symmetrically (radially) distributed zirconium strip is attached by TIG arc welding to the entire length of the ingot sidewall in the amount equivalent to that needed in the final composition. The material is then fed as the electrode into the consumable arc melter.

Chemistry of the alloy before and after arc remelting follows :

CHEMICAL COMPOSITION DURING MANUFACTURE OF THE E-BEAM ELECTRODE AND FINAL ARC CAST OF AN FS-85 INGOT

CHEMICAL COMPOSITION: (Analysis by Emission Spectrograph Except C, O, N: mid-radius sample.)

Element	E-Beam Ingot (Electrode)	Arc Melted
Fe	<20	<20
Ni	<20	<20
Cr	<20	<20
W	10.0%	9.0%
Mo	200	100
Ti	<20	<20
Zr*	0.26%	1.10%
Hf	0.13%	0.10%
Ta	26.4%	26.0%
O	72	85
N	15	26
C	<10	<10
H	<5	<5
B	<1	<1
Si	<20	<20
Cb	Bal.	Bal.

*Zr is added to E-Beam ingot to produce final alloy composition.

Typical operating conditions for E-beam melting of tantalum, columbium thermite and FS-85 alloy ingot are compared as follows :

OPERATING COMPARISON FOR E-BEAM MELTING

OPERATING CONDITIONS:	Ta Melt No. 1	Ta Melt No. 2	Cb Melt No. 1	Cb Melt No. 2	Cb Melt No. 3	FS-85 (Electrode) Melt No. 1	FS-85 (Electrode) Melt No. 2	FS-85 (Electrode) Melt No. 3
Ingot wt. (final)	2984	2925	1517	1457	1442	992	903	890
Ingot dia., in.	8	8	8	8	8	5.5	5.5	5.5
Metal yield, %	92	98	86	96	99	95	98	98.5
Melt time, hr.	40.0	23.6	49	16.9	13.4	20.7	13.0	10.0
Total time, hr.	68.4	33.3	74.6	24.3	20.0	38.5	19.7	16.0
Clean out time, hr.	←11.1→		←13.2→			←6.2→		
E-beam power, kw.	395	520	380	420	460	350	380	400

SUMMARY

Because of the high investment and operating costs of E-beam furnaces, use of production melting equipment is limited to high unit value materials, such as the refractory metals. As industrial melting capacity has grown, the markets for E-beam melted products have become very competitive, and the producers have been required to optimize furnace operation. There are three major considerations in the economic equation. First, it is necessary to maximize "on-line" melting time, keeping interruptions and downtime minimal. Key factors are operator skill, preventive maintenance, and proper scheduling. Second, final ingot (i.e., crucible) size must be accommodated to subsequent processing requirements, such as arc remelting or forging. Third, costs may be elevated by excessive remelting to achieve purity not necessarily required by the end-user. Thus, the melt-shop operator must balance the costs of alternative feed materials and E-beam processing to meet customer specifications.

Tantalum in the automotive industry

The following paper was presented by Dr Robert B. Costello, Executive Director of Purchasing Activities for General Motors Corporation, at the T.I.C. meeting held in Boston, Massachusetts, U.S.A. on June 13th 1985.

Today I want to share with you some thoughts about our business — yours and mine. For several years now, the greatest challenge in the American auto industry has been the internationalization of our marketplace. We don't compete in regional or national markets any longer, but on a worldwide basis with very sophisticated competitors. And it's been very difficult for American automakers, with their higher cost structure, to be fully competitive with lower cost foreign producers, particularly the Japanese.

Clearly, the challenge is there. And meeting that competition is forcing us to take a good look at the way we've done business in the past. We need to assess the deficiencies of our relationships and incorporate new programs with fresh views. Views such as cost-justified pricing and new quality methods — necessary elements of the kinds of programs we need to meet the changing, ever more demanding world in which we all work. To be competitive in this world market, we must provide our customers with higher quality products with more diversity and more value. Meeting this challenge will require greater reliability and innovation in product and process engineering than ever before.

We need new relationships to achieve these goals, and GM is setting out in earnest to establish totally new relationships within our structure and with those in our supplier community.

WHERE DOES THE TANTALUM INDUSTRY FIT INTO THIS PICTURE ?

GM's major use of tantalum is in the capacitors for parts like an ETR radio. There is also a small amount in the carbide tips of cutting tools. Since we are using higher strength steels which require higher speed cutting, more tantalum tips will be used in the future.

We use tantalum in our engine control devices. The capacitors, as well as the resistors and semiconductors in the engine control device, regulate many functions of the vehicle. They monitor engine performance and signal the driver when something is not performing precisely as it should. The control circuit board is housed in a case which is mounted under the hood to send and receive signals from all parts of the engine. In the future, these engine control devices may also be mounted in the rear of a car and joined to the front device by a multiplexer. This will eliminate some of the cables and wires we currently have and may head off some problems before they occur.

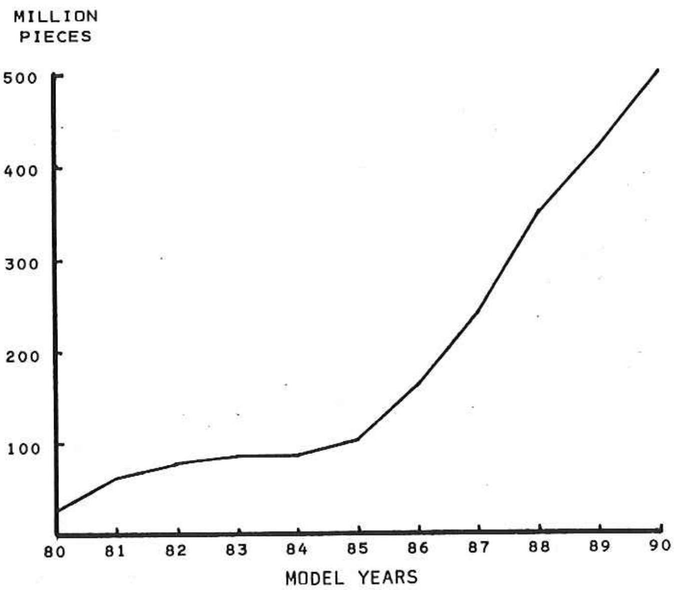
Similar to these units, a computer command control system regulates a wide variety of vehicle functions. Parts such as the throttle sensor, idle speed actuator, oxygen sensor and the dual bed converter must operate at optimum level in order to gain maximum efficiency and the best gas mileage.

Our knowledge is constantly expanding in the electronics field as circuit board evolution demonstrates. In 1982, we used three circuit boards for our computers, but they were too large and cumbersome for what we envisioned for future cars. In 1984, we advanced our technology so much that what used to take three boards could now be put on one large board. This was a 68 % size reduction in only two years. And for our 1986 models, we reduced that board another 40 %. What an accomplishment in just four years !

With these downsized computers come smaller components. The packaging technology of these components has been greatly improved in the last few years. Integrated circuits, capacitors and resistors have decreased dramatically in size — yet they contain more capability at a higher speed than their earlier, larger predecessors.

Most of the capacitors in 1982 were either ceramic discs or aluminium electrolytics. Tantalum had been minimized due to its higher cost. However, the evolution of surface mount technology has given tantalum capacitors a new life.

The size of many components may be decreasing, but their use in electronics is growing by leaps and bounds. To illustrate, this chart shows tantalum capacitor growth at our largest using division — Delco Electronics — from 1980 thru 1990.



In 1980, we used about 25 million pieces, projecting an increase to around 500 million pieces by 1990. That's an enormous potential increase ! In some of our 1985 models there is about $ 350 worth of electronics per car. We expect electronics to increase three to four times this present amount by the 1990's as new technology emerges in our future vehicles.

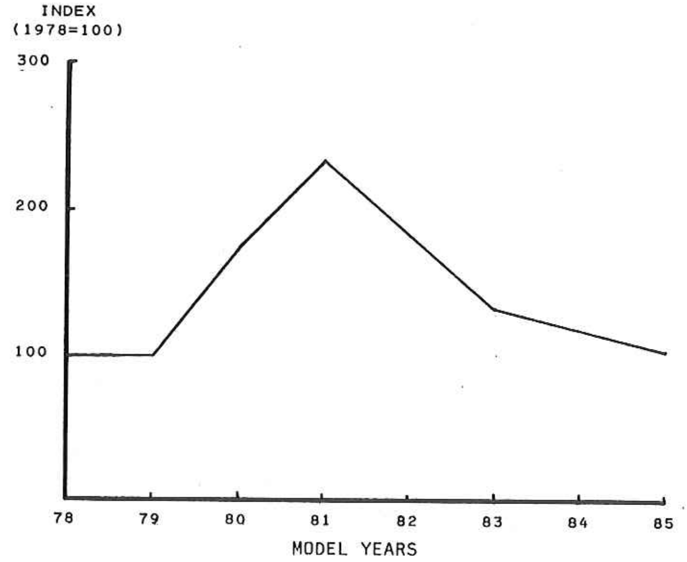
The major area of growth for tantalum in the automotive industry is in chips — the surface mounted components. These tantalum chips, which are soldered directly to the circuit board, are ideal for electronic applications. Their electrical characteristics are especially suited to handle the various temperature ranges of a vehicle. Surface mounted parts are less expensive to use because the procedure can be automated; and by using tantalum parts that are mounted directly to the board, we might be able to obtain better circuit efficiency.

We currently use aluminium electrolytics as well as the tantalum capacitors. As leaded parts, electrolytics require leads to the circuit board. The procedure can't be automated, so the components are applied manually. This leaves room for error in the assembly stage. As a result, the direction is toward tantalum capacitors for automation and efficiency.

COST-JUSTIFIED PRICING

As we look for the best materials to make our parts with, we also look at the cost of those materials and the finished parts. This graph shows our average cost of tantalum capacitors over the years.

If we set the 1978 model year equal to 100, we can see that during the 1980-1982 period, demand exceeded supply; and combined with high inflation rates, the price per unit soared. Prices are now at a more reasonable level, but we need to control them rather than prices controlling us. One way we can do that is to look at costs. A way to monitor costs is through a cost-justified approach.



We are looking at and already using this approach in a wide variety of industries — steel, copper, plastics and electronics. What we are striving for is stability and predictability in our pricing. We need to look at the components of cost — mining, refining, finished part — so that we can plan our future material requirements.

CHANGING ROLE OF PURCHASING AND SUPPLIERS

Along with changing our approaches to pricing, Purchasing's role in this new environment must change as well. We need to increase our knowledge of your industry and learn how better to link it with ours. A way to achieve that is to set up long-term relationships. This will ensure that the tantalum and automotive industries work together and keep each other apprised of new developments and technologies. Utilizing supplier technology along with our own technological advancements will be of mutual benefit.

By working together, our relationships will become more of a partnership — one in which we will both have an investment and result in a win-win scenario.

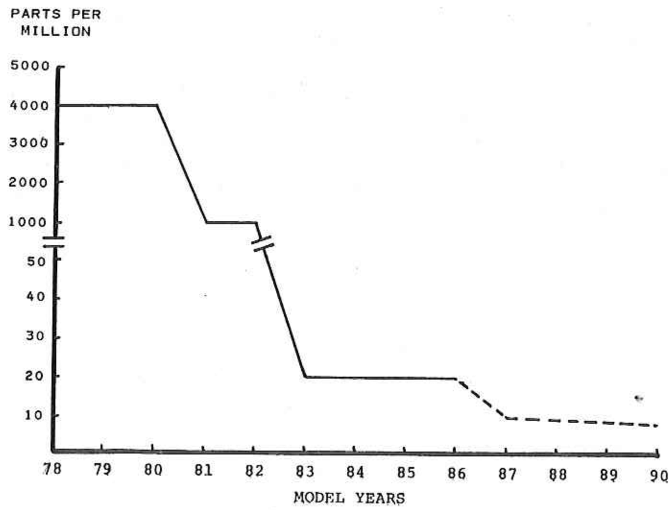
As the role of Purchasing changes, so must that of our suppliers. Suppliers should be involved in the development stage of a project or part which enables us to add your expertise to ours. In order to justify costs, we need to share available data and current technology.

We need suppliers to become part of our family, to make long-term commitments to the automotive industry; and although we currently have suppliers that can meet these objectives, we need to continue adding partners to our family.

QUALITY

Quality is another important factor for both of us. It's the key to customer satisfaction — something we all want to maintain. Zero defects is our goal — and the only way to obtain it is with top-notch quality. By improving our products and processes, we can achieve higher, better quality output through faster, more efficient methods and at a lower cost.

This graph shows the acceptable quality level achieved for tantalum capacitors.



As you can see, the level was 4,000 defective parts per million in 1978. By 1981, it dropped to 1,000 parts and, now, it's 20 parts per million. What an achievement ! Down the road, however, we need to continue lowering the number of unacceptable parts. This is a goal for all our suppliers — to obtain the highest quality rate possible.

Let me give you an example of how we achieved a high quality level in one of our processes. The people who mount components directly to the circuit board were given a clean sheet of paper and told to plan their procedures from the ground up. Since surface mount components can be easily automated, the opportunity for implementing new and innovative programs was at their fingertips. And the effort was a success.

Although high quality can be achieved in a process or product through conventional methods, we encourage the use of another method to achieve it. Corporate-Wide Quality Control — C.W.Q.C. — is a top management commitment to quality and includes a timed action plan with supportive resources. Statistical Process Control — S.P.C. — is a way of gaining corporate-wide quality control through team approaches to problem solving and process control using statistical methods.

C.W.Q.C. and S.P.C. are keys to getting production yield up and costs down, while ensuring few rejected parts.

A reduction in package styles will also make it easier to attain higher quality at lower costs. In the last five years, we have lowered the number of tantalum capacitor packaging standards that we use to three. The industry in general, however, has many more than that. If we eliminate some of those, we will have more consistency in the parts manufactured for our finished products.

SUMMARY AND CHALLENGES

In summary, tantalum usage, especially in the electronics field, will continue growing as long as we are offered a package we can't resist.

I'd like to pose some challenges to you that are actually challenges for all of us. We need your help to continue improving quality. By utilizing methods such as corporate-wide quality control and statistical process control, we can reach higher quality levels.

Costs are always a challenge. If we institute pricing on a cost-justified basis, it will be easier and more efficient to monitor increases — or decreases — in raw material and finished part costs.

A third challenge will be to standardize the capacitor package style. This can set the stage for more standardization in the electronics industry. Overall, this will benefit all of us.

By meeting these challenges, we will be more competitive in this changing, more demanding world.

Since electronics will be a key factor in our future cars and tantalum is a part of that, who knows how far we can develop computer controlled vehicles ? Maybe down the road, we'll have a car that can be programmed to drive itself and all we'll have to do is sit back and enjoy the ride.

Current technical papers

The following three papers have been offered to the T.I.C. "Bulletin" for inclusion in our publication. In view of the space limitations at the present time and the considerable delay which would occur before these papers could be published in their entirety, these articles are offered in synopsis form for the benefit of readers so that they may be able to identify their interest and seek the original publication.

"PRODUCTION OF LOW INTERSTITIAL CONTENT COLUMBIUM SHEET"

— A paper co-authored by H. Padamsee, Laboratory of Nuclear Studies at Cornell University in Ithaca, New York, by R. Droegkamp and K. Jensen of Fansteel Inc. in North Chicago, Illinois, and by F. Schmidt, Ames Laboratory at Iowa State University in Ames, Iowa. The paper was presented at the 2nd Workshop on RF Superconductivity at CERN in Geneva, Switzerland during July 1984 and later at the Electron Beam Melting and Refining State of the Art Conference held in Reno, Nevada on November 9 and 10, 1984.

Abstract

Due to the growing utilization of radio frequency superconducting devices in nuclear physics and high energy physics accelerators, it is anticipated that the particle accelerators, LEP and TRISTAN, currently under construction in Europe and Japan, will install over 1/2 mile of columbium (Nb) accelerating cavities. For these projects, over 100 tons of pure Nb will be required within the next five years. The success of these projects could provide impetus to a comparable demand in the U.S. for the next generation of electron-positron accelerators.

A physical parameter that plays an important role in the performance of cavities is the thermal conductivity of Nb between 4 and 9° K. This parameter, in turn, depends strongly on the purity of the metal. In particular, the interstitial impurities O, N, C and H degrade the conductivity substantially. These are found present at the levels of 100-150 ppmw for 0 and 10-50 ppmw for N and C in commercially pure Nb available today. The residual electrical resistivity ratio (RRR), which conveniently characterizes the total interstitial content is ~20 at these purity levels. We have produced, in an industrial environment, Nb sheet with final product RRR values between 60 and 90 by carefully monitoring and controlling all production steps from repeated electron beam melting and on through the forging, rolling and annealing processes. The conditions for electron beam melting are found to be of paramount importance in producing a high RRR starting ingot. The RRR of the purified sheets can be improved further to ~300 by a special yttrium treatment process invented at Cornell (patent pending).

Introduction

The phenomenon of superconductivity has been known for a long time and is today being applied in many diverse fields, e.g. cables for power transmission, generators and motors, magnetically levitated vehicles, high speed computers, ultra-sensitive magnetic sensors, high field magnets for fusion energy, nuclear physics and high energy physics. We are presently exploring the application of superconducting microwave resonant cavities to particle accelerators for high energy physics research. Programs of research and development in radio frequency superconductivity are being carried out at a number of institutions both here and abroad. In the United States, work is being carried out at Argonne National Laboratory, Cornell University, Stanford University, Stanford Linear Accelerator Center and the State University of New York at Stony Brook. Institutions abroad engaged in this work are CERN, Switzerland (Centre Européen pour Recherche Nucléaire), DESY, West Germany (Deutsches Electron Synchrotron), KEK, Japan (National Laboratory for High Energy Physics), CEN, France (Centre d'Etudes Nucléaires de Saclay), and University of Wuppertal (West Germany).

As is well known, for d-c currents the resistance of the superconducting material is exactly zero below the critical temperature, T_c. For a-c currents, the resistance below T_c is finite and increases with frequency, becoming appreciable at radio frequencies. Nevertheless, the resistance is still many orders of magnitude (e.g. 10^{-6} at 3×10^9 Hz) smaller than for normal conductors of electricity.

In particle accelerators the acceleration of charged particles such as electrons, protons or heavy ions is provided by radio frequency resonant cavities which are synchronized in such a manner that particles always see an accelerating field as they travel through the cavities. Conventional accelerators use copper cavities and require large amounts of rf power (~ megawatts) due to ohmic losses in the walls of the accelerating device. Cavities made from superconducting material, such as Nb, offer the possibility of drastically reducing this power consumption as well as increasing the electric fields (typically several million volts per meter) needed for acceleration, thereby providing higher particle energies to probe deeper into the structure of matter. Due to their larger voltage capability, structures designed for superconducting operation can have a larger aperture than copper structures, as well as shorter lengths along the beam line. Both larger beam holes and fewer number of cavities reduce the beam-cavity interaction and allow storage of larger beam currents to increase substantially the interesting high energy reaction rates (luminosity). Depending on the chosen rf frequency, superconducting cavities operate at temperatures between 1.8 and 4.2° K.

There has been significant and growing utilization of rf superconductivity for heavy ion accelerators as exemplified by ATLAS (Argonne Tandem Linear Accelerator System) and at Stony Brook. For high energy physics, tests of superconducting rf systems have been successfully carried out in electron storage rings CESR (Cornell Electron Storage Ring), PETRA (Positron Electron Tandem Ring Accelerator) at DESY and in the accumulator ring for TRISTAN (Tri-Ring Intersecting Storage Accelerators in Nippon) at KEK. More tests of this nature are planned for the near future. It is anticipated that this work will eventually lead to large scale application of superconducting accelerating systems to LEP (Large Electron Positron) accelerator at CERN, to HERA (Hadron Electron Ring Accelerator) at DESY and to TRISTAN at KEK.

Perhaps the most ambitious planned application is to LEP, a 30 kilometer circumference storage ring for colliding electrons with positrons. In the first stage, which is already under construction, LEP is designed to produce particles of 50 billion electron volt (GeV) energies, using normal conducting cavities that dissipate ~ 100 megawatts. Several meters of superconducting cavities will be installed at this stage (due for completion in 1988) on a trial basis. Success of these sections should lead to an upgrading of LEP to 100 GeV using several hundred meters of superconducting cavities. Together with similar projects at TRISTAN and HERA, almost one kilometer of superconducting cavities could be in place by 1990, requiring over 100 tons of pure Nb.

Conclusions

Sufficient progress in rf superconductivity has been made in recent years so that superconducting accelerating systems are now planned for LEP and TRISTAN and perhaps for HERA or PETRA. A shift to using high RRR Nb over commercial purity Nb improved cavity performance. Expectations are that this technology is now capable of achieving 5 MV/M, reliably and reproducibly under accelerator conditions. Accelerating fields above 6 MV/M, coupled with interesting high energy physics results forthcoming from the superconducting machines could open the possibility of another generation of storage rings in the several hundred GeV energy range. Higher purity Nb is one requirement for achieving these performance levels. Along these lines, progress toward achieving the theoretically expected values of accelerating fields (20-30 MV/M) could eventually allow the application of rf superconductivity to linear colliding accelerators in which the entire length of ~ 50 Km is comprised of accelerator sections capable of providing 1 trillion electron volt beams.

"CORROSION RESISTANCE OF TANTALUM BASE ALLOYS — ELIMINATION OF HYDROGEN EMBRITTLEMENT IN TANTALUM BY SUBSTITUTIONAL ALLOYING"

— A paper written by L.A.Gypen, Quality Manager at Mietec, N.V. in Oudenaarde, Belgium and by M. Brabers and A. Deruyttere of the Metallurgy Department of the Catholic University Leuven in Heverlee, Belgium, published by Verlag Chemie GmbH.

ABSTRACT

The corrosion behaviour of substitutional Ta-Mo, Ta-W, Ta-Nb, Ta-Hf, Ta-Zr, Ta-Re, Ta-Ni, Ta-V, Ta-W-Mo, Ta-W-Nb, Ta-W-Hf, and Ta-W-Re alloys has been investigated in various corrosive media, i.e. (1) concentrated sulfuric acid at 250 °C, (2) boiling hydrochloric acid of azeotropic composition, (3) concentrated hydrochloric acid at 150 °C under pressure, (4) HF-containing solutions and (5) 0.5 % H_2SO_4 at room temperature (anodisation).

In highly corrosive media such as concentrated H_2SO_4 at 250 °C and concentrated HCl at 150 °C tantalum is hydrogen embrittled, probably by stress induced precipitation of β-hydride. Both corrosion rate and hydrogen embrittlement in concentrated H_2SO_4 at 250 °C are strongly influenced by alloying elements. Small alloying additions of either Mo or Re decrease the corrosion rate and the hydrogen embrittlement while Hf has the opposite effect. Hydrogen embrittlement in concentrated H_2SO_4 at 250 °C is completely eliminated by alloying Ta with 1 to 3 at % Mo (0.5 to 1.5 wt % Mo). These results can be explained in terms of the oxygen deficiency of the Ta_2O_5 film and the electronic structure of these alloys.

INTRODUCTION

This paper deals with the influence of alloying elements Mo, W, Nb, Zr, Re, Ni and V on the corrosion resistance and hydrogen embrittlement of tantalum.

From the literature data, it has been concluded in a review of the corrosion behaviour of tantalum and Ta-base alloys that it is unlikely that the addition to Ta of a metallic element, the corrosion resistance of which is less than that of Ta is a given medium, will improve tantalum's corrosion characteristics. That this conclusion is not verified by experiment is illustrated below.

CONCLUSIONS

1. The corrosion rate of Ta in concentrated H_2SO_4 at 250 °C can be reduced by a factor 3 to 4 by alloying Ta with small additions of Mo or Re. This decrease in corrosion rate is believed to be related with the oxygen deficiency of Ta_2O_5. Small additions of alloying elements with a higher valence than pure Ta such as W, Mo and Re reduce the number of oxygen vacancies and thus also the corrosion rate. In contrast, elements with a lower valence such as Hf increase the corrosion rate. Nb and V which have the same valence as Ta have only a slight influence on the corrosion rate of Ta.
2. In highly corrosive environments such as 95 % H_2SO_4 at 250 °C as well as 38 % HCl at 150 °C Ta is hydrogen embrittled. This embrittlement is believed to be due to the stress induced precipitation of β-hydride from the α solid solution.
3. The hydrogen embrittlement of Ta is drastically increased (Hf) or decreased (Mo, Re) by adding small amounts of alloying elements in solid solution. These effects are believed to be due to variations in the electronic structure of Ta by alloying. In concentrated H_2SO_4 at 250 °C the severe hydrogen embrittlement of pure Ta is completely eliminated by alloying Ta with 1 to 3 at % Mo (0.5 to 1.5 wt % Mo).
4. The corrosion rate of Ta and the investigated Ta-alloys in boiling hydrochloric acid of azeotropic composition during 3 months was negligible (<1 μm/year). None of the compositions were embrittled.

5. The corrosion rate of Ta in concentrated hydrochloric acid is only slightly influenced by the addition of 0.4 at % Nb and 3.5 at % W.
6. Dilute Re-containing Ta-alloys form a non-adhering Re deposit in 40 % HF at room temperature. This deposit is thought to be responsible for the abnormally high corrosion rate of these alloys in several HF containing environments.

"NEW TANTALUM BASE ALLOYS FOR CHEMICAL INDUSTRY APPLICATION"

— A paper also written by Dr. L.A.Gypen and Dr. A.Deruyttere and published in the February 1985 issue of "Metal Progress".

SUMMARY

The general trend in the chemical industry to increase operating temperatures and pressures requires stronger materials with better corrosion resistance. For this reason, the influence of the alloying elements tungsten, molybdenum, columbium, hafnium, zirconium and rhenium on both mechanical properties and corrosion behaviour of pure tantalum has been studied.

In the authors' laboratory an extensive research program on tantalum-base alloys for the chemical industry has been finished and the results are partially published. The aim was to develop substitutional tantalum-base alloys with a higher strength than pure tantalum, good room temperature ductility and corrosion properties which are still comparable with those of pure tantalum.

Powder mixtures of Ta-W, Ta-Mo, Ta-Cb, Ta-Hf, Ta-Re, Ta-W-Mo, Ta-W-Cb, Ta-W-Hf, and Ta-W-Re were presintered and melted in an ultrahigh vacuum electron beam melting furnace. The recrystallization behaviour of these alloys, their athermal solid solution hardening properties, thermally activated deformation behaviour, mechanical properties and their corrosion properties have been investigated.

Some important experimental results are summarized and suggestions are made for the industrial development of a new type of tantalum base alloy for the chemical industry.

Statistics

Members of the association have reported the following statistics, as collected by Price Waterhouse on behalf of the T.I.C. :

PRODUCTION AND SHIPMENTS

1st quarter 1985
(quoted in lb Ta_2O_5 contained)

Category	*Material grade*	*Production*	*Shipments*	*Response*
A/B	Tin slags	273 105	72 459	22/25
C/D/F	Tantalite and other materials	112 025	166 192	
	Total	385 130	238 651	

Note : In accordance with the rules of confidentiality, categories A and B, and C, D and F, have been combined because certain individual returns accounted for more than 65 per cent of the total of the category concerned.

PROCESSORS' SHIPMENTS

1st quarter 1985
(quoted in lb tantalum contained)

Product category	*Shipments*	*Response*
Tantalum oxide	24 634	18/19
Alloy additive	30 793	
Carbides	138 734	
Powder/anodes	236 535	
Mill products	86 862	
Scrap, ingot, unworked metal and other	101 865	
Total	619 423	

Note : In accordance with the rules of confidentiality, the categories "Scrap" and "Ingot, unworked metal and other" have been combined, because in each category one individual return exceeded 65 per cent of the total of the category concerned.

QUARTERLY PRODUCTION ESTIMATES

(quoted in lb Ta_2O_5 contained)

LMB quotation	*US$ 30*	*US$ 40*	*US$ 50*
2nd quarter 1985	402 810	434 340	549 900
3rd quarter 1985	391 750	453 280	574 350
4th quarter 1985	409 950	461 480	587 350
1st quarter 1986	389 610	441 140	567 400
2nd quarter 1986	392 810	454 340	580 600

Note : These estimates are based on information received to date, and do not necessarily reflect total world production.

Capacitor statistics

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

(Data from Electronic Industries Association)

1st quarter 1985

Type	*Manu-facturers*	*Distri-butors*	*Export*	*Total*
Foil	231	99	12	342
Metal cased solid	33 789	10 967	13 339	58 095
Non-metal cased solid	125 442	18 143	21 401	164 986
Chips	12 521	245	2 356	15 122
Wet slug	1 918	942	199	3 059
Total	173 901	30 396	37 307	241 604

JAPANESE TANTALUM CAPACITOR SALES (Thousands of Units)

(Data from Japanese Electronic Industry Development Association)

The "Export" data cover sales to eight main overseas countries only.

1st quarter 1985 Production 568 988 Of this, export114 814

EUROPEAN CAPACITOR SHIPMENTS (Thousands of units)

The European Capacitor Trade Statistical Program (ECTSP) is making available to the T.I.C. on quarterly basis European total tantalum capacitor unit shipment figures. These are shipment statistics by European members of ECTSP to European located end-users, whether the units are made in Europe or imported.

1st quarter 1985	Shipments	155 251
Total for 1984	Shipments	581 517

MEMBERSHIP

The following three companies were elected to membership by the Twenty-third General Assembly :

Kamativi Tin Mines Ltd.
P.O. Box 1479,
Bulawayo, Zimbabwe.

Nichicon-Sprague Corp.
3rd Floor, Uehara Building,
Oikedori, Karasuma Higashi-Iru, Nakagyo-Ku,
Kyoto 604, Japan.

Sassoon Metals and Chemicals AG
50 Chamerstrasse,
6300 Zug, Switzerland.
Correspondence : Avenue Louise 283, Bte 9,
1050 Brussels, Belgium.

Charter Consolidated Metals and Ores resigned from membership.

Following recent reorganisation within the Derek Raphael group and associated companies, the membership of Northbrook Metals has been transferred to

Derek Raphael & Co. Ltd.
DRC House,
2 Cornwall Terrace,
London NW1 4QP, England.

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