# THE PRODUCTION AND USE OF VANADIUM WORLDWIDE

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**1. Introduction**

Vanadium, a member of Group V of the periodic table, has atomic number 23, atomic weight 50.942, melting point 1887℃ and boiling point 3337℃. In its pure state it is brilliantly White, is hard and has a body-centred cubic structure, of lattice parameter 3 .024Å. It is the seventeenth most commonly occurring element in the earth's crust and is hardly ever used in its own right. Vanadhan is, however, an invaluable alloying element in iron steel and Ti-Al-V alloys for aerospace uses. Its compounds are also very useful in a diverse range of other applications extending from catalysts, to ceramics, to pigments, to batteries etc.

Based on this diverse range of uses a worldwide industry aimed at recovering and using vanadium has developed. This industry exists on most of the world's continents and it is the purpose of this paper to give some background information on the sources, production and use of vanadium.

**2. Sources**

As noted above, vanadium is the seventeenth most commonly occurring element in the earth's crust and it has very wide distribution throughout the globe. Some of the mere important deposits are shown in Figure 1. These deposits include the titaniferrous of China, Russia, South Africa, Western Australia and New Zealand, as well as the oil-related deposits of Venezuela, Alberta-Canada, the Middle East and Queensland-Anstralia, in addition to ore and clay deposits in the USA.


● Magnetite/Iron Sands ■ Oil Based ◊ Phosphorous Ores Uranium Ores ◊ Vanadiferous Clays

Fig 1. Main Deposits of Vanadium

At present the most important deposits are the titaniferrous magnetites which can contain up to, perhaps, l.8% $V_20_5$ followed some way behind by the oil-based deposits. As far as is known, no significant recovery of vanadium is presently obtained from the ores and clays in the USA, the titaniferrous magnetites of Scandinavia or from the deposits in Brazil and Chile.

Table 1 [l] gives an indication of the world's exploitable reserves and the reserve base. The exploitable reserves are those which are deemed to be economically viable using existing technology. The reserve base contains those which may become viable at some future date, possibly using as yet undeveloped technology. Of the 63 million tonnes V of total reserves which are available, just over 1 0 million tonnes V are in the exploitable reserves, With a further 31.1 million tonnes V in the reserve base. Table I also shows that the vast majority of the exploitable reserves are contained within the titaniferrous magnetites of China, Russia and South Africa.

**Table I. Commercially Exploitable reserves and Reserve Base**

| | Commercially Exploitable reserves (10.2mt) % | Reserve Base (31.094mt) % |
|---|---|---|
| Australia | 1.6 | 7.7 |
| China | 19.6 | 9.6 |
| Russia | 48.9 | 22.5 |
| South Africa | 29.4 | 40.2 |
| U.S.A | - | 12.9 |
| Others | 0.5 | 7.1 |

It is also worth noting that, at the current rate of usage of Vanadium, the exploitable reserves will last for almost three hundred years.

## 3. Recovery of Vanadium

In most cases, the primary Production of vanadium is as a by-product associated with the extraction or use of other metals and oil. This production of Vanadium is almost always as an oxide, either $V_20_5$ or $V_20_3$. There are three important routes for recovery and these are summarised in Figure 2.

In the most important route, Vanadium is recovered as $V_20_5$ contained in an intermediate slag which is formed between ironmaking and steelmaking in integrated steelworks, such as at Panzhihua in China, Highveld in South Africa and Nzhny Tagil in Russia. At these steelplants the Vanadium contained in the iron ore is taken into solution in the iron during the ironmaking process. The hot metal is then oxidised and a slag, which contains between 10% and 25% $V_20_5$, is formed and removed before the hot metal is passed on for final steelmaking. The slag containing l0-25% $V_20_5$ is then treated in a roast/leach process, the end product of which is Vanadates or Vanadium oxides. Between 50% and 60% of the world's primary Vanadium units are recovered in this manner.

The second most important route for recovery of primary Vanadium involves the direct treatment, in a roast/leach process, of ore which, as mentioned above, can contain up to 1.8% $V_20_5$, once again producing vanadates or Vanadium oxides. There are five or six companies, mainly in South Africa and Australia, involved in this type of processing and it probably accounts for 25-30% of the world's supply of primary Vanadium units.

The third route for recovery involves reclamation of Vanadium contained in the ash from power plants, in spent catalysts and in other residues. Processing is, once again, by roast/leach to form Vanadates and oxides and, in the case of catalysts, is frequently associated with the co-recovery of cobalt, molybdenum and nickel. This route for recovery accounts for l5-20% of the world's supply of Vanadium and involves eight to ten companies, mainly in North America and Japan. However, as environmental legislation becomes tougher, increasingly ruling out the possibility of dumping the waste materials which contain Vanadium, it is expected that this area of recovery will grow and will account for at least some of the feedstock at most, if not all, primary Vanadium producers.

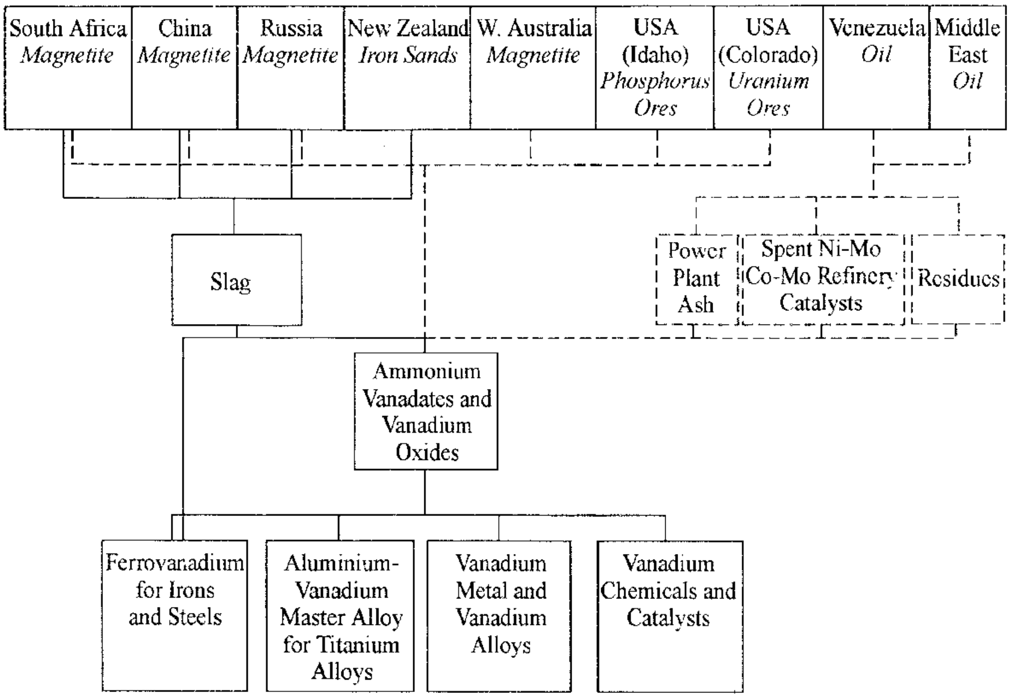


Fig. 2. Recovery of Vanadium

The world capacity for Production of primary Vanadium as vanadates and oxides, is believed to be of the order of 127000 tonnes of $V_2O_5$ and a breakdown, by region, is shown in Table II.

This clearly indicates the important roles played by China, Russia and South Africa in thc recovery of vanadium, as well as the less important role played by Japan. It is also notable that there is no significant primary production of Vanadium in Europe.

**Tabale Ⅱ World Capacity for Production of Primary Vanadium**

| Country/Region | Estimated Production Capacity % |
|---|---|
| Australia | 5.8 |
| China | 18.4 |
| Japan | 1.3 |
| N. America | 14.1 |
| Russia | 18.6 |
| S. Africa | 37.7 |

After primary recovery, most of the Vanadium is converted by alumino-thermic, thermal or chemical means, into the products which are used worldwide including FeV, V-Al master alloys, Vanadium chemicals and catalysts and also some Vanadium meal and alloys. Such conversion activities, involving over 25 companies, take place in every industrialised region of the world, with the emphasis moving away from countries which are primary producers, to countries which are consumers. This is illustrated in Table III from where it can be seen, for example, that Europe which did not figure in the list of primary producers, does have significant conversion activities. Furthermore, Japan and North America have significant conversion activities while South Africa and China both have lower levels of conversion than might be expected from their levels of primary recovery.

It should also be noted that some Vanadium-containing steelmaking slag is converted directly to FeV without being processed in a roast leach process. However, this is very much a minor route.

## 4. Consumption of Vanadium

During 1999, estimated consumption of Vanadium was 33,250 tonnes V. An estimate of the geographical distribution for this consumption along with the distribution of primary production of Vanadium for 1999 is shown in Table IV. Comparison of the table with Table III emphasises that Vanadium conversion tends to take place close to areas of consumption. It also suggests that there is a significant international trade in primary Vanadium units with China, Russia and South Africa being the main suppliers and Japan, North America and Europe being the main consumers. At the end of 1999 beginning of 2000 Australia also joined the supply chain and is expected to contribute approximately 13% to world production of Vanadium.

**Table III. Geographical Distribution of FeV Conversion Production Capacity in 1999**

| Country/Region | Estimated % of World Production Capacity for FeV |
|---|---|
| China | 13.5 |
| Japan | 14.9 |
| N. America | 18.6 |
| Russia | 19.0 |
| S. Africa | 22.0 |
| W. Europe | 26.0 |
| Others | 5.3 |

**Table IV. Geographical Distribution of Consumption of Vanadium and Primary Production of Vanadium, in 1999**

| Country/Region | Estimated % of World Consumption, in 1999 | Estimated % of World Production, in 1999 |
|---|---|---|
| China | 9.3 | 20.1 |
| Japan | 12.8 | 2.2 |
| N. America | 30.3 | 12.2 |
| Russia | 7.7 | 14.5 |
| S. Africa | 1.0 | 45.5 |
| W. Europe | 25.9 | 2.6 |
| Others | 13.0 | 2.9 |

While Vanadium is utilised in a wide range of industries, by far the most important consumer is the steel industry. Data compiled by the US Geological survey indicates that, in l998, 87% of Vanadium recovered was used by the steel industry, while the remaining 13% was consurned in a range of industries including aerospace, chemicals and catalysts. Of this 13%, around 8-l0% was probably utllised in the manufacture of Ti-Al-V alloys for aerospace applications with the other applications being responsible for the remainder.

As can be noted from Figure 3 (a) and (b), as steel production has increased, so has vanadium consumption. However, it is also apparent from comparison of these figures that, recently, Vanadium consumption has increased more rapidly than steel production. indicating new consumption. A good indication of this new consumption can be obtained by dividing total Vanadium consumption in any one year by crude steel production in that year. While this indicator may overestimate the specific consumption of vanadium by about 13%, it does have the attribute of tending to iron out the effects of variability in steel manufacture from one year to the next.

Figure 4 shows the change in specific consumption of Vanadium since the late 1970's, up to the present day. The important point to note is that, after a period of relative decline in the 1980's and early 1990's, which was probably due to the wide application of continuous casting with its improved yield and the general moves to improve steelmaking efficiency, new consumption of Vanadium has recovered Strongly to reach a world average of 0.043kg/T in 1999, the average in the West being some 16% higher at 0.05kg/T.

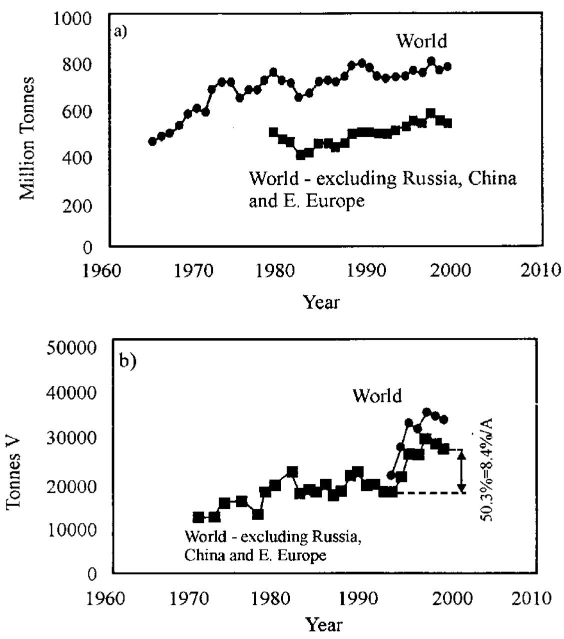


Fig 3. a) Steel Production and b) Vanadium Consumption for 1960 to 1999

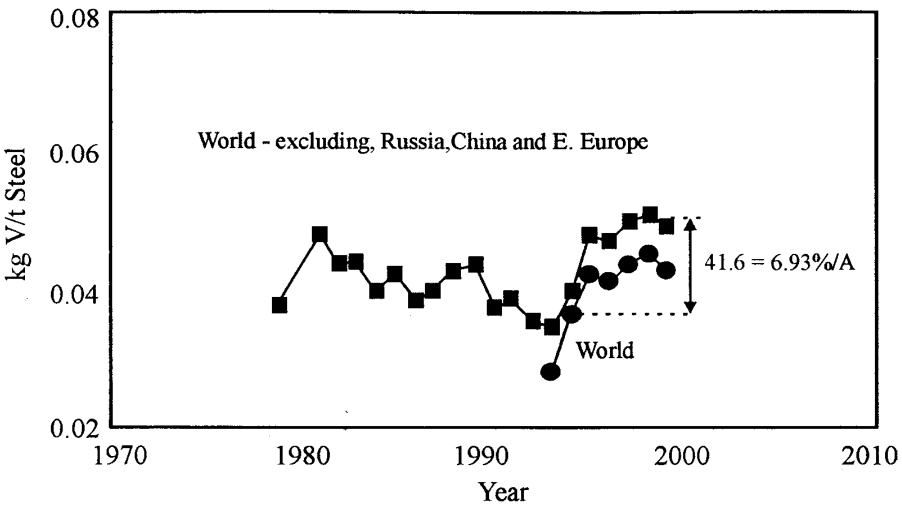


Fig. 4. Change in Specific Consumption of Vanadium Since 1970

**5. Use of Vanadium in Steel**

Examination and comparison of some of the available Statistics on the use of Vanadium in Steel from three different steelmaking countries, ie, Germany, Japan and the USA (Figure 5), indicates that there are both similarities and apparent differences in the pattern of use of Vanadium in these countries.

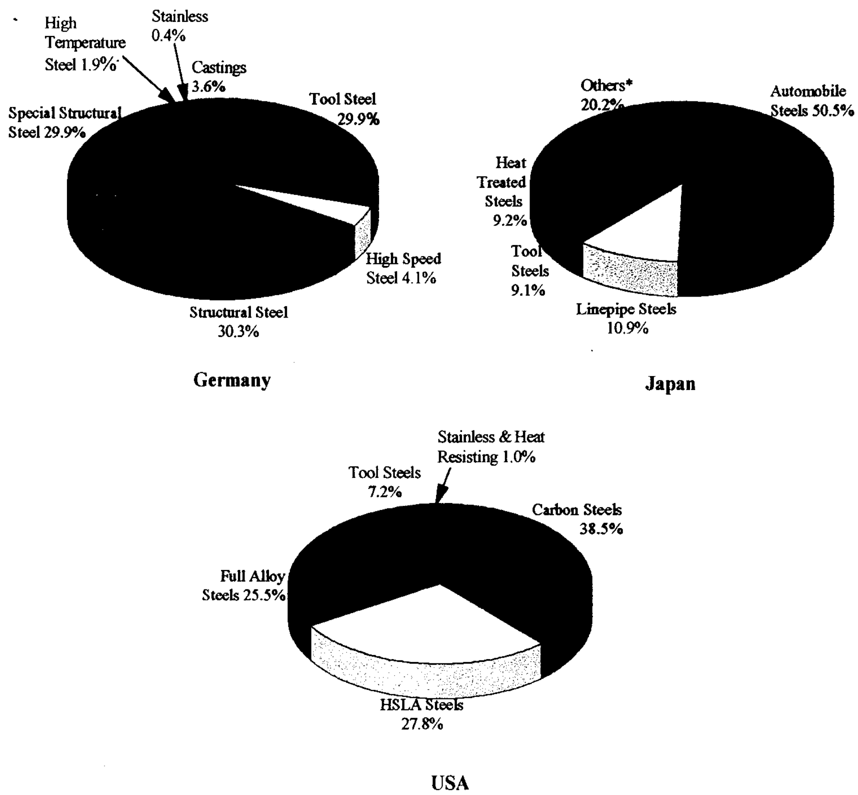


Fig. 5. The Consumption of Vanadium, by End Use, for Germany, Japan and USA, in 1998
Including Shipbuilding, Heat Resistant, Forging & Rebar Steels

It is clear that Vanadium is used in tool steels in all three countries. On the other hand, the German category for special Structural steels do not appear to be repeated in Japan, or the USA. However this category includes linepipe (Japan) which is an HSLA Steel (USA) and, consequently such use of vanadium is also similar in all three countries.

Despite these similarities and possible differences, the important facts to recognise are that when vanadium is added to steel it is because it results in a benefit to steel production (low reheating temperatures, reduction in transverse cracking, reduction in rolling loads, properties relatively insensitive to rolling conditions etc) and/or an improvement in properties (strength, toughness, ductility, formability, weldability, wear resistance etc) leading to a reduction in cost. This reduction in cost may not only be that of the steel but also of the products manufactured using the steel, eg. buildings, bridges, ships, cars, railroads etc.

During the remainder of this seminar it is hoped that you will hear about many examples Where vanadium can assist you, as Steelmakers, in realising these production, property and cost benefits.