INFORMAL MEETING

On the morning of Tuesday April 27th 1993 delegates are invited to join members of the Executive Committee for informal discussions at 40 rue Washington, 1050 Brussels, followed by lunch. The Committee will report on its meeting to be held on April 26th, and in particular on the progress of plans for the General Assembly in October.

GENERAL ASSEMBLY IN VIENNA

The Thirty-fourth General Assembly will take place in Vienna on October 5th 1993. The conference will open with the traditional reception on Monday October 4th, and following the Assembly on Tuesday there will be a full programme of technical presentations, with a gala dinner in the evening.

On October 6th participants will be taken to Treibach by bus for a plant tour of Treibacher Chemische Werke, returning to Vienna in the evening at the close of the meeting.

Invitations will be sent to member company delegates some two months before the meeting. Others who might be interested in attending should contact

T.I.C.
40 rue Washington
1050 Brussels, Belgium
telephone (02) 649.51.58
fax (02) 646.05.25
telex 65080

PRESIDENT'S LETTER

This newsletter should arrive at your desk near the arrival of Springtime, a good time to consider attending the T.I.C. meeting in Brussels. This informal meeting provides a useful opportunity to review the current situation of our industry with other T.I.C. members and delegates and, most importantly, to contribute your insights.

The months since the conclusion of our General Assembly have included a number of important holidays throughout the world and it is rather difficult to draw a clear picture of the prospects for our industry. However, change continues to be the most predictable feature of our environment. The short time since we met in Phuket has already brought a new administration in the United States, clear improvement in the U.S. economy, a mellowing of expectations for “Europe 93”, and major questions regarding the future directions of world trade and other micro and macro changes which will undoubtedly influence our industry.

The tantalum/niobium industry continues to see changes in the form of further consolidations, vertical integration, and the departure of familiar participants. In common with most commodity-based industries our business will continue to be driven by the imperative of doing more with less, that is, providing greater value to its customers and users. Success in this environment means focusing on higher-grade, higher-quality products and searching out new applications where our materials can be particularly valuable to a product or process. It is in this latter area that the T.I.C. must do more if it is to be of real worth to its membership.

Best wishes,

Peter Maden
PRESIDENT

TANTALUM POWDER: PAST, PRESENT AND FUTURE

A résumé of a talk given by Mr David Maguire (Chairman and C.E.O. of Kemel Corporation) to the T.I.C.'s Phuket meeting in November 1992.

I have recently been looking through the T.I.C. tantalum statistics with our Technical Adviser and using them to prepare some material balances for the metal, and then looking more closely at tantalum powder production and usage. I will show them in graphical form and give my observations on the figures, and finally I will review trends in capacitor consumption.

My first chart (1) shows the material balances for the five years 1988 to 1992 (final year is first half times two). The hard numbers from the T.I.C. are given in large bold type,
T.I.C. STATISTICS

TANTALUM

PRIMARY PRODUCTION

(quoted in lb Ta₂O₅ contained)

<table>
<thead>
<tr>
<th>Quarter</th>
<th>1992</th>
<th>1993</th>
<th>1994</th>
</tr>
</thead>
<tbody>
<tr>
<td>4th quarter</td>
<td>52,863</td>
<td>314,000</td>
<td>314,000</td>
</tr>
<tr>
<td>Tin slag (2% Ta₂O₅ and over)</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Tantalite (all grades), other</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Total</td>
<td>196,304</td>
<td>353,000</td>
<td>453,000</td>
</tr>
</tbody>
</table>

Note: 14 companies were asked to report, 14 replied.
The companies which reported included the following, whose reports are essential before the data may be released:
- Datuk Keramat Smelting, Gwalia/Greenbushes, Malaysia Smelting,
- Manaro Mineração e Metalúrgica, Metallurg group, Pan West
- Tantutlam (Wodgina Mine production), Tantutlam Mining Corporation of Canada, Thailand Smelting and Refining

QUARTERLY PRODUCTION ESTIMATES

(quoted in lb Ta₂O₅ contained)

<table>
<thead>
<tr>
<th>Quarter</th>
<th>1992</th>
<th>1993</th>
<th>1994</th>
</tr>
</thead>
<tbody>
<tr>
<td>1st quarter</td>
<td>314,000</td>
<td>341,000</td>
<td>353,000</td>
</tr>
<tr>
<td>2nd quarter</td>
<td>314,000</td>
<td>391,000</td>
<td>403,000</td>
</tr>
<tr>
<td>3rd quarter</td>
<td>314,000</td>
<td>391,000</td>
<td>453,000</td>
</tr>
<tr>
<td>4th quarter</td>
<td>314,000</td>
<td>391,000</td>
<td>453,000</td>
</tr>
</tbody>
</table>

Note: The quarterly production estimates are based on information available, and do not necessarily reflect total world production.

NIOBiUM

PRIMARY PRODUCTION

(quoted in lb Nb₂O₅ contained)

<table>
<thead>
<tr>
<th>Quarter</th>
<th>1992</th>
<th>1993</th>
<th>1994</th>
</tr>
</thead>
<tbody>
<tr>
<td>4th quarter</td>
<td>9,933,445</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Concentrates: columbite, pyrochlore</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Occurring with tantalum: tin slag (2% Ta₂O₅), tantalite, other</td>
<td>87,056</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Total</td>
<td>10,020,501</td>
<td></td>
<td></td>
</tr>
</tbody>
</table>

Note: 15 companies were asked to report, 15 replied. The companies which reported included the following, whose reports are essential before the data may be released:
- Cober, Mineração Caiapó de Goiás, Niobium Products Co. (CBMM)

PROCESSORS’ SHIPMENTS

(quoted in lb Nb contained)

<table>
<thead>
<tr>
<th>Quarter</th>
<th>1992</th>
<th>1993</th>
</tr>
</thead>
<tbody>
<tr>
<td>4th quarter</td>
<td>21,038</td>
<td>55,761</td>
</tr>
<tr>
<td>Compounds and alloy additive: chemical and unwrought forms (e.g. NbCl₅, Nb₂O₅, N₉N₉, Fe₉N₉) [excluding HSLA grades]</td>
<td></td>
<td>5,791,732</td>
</tr>
<tr>
<td>Wrought niobium and its alloys in the form of mill products, powder, ingot and scrap</td>
<td>440,837</td>
<td></td>
</tr>
<tr>
<td>(i) Pure niobium</td>
<td></td>
<td></td>
</tr>
<tr>
<td>(ii) Niobium alloys</td>
<td>5,791,732</td>
<td></td>
</tr>
<tr>
<td>(such as NbZr, NbTi and NbCu)</td>
<td></td>
<td></td>
</tr>
<tr>
<td>HSLA grade Fe₉N₉</td>
<td></td>
<td>6,309,368</td>
</tr>
<tr>
<td>Total</td>
<td></td>
<td></td>
</tr>
</tbody>
</table>

Note: 19 companies were asked to report, 18 replied. Reports by the following companies are essential before the data may be released:
- Cabot Performance Materials, W.C. Herceus, Kennametal, Metallurg group, Mitsu Mining and Smelting, Niobium Products Co. (CBMM),
- H.C. Starck Inc. (NRC), H.C. Starck, Teledyne Wah Chang Albany, Thai Tantalum, Treibacher Chemische Werke, Vacuum Metallurgical Company

CAPACITOR STATISTICS

CONSUMPTION BY AREA

(figures in millions of units)

<table>
<thead>
<tr>
<th>Area</th>
<th>1988</th>
<th>1989</th>
<th>1990</th>
<th>1991</th>
<th>Average per year</th>
</tr>
</thead>
<tbody>
<tr>
<td>North America</td>
<td>340</td>
<td>302</td>
<td>337</td>
<td>356</td>
<td>334.2</td>
</tr>
<tr>
<td>Europe</td>
<td>220</td>
<td>206</td>
<td>232</td>
<td>230</td>
<td>221.8</td>
</tr>
<tr>
<td>Japan</td>
<td>635</td>
<td>681</td>
<td>808</td>
<td>965</td>
<td>733</td>
</tr>
<tr>
<td>Rest of world</td>
<td>207</td>
<td>304</td>
<td>361</td>
<td>492</td>
<td>300.8</td>
</tr>
<tr>
<td>World</td>
<td>1402</td>
<td>1493</td>
<td>1738</td>
<td>2043</td>
<td>1707</td>
</tr>
</tbody>
</table>

Quarter: 1st 2nd 3rd 4th

<table>
<thead>
<tr>
<th>Area</th>
<th>1992</th>
</tr>
</thead>
<tbody>
<tr>
<td>North America</td>
<td>392</td>
</tr>
<tr>
<td>Europe</td>
<td>245</td>
</tr>
<tr>
<td>Japan</td>
<td>847</td>
</tr>
<tr>
<td>Rest of World</td>
<td>541</td>
</tr>
<tr>
<td>World</td>
<td>2025</td>
</tr>
</tbody>
</table>

Source: Members' estimates
assumptions (mostly related to stocks) are given in bold italics, and derived numbers are in small bold type.

<table>
<thead>
<tr>
<th></th>
<th></th>
<th></th>
<th></th>
<th></th>
<th></th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>1st 1/2 times 2</td>
<td>1st 1/2 times 2</td>
<td>1st 1/2 times 2</td>
<td>1st 1/2 times 2</td>
<td>1st 1/2 times 2</td>
</tr>
</tbody>
</table>

**PRIMARY PRODUCERS**
Production (lbs of Ta oxide) 1694 1638 1628 1450 1423
Shipments (lbs of Ta contained) 1254 1212 1205 1073 1060

**PROCESSORS (Ta contained)**

<table>
<thead>
<tr>
<th>Category</th>
<th>1st 1/2 times 2</th>
</tr>
</thead>
<tbody>
<tr>
<td>Beginning inventory</td>
<td>5000 4389 4185 4404 3881</td>
</tr>
<tr>
<td>Plus receipts</td>
<td>1850 1850 2310 1481 1594</td>
</tr>
<tr>
<td>Less shipments</td>
<td>2461 2054 2091 2004 2012</td>
</tr>
<tr>
<td>Ending inventory</td>
<td>4389 4185 4404 3881 3463</td>
</tr>
</tbody>
</table>

**USERS (Ta contained)**

<table>
<thead>
<tr>
<th>Category</th>
<th>1st 1/2 times 2</th>
</tr>
</thead>
<tbody>
<tr>
<td>Beginning inventory</td>
<td>1000 1301 1195 1126 970</td>
</tr>
<tr>
<td>Plus receipts</td>
<td>2461 2054 2091 2004 2012</td>
</tr>
<tr>
<td>Less and consumption</td>
<td>1800 1800 1800 1800 1800</td>
</tr>
<tr>
<td>Less scrap and recycle to 20%</td>
<td>360 360 360 360 360</td>
</tr>
<tr>
<td>Ending inventory</td>
<td>1301 1195 1126 970 822</td>
</tr>
</tbody>
</table>

**TIC DATA**

<table>
<thead>
<tr>
<th>Type</th>
<th>Estimated</th>
<th>Calculated</th>
</tr>
</thead>
</table>

**Chart 1:**
Tantalum metal summary balance (thousands of pounds)

If we start with the assumption that processors produced 8 million pounds of contained tantalum in their inventories at the beginning of 1988, and in each of the first two years they received 1.85 million pounds for treatment (from January 1990 actual receipts have been reported), then their current inventory amounts to 8.5 million pounds, or 18 months' deliveries.

At the user level, if we begin with 1 million pounds of stock, and assume 1.8 million pounds net consumption each year and scrap recycle at 20%, then we are showing an inventory at the end of 1992 of only 18 months' net consumption. I consider this to be consistent with the worldwide trend towards faster cycle times and lower inventories. [Readers can make their own assumptions on opening inventories, and may well have data on powder consumption that differs from mine, but I think the conclusion will be similar.]

My second chart (2) shows graphically the T.I.C. statistics for primary production of tantalum, split between tin slags and mineral sources (mostly tancite). The shift away from tin slags is clearly shown. This has resulted from the low production of tin and the increased availability of relatively low-cost tantalite from Australia.

Chart 3 shows processors' shipments of tantalum products over the last five years. In 1988 shipments totalled 2.5 million pounds of contained tantalum, but price rises in January 1989 coincided with a 20% fall in offtake to 2 million pounds annually, where it has since stayed. You will note a significant fall in the use of tantalum carbide, from 25% of total shipments to 15%.

**Chart 4:**
Tantalum powder: monthly shipments

Just under half of the total represents tantalum powder, shipments of this are shown in more detail separately by month on Chart 4. Anticipation of the price rise mentioned above resulted in very heavy purchases by consumers in the third and fourth quarters of 1988. Intake naturally dropped in 1989 while user inventories were worked off — fortunately it coincided with a period in which capacitor makers were at full production. Powder offtake now has stabilised at about 75,000 pounds per month.

**Chart 5:**
Tantalum capacitor consumption by region, from which it can be seen that U.S. consumption has grown since 1989 from 300 million pieces per quarter to the present 400 million. Europe is flat at an average of 225 million per quarter, but Japan showed a dramatic rise between 1988 and 1991 from just under 600 million to over 1 billion per quarter. Demand has fallen by 30% in the past year as consumer demand has softened, and more manufacturing has moved offshore. This is in the "rest of the world" category, much of it in East Asia, and these markets (many being subsidiary companies of Japanese, European or U.S. parents) have shown a trebling of consumption in the five years being reviewed. Total world production was just under 6 billion units in 1988, and is over 8 billion units per year today. It is clear that recovery of Japanese demand would soon push this total beyond 9 billion.
Chart 6 is produced from figures of powder shipment divided into the consumption of capacitors for each quarter. This gives the “learning curve” shown (inventory movements of powder account for most of the quarterly variations from the general line). You will see that the world is currently making 1,000 capacitors from 0.11 pounds of tantalum: in 1963 it took 4.0 pounds of powder to make the same number.

Chart 7:
Tantalum powder usage

At the 1985 T.I.C. meeting in Boston, the diagram of Chart 7 was displayed and it shows the “learning curve” in a different way (against cumulative production in the United States). For many years there was a 30% decline in powder used per unit each time the cumulative volume produced doubled. The 1980 price run-away in the tantalum industry so shocked the system that extraordinary efforts accelerated usage reduction (and incidentally depressed the market growth). As the cost pressures were relieved in 1984 it was then projected that usage reduction would return to the old slope. This has in fact happened. As U.S. cumulative production of capacitors passed 25 billion units in 1992, the usage rate was just over 0.125 pounds per thousand pieces.

Chart 8:
Capacitor market — worldwide total

Chart 8 compares the markets for tantalum capacitors and their competitors. Tantalum has shown a 13% annual quantity growth rate since 1988 (second only to a multilayer ceramic), but the learning curve works on prices as well as powder consumption; so annual value growth has been only 4%. It is important to note that if we could drive the cost of tantalum capacitors closer to that of aluminum capacitors, there could be a very large growth in sales volume (industry currently uses more than five times as many aluminum capacitors as tantalum).

To summarise the economic factors in tantalum capacitor manufacture over the past five years:
1. The amount of powder used annually is flat.
2. The price has increased by 14% per year.
3. The number of capacitors produced has grown at the rate of 13% per year.
4. The average unit price of capacitors has declined at the rate of 8% per year.

As a result, the tantalum capacitor industry value has increased by only 4% per year. The cost of the powder, as a proportion of total direct cost of capacitors, has increased from 21% to 35% in the five-year period. This indicates very clearly how the future health and potential growth of all three elements of the tantalum industry — producers, processors and capacitor-makers — are today even more closely linked.

ELECTRIC ENERGY CONSUMPTION IN THE EXTRACTIVE METALLURGY OF NIOBium AND TANTALUM

(Note on a talk given by Dr Peter Paschen, Montanuniversitat, Leoben, Austria, to the T.I.C. meeting in Phuket, Thailand on November 17th 1992.)

Every stage in the preparation of niobium (or ferroniobium) and tantalum from the appropriate mineral deposit (usually pyrochlore for niobium, columbite or tantalite for tantalum) involves an expenditure of energy, and it is instructive to determine what the total expenditure is for different source materials and process routes and alternative technologies. The typical flowsheets for niobium and tantalum are shown in figures 1 and 2 respectively.
We can put values on the energy consumed at each stage for the preparation of the three metal products (ferroniobium, pure niobium and pure tantalum) with which we are concerned, but first we must specify values for the sources of that energy. Electricity is the most common source and the theoretical conversion is 1 kWh = 3.6 Megajoules (MJ). However, after allowing for generation efficiency and losses in distribution, this efficiency is only 36%, so we have used 1 kWh = 10 MJ in our calculations. Other sources of energy considered are fuel oil (1 kg = 41 MJ), natural gas (1 m³ = 32 MJ), coal (1 kg = 29.6 MJ), and electrode graphite (1 kg = 144 MJ).

**FERRONIOBIUM**

The literature indicates the energy cost for the mining of one ton of niobium ore (at 3% Nb₂O₅, or 2.1% Nb) is 78 MJ. This however must be adjusted for the niobium recovery in mining and ore dressing (taken as 65%), and the recovery in reduction metallurgy (taken as 86.5%). After applying these corrections, mining energy cost per ton of FeNb at 60% Nb is 3.55 Gigajoules (GJ).

Mineral dressing is quite energy intensive, not just from the use of electricity in grinding, flotation and calcining, but also from the consumption of such materials as flotation agents and steel balls for comminution. Leaching with HCl is, by comparison, cheap in energy cost.

**NIOBIUM METAL FROM ORE**

Much of pure niobium has been traditionally recovered from columbite ores which are found in much lower concentrations than those of pyrochlore (0.1% Nb₂O₅ against 3.0% Nb₂O₅).

Reduction is, as would be expected, the principal consumer of energy, almost all in the form of aluminium powder (which was itself produced by an electrical process).

<table>
<thead>
<tr>
<th>Stage</th>
<th>Energy Consumption (GJ/t)</th>
<th>Notes</th>
</tr>
</thead>
<tbody>
<tr>
<td>Mining</td>
<td>17.6</td>
<td></td>
</tr>
<tr>
<td>Dressing</td>
<td>7.90</td>
<td>Flotation</td>
</tr>
<tr>
<td>Calcining</td>
<td>3.03</td>
<td></td>
</tr>
<tr>
<td>Leaching (HCl)</td>
<td>0.24</td>
<td></td>
</tr>
<tr>
<td>Calcining</td>
<td>3.03</td>
<td></td>
</tr>
<tr>
<td>Reduction</td>
<td>14.72</td>
<td>Reactants</td>
</tr>
<tr>
<td>Total</td>
<td>172.2</td>
<td></td>
</tr>
</tbody>
</table>

**Figure 3:** Energy consumption for production of ferroniobium

The grand total of energy consumed in the production of ferroniobium is 172 GJ/t; the details are given in figure 3.
If we take mining energy cost per ton of ore as the same in both
cases then the cost is much greater per ton of niobium
recovered. * It would be even greater than that shown in the
schedule if not for the credit given for the co-production of
tantalum. Ore dressing, including some comminution, tabling
and magnetic and electrostatic separation is expensive in
energy because of the relatively low grade of feed.

The separation of the niobium from tantalum and the
purification of the resulting oxide involves several energy
intensive steps. Leaching with hydrofluoric acid (which has an
energy content of 17 GJ per ton) requires 1.8 tons of acid for
each ton of niobium, and the ensuing liquid-liquid extraction
incurs energy expense in consumption of the organic phase and
for electrical power. Precipitation and filtration, with final
calcining to produce a 99.9% pure niobium oxide, result in a
grand total for the separation of 87 GJ per ton.

The oxide is reduced with aluminium, in a similar way to
that used for producing ferro niobium, but an additional step is
required for refining which is affected by electron beam melting.
In the latter, energy is not only consumed in the melting as such,
but also in vacuum pumping and water cooling. The energy
consumption is estimated at 76 GJ per ton of niobium, and this
brings the grand total of energy required to produce a ton of
pure niobium metal to 369 GJ (see figure 4).

<table>
<thead>
<tr>
<th>Process</th>
<th>Energy Consumption (GJ/ton)</th>
</tr>
</thead>
<tbody>
<tr>
<td>Mining</td>
<td>78 M/1 t ore</td>
</tr>
<tr>
<td></td>
<td>= 37.49 GJ/1 Nb</td>
</tr>
<tr>
<td>Dressing</td>
<td>9.88 GJ/1 Nb</td>
</tr>
<tr>
<td></td>
<td>5.77 GJ/1 Nb</td>
</tr>
<tr>
<td></td>
<td>4.11 GJ/1 Nb</td>
</tr>
<tr>
<td>Nb/Ta separation</td>
<td>0.25 GJ/1 Nb</td>
</tr>
<tr>
<td></td>
<td>35.32 GJ/1 Nb</td>
</tr>
<tr>
<td></td>
<td>29.69 GJ/1 Nb</td>
</tr>
<tr>
<td></td>
<td>18.24 GJ/1 Nb</td>
</tr>
<tr>
<td></td>
<td>0.71 GJ/1 Nb</td>
</tr>
<tr>
<td>Reduction</td>
<td>151.80 GJ/1 Nb</td>
</tr>
<tr>
<td></td>
<td>133.14 GJ/1 for aluminium</td>
</tr>
<tr>
<td>Refining</td>
<td>76.50 GJ/1 Nb</td>
</tr>
<tr>
<td></td>
<td>368.65 GJ/1 Nb</td>
</tr>
<tr>
<td></td>
<td>369 GJ/1 Nb</td>
</tr>
</tbody>
</table>

* This may go some way towards explaining the development work at this time
  on the recovery of niobium direct from pyrochlorite or ferro niobium. Ed.

[2] Precipitation of the tantalum in its separation from niobium is
by potassium fluoride as the double fluoride, a cheaper route
than that of niobium by ammonium as niobic acid.

[3] Sodium is used to reduce the fluoride of tantalum, as opposed
to aluminium for the oxide of niobium. The cost of reductant
(whose amount is influenced by consideration [1] above) plus
that of other minor consumptions come to 108 GJ per ton in
the case of tantalum against 152 GJ for niobium.

[4] In some cases, it is sufficient to refine tantalum metal by
sintering by direct current traverse, or by melting in an arc
furnace, thus avoiding expensive electron-beam melting.
The arc melting is estimated to cost 25 GJ/t against
96 GJ/t for EB.

The total energy cost is shown in detail in figure 5.

<table>
<thead>
<tr>
<th>Process</th>
<th>Energy Consumption (GJ/ton)</th>
</tr>
</thead>
<tbody>
<tr>
<td>Mining</td>
<td>78 M/1 t ore</td>
</tr>
<tr>
<td></td>
<td>= 37.49 GJ/1 Ta</td>
</tr>
<tr>
<td>Dressing</td>
<td>9.88 GJ/1 Ta</td>
</tr>
<tr>
<td></td>
<td>5.77 GJ/1 Ta</td>
</tr>
<tr>
<td>Nb/Ta separation</td>
<td>0.25 GJ/1 Ta</td>
</tr>
<tr>
<td></td>
<td>35.32 GJ/1 Ta</td>
</tr>
<tr>
<td></td>
<td>29.69 GJ/1 Ta</td>
</tr>
<tr>
<td></td>
<td>18.24 GJ/1 Ta</td>
</tr>
<tr>
<td></td>
<td>3.71 GJ/1 Ta</td>
</tr>
<tr>
<td>Reduction</td>
<td>108.20 GJ/1 Ta</td>
</tr>
<tr>
<td></td>
<td>25.00 GJ/1Ta</td>
</tr>
<tr>
<td></td>
<td>96 GJ/1Tb</td>
</tr>
</tbody>
</table>

**Figure 5:**
Energy consumption for production of tantalum metal (from ores)

**NIOBiUM METAL FROM TIN SLAGS**

In this case, there is no mining step (but it should be pointed
out that the tin metallurgists have already paid the energy bill 1). In
place of mineral dressing, we have, in the case of lower-
grade tin slags (say, those with less than 5% each of Nb2O5 or
Ta2O5), a pyrometallurgical concentration in an arc furnace to
produce "synthetic concentrates" (see figures 1 and 2).

This is estimated to cost 25 GJ per ton of niobium, and the
effect on the overall energy cost of producing the niobium metal is
to bring the total down to 341 GJ (high-grade tin slags can go
straight into the Nb/Ta separation for a further saving of 25 GJ).

**TANTALUM FROM ORES**

Much the same sequence is followed for tantalum, but the
following differences are important in energy terms:

1) The cost per ton of resulting metal is significantly less for
tantalum where reduction is involved because of its greater
atomic weight (181 against 93).

**CONCLUSIONS**

A summary of all the above calculations is shown in
graphical form in figure 6. Not surprisingly, the preparation
of ferrocobaltum (for use as an additive in steel-making) is far less
energy intensive than that of high purity niobium and tantalum
metal. The reduction stage, mostly by consumption of
aluminium, is the most expensive (which justifies the recent surge
of interest shown in the technical literature in the development of
carbothermic processes for niobium and Fe-Nb production : Ed.).

The diagram indicates just how much energy is required for
the Nb/Ta separation, and for reduction (by metals which
themselves have consumed a very high amount of secondary
energy — electricity — in their production). These are clearly
fruitful areas for research. In the case of reduction, interest is
strong in fused salt electrolysis, and in Leoben tantalum has
been produced at energy consumption figures between 15 and
30 GJ/ton. There are, however, still many problems to be
resolved.

A final observation: if the reduction step could be made to
yield a higher purity metal, then much of the high energy cost
for refining could be saved.
TANTALUM WIRE AND ROD
AT H.C. STÄRCK INC.

by Mr. Gerard J. Villani, Product Manager for the wire group at H.C. Starck Inc., Newton, Massachusetts

Tantalum wire production at H.C. Starck Inc. at Newton in the United States is a unique marriage of chemistry and metallurgy, high vacuum, high temperature and metalworking technology and personnel with over 50 years of experience in the industry. Its NRC(tm) brand of high purity products derives its name from National Research Corporation, which was founded in 1940 as a company specializing in research and development, including the extraction and refining of refractory and reactive metals such as titanium, zirconium, hafnium, tantalum and niobium.

In 1976, NRC Inc. became a member of the Hemmann C. Starck Group. By the end of 1992, the name "NRC Inc." was changed to H.C. Starck Inc. when HCST's New York sales office, which sells molybdenum, tungsten, tantalum, niobium, thorium, their compounds and a host of other space age materials from its European facilities, was merged with the Newton facility. Similar mergers took place at the same time between H.C. Starck Japan Ltd. and V Tech Corporation in Japan. The name "NRC" was retained as a trade mark to distinguish the products made in HCST's Newton facility from those made elsewhere.

Today, HCST's Newton facility manufactures tantalum and niobium products for the electronic, chemical, aerospace and nuclear industries. Among these products are high capacitance tantalum powders and stabilized tantalum wire for the electrolytic capacitor industry. In the manufacture of electrolytic capacitors, tantalum powder is pressed and sintered at high temperatures with a tantalum lead wire as the anode conductor. Electrolytic capacitors may be found throughout high tech consumer and industrial equipment, including computers and communication equipment. The consumption of tantalum wire is expected to grow faster than that of tantalum powder as capacitors become smaller but more numerous.

The Newton facility is one of the world's largest tantalum and niobium production facilities of its kind. It is completely integrated with research, development and testing laboratories along with a full range of manufacturing systems, including powder production, arc melt, plasma melt and electron beam melt, forging, rolling, swaging, drawing, heat treating and fabricating.

As an addition to the Newton facility, HCST acquired Fansteel's tantalum mill products and wire assets and transferred them to the Newton complex where they became fully operational by 1991. One of the unique aspects of the Fansteel acquisition was the powder metallurgy route for making capacitor grade tantalum wire. The two brands, TPX and GPX, are highly desired by the capacitor industry because of their grain size stability, electrical characteristics and other physical properties.

Powder metallurgy wire begins with a special mixture of tantalum powders produced in Newton. The powder blend is compressed under very high pressures and sintered at high temperatures in vacuum furnaces with powerful electrical equipment. The sintered bars are then rolled into coarse rods using heavy equipment, and subsequently formed into finer rods with moderately sized machines. Throughout the rod rolling process, the metal work-hardens and must be annealed periodically in large, high temperature, vacuum furnaces designed for this purpose. The rods are progressively drawn into fine wire using staged wire drawing machines and space age lubricants.

The final wire product, which is available in four basic tempers: annealed, half-hard, hard and extrahard is strengthened and spoiled for delivery to customers world wide under the NRC(tm) brand of TPX and GPX wire. Sales and service are also made through sister divisions of HCST Newton in Tokyo, Japan (H.C.Starck/V Tech Ltd) and Goslarn, Germany (H.C. Starck GmbH & Co. KG).

Throughout the wire manufacturing process, HCST's extensive analytical and metallurgical testing facilities in Newton provide the necessary testing and statistical process control to ensure high quality wire with respect to chemical, electrical and metallurgical properties. These laboratories are also available to provide technical support to customers and to assist in the development of new materials.

As can be seen, the manufacture of tantalum wire at H.C. Starck Inc. is a highly capital and labor intensive process requiring a variety of technologies and skills, equipment and processes that are uniquely suitable to the HCST Newton facility. In addition, the capacity at Newton is sufficient to supply high quality wire for all of HCST's customers for the foreseeable future.
### Industry Survey of T.I.C. Members

**Raw Materials**
- Tantalite
- Columbite
- Sphalerite
- Tin dioxide
- Potassium concentrate
- Other

**Compounds**
- Tantalum oxides, standard-grade
- Tantalum oxides, optical-grade
- Tantalum oxides, radioactive-grade
- Tantalum oxides, ceramic-grade
- Other

**Ceramics**
- Tantalum ceramics
- Nibotium ceramics
- Mixed ceramics
- Other

**Alloy Additives**
- Nickel-based
- Ruthenium
- Nickel-based, precipitation-hardened
- Other

**Metallurgical-grade Products**
- Tantalum metal
- Tantalum oxide, sputtering
deploy
- Tantalum oxide, evaporated
- Tantalum oxide, deposited
- Other

**Capacitors**
- Powders, Smelting
- Wire, Cable
- Anodes, Capacitors
- Other

**AUX**
- Cabot Performance Materials

**Other**
- Goldmining
- Quebec/Silverhives
- Harosaic
- Kremetec
- Almaden, H. Knight
- Malaysian Mining
- Malaysian Smelting
- Metallurgy Group
- Minerals Manganese e Metuburgia
- Mita Mining & Smelting
- National Resources Trading
- Nickel Products (CBMAMA)
- H.C. Starck Inc. [NRC]
- FCI West Tantalum
- Sona Tools
- Shovex-Cobalt Supematals
- Sogen-Afrimet
- Stohlanik Magnesium Works
- Soninkii
- Yukay Sproague
- H.C. Starck GmbH & Co KG
- Alex Stewart [Amergy]
- Stralls Trading
- Tantulium Mining Corp Canada
- Technologies International
- Tekesynie Wai-Chang Aliancy
- Thai Pioneer
- Thailand Smelting & Refining
- Treibacher Chemische Werke
- Vacuum Metallurgical Co
- H.C. Starck-V Tech

**Analysis, Testing, Other Services**
- Analyzing, Testing, Other Services