

TANTALUM-NIOBIUM INTERNATIONAL STUDY CENTER

PRESIDENT'S LETTER

Dear Friends,

I would like to begin my tenure as President of the T.I.C. by thanking my predecessor for a job well done. Mr Peter Köhler has served the T.I.C. in a very professional manner over the past year. This year's General Assembly and Symposium in Goslar was the culmination of a lot of hard work on the part of many people. The comments I have received about the organization, execution and content of this meeting have all been very positive. On behalf of all the member companies of the T.I.C., I would like to thank Peter for his efforts.

The business conditions look very promising over the next year, and I believe the T.I.C. will continue to play an important role in meeting the challenges and opportunities facing the tantalum and niobium industries. As we heard at the Symposium, the use of tantalum in the electronics end of the business looks quite attractive. There will be challenges to satisfy this growth in the business without interruption and negative impact on the drivers of that growth.

The success of the Symposium in Goslar has put the T.I.C. on a sound financial footing. In the past, we have viewed the Symposium as a means to cover the ongoing losses of the association. We must put the year-to-year performance of the Center on a sound footing and potentially use the profits from the Symposium to help promote the use of tantalum and niobium. Because of the improved business conditions, there is an opportunity to attract more members, and a subcommittee formed last year will focus on those efforts this year.

Next year's General Assembly will be held in Greenville, South Carolina in the United States. Kemet has agreed to act as our host for the meeting and the dates they have booked at the Hyatt, Greenville are October 20th, 21st and 22nd in 1996. Please mark your calendars.

I end by wishing you and your families a happy holiday season and a healthy and successful year in 1996.

Sincerely,

R.S. Barron, President

SUMMARY

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INTERNATIONAL SYMPOSIUM

The International Symposium on Tantalum and Niobium, organised in Goslar, Germany, from September 24th to 28th 1995 has been hailed as a great success. Registered participation was almost 200, rivalling the attendance at the preceding Symposium, held in Orlando in 1988.

The programme covered the industry from raw materials to end uses, with particular emphasis on applications in optics, electronics and in newer fields, and discussion of potential developments. The Proceedings of the Symposium are to be printed in a hard cover book: a copy will be sent to each participant in the conference, others interested should order the book from the T.I.C., at \$150 per copy, including postage and packing.

Hosts were H.C. Starck companies H.C. Starck GmbH, H.C. Starck Inc. and H.C. Starck-V Tech, and all present appreciated the hospitality of the group members. A plant tour of H.C. Starck metallurgical works completed the technical programme. A remarkable exhibition on the history of the tantalum and niobium industry had been assembled by Dr Wilfried Rockenbauer: it was presented by Starck as a complement to the plant visit and was a high point of the conference.

Social events were crowned by a mediaeval banquet in the Kaiserpfalz - the guests were welcomed by troubadours and entertained with a history of Goslar, and by jugglers and clowns. A huge barrel of beer brewed for the occasion was tapped by Mr Hellwarth Lahusen and Dr Rockenbauer. A procession announced the arrival of the dinner, with the cooks bearing in the venison on display. The dishes on the menu were taken from an ancient Goslar cookery book, and if the flavours were traditional the enjoyment of the diners was entirely contemporary. We are most grateful to our hosts for this exceptional banquet in the splendour of its historic setting, which will long be remembered by all fortunate enough to be there.

There was a varied sightseeing programme for those accompanying the delegates to the meeting but not taking part in the technical sessions. In a tour of the Harz mountains they visited a prehistoric cavern, then the Michaelstein monastery whose exhibits include a musical instrument museum - some of the instruments were played and demonstrated by a curator. On Tuesday the group enjoyed a guided walk round Goslar, illustrating the life of women in the middle ages. On the last day a trip to Clausthal-Zellerfeld took the party to a baroque house which is now the studio of a designer of clothes of hand-painted silk: a fashion show culminated in some memorable shopping.

GENERAL ASSEMBLY

The Thirty-sixth General Assembly was held at the beginning of the meeting to carry out the business of the Tantalum-Niobium International Study Center.

Four new members were elected, Hitachi AIC, Saha Electro Components, Southern Prospecting Holdings (Pty) and Specialty Metals Company, while two resignations were accepted, bringing membership to 50. The audited accounts for the year to June 30th 1995 were approved, showing a small deficit, expenditure slightly exceeding income.

The Technical Adviser, Dr George Korinek, reported on his activities during the past year, including participation in conferences and publication of articles with the express intention of promoting knowledge and application of tantalum and niobium and bringing them to the attention of potential users.

Mr Peter Kahlert, who had brought the present Symposium to fruition during his term of office, completed his Presidency, and was succeeded by Mr Robert Barron of Cabot Performance Materials to serve for the coming year. Mr William Millman of AVX was elected to the Executive Committee, and Mr David Ratcliffe, formerly of Thaisarco, had resigned. The other members of the Committee were re-elected for a further year in office.

There will be an informal meeting in Brussels on Tuesday April 23rd 1996, and the Thirty-seventh General Assembly will be part of the meeting to be held in Greenville in October 1996.

SYMPOSIUM PRESENTATIONS

The International Symposium on Tantalum and Niobium covered many aspects of tantalum and niobium. Sessions were:

- The industry in general (3 papers)
- Tantalum and niobium processing (4 papers)
- Niobium in steels (3 papers)
- Tantalum and niobium in electronics (15 papers)
- Compounds and applications (13 papers)

Because of the importance of electronics for the tantalum industry, it is not surprising that it was the session which comprised the largest number of papers. We were very fortunate to have had presentations from industries such as personal computers, automotive electronics and telecommunications, all very important users of tantalum capacitors. From the point of view of future potential growth of tantalum capacitor manufacture, the presentation from Motorola was certainly the most impressive: we are therefore reprinting this presentation in full in this issue of the T.I.C. Bulletin.

EXPECTATIONS OF TANTALUM CAPACITORS FOR WIRELESS COMMUNICATIONS

Presented by Mr James B. Crego, Motorola Incorporated, at the Symposium held in September 1995.

It is my pleasure and honour to represent Motorola at the International Symposium on Tantalum and Niobium here in Goslar, Germany.

Motorola would like to express its appreciation to all those involved in the supply of tantalum capacitors, because if it were not for their support, Motorola would not have been as

successful as it has been. The timely delivery of high quality material at competitive prices has contributed to Motorola's success. Even during 1995, your deliveries have met our needs, although only barely. As the head of purchasing activities for the Cellular Subscriber Group of Motorola, I would describe the rate and the growth rate of the cellular industries as astronomical.

In just two days in December of 1994, we built more cellular telephones in Northern Illinois than we did in the entire year of 1986. The production which took 365 days eight years ago to accomplish only took two days. This is the type of business that you support. I would suggest to you, but then you already know, that this is a very demanding task. While we all acknowledge the challenges of our shared growth, none of us would want to see our business slow down.

One way of demonstrating how fast the cellular industry is growing is by comparing the number of years required to reach one million users. It took black and white TV 20 years to reach one million users. Color TV only took half that time. VCR's and PC's, which were considered very fast growing commodities, took eight and six years respectively before reaching the one millionth user.

It took cellular phones only four years before reaching this one million user mark, and Motorola's cellular growth has been even faster. But wireless communication is more than just cellular telephones: paging, one of the other major segments, is also growing very rapidly.

The principal categories of products manufactured by Motorola are:

- Semiconductors
- Cellular telephones
- Pagers
- Two way radio communications
- Modems and integrated management systems
- Automotive electronics
- Defense electronics

It is clear that Motorola competes in three major areas of wireless communication - cellular phone, pagers and two-way radio products.

This presentation will address the growth of the wireless industry, for example, the growth experienced during the 1990's and the growth which we can expect for the rest of the 1990's.

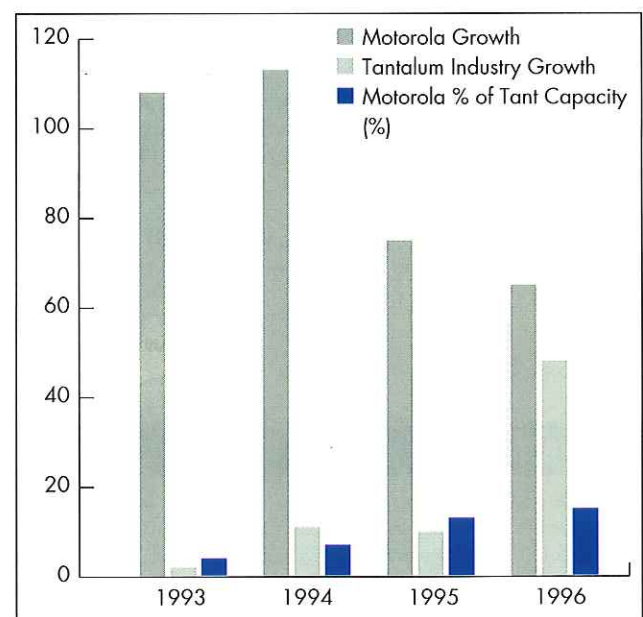


Figure 1 : Motorola growth vs. tantalum capacitor industry growth, 1993-1996

Figure 1 shows the growth rate from 1993 through 1996. This chart has several key points of interest:

1. The huge growth of Motorola since 1992.
2. The significantly smaller growth rate of the tantalum capacitor industry.
3. Motorola's percentage of industry capacity continues to increase.

Figure 2 translates that growth from percentage to absolute numbers: the industry capacity has grown from about 7 billion units in 1992 to over 14 billion units in 1996; during the same period of 1992 to 1996, Motorola's demand has grown from less than 200 million units to more than 2 billion units. Cellular and paging products have been the major reason for this growth. One of the reasons that cellular has been able to maintain this growth rate is the diversity of the markets to which it sells.

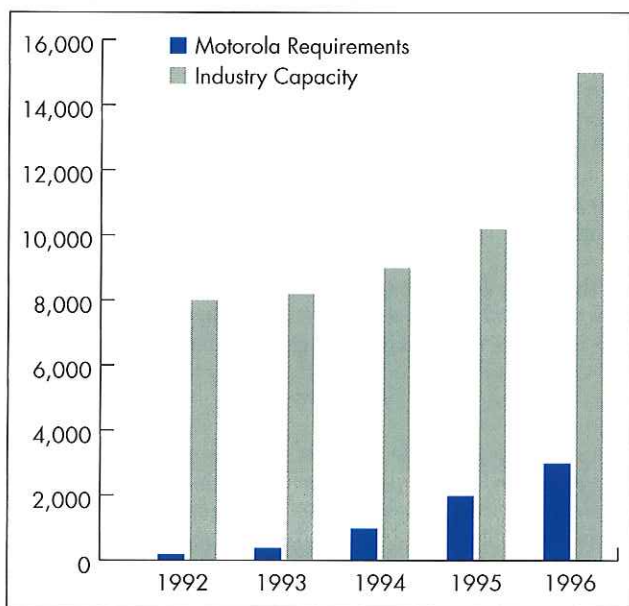


Figure 2 : Tantalum capacitors : Motorola requirements vs. industry capacity, 1992-1996

The following table shows, as a percentage of total sales, which markets consumed our radios in 1992, and the shifts we are experiencing now and expect to see by the end of 1997.

| Region | 1992 | 1997 |
|--------------|------|------|
| Pan-America | 66% | 58% |
| Europe | 19% | 14% |
| Asia-Pacific | 13% | 24% |
| Japan | 2% | 4% |

Significant points in this table are:

1. The Pan-American market will be a smaller portion of our total sales, although the absolute number will continue to grow.
2. In general, non-U.S. sales will become a bigger portion of our sales.
3. The fastest growing region in the world will be Asia-Pacific.

The other interesting piece of information regarding our consumption comes from looking at our consumption by usage size, shown in Figure 3. In general we are using more parts with smaller case size. The reason for the recent flattening out of the cases is that there are tantalums we are converting to ceramic.

As to the future, the next charts reflect Motorola's projection of its needs, providing the industry can continue its performance

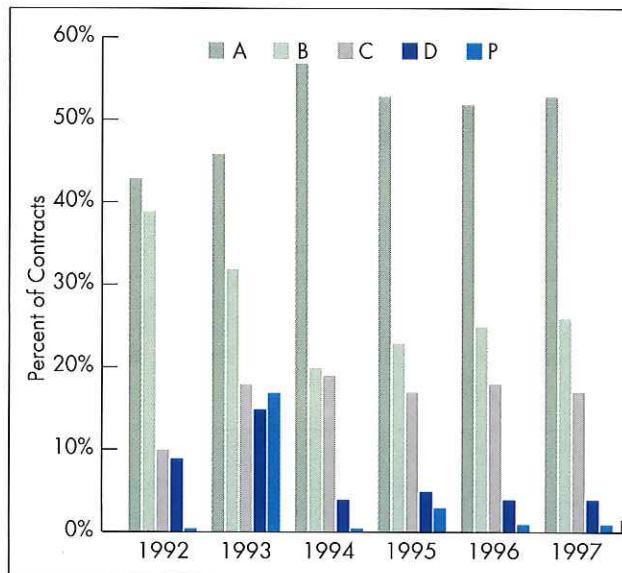


Figure 3 : Tantalum capacitors, case size (Northern Illinois contract awards)

on delivery and quality and can maintain its relative competitive position with regard to price. Relative competitive position means that tantalum capacitors become no more expensive than at present compared to alternatives.

For the wireless industry as a whole, it can be broken down into three major categories, as illustrated in Figure 4:

- Cellular and PCN. The PCN phones are the new radio frequencies just released in the U.S. at 1.8GHz.
- Paging.
- PMRS. (This category includes all two way radios.)

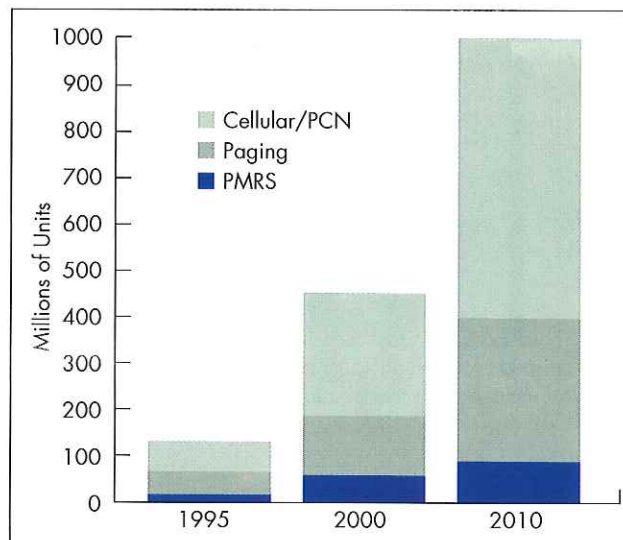


Figure 4 : Worldwide wireless devices in service

As you can see from 1995, 2000 and 2010, there is tremendous growth in the industry.

The total for 2000 is more than three times that for 1995, and the growth rate from the year 2000 to 2010 is approximately two times. What will cause all this growth? The worldwide nature of the growth is certainly significant. There are many countries which are just starting their economic development that will put in place wireless systems, they will never install wireline systems. Countries such as China and India will have huge needs for wireless products as their economies continue to develop.

South America also offers a similar situation where wireless systems will be put in place instead of wireline systems. However, growth will also come from the U.S., Britain, Germany, Japan and developing countries other than those named above. Today the U.S. has the highest penetration among the countries just mentioned.

This table tells us that as cellular service becomes less expensive, the number of subscribers will rise. In the U.S., we believe, as PCN systems are added to major cities, the competition for users will increase. Since subscriber units are already free, air time will have to be used to compete for users. Also, as the number of competitors increases, the providers will become more aggressive.

| | Population using cell services (million) | Average monthly cost (\$) |
|---------|--|---------------------------|
| U.S. | 8.4 | 49 |
| Britain | 6.8 | 67 |
| Germany | 3.0 | 106 |
| Japan | 2.6 | 136 |

This growth can be considered in terms of tantalum capacitor demand which shows Motorola's projection of its growth rate for tantalum capacitor consumption, see Figure 5. The decline in the growth rate can be clearly seen: it is caused by the sheer magnitude of the base, as you can see on Figure 6. Motorola's projection is that the tantalum industry will grow at about 14%. When we look at the results of Motorola's growth compared to the tantalum industry, it shows Motorola's share of the industry capacity continuing to increase.

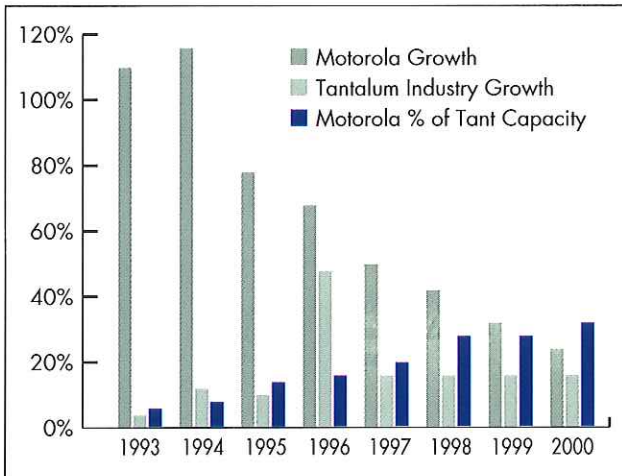


Figure 5 : Motorola growth vs. tantalum capacitor industry growth

If we look at the growth in units, it shows the industry capacity climbing to about 25 billion capacitors by the end of the century. Motorola consumption increase from 1.3 billion units in 1995 to over 7.2 billion units in the year 2000. This projected growth represents tremendous opportunity for Motorola and the tantalum capacitor industry.

I believe we are at a cross road. There are a number of issues which will determine what will happen. Will the tantalum capacitor industry be able to support this new growth rate? This support will have to be both real and perceived. If not, it will

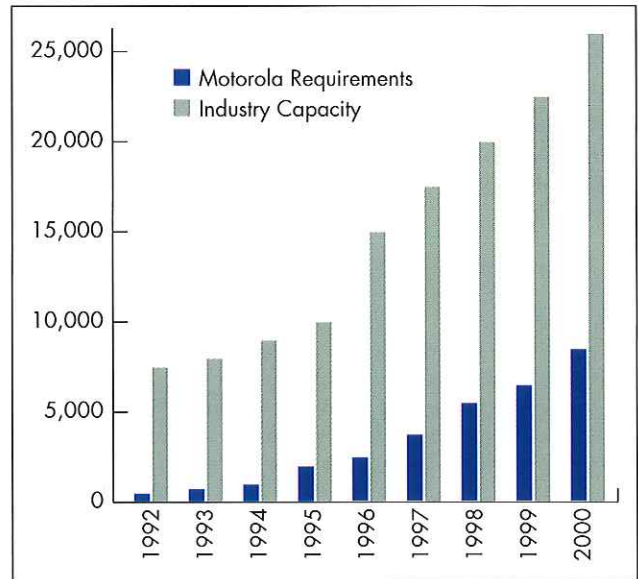


Figure 6 : Tantalum capacitors : Motorola requirements vs. industry capacity, 1992-2000

push both cellular and wireless industry to look for substitutes for tantalum.

The next area where the tantalum capacitor industry needs to improve is flexibility. By this I mean the ability to switch between case sizes. So, if the industry changes its size mix, the tantalum capacitor industry can switch quickly. Also, as the size continues to decrease, the capacity will need to shift.

Last is relative competitive position with regard to price. Figure 7 shows how tantalum capacitors have compared to ceramic capacitors. As you can see, the price pressure to find ceramic alternatives is increasing. This is of special concern during a time when there is a potential shortage of tantalum capacitors.

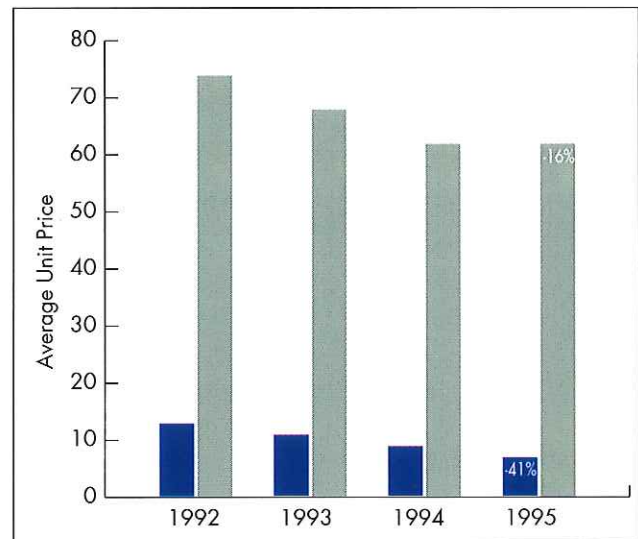


Figure 7 : Capacitor unit pricing, ceramics and tantalums

I believe the growth I have projected for the tantalum capacitor industry will come true. As has been the case with past support, I believe the future support will be there. I thank you now for this support and look forward to a prosperous and exciting future.

OUTLOOK FOR TANTALUM CAPACITOR DEMAND

This is a shortened version of the paper presented by Mr David E. Maguire, Kemet Electronics, at the Symposium. The presentation will be published in full in the Proceedings.

GROWTH DRIVERS

The primary growth driver for the consumption of capacitors is the growth in the electronics industry as highlighted in Figure 1. The electronics industry provides more value at less cost to the end consumer every year. In addition, electronics is at the heart of the technology-led surge in capital investment which is changing the way we all work and live. The historical growth rate of the electronics industry has been about 10% per annum. The current growth from 1994 has been about 14%, and the future growth rate is forecast to be about 11% per annum. The growth rate of total capacitor consumption approximates the electronics industry growth because all electronic equipment requires capacitors to function properly.

- More value at less cost every year
- Electronics is the heart of the technology-led surge in capital investment
- Fundamental change in how we work and live
- Growth rate accelerating from 10%

Figure 1: Electronics industry

The purpose of a capacitor is to remove or smooth variations in the voltage along electronic power lines caused by changes in the active load components attached to the line. The number and size of the capacitors required varies directly with the speed of the switch and/or the size of the load current. So the second driver for the growth of capacitors is the increasing functionality and speed of electronic circuits.

Figure 2 shows the relationship of capacitor cost to the capacitor size for ceramic multilayer, tantalum and aluminum capacitors. Not shown are single layer ceramics and film capacitors which are inexpensive but small in capacitance value and large in physical size. The cost of the capacitor for a required capacitance value has been a major factor in design choice.

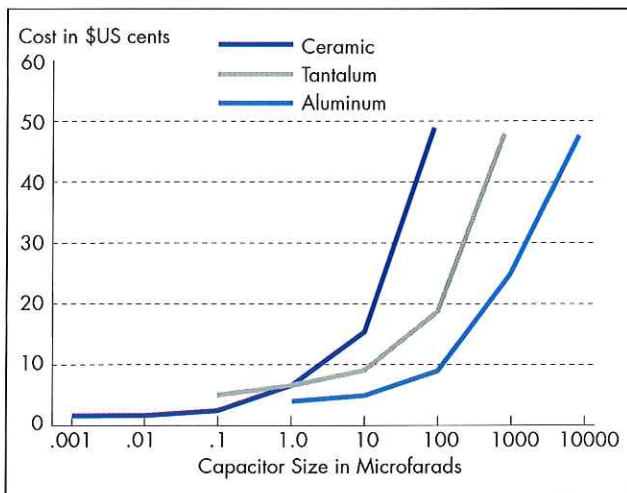


Figure 2: Capacitor cost versus size & material

The third driver for the growth in the consumption of tantalum capacitors is the changing technology in electronic circuit assembly. Conventional electronic components were attached to electronic circuit boards by inserting their lead wires through

holes in the board and then soldering the leads to the boards. As electronic equipment becomes smaller, the size of the components, including capacitors, must also become smaller. This is done by constructing the capacitor element in such a way that it can be soldered directly to the surface of the circuit board. This assembly method saves space and the capacitors can be mounted on both sides of the circuit board to save even more board space, but the entire capacitor element is now exposed to the high temperature assembly solder. Of all the capacitor materials available, only ceramic multilayer and tantalum will withstand the high temperature assembly solder. The result is that all of the capacitor usage growth for new applications, which utilize surface mount assembly technology, is focused on the ceramic multilayer and tantalum style capacitors.

CAPACITOR CONSUMPTION

Figure 3 shows the world wide consumption of capacitors by type in 1988, 1994, and compound annual growth rates. The total capacitor growth rate of 10% per annum approximates the total growth in the electronics industry over this six year period. The preferred ceramic multilayer, tantalum and aluminum capacitors showed growth rates of 12% per annum, while the single layer ceramics and films had growth rates of 7% per annum.

| Capacitor type | 1988 Billions of units | 1994 Billions of units | Growth rate Annualized percent |
|------------------------|------------------------------|------------------------------|--------------------------------------|
| Ceramic (Multilayer) | 73 | 142 | 12 |
| Tantalum | 5 | 10 | 12 |
| Aluminum | 39 | 76 | 12 |
| Ceramic (Single layer) | 44 | 68 | 7 |
| Film | 17 | 26 | 7 |
| Other | 1 | 1 | n/a |
| Total | 179 | 323 | 10 |

Figure 3: Historical growth, world wide capacitor consumption

Figure 4 shows our estimate for the future growth in the consumption of capacitors. Total capacitor consumption is forecast to grow at a compound rate of about 11% per year, reflecting the increased rate of growth in the electronics industry. Ceramic multilayer and tantalum capacitors should remain the preferred capacitor types due to the continued trend of increased functionality, complexity, and speed in integrated circuits, and the shift to surface mount assembly technology on a world wide basis.

| Capacitor type | 1995 Billions of units | 2000 Billions of units | Growth rate Annualized percent |
|------------------------|------------------------------|------------------------------|--------------------------------------|
| Ceramic (Multilayer) | 180 | 350 | 14 |
| Tantalum | 13 | 25 | 14 |
| Aluminum | 80 | 120 | 8 |
| Ceramic (Single layer) | 65 | 80 | 4 |
| Film | 28 | 34 | 4 |
| Other | 1 | 1 | n/a |
| Total | 367 | 610 | 11 |

Figure 4: Future growth, world wide capacitor consumption

(Continued on page 8)

PHOTOGRAPHIC REPORT

(Photos courtesy of HCST)



Technical session at Hotel Der Achtermann.

The technical sessions of the Symposium took place in the conference hall of the Hotel Der Achtermann, in the historic centre of Goslar, a most attractive town.

*Sightseeing group
(Photos by Emma Wickens)*

Setting out to see Goslar.



Plant tour of H.C. Starck: a very illuminating laboratory scale demonstration of extraction and separation of tantalum and niobium.



Fashion studio of Christel Keller.

*In the
monastery garden.*

Special events marking the 75th anniversary of H.C. Starck included the publication of a book of its history, setting up a fascinating exhibition, and the mediaeval banquet for our Symposium, with the Kaiserpfalz specially decorated with flowers and plants which would have grown here in the Middle Ages.



Mr Peter Kähler, Managing Director of H.C. Starck GmbH & Co KG, and President of the T.I.C.



Exhibition on the history of the industry. (foreground: statue of Niobe)

The barrel of beer successfully tapped, dignitaries of H.C. Starck toast the guests: (l. to r.) Mr Peter Kähler, Mr Hellwarth Lahusen, Dr Wilfried Rockenbauer



Mediaeval Banquet in the imperial setting of the Kaiserpfalz.

TANTALUM POWDER AND WIRE CONSUMPTION

Figure 5 shows a 'learning curve' for the per-unit requirement of tantalum powder in tantalum capacitors. The 'learning curve' shows that the unit consumption of powder declines by 30% for each doubling of the cumulative volume of capacitors produced. Powder requirements have dropped from 400 pounds per million units in 1980 to 100 pounds per million units in 1994 as the cumulative volume produced has grown by a factor of 12. At the current product maturity, the decline in per-unit powder requirement is about 6% per annum.

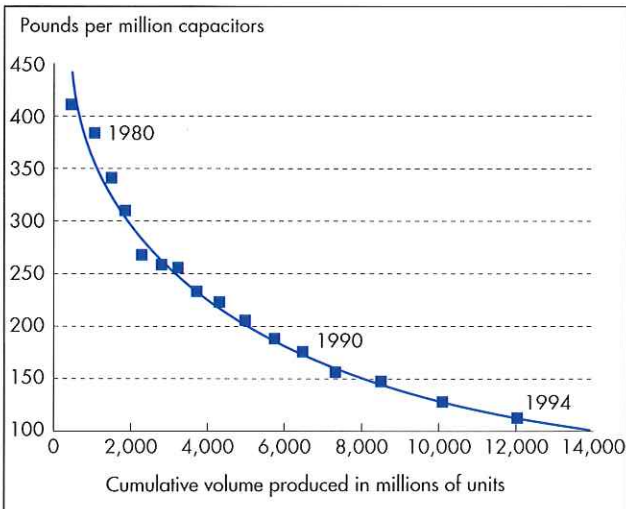


Figure 5: Tantalum powder learning curve

Figure 6 shows the 'learning curve' for tantalum wire. The per-unit requirement for tantalum wire in tantalum capacitors has declined 25% for each doubling of the cumulative volume produced. Tantalum wire usage has dropped from 60 pounds per million capacitors to 20 pounds per million as the cumulative volume has increased by a factor of 12. At the current product maturity, the per-unit requirement for wire is declining at about 5% per annum.

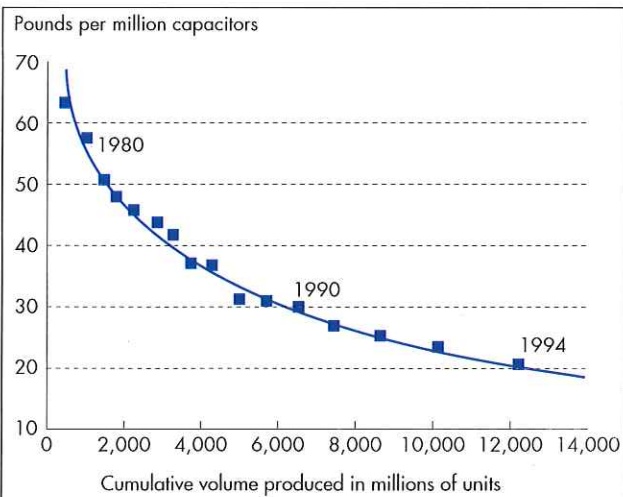


Figure 6: Tantalum wire learning curve

SYMPOSIUM PROCEEDINGS

The Proceedings will be available shortly in a hard cover book: please send your order to the T.I.C., 40 rue Washington, 1050 Brussels, Belgium, accompanied by a cheque for \$US150, or by a request for an invoice. This price includes postage and packing.

Figure 7 combines the world wide consumption of tantalum capacitors with the 'learning curve' unit requirements for tantalum powder to balance with the total tantalum powder consumed. The historical tantalum powder consumption amounts agree with the T.I.C. reported tantalum powder shipment data, except for 1988 where the world powder consumed is less than shipments by an amount of 220 000 pounds which reflects an inventory build hedge against the January 1989 price increase. Tantalum powder consumption is forecast to increase by 20% from 1994 to 1995, reflecting the surge in tantalum capacitor consumption. The forecast consumption of 25 billion tantalum capacitors in the year 2000 will require about 70 pounds of tantalum powder per million units for a total requirement of 1 750 000 pounds. The tantalum wire requirement for 25 billion tantalum capacitors in the year 2000 is forecast to be 350 000 pounds.

| Year | Capacitors Billions of units | Powder usage Pounds per million units | Powder used Total pounds (000's) |
|------|------------------------------------|---|--|
| 1988 | 5.4 | 170 | 917(*) |
| 1994 | 10.2 | 106 | 1085 |
| 1995 | 13.0 | 100 | 1300 |
| 2000 | 25.0 | 70 | 1750 |

(*) An additional 220,000 pounds were shipped to inventory in 1988 to hedge against price changes.
Tantalum Wire demand in pounds is forecast to add 18% to powder demand.

Figure 7: World wide tantalum powder consumption

MEMBERSHIP

The following companies were elected to membership by the Thirty-sixth General Assembly:

Hitachi AIC Inc.

16 Ohdaira, Kumagami,
Miharu-Machi, Tamura-Gun,
Fukushima-Ken, Japan 977.

Saha Electro Components Ltd.

Saha House, #37, SEEPZ,
Andheri (E), Bombay, 400 096, India.

Southern Prospecting Holdings (Pty) Ltd.

P.O. Box 61409, Marshalltown 2107, South Africa.

Specialty Metals Company S.A.

Rue Tenbosch 42A, 1050 Brussels, Belgium.

Resignations were accepted from Malaysia Smelting Corporation and Straits Trading Corporation.

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