

## President's Letter

Anniversaries are a time for assessment of the past and planning for the future. In the ten years that it has existed, the T.I.C. has achieved significant progress in bringing about greater understanding of the way of life of the different sectors of our industries. Generalisations have been given substance in the form of statistics, industry surveys and papers presented at the Assemblies and in the Bulletin. The T.I.C. reports are regularly quoted in articles and surveys issued by other organisations.

Obviously these activities will continue and be expanded. A full-time technical officer is being recruited for this purpose. However, time will be required to get to know individual members' organisations and their needs before full effectiveness can be achieved. You can all help here by continuing to supply books and papers concerning your particular operations. Much of the background information on both tantalum and niobium can only be obtained from such sources. Also, visits to representative operations in the different sectors would be a necessary part of the training programme: your full cooperation in this area would be appreciated.

But then, having established a wider base for our organisation, what do you, as members, require in the future? If members wrote in to the T.I.C. office with their views, we could analyse the responses and adjust the programme accordingly. It would also be of interest to publish the main points of your letters in the Bulletin to promote further discussions.

Finally, I would like to thank you for your support in my year in office. My best regards to Carroll Killen for his term as President.

R.W. Franklin  
President

TaC-Ni hard metal by the name of Ramet was introduced in the USA (1). This was soon replaced in the USA by grades based on WC-TaC-TiC-Co. In Europe the use of TaC started later. Kieffer worked during the second world war with grades containing TaC and NbC, but the situation as regards raw materials during and immediately after the war restricted the spreading of these grades (2).

During the 1950's, a very intensive period of development started in the field of hard metals and this resulted in the alloy analyses which still form the basis of the ISO groups P, K and M. Insert technique, which was introduced at the end of the 1950's, revolutionized chip removal. The feared decrease in the consumption of hard metals after the introduction of throw-away tips with eight edges, as compared to the single edge of the traditional brazed tip, did not take place, thanks to the insert technique which radically increased the possible applications of hard metal in competition with high-speed steel.

At the end of the 1950's, hard metal grades were developed with high contents of TiC, TaC and NbC, the so-called premium grades, which are particularly suitable for steel cutting at high cutting speeds (3).

Development during the 1960's was above all aimed at producing grades for specific cutting problems within series-production industry. We can name as one example of this Seco S 25 M which was originally developed for crankshaft milling.

Entirely new possibilities for tool material development were opened up at the end of the 1960's when hard metals coated with titanium carbide were introduced. Up to this point the tantalum content in hard metals had been continuously increased in order to improve the high-temperature properties. The high-temperature properties of hard metals now played a minor role due to the fact that they became primarily the carrier of the wear resistant surface layer. The large increases in productivity brought about by the coated hard metals (4) meant that their share of the market increased very rapidly, particularly in the field of turning.

## The role of tantalum in tools for metal cutting

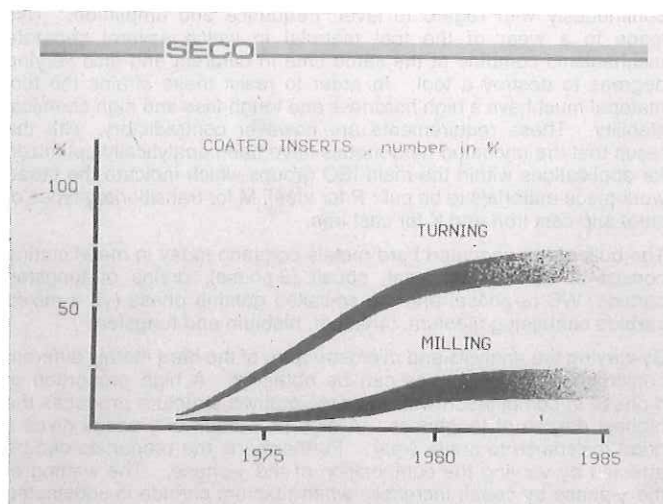
The following paper, prepared by Mr. P.O. Snell and Mr. K. Nordlund of Seco Tools Fagersta, was presented at the Twenty-first General Assembly of the T.I.C. in Stockholm on June 5, 1984. The paper is provided in its entirety without significant editing in view of its technical detail and contribution to the understanding of the role of tantalum in the metal cutting tool business. Due to its length, however, it will be offered in two parts, the first half in this issue of the T.I.C. "Bulletin" and the second half in Issue no. 41.

### SUMMARY

A review of modern tool materials for different cutting applications in reference to their tantalum content is made. The cutting performance in the turning and milling of steel with carbide grades based on a varying tantalum content is described with special emphasis on the beneficial effect of tantalum in uncoated grades for milling. The influence of future trends and developments in grade composition, coating technology, insert shape and machining procedure on the future need of tantalum is described.

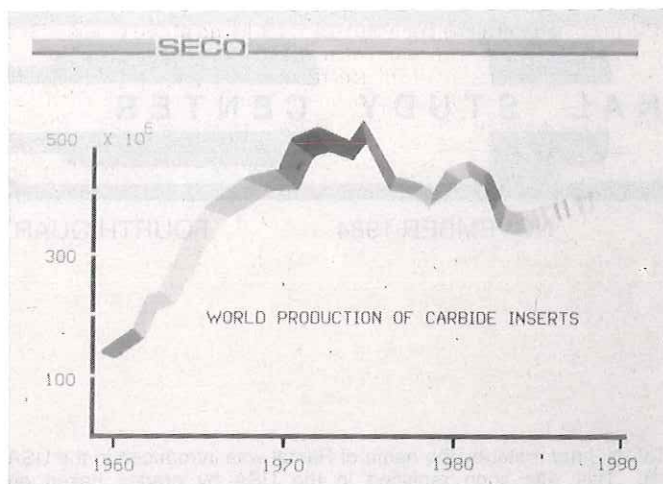
### INTRODUCTION

Ever since the first hard metals of the type WC-Co were introduced in 1926, constant efforts have been made to expand the field of application of tool materials as far as higher cutting speeds are concerned. The first step in this direction was taken in 1930, when a



The large increases in tool life made possible by tools coated with carbides, nitrides and/or oxides, in combination with the continuous change-over from brazed tips to throw-away tips, have now lead to the decrease in volume of cutting tips that was feared during the 1950's. The change in tool production in the Western world between 1960 and 1983 (5) is characterized by almost a five-fold increase by the mid-1970's with a continuing slow decline afterwards. The decrease in tool production, combined with substantial increases in the price of tantalum at the end of the 1970's resulting in grade rationalizations, has meant that the tantalum requirements of the hard metal industry have been drastically reduced.





With the major consumption areas of throw-away tips being taken as a starting point, estimated in the table below, this paper will discuss the development trends in the fields of turning and milling of steel and cast iron and the effect of these upon the future consumption of tantalum.

Work Piece Material	% of throw-away tips consumed		
	Steel	Cast Iron	Others
Turning	48	15	2
Milling	18	10	2
Other	2	2	1

### TURNING OF STEEL

During the turning of steel extreme conditions prevail in the tool/chip contact. These conditions can be illustrated most simply by means of a graded specification :

$$\text{Temperature in the crater surface} \quad T \leq 1200^{\circ}\text{C} \quad (6)$$

$$\text{Temperature gradient beside the crater surface} \quad \frac{\delta T}{\delta x} \approx 10^7^{\circ}\text{Cm}^{-1} \quad (6)$$

$$\text{Pressure of contact between tool and chip} \quad P \approx 100 - 200 \text{ MPa} \quad (7)$$

$$\text{Strain rate} \quad \epsilon \approx 10^3 - 10^6 \text{ sec}^{-1} \quad (8,9)$$

$$\text{Heating rate} \quad \frac{\delta T}{\delta t} \approx 10^6 - 10^9^{\circ}\text{C sec}^{-1} (9, 10)$$

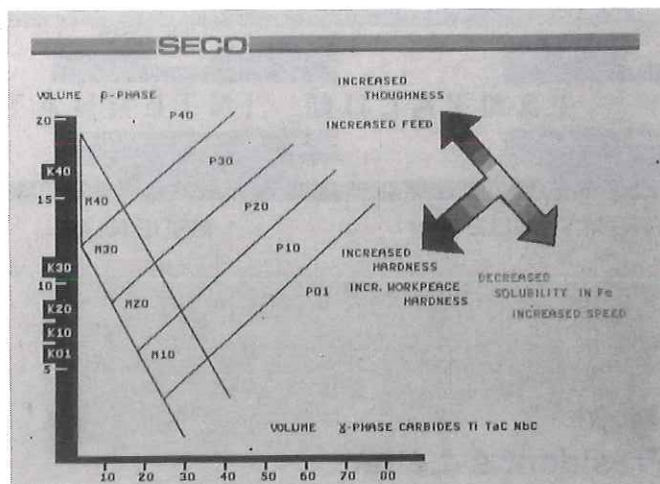
$$\text{Time of contact between tool and chip} \quad t \approx 10^{-3} \text{ sec} \quad (9)$$

A tool is thus subjected to temperatures and forces which change continuously with regard to level, frequency and amplitude. This leads to a wear of the tool material in which several separate mechanisms combine at the same time in different and also varying degrees to destroy a tool. In order to resist these strains the tool material must have a high hardness and toughness and high chemical stability. These requirements are however contradictory, with the result that the uncoated hard metals have been analytically optimized for applications within the main ISO groups which indicate the broad work-piece materials to be cut : P for steel, M for transitional types of steel and cast iron and K for cast iron.

The bulk of the uncoated hard metals common today in metal cutting consist of the binder metal, cobalt ( $\beta$ -phase), grains of tungsten carbide, WC ( $\alpha$ -phase) and the so-called gamma phase ( $\gamma$ ), a mixed carbide containing titanium, tantalum, niobium and tungsten.

By varying the analysis and microstructure of the hard metals different combinations of properties can be obtained. A high proportion of  $\beta$ -phase in combination with a coarse-grained structure produces the highest degree of toughness. A high proportion of  $\gamma$ -phase gives a good resistance to crater wear. Furthermore, the properties can be affected by varying the composition of the  $\gamma$ -phase. The wetting of the  $\gamma$ -phase by cobalt increases when titanium carbide is substituted by tantalum carbide. This is one of the reasons why the substitution of titanium carbide with tantalum carbide results in improved toughness behaviour and an increased ability to resist plastic deformation and thermal fatigue. In addition, flank wear resistance is improved whereas crater wear resistance is reduced, which can be explained by the lower solubility of titanium carbide in steel.

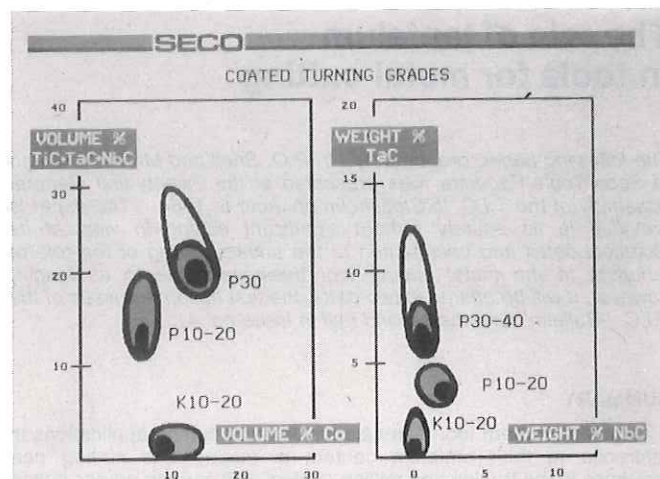
With these general principles as a starting point, the analysis and micro-structure of hard metals have been optimized to cover different ISO groups. The typical compositions with regard to the volume percentage of  $\beta$ -phase and  $\gamma$ -phase for a number of ISO standardized application areas are shown in the chart for the application of uncoated grades.



Among the hard metals that constitute the P- and M-group are three phase alloys, where the sum of the three phases  $\alpha$ ,  $\beta$  and  $\gamma$  is 100 %. In the K-group the hard metals are mainly two phase alloys consisting of  $\beta$ - and  $\alpha$ -phase. Even though the uncoated grades for turning have become of less importance since the introduction of the coated hard metals, analysis adjustments have been made after the substantial increases in the price of tantalum at the end of the 1970's. This is particularly obvious in the K-group where previously you could find a large number of alloys with up to 4 wt. % of tantalum carbide. As these additions have been chiefly made for the purpose of grain size control, which is achieved even for contents of about 0.2 wt. % of tantalum carbide, substantial adjustments downwards have been made in many cases. In addition to tantalum carbide the cheaper vanadium and chromium carbides are now being used to a greater extent for this purpose.

The first coated grades had conventional ISO P, M and K grades as substrates (11). However, when coated the hard metal becomes more universal. A grade that produces good results in the P-group can also produce excellent results in the turning of cast iron, which indicates that the essential function of the substrate is to act as a support to the wear resistant layer.

As the hard metal substrate is protected by the wear resistant layer during a large part of its active life, lower demands can be made even in steel cutting as regards good high temperature properties. Greater demands can instead be made on the mechanical properties of the substrate. The development of coated grades has also gone in this direction. In a  $\beta/\gamma$ -diagram, below, the groups into which the substrates from coated turning grades for 15 hard metal producers fall are marked. In addition, the TaC/NbC content in these alloys is stated. Even if a direct ISO grouping is not possible for coated grades, they have, in this case, been arranged according to their chief application areas.

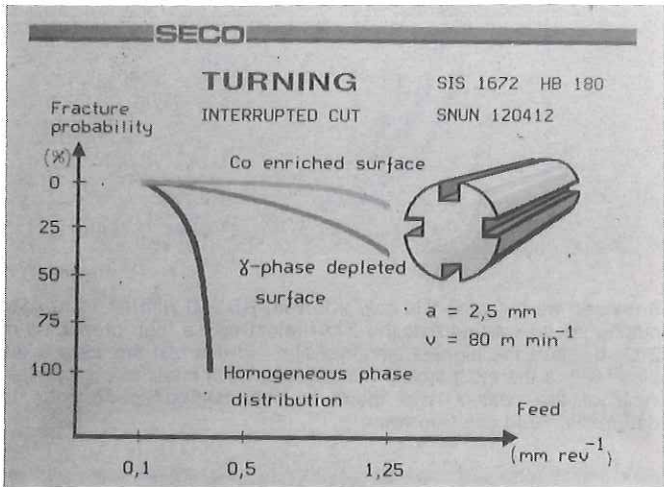


The P 30 group contains a large number of old grades that were introduced in certain cases more than ten years ago. This can probably explain why these grades contain such high proportions of tantalum. The weighted average for the tantalum carbide content is for these grades of the order of 6 wt. %. The central area in steel cutting with the largest tool consumption is in the P 10-20 group. The analysis deviations between substrates from different producers are in this case small. By starting with a M 20 analysis with a tantalum carbide content of 3.5 wt. % and adapting the microstructure and carbon content a universal substrate has been obtained.

The coated K 10-20 grades, which in many cases are excellent for the turning of hard steels, contain about 0.5 wt. % of tantalum carbide.

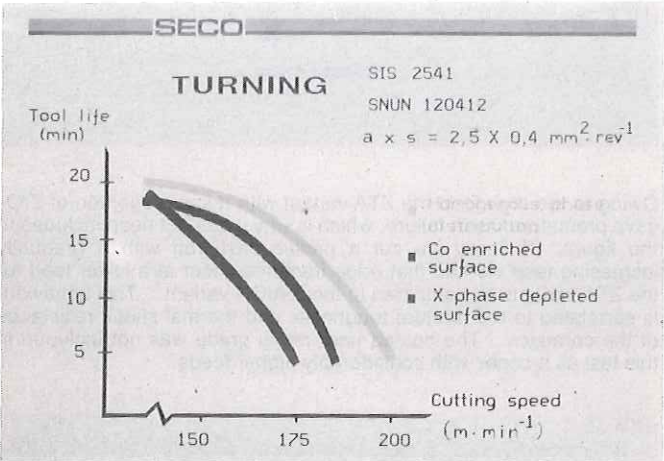


When a surface coated hard metal is loaded the coating cracks for a low load and we get a "precrack" as big as the thickness of the coating (14). It follows from fracture mechanics that the alloy can stand an increasing load before fracture, if we increase  $K_{IC}$  in the surface zone, which increases the ability of the material to prevent growth of cracks by plastic blunting and energy dissipation at the crack tip. In order to verify this, a comparison can be made of the edge strength for three of the variants in a slotted bar machine test, an interrupted turning test which demonstrates the improvement in edge strength due to surface roughening :



The test was run over a range of feed rates from 0.1 to 1.25 mm rev<sup>-1</sup>. For each feed rate the machined length was 1 cm. The fracture probability curves show that a tangible increase of the edge toughness is obtained in the surface-toughened variants. This is completely in agreement with the results Nemeth (15) has reported for cobalt enriched surface layers.

There is however a drawback with tough surface zones : owing to increased deformation and lower wear resistance in the surface zone of the substrate the surface-toughened variants also display a greater wear, particularly at increased cutting speeds, as compared to the homogeneous variant. This can be seen by observing the tool life during the turning of a hardened and tempered steel as a function of the cutting speed.



On the analogy of the development that took place of the uncoated grades at the end of the 1960's coated grades suited to specific cutting problems are now being developed. It is possible to produce from the same basic analyses substrates with different phase distribution in a thin surface zone compared to the bulk. In this way coated hard metals with completely different properties and applications can be obtained from the same basic analysis.

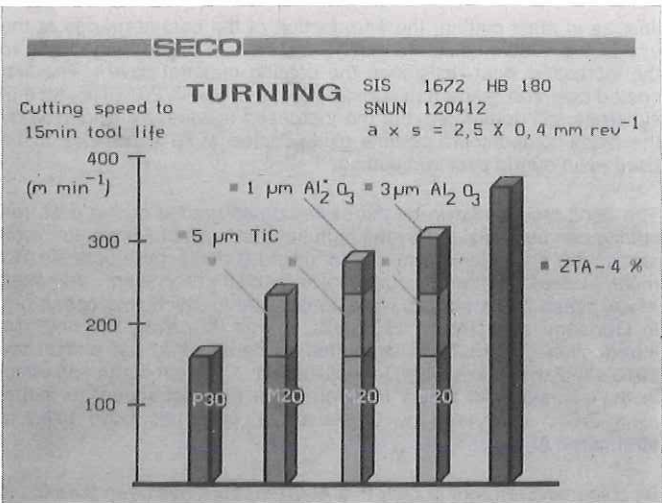
The mechanical properties of the different variants are given as follows :

Grade	HV (GNm <sup>-2</sup> ) 10 μm from surface	TRS (MPa)	$K_{IC}$ (MPa m <sup>-3/2</sup> )		"ISO-equivalent" surface zone
			Measured	Calculated for surface zone	
γ-phase enriched surface .....	16.4	1670	10.8	8.8	M 10-P 10
Homogeneous phase distrib- ution .....	15.8	2040			M 20
γ-phase depleted surface .....	13.5	2240		11.9	K 30
γ-phase enriched surface .....	12.1	2510		13.3	M 40-P 40

The microhardness has been measured for a load of 100 grams. The transverse rupture strength constitute the average value for 20 unground bars measured in accordance with the ASTM B 405-70 standard. For the fracture toughness measurement the short rod fracture toughness tester from Terra-Tek was used (12). By assuming that the defect size in the different materials is the same, which is a reasonable assumption as the defect size is determined by the manufacturing process, we have using Griffith's theory (13) calculated the inherent strength,  $K_{IC}$ , in the surface layer of the different variants. The defect size 7.3 μm has been estimated by putting in Griffith's formula the values measured for  $K_{IC}$  and TRS for the variant with a homogeneous phase distribution. The calculated  $K_{IC}$ -values indicate that by starting from a M 20 analysis we can produce grades with surface zones having toughness values ranging from M 10/P 10 to M 40/P 40.

This development indicates that it is no longer the basic analysis of the hard metal that determines its substrate properties. By manipulating the sintering the different phases can be directed to or from the active part of the tool, which is the edge.

Rapid progress has been made as regards coating technique since the TiC coated variants were introduced in 1969. The  $v_{15}$ -value, which gives the possible cutting speed for a tool life of fifteen minutes, has increased from 160 m min<sup>-1</sup> for the uncoated variants to 310 m min<sup>-1</sup> for the latest oxide-coated variants.



This increase in cutting speed translated into an increased length of life means that with the oxide-coated variant you can turn for 21 times as long a time as with the uncoated variant at a cutting speed of 160 m min<sup>-1</sup>. As the coated hard metals can also be used for higher feed rates than the uncoated variants it is evident that the increase in demand for hard metal inserts must be very large in order to allow a growth in volume of cutting tips.

It is estimated that the coated tools today account for about 70 % of the number of turning inserts. The saturation limit for coated inserts in turning has been estimated to approximately 85 % (3). We can therefore in the future only expect a slight increase in the proportion of coated tools. This does not mean however that the decrease in volume will stop. A continuous switch-over is now taking place from carbide and nitride coated grades to oxide coated ones, which has a negative effect on the volume development. In addition, we can see a slight increase of cermets in operations that require sharp edges, which cannot be obtained with coated grades.

The number of brazed tips that in 1970 would probably have been equivalent to more than half the tool potential is now most likely less than 20 per cent. As the machine tools in the engineering industry are renewed the proportion of brazed tips decreases rapidly. The above chart shows the oxide coated tool materials approaching the ceramic materials as far as performance is concerned. Even if a



change-over to ceramic tool materials could theoretically result in large gains in productivity, it is unlikely that these materials will achieve any great significance in steel turning in the near future. The reason for this is partly because of their low fracture toughness, partly because of problems connected with producing chip breaker inserts with a suitable clamping. The coated hard metal inserts will therefore continue to dominate the turning of steel in the foreseeable future.

## TURNING OF CAST IRON

Cast iron is noted for the rapid tool-wear characteristics which it exhibits when machined. The rapid wear probably results from two sources: the graphite in the metal and the scale on the surface of the casting. The scale on cast iron often contains both iron oxide and entrapped particles which make this scale very abrasive. The scale thus severely tests the wear resistance of the tool material.

Turning of cast iron was, up to the end of the 1960's, dominated by fine-grained WC-Co grades in the K 01-K 20 group. Small additions of TaC have been used mainly for the purpose of grain size regulation. These grades display a high resistance to abrasive wear at moderate cutting speeds, which has made them useful for both the finishing and roughing of alloyed and unalloyed cast iron.

Just as in steel cutting, the introduction of the coated grades at the end of the 1960's caused a distinct increase in productivity owing to the increased wear resistance the coating material gave. The first coated cast iron grade had substrates of the type K 20. This type of substrate still dominates, but the increased universality displayed by the oxide-coated tools permits oxide-coated M 20 substrates to be used even during cast iron cutting.

The good results shown by the oxide-coated grades during cast iron cutting can be explained by the high hot hardness of aluminium oxide and its low solubility in iron. This indicates that a pure ceramic tool material would be the optimum choice for cast iron cutting. Although  $Al_2O_3$  based tool materials were considered in machining operations in Germany as early as 1905 (16), it was, however, not until the introduction of dispersion strengthened ceramics at the end of the 1970's that they gained a wider application. The strengthening effect in the enantiotropic phase transformation from tetragonal to monoclinic  $ZrO_2$ , discovered by Garvie et al. (17), has been used to strengthen  $Al_2O_3$ .

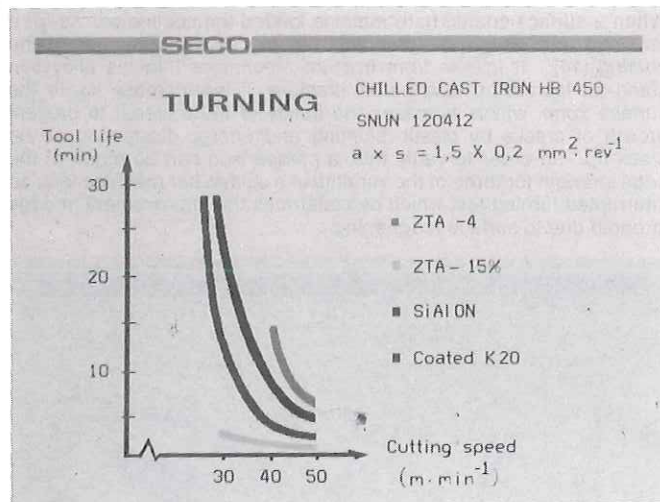
By dispersing tetragonal  $ZrO_2$  in a  $Al_2O_3$  matrix it has been possible to raise the fracture toughness considerably, which has improved the performance of the  $Al_2O_3$  tool material (18, 19, 20). By means of transformation toughening a higher load can be supported, compared to that of a conventional ceramic, for the same crack geometry. A crack propagates, however, as disastrously in both variants. It is therefore not a question of a ductilization of the material.

There are on the market today two main groups of zirconia toughened alumina (ZTA), a wear resistant variant with about 4 wt. %  $ZrO_2$  and a tough variant with about 15 wt. %  $ZrO_2$ . An increased proportion of  $ZrO_2$  increases the toughness but at the same time lowers the hardness.

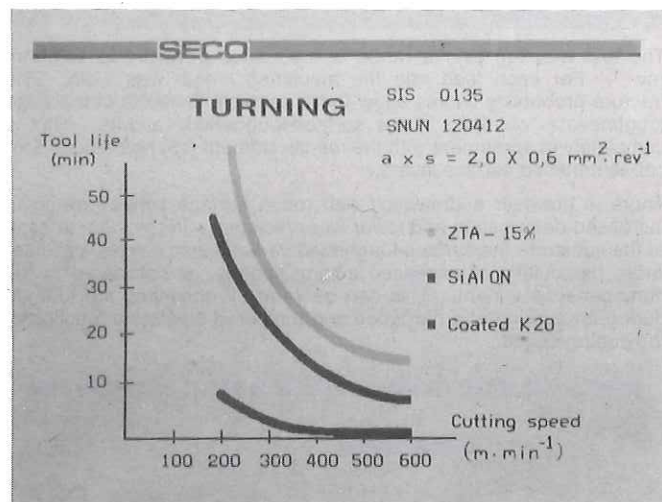
A further step in the development of the ceramic tool materials was taken at the beginning of the 1980's with the introduction of SiAlON ceramics (21). SiAlON's are solid solutions of metal oxides such as  $Al_2O_3$ ,  $Y_2O_3$ ,  $MgO$ ,  $BeO$  and others in  $Si_3N_4$ . The potential possibilities of using  $Si_3N_4$  in tool materials was investigated by Whitney et al. (22) as early as in the 1960's, but production technique had then still not been developed. The  $Si_3N_4$  based tool materials are, as regards toughness and wear resistance, comparable to the tough ZTA materials, but they also possess a very high thermal shock resistance because of the low thermal expansion coefficient of  $Si_3N_4$ .

In order to prove the potential of the ceramic materials in the turning of cast iron a comparison has been made between two zirconia toughened alumina grades with 4 and 15 wt. %  $ZrO_2$  respectively, a SiAlON with 94 wt. %  $Si_3N_4$ , 5 wt. %  $Y_2O_3$  and 1 wt. %  $Al_2O_3$  and a K 20 alloy coated with 4  $\mu m$  TiC and 3  $\mu m$   $Al_2O_3$ .

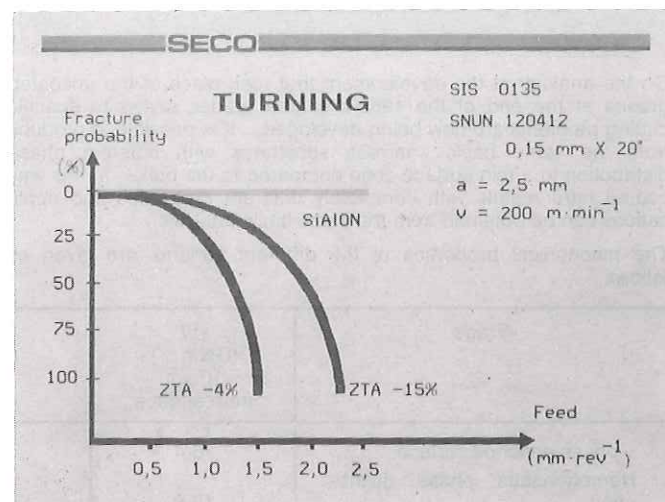
The wear resistance of the ceramic tool materials was determined by turning a cast iron with a hardness of 450 HB. The wear criterion was insert breakage. The tool life curves below show that the ZTA variant with a high proportion of  $ZrO_2$  has the shortest length of life and that the one with a low proportion of  $ZrO_2$  has the longest length of life. This can be explained by the fact that  $ZrO_2$  has a very low hardness compared to  $Al_2O_3$ . The SiAlON-variant and the coated hard metal occupy an intermediate position to both the ZTA-variants. In this cutting test high edge hardness is rewarded.



If instead we cut a perlitic cast iron with HB 200 with an increasing cutting speed we find that the ZTA-variant with a high proportion of  $ZrO_2$  displays the highest length of life. In this test the wear takes place with a thermochemical mechanism which leads to a very rapid wear of the coated hard metal at high cutting speeds due to deformation and diffusion wear.



Owing to the high feed the ZTA-variant with a low proportion of  $ZrO_2$  gave premature insert failure, which is why it has not been included in the figure. If finally we cut a perlitic cast iron with a gradually increasing feed we find that edge fractures occur at a lower feed for the ZTA variants as compared to the SiAlON-variant. This behaviour is correlated to the fracture toughness and thermal shock resistance of the ceramics. The coated hard metal grade was not included in this test as it copes with considerably higher feeds.



The results shown may give the idea that ceramic tool materials could entirely replace hard metals. This is however still not possible. In



many cutting operations where the cutting forces have to be kept down, for instance in the turning of thinwalled work pieces, positive cutting geometries are necessary and the ceramics produced today cannot meet this requirement because of insufficient toughness. Nevertheless, in our estimation, the new ceramics will be the entirely dominating tool materials in the mass production of brake discs, brake drums, flywheels and similar parts during the 1990's, when the machine tools industry has had time to adapt to the new tool materials.

(The second half of this presentation which covers milling and the development of demand for tantalum will be published in the next issue of the T.I.C. Bulletin.)

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## Exploration for tantalum in Sweden

The following article has been based upon a presentation made by Mr. Dag Bjurström, of Axel Johnson Ore and Metals AB, at the Twenty-first General Assembly of the T.I.C. in Stockholm on June 5, 1984.

Element number 41 was discovered by Hackett, an English chemist, in 1801 while analysing the mineral columbite. He named the new element columbium. In the next year, 1802, the Swedish chemist Ekeberg discovered a new metal oxide in the mineral tantalite. Ekeberg called this new element "tantalum" after the Greek god Tantalus.

Columbium and tantalum were believed to be the same element for several years. In 1844, however, Heinrich Rose showed that both columbite and tantalite contained two different elements, namely niobium and tantalum. The name "niobium" was chosen for the then believed new element after the goddess Niobe, the daughter of the god Tantalus. It soon became known that columbium and niobium were the same element but it was not until 1949 that it was agreed internationally that niobium would be used for the name of element 41 rather than columbium.

The history of discovery and the early confusion between columbium from columbite and niobium from tantalite imply that both tantalum and niobium carry several geochemical similarities. This is borne out by their position in the periodic chart of elements.

Therefore, it is reasonable that tantalum and niobium should occur together commonly in nature.

Tantalum-niobium deposits can be classified in many ways, for example, by their mode of origin, by their form and by their mineralogy. From a geological viewpoint a genetic classification is most desirable. A classification established by Rowe for Canadian deposits is certainly of use in other areas.

### Classification of Niobium - Tantalum Deposits

- A. Deposits associated with or derived from granitic rocks.
  - (1) Deposits in granite.
  - (2) Granitic pegmatite deposits.
  - (3) Eluvial deposits.
  - (4) Placer deposits.
- B. Deposits associated with or derived from alkaline rocks.
  - (1) Deposits in alkaline silicate rocks.
  - (2) Deposits in carbonate rocks.
  - (3) Syenitic pegmatite deposits.
  - (4) Deposits in fenites.
  - (5) Eluvial deposits.
  - (6) Placer deposits.

The deposits of major importance are those in pegmatites, alkaline rocks, carbonatites and the placer deposits derived from these.

There are many tantalum/niobium minerals which can be of economic importance. Oxides such as columbite, tantalite and pyrochlore are, however, most common. Associations with rare-earth metals and uranium sometimes occur.

Looking at the important tantalum deposits in the world it can be observed that many are associated with tin-bearing pegmatites. Examples of this are the Greenbushes deposits in Western Australia, the Phuket Island area of Thailand and many of the pan-African pegmatites, especially those in Nigeria and Zambia. The close relationship between niobium and tantalum with tin in pegmatites, whether as primary or secondary occurrences, is clearly demonstrated in terms of the production of tantalite. In 1983, as an example, a major part of the world tantalum production was derived as a co-product or by-product of tin mining and smelting.

In desert areas and in humid regions with strong weathering, placer deposits are by far the most important.

Alkaline rocks and carbonatitic complexes with pyrochlore are other important sources. A number of occurrences are, or have been, mined such as Oka in Quebec, Arasha in Brazil, Palabora in South Africa, Lueshe in Congo and Khibina and Kovdor in the Kola peninsula.

The Lake Nipissing deposits in Ontario are associated with syenites while loparite is the characteristic niobium mineral in the Russian Lovozero massif, an occurrence considered to be the largest for niobium and tantalum in the U.S.S.R.

Summarizing, niobium and tantalum occur in many different geological situations. Among them, tin-niobium-tantalum-pegmatites, as well as pyrochlore occurrences, seem to be of the greatest value.

The prospecting technique for these metals is, of course, dependent on their very different mode of occurrence. As in other explorations, high quality geological maps are most necessary. In that many occurrences are associated with radioactive minerals, radiometric surveys should be of great use.

Complexes with alkaline rocks, perhaps with mafic derivatives, and carbonatites can often be detected by airborne magnetic surveys.

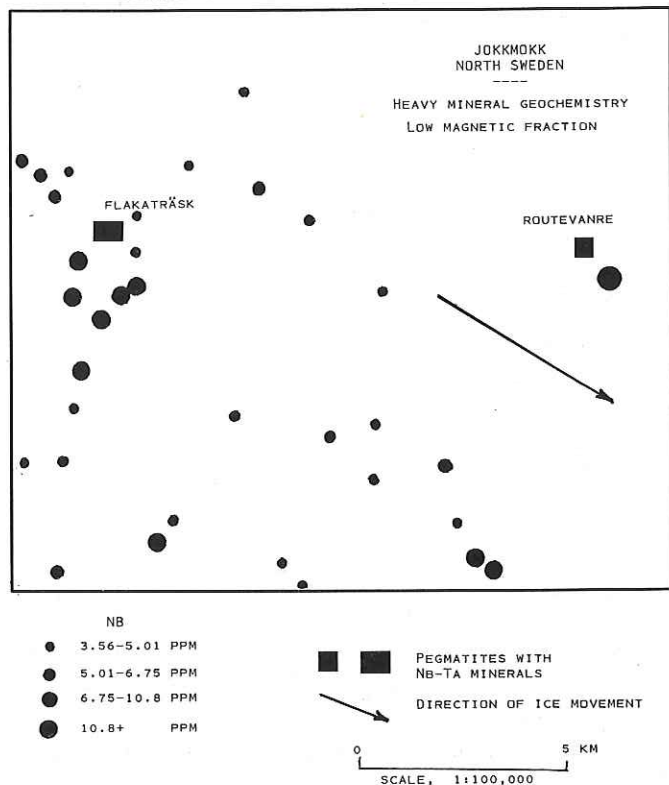
In combination with ground geophysical measurements, useful structural information can be obtained. Heavy-mineral geo-chemistry has been successfully applied in situations where geological or geophysical information is poor. Thus, heavy-mineral concentrates from soil samples in combination with litho-geochemical studies have been a very successful prospecting method.

The Swedish history of mining is both long and successful when considering base-metals and iron. Indeed, the Swedish mining industry involves several famous mines and mining companies. Its

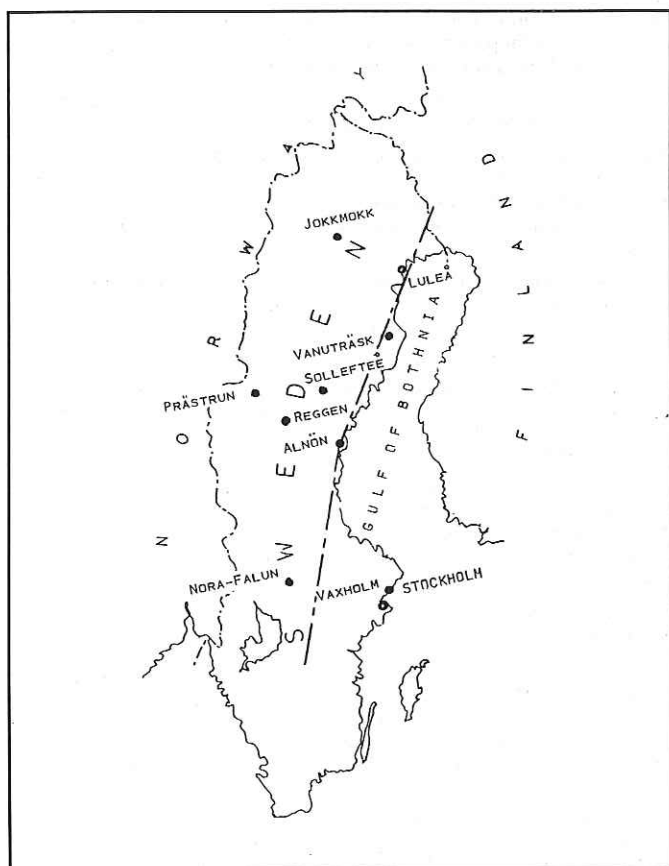


technology has resulted in innovative exploration techniques used on a worldwide basis. Names such as Falun, Sala, Boliden, LKAB, Atlas Copco and so on are well known to everyone engaged in the metal and mining industries. Rather little is known, however, about niobium and tantalum in Sweden. Therefore, the question is rather open as to whether there are significant possibilities of finding niobium/tantalum deposits in Sweden. This situation is unsatisfactory in that Sweden is a major consumer of tantalum and niobium due to the large production of hard metals and alloy steel.

Some smaller occurrences do exist as shown in this area map of a small section of northern Sweden.



Looking at the entire country, a rather interesting zone occurs in and about the northeast to southwest tectonic belt along the eastern coast of the Baltic Sea.



The prospecting for alloy metals, and especially for tantalum, is, of course, still very young and some of the occurrences shown may indicate that there are really some interesting situations and target areas. The well known carbonatite on the island of Alnön (see the map) is the largest potential reserve in Sweden. The content of tantalum, however, is rather low. A newly discovered occurrence in Prästrun was discovered by radiometric surveys. The economic potential of this deposit is not known at the moment. Occurrences of the same type have been found in both Norway and Finland.

In conclusion, the possibilities of discovery of new niobium/tantalum deposits in Sweden will therefore be :

1. Modern and effective prospecting methods do exist and the combination of radiometric surveys with heavy-mineral geochemistry could be very useful.
2. There are some interesting geological situations which could evolve more niobium-tantalum than that which is known today. These situations are complex pegmatites, carbonatitic massifs and alkaline intrusions.

## Statistics

### TANTALUM PRODUCTION AND SHIPMENTS

(figures for the first quarter are given for reference)

Quoted in lb.  $Ta_2O_5$  contained

	Production	Shipments
1984 - 2nd quarter		
Tin slag	220,257	424,504
Tantalite under 25 % $Ta_2O_5$	19,024	28,470
Tantalite over 25 % $Ta_2O_5$	94,701	54,389
Other materials	22,997	7,507
<b>Total</b>	<b>356,979</b>	<b>514,870</b>

1984 - 1st quarter

Tin slag	226,705	46,452
Tantalite under $Ta_2O_5$	13,319	8,267
Tantalite between 25 % and 60 % $Ta_2O_5$	56,312	66,075
Tantalite over 60 % $Ta_2O_5$	9,471	31,244
Other materials	9,259	Nil
<b>Total</b>	<b>315,066</b>	<b>152,038</b>

Note : 2nd quarter : 22/25 companies reported  
1st quarter : 19/26 companies reported

### TANTALUM PROCESSORS' SHIPMENTS

(figures for the first quarter are given for reference)

Quoted in lb. tantalum contained

	2nd quarter	1st quarter
1984		
Tantalum oxide	29,000	27,471
Alloy additive	25,776	29,130
Carbides	158,758	124,411
Powder/anodes	271,307	257,066
Mill products	98,778	82,160
Scrap	41,053	
Ingots, unworked metal, other	31,778	88,812
<b>Total</b>	<b>656,450</b>	<b>609,050</b>

Note : 2nd quarter : 17/19 companies reported  
1st quarter : 19/19 companies reported

## 1983 U.S. shipments of tantalum and columbium products

The available data for shipments of tantalum products by the processors in the United States in 1983 show an increase from 1982 of 15.3 % which seems to clearly indicate that the consumption of tantalum is again on the upswing.

PRODUCT	1979	1980	1981	1982	1983
<b>TANTALUM</b>					
Oxides and Salts	35.4	48.7	50.7	36.5	14.2
Alloy additive	23.7	8.1	—	31.7	104.0
Carbide	190.1	125.7	137.2	82.2	114.2
Powder and anodes	928.2	852.9	520.2	451.1	503.8
Ingot	6.6	23.0	7.1	16.7	5.7
Mill	365.2	318.8	196.7	168.0	214.1
Scrap	151.0	130.9	72.7	94.5	59.7
Other	—	1.7	—	—	—
Total	1,700.2	1,509.8	984.5	880.7	1,015.7
% Change	12.2	(11.2)	(34.8)	(10.5)	15.3
<b>COLUMBIUM</b>					
Compounds	1,627.8	1,066.6	632.2	562.7	1,049.5
Metal	329.5	344.7	260.5	355.4	424.4
Miscellaneous	64.2	18.5	20.5	29.7	20.0
Total	2,021.5	1,429.8	913.2	947.8	1,493.9
% Change	9.4	(29.3)	(36.1)	3.8	57.6

Although there was a significant gain in 1983 over 1982, the total quantity of product shipped by the U.S. processors is the least in a non-recession year since the beginning of the 1970 decade. The rebound from the recession is more like that in 1972 when shipments increased only 13 % over 1971 rather than the rebound in 1976 when shipments increased 50 % over 1975. The difference from the 1975 recession, however, could well be the result of the current recession carrying over to the middle of 1983. This is substantiated, as an example, by the fact that the unit shipments of capacitors in the fourth quarter of 1983 were 36 % greater than they were in the first quarter of 1983. Thus, it may be expected that total shipments of tantalum products in 1984 will be greater than those in 1983 as the recovery is sustained.

The recovery is evident in each of the principal product classes, powder and anode increasing by 11.7 %, carbide increasing by 38.9 %, mill products increasing by 27.4 % and alloy additive increasing by 228.7 %. The use of tantalum as alloy additive has become a major item of consumption representing 10.3 % of the total shipments. This may reflect only a greater use of virgin tantalum by the superalloy melters and a reduction in the use of prime scrap. It is evident that the accumulation of prime scrap in the hands of the processors has dwindled as the sales of such by the processors in 1983 amounted to only 5.9 % of total shipments as compared to 7.4 % in 1981 and 10.7 % in 1982. In any case, the use of tantalum in superalloys remains a strong segment of the total tantalum market.

Even though the general economy in the United States has recovered from the recession, the effect of reducing the use of prime tantalum by the capacitor and the hard-metal industries is evident. Shipment of powder and anodes at 503,000 lb. is no greater than it was at the beginning of the 1970 decade. Even if capacitor shipments during 1984 are sustained at the level of the fourth quarter of 1983, the 1984 shipments of powder and anodes can be expected to reach only about 575,000 lb. This quantity is only 60 % of the shipments in both peak years, 1974 and 1979. The effect of the trend to smaller capacitors on the use of tantalum is thus confirmed.

Although shipments of all columbium products have recovered to the level of 1980, the amount of columbium metal used has reached an all time high continuing the steady trend. The annual growth since 1972, after the Dynosaur Project was terminated, has averaged 13.8 % per year. Considering the difference in density between columbium and tantalum, the volume of columbium metal alone shipped by the U.S. processors has reached, in 1983, 80 % of the volume of tantalum. The volume of all columbium products, on an equivalent metal basis, reached 2.85 times the volume of tantalum. The ratio of columbium to tantalum, on a weight basis, reached 1.47 in 1983, the highest level during the more than fifteen years for which these data have been available, indicating the growing importance of columbium as a product for the tantalum processors.

## Capacitor statistics

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

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

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

(Data from Electronic Industries Association)

Type	Manufacturers	Distributors	Export	Total
<b>1st quarter 1984</b>				
Foil.....	256	84	11	351
Metal cased solid.....	52 041	13 855	16 962	82 858
Non-metal cased solid.....	149 809	30 683	21 673	202 165
Chips.....	6 596	37	2 756	9 389
Wet slug.....	2 195	794	341	3 330
Total.....	210 897	45 453	41 743	298 093
<b>2nd quarter 1984</b>				
Foil.....	250	90	8	348
Metal cased solid.....	54 749	15 101	15 011	84 861
Non-metal cased solid.....	152 856	26 961	24 008	203 825
Chips.....	8 593	111	3 092	11 796
Wet slug.....	2 476	925	403	3 804
Total.....	218 924	43 188	42 522	304 634

### JAPANESE TANTALUM CAPACITOR SALES (THOUSANDS OF UNITS)

(Data from Japanese Electronic Industry Development Association)

	Production	Of this, export
1st quarter 1984 .....	479 731	105 431
2nd quarter 1984 .....	516 107	121 967



## Seco Tools

To illustrate further the technical paper by Mr Snell and Mr Nordlund, the following photographs show tools at work and the testing and development area at the Seco Tools factory :

