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The Availability and Marketing of Vanadium

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The major use of vanadium is still as a micro-alloy in steel. Vanadium is abundant in the earth's crust in many forms, but the main sources at present are magnetite ores in South Africa, the USSR, and the People's Republic of China. The largest quantities arise in co-product steelworks producing iron and vanadium.

The key step in the vanadium production–usage chain is the production of the oxide form, generally fused vanadium pentoxide. The price stability of the vanadium market hinges on this stage and, while co-product or by-product producers can withhold large volumes for a period, the main strain falls on the smaller producers, who need to moderate their production rates as well if producers are to have adequate ability to respond to rapid changes in supply and demand.

Too fragmented an industry can be a disadvantage, but there need be no concern about reliable supplies from South Africa.

There is a need for market development, both by individual producers of final products and also through the Vanadium International Technical Committee (VANITEC). Changes in the USSR and the People's Republic of China are impossible to predict but, in the longer term, could be beneficial to vanadium.

Introduction

The object of this paper is to establish a broad perspective on the vanadium business and draw some logical conclusions. As such, it will be superficial in some respects in order not to cloud the main issues.

Uses of Vanadium

Henry Ford used vanadium in the crankshafts of his early automobiles, and the primary use of vanadium is still as an alloying element in steel, where it gives additional strength and toughness. This use can be subdivided into micro-alloyed or low-alloy steels, which generally contain less than 0,15 per cent vanadium, and higher-alloy steels. Together, these account for about 85 per cent of vanadium usage, the remaining 15 per cent being in light alloys such as Ti–Al–V for the aerospace industry and a variety of chemicals.

There have been quite dramatic shifts in the pattern of vanadium usage in steel, which will be addressed by a colleague in another paper at this Congress. Suffice it to say that, in the early 1980's, the major use was in high-strength low-alloy (*HSLA*) controlled rolled steels for pipelines, which were being produced in large quantities while, at present, an increasing proportion is going into the wide range of micro-alloyed steels used in the as-forged or as-rolled condition to replace heat-treated steels in the automotive and railroad industries. The use of vanadium in higher-alloy steels, high-speed steels, tool steels, and high-temperature steels continues to be very significant.

For these purposes the vanadium is sold as 50 or 80 per cent ferrovanadium, or as modified forms of ferrovanadium of higher carbon or nitrogen content.

It is worth noting that the steel industry is by no means homogeneous, and vanadium is used in highly developed and technically advanced steel companies with their own 'state-of-the-art' research-and-development facilities for the improvement of products and processes, but can also be used by unsophisticated small mills producing, for example, reinforcing bars in great quantities for developing countries, since vanadium is very simple, effective, and non-critical in these applications.

The 13 to 15 per cent of vanadium that is used outside the steel industry tends to be in the form of specialized niche products involving sophisticated production techniques and customer support. The further expansion of these 'non-steel' applications would be desirable, firstly, to smooth the demand cycle and, secondly, to create a differentiated market.

Sources

Vanadium is one of the most abundant elements in the earth's crust, and is more common than carbon, chromium, or nickel. While it occurs in many forms, the most significant commercially are those associated with other exploitable products, or where the concentration of vanadium, while still relatively low, is enough to justify extraction on its own.

At present, vanadium is extracted from the following sources.

(1) Vanadium-bearing oil deposits (e.g. in Venezuela). Vanadium is extracted, not from the oil, but from residues and ashes after combustion in power generation, or from catalysts that have been used in the petrochemical industry.

(2) Uranium ores containing vanadium, where vanadium arises from the extraction of the uranium.

(3) Magnetite iron ores, where vanadium and titanium have replaced some of the iron in the crystal structure. In some cases, the vanadium content is high enough for economic extraction on its own. Co-exploitation of iron and vanadium is also practised. At Highveld Steel & Vanadium, it is estimated that, of the total vanadium units produced and consumed by industry in 1991, at least 80 per cent came from magnetite iron ores. The figure could be higher, but uncertainty arises from the lack of precise knowledge about the production in the USSR and China during that period.

The vanadium produced from residues and catalysts was considerably less than 20 per cent of the total and, while production from this source can be expected to grow, it will not be at the exponential rate proposed by some observers at the height of the 'green' movement. These sources are relatively insensitive to price but equally unable to provide surge capacity.

The major producers are based on deposits of magnetite ore. Calculations of ore reserves can be misleading, but it is generally accepted that the 'top league' on ore reserves consists of the USSR (as it was), South Africa (as it will be, including Bophuthatswana, etc.), and the People's Republic of China.

In fact, all the plants at present extracting vanadium from magnetite ore are situated in these three countries, with the exception of New Zealand Steel. Australia has deposits that could be exploited, as do Finland, Norway, Brazil, Chile, and several other countries to lesser degrees. The total world reserves are immense, and they are more than adequate for centuries.

With this picture in mind, it is important to understand that two distinct routes are generally employed for the extraction of vanadium from magnetite ores.

(a) Dual-product iron and vanadium recovery in an integrated steelworks. This involves major capital expenditure, but can produce large volumes cost effectively. These plants are major producers of rolled-steel products, and the vanadium arises as a slag with a V_2O_5 content of between 10 and 25 per cent, which requires further processing to the pure oxide form (V_2O_5 or V_2O_3). Prime examples of such dual-product plants are Highveld Steel in South Africa, with an output of around 40 million pounds of V_2O_5 per annum contained in the slag, Panzihua in China, and Nizhni-Tagil in the USSR, with similar production potential.

(b) Vanadium producers who use a roast–leach process to extract the vanadium only, which is produced as fused V_2O_5 (or V_2O_3). These plants can be, and generally are, smaller and involve much less capital. They are much more sensitive to the quality of the ore deposit, and are critical on process efficiency. Typical examples are Transvaal Alloys and Vametco in South Africa.

Forms of Vanadium

Most of the vanadium produced goes through a pure oxide stage—normally fused vanadium pentoxide. Thereafter, it may be converted to ferrovanadium for steelmaking or other chemical forms for special applications. (Figure 1).

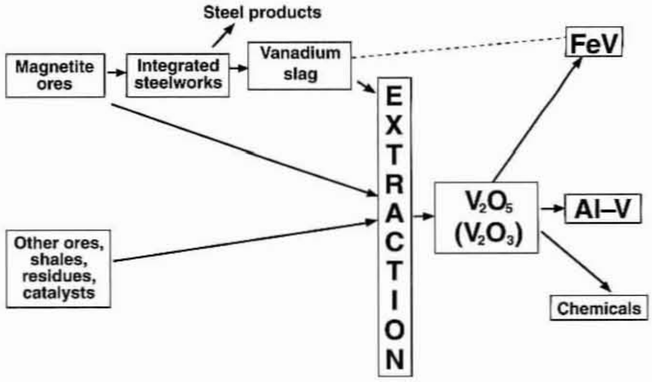

FIGURE 1. The vanadium chain

The following are the primary commercial products:

(i) vanadium slags sold by steelmakers to converters,

(ii) vanadium oxides (primarily fused vanadium pentoxide) sold by primary producers to converters, and

(iii) ferrovanadium (or other alloy or chemical forms) sold to end-users.

Production Capacities and Operating Levels

The key step in the vanadium chain is extraction to the oxide form. It is possible to bypass this—to go direct from slag to a grade of ferrovanadium, or to use slag direct in a steelmaking vessel, etc., but these are only economic in special circumstances. The process is capital-intensive and very dependent on efficient operation to be economically viable. Let us for the moment ignore the USSR (or its successors) and China, i.e. the old Eastern Bloc, and look at the oxide producers.

Firstly, the plants operating on waste products such as residues, sludges, and spent catalysts will produce at levels determined more by the industries they serve than by the vanadium market. They will need very low-priced input materials since their conversion costs are high. In the short to medium term, they will be inflexible on volume and will run at whatever input they receive or can handle.

Secondly, the primary producers from ores of vanadium only will be highly dependent on the quality of the feedstock to the extraction units, those having low-grade deposits being at a noticeable disadvantage despite any possible upgrading. Incidentally, the manner in which vanadium replaces other elements in the crystal lattice sets a very definite limit on possible upgrading. Since these plants are relatively capital-intensive and each perceives itself as a small factor in the market place (say 5 to 10 per cent of Western production), they generally run at full production. In common with the first group of producers, they will have no extra capacity to deal with surges in demand.

The only exception to this has been the Vantra Division of Highveld Steel, which has a capacity of around 15 per cent of world production, and which we have actively used to stabilize the vanadium price by flexing production levels quite dramatically. We, of course, have the advantage of a major mining operation to supply our steelworks, and we can completely decouple our mining operation from the Vantra operating level.

Thirdly, the producers from steelmaking slags have the very significant advantage of a high-grade input conferring high recoveries in plants that can be smaller, and that are therefore less costly for a given production rate in terms of both capital and operating costs. This advantage I can state with certainty for our own Highveld slag, which we have now processed in large quantities at Vantra, and I am sure it is true, albeit to a lesser degree, for New Zealand, Russian, and some Chinese slags.

In a policy consistent with that applied at our Vantra Division, Highveld has held a significant stockpile of slag over the past few years, and has held back material at times. Highveld, as a major co-product producer, is prepared to do this. There are limits, however, to how much can be done since such action can impact adversely on some of our slag-conversion customers, and there are limits also to its effectiveness in that there may be a long and rather indeterminate reaction time into the final ferrovanadium market. There can also only be timing differences since eventually, over perhaps two to three years, the slag will be sold.

Similarly, Umetco in the USA, as a co-producer of uranium and vanadium, can and does assist in holding back oxides in times of low prices.

Essentially, I have painted a rather inflexible picture of the supply side and, before leaving this temporarily, I think it is worth looking at the current estimate of capacity in the Western World (Table I). Intentionally, I have said very little about the production of the final form from the oxide in order not to detract from the main area of concern. The costs of this step are significant, being about 25 to 30 per cent of the ferrovanadium price, but consist largely of the cost of energy in the form of aluminium or electricity. The capital required is small. In principle, there are two activities by ferrovanadium producers: firstly, those who have stable relationships for the supply of oxide and who market the product themselves to customers with whom they develop mutually beneficial relationships; and then the 'toll conversion' or speculative operations. Both types of activity may well be carried out by the same companies, and we recognize that there will always be a place for toll-conversion activities and the selling of an undifferentiated ferrovanadium commodity on price. However, there is almost no barrier to entry in this business, and those with good, stable marketing will have an important edge.

TABLE I
CAPACITY FOR VANADIUM PRODUCTION

Producer		Capacity lb x 10^6
South Africa		
Highveld slag		
converted to oxide in	Austria	
	China	
	Germany	
	South Africa	
	USA	37*
Highveld Vantra ex ore		18
Vametco		9
Transvaal Alloys		5
Vantech		6
Total		75
North America		
Stratcor		12
Umetco		12
Gulf Chemicals		4
Kerr McGee		4
Residues		3
Amax		3
Total		38
Europe		
Net USSR/E. Europe flow in		3
Residues		2
Total		5
Far East		
New Zealand (converted in China)		2
Net Chinese flow to west		2
Japan and Taiwan residues		3,5
Total		7,5
Grand total		125,5

*After 90 per cent yield

Markets

Both the USSR and China are major producers and consumers of vanadium, while the major Western markets are Europe, North America, and Japan.

Europe

In 1991 this market consumed the equivalent of about 30 million pounds of V_2O_5, largely in Western Europe. It has a modern steel industry, with flexibility and the ability to control production parameters within narrow limits. A duty of 4,9 per cent on ferrovanadium imports and, until 1990, 5,5 per cent on V_2O_5 imports from South Africa, tended to promote the use of slag as a primary input. The Chinese material is duty-free.

North America

In 1991 the consumption was about 20 million pounds. The steel industry is polarizing into the new scrap-based mini-mills and the older integrated producers. There appears to be considerable potential for technical marketing and promotion of vanadium with the end-user. In the USA there is a 16 per cent duty on vanadium oxides, but none in Canada. Domestic production satisfies over three-quarters of the usage.

Japan

A market that consumed about 15 million pounds in 1991, Japan has an extremely sophisticated steel industry, which does not appear to need technical support from suppliers.

People's Republic of China

The Chinese steel industry is growing rapidly, but it is still largely unsophisticated. Maximum use appears to be made of vanadium in structural steels, rails, reinforcing bars, spring steels, etc. Despite their own production from ores and from Russian slag, it has been stated by *Metal Bulletin* that the Chinese have imported quantities of slag from South Africa and New Zealand in the past three years, possibly averaging between 5 and 8 million pounds per annum. Most of this has re-appeared as oxides sold to Japan and Europe, but not all of it. Some of the shortfall is prob-ably accounted for by poor recovery in the conversion process, but it would seem that China has almost been a net importer rather than an exporter. This should continue, given their very low *per capita* consumption of steel and their plans to increase their steel output and improve their infrastructure.

USSR

Prior to the collapse of the Soviet economy and the fragmentation of the USSR, this was the largest steel industry in the world, and probably the largest user of vanadium in high-speed and tool steels, armaments, structural steels, and heavy-duty rails. In contrast to other primary products, coal, and ferroalloys, which have continued in production while the steel industry that used to absorb their production has collapsed, the output of vanadium, which is largely a co-product, seems to be declining with the steel industry. This is evidenced by the present lack of slag, which has for years been sold to, or converted in, China, Europe, or Czechoslovakia. Instead, some quantities of ferrovanadium have been sold in Europe but, overall, less Russian vanadium units are finding their way into other markets.

Depending on the form of the Russian steel industry after the political and economic transition, there is great potential for the internal use of vanadium since well-developed techniques exist for its use, and it offers many advantages in their mills.

Vanadium Competitors

Vanadium has competitors but no substitutes in the sense that each micro-alloying element such as vanadium, titanium, niobium, and molybdenum has its own properties. Direct substitution of one for the other is generally not possible without process changes because very precise process control, rolling speeds, and temperature control are often required. In addition, while the properties of the rolled steel may be obtained, the effect on other parameters, for example weldability, particularly for low-temperature applications, can be very complex, as can the interaction between combinations of micro-alloys on the one hand, and micro-alloys and nitrogen on the other.

The steel industry may be mature, but it is still going through technical change and this will inevitably reflect on the use of alloying elements. During the past decade, the use of micro-alloys in structural steels has decreased because of improved steelmaking practices and better rolling mills producing cleaner steels, which make more effective use of smaller alloy additions and extensive use of thermomechanical processing to achieve similar steel properties without alloys. It should be noted that, in many cases, these alternative processing methods are more time-consuming and reduce mill throughputs. They may thus be attractive in poor markets, but mills can revert to vanadium and other micro-alloys in boom conditions.

Vanadium lost some ground during this period, notably to niobium in the area of structural steels. If these changes are cost-effective and lead to a more viable steel industry, they are positive in the long term. If they have come about simply as the result of perceptions of price stability, they are to be regretted. At the same time, vanadium has gained acceptance in applications where the addition of alloys has avoided the use of expensive post-forming heat-treatment, with benefits to the customer.

I believe that the next generation of steelmaking techniques, such as thin-slab and strip casting, will again bring opportunities for micro-alloys, and particularly for vanadium.

Finally, let us recognize that, while each micro-alloy will have its own applications, and that simple, quick substitution is not easy, it is possible to achieve similar results with other alloys, which is why runaway prices (as occurred with vanadium in 1988) are damaging. More importantly, this threat of substitution provides protection against the driving of prices to high levels by cartels or monopolies.

Reliability of Suppliers

Two major concerns have been aired about the vanadium industry in the past three to four years:

(1) the poor price stability, by which is meant the dramatic rise in price in the second half of 1988 and early 1989, and

(2) the reliability of supply in terms of both the ability to cope with a surge in demand and the failure of major producers to deliver either by design or *force majeure*.

Here, it is important not to hold ambivalent views. Dependence on one source can be a major risk: imagine if the USSR had been the dominant supplier of vanadium to the West; imagine if Brazil could not supply niobium; or look at cobalt, which is going through another hectic surge in price levels due to unrest in Zaire. However, if customers are enamoured with price stability from a single supplier, as they are reputed to be in niobium, there should be absolutely no concern about South Africa's position in vanadium. In fact, the opposite is a more real concern in that too fragmented an industry facing cyclical demand is a recipe for instability. As I have been at pains to point out, the smaller producers do not adjust their production rate and, with marked differences in production costs, any extended downturn in demand carries high risks of capacity closure. The net result is less ability, real or perceived, in the industry to cope with the next upturn, and hence situations like that in 1988 arise.

There are only two possible solutions to avoid this: either all producers can cut back production in times of slack demand, or the production of V_2O_5 can be concentrated into larger units. This can be challenged as an over-simplification, but it is fundamentally true and will become obvious again in the current over-capacity situation and the need to cope with the trauma in the USSR and changes in China. Vanadium has never been in short supply; even in 1988/89, no customer ran out of vanadium and, in fact, inventories increased.

South Africa is the major producer of traded vanadium. As a country, we are going through an exciting period of political and social change. Any future government will ensure continuity of exports—all South Africans are experts on the negative effects of trade sanctions and the need to promote exports. Vanadium is a product of great significance to South Africa, and we are fortunate in the quality of our vanadium-bearing deposits, their accessibility, our world-class mining and mineral-extraction industry, and our magnificent climate.

As a company, Highveld has a track record of responsible and reliable behaviour, and we recently made improvements to our Vantra Division to give flexibility on the input material, either ore or slag, and also to be better able to respond to rapid changes in demand for V_2O_5.

Conclusions

(a) Vanadium's main market will continue to be the steel industry, and the demand will broadly follow the changes in steel production.

(b) There is a need for continual market development for vanadium. Much of the work towards niche markets can and will be done by specialist producers of final products with close relationships to end-users.

(c) Changes in the USSR and China will be important and difficult to predict, particularly the shorter-term effects on the balance between supply and demand. While these changes may cause short-term problems, they probably offer more positive benefits in the longer term owing to the expertise in these countries in the use of vanadium and the need for construction and infrastructure.

(d) South Africa and the vanadium industry are mutually important to each other. This will continue with a medium-term trend towards further beneficiation in South Africa.

Further to (b), the need for market development is two-fold in the key market of the steel industry:

- basic investigation into alloy mechanisms, and research aimed at extending boundaries and clarifying interactions, so that these concepts can then be used by major steel producers in developing their own products and processes;
- promotion of established uses and applications to suitable end-users.

Both of these are being done very actively by certain ferrovanadium producers, who then have the advantage of close relationships with the market and a degree of loyalty from customers.

In addition, the Vanadium International Technical Committee, or VANITEC, which is an organization of vanadium producers, has the primary purpose of addressing these needs. Its activities on basic work must be maintained, and the people marketing ferrovanadium will preferably take a more active role in technical liaison with customers and in promoting specific applications.