Vanadium

Market Developments, and their Implications for Titanium

INTERNATIONAL TITANIUM ASSOCIATION CONFERENCE
SCOTTSDALE, ARIZONA
SEPTEMBER 27, 2005
VANADIUM-OXIDE PRICE HISTORY
USES OF VANADIUM

- Steelmaking 91%
- Chemical and Catalyst 5%
- Titanium 4%
VANADIUM CAPACITY UTILIZATION

![Graph showing capacity utilization for different categories of vanadium production.](chart.png)

- **Steel Slag**: Capacity Utilization 88%
- **Vanadium Ore**: Capacity Utilization 92%
- **Oil Residues**: Capacity Utilization 70%
- **Spent Catalysts**: Capacity Utilization 63%
- **Uranium By-Products**: Capacity Utilization 7%
WORLDWIDE CRUDE-STEEL PRODUCTION RATE
WORLDWIDE CRUDE-STEEL PRODUCTION RATE

Thousands of Metric Tons per Year

Increasing for Four Years

1998  1999  2000  2001  2002  2003  2004  2005
WORLDWIDE VANADIUM-CONSUMPTION RATE
WORLDWIDE VANADIUM-CONSUMPTION RATE

Record Vanadium Usage

Millions of Lbs. of V₂O₅ per Year

1998 1999 2000 2001 2002 2003 2004 2005
CONSUMPTION AND PRODUCTION

<table>
<thead>
<tr>
<th>Year</th>
<th>Consumption</th>
<th>Production</th>
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<tbody>
<tr>
<td>2003</td>
<td>182</td>
<td>171</td>
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<tr>
<td>2004</td>
<td>209</td>
<td>189</td>
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<tr>
<td>2005</td>
<td>196</td>
<td>202</td>
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</tbody>
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Millions of Lbs. of V$_2$O$_5$ per Year
# CONSUMPTION EXCEEDS PRODUCTION

<table>
<thead>
<tr>
<th></th>
<th>Millions of Lbs. of V₂O₅ per Year</th>
</tr>
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<tbody>
<tr>
<td><strong>Consumption</strong></td>
<td></td>
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<tr>
<td>All Others</td>
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<td>FSU / CIS</td>
<td>23</td>
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<td>North America</td>
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<td>Western Europe</td>
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<tr>
<td>China</td>
<td>38</td>
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<tr>
<td>Other Asia</td>
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<table>
<thead>
<tr>
<th><strong>Production</strong></th>
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<tbody>
<tr>
<td>All Others</td>
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<tr>
<td>U.S.A.</td>
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<tr>
<td>China</td>
<td>37</td>
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<td>Russia</td>
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</tr>
<tr>
<td>South Africa</td>
<td>78</td>
</tr>
</tbody>
</table>
PRODUCTION EXCEEDS CONSUMPTION

Consumption: 196
Production: 202

- U.S.A. 20 (2005)
- China 42 (2005)
- Russia 49 (2005)
- South Africa 30 (2005)
SURPLUS WORLDWIDE INVENTORY
SURPLUS WORLDWIDE INVENTORY

Vanadium Pentoxide Equivalent

Projected
SUMMARY AND OUTLOOK

• Vanadium Consumption: Strong and Growing, Especially in China

• High Pricing Led to Strong Increase in Production from Existing Sources
SUMMARY AND OUTLOOK

• Rapid Growth in By- and Co-Product Sources in China, U.S., and Russia

• Volatile Market: Upward Momentum with Sudden Declines Likely
SUMMARY AND OUTLOOK

• Titanium Industry Should Strengthen Long Term Arrangements with Vanadium Sources of Both Master Alloys and Vanadium Oxides
Vanadium Market Developments, and Their Implications for Titanium

Overview

The last year has seen much turmoil in the Vanadium Market. This has had a significant impact on what the Titanium Industry has had to pay for Vanadium, and there is now much uncertainty about what may happen in the future.

I’m sure that everyone here is well aware of the critical importance of vanadium in titanium alloy production, most notably in 6/4 alloy.

Historically, vanadium has exhibited a pattern of enduring long periods of low (often below cost) pricing followed by a spike and then a crash. (See Chart 1).

Long periods of oversupply, usually the result of unneeded and unwise speculative investments in new capacity during periods of high pricing, have repeatedly led in turn to capacity cutbacks – thus setting up the scene for the next price spike.

During 2004 and the first half of 2005, a spike in vanadium pricing occurred with such force that all previous price spikes were dwarfed. (See Chart 2).

The intent of my paper today is to describe the factors which led to this huge spike and to examine the possibilities for what may happen in the future. Hopefully this will be of some assistance to the titanium industry in managing the role of vanadium on an on-going basis.

Uses of Vanadium

More than 90% of vanadium usage is in Steelmaking, mainly as an alloying element in the production of specialty steels, tool steels and (most of all) high strength low alloy (HSLA) steels. Titanium alloy production consumes less than four percent of worldwide usage, and the balance is consumed by a wide variety of chemical and catalytic applications. (See Chart 3).

Since steelmaking plays such a dominant role in the use of vanadium, it is steel demand that drives the vanadium market.
The vanadium used by these different sectors is not chemically identical. Steelmaking uses vanadium as ferrovanadium and vanadium carbonitride (Stratcor’s Nitrovan® vanadium), titanium uses vanadium as vanadium aluminum and in some other masteralloys, and the chemical and catalyst applications use a variety of oxides and other vanadium compounds.

The most chemically stringent requirements are in titanium and some chemical applications. In addition, vanadium for titanium alloying must be thoroughly inspected for inclusions to ensure that no unwanted foreign particles are present.

What this all means is that the cost of producing vanadium in a form suitable for titanium alloy production is significantly higher than the cost of producing vanadium for its main application, steelmaking.

Vanadium for steelmaking is treated as being a commodity. Vanadium for titanium alloy production is not a commodity, and should not be handled as such.

**Sources of Vanadium and Capacity**

Vanadium is a common and widely dispersed element. It frequently occurs as a minor constituent in other ores, notably iron ore and uranium ore, and there are many specific vanadium ore bodies. It also occurs in fossil fuels, for example in crude oil from the Caribbean region and in coal (notably in China). (Chart 4).

Producing vanadium depends much more on the economics of extraction from any given source than on finding vanadium by exploration.

In other words, there is plenty of vanadium lying around but the cost of building a plant to extract it and the cost of processing in such plants covers a wide range. Unlike most metals, finding vanadium sources is easy, but extracting it economically is the hard part.

Vanadium bearing iron ore is by far the biggest and, in general, the most economic source of vanadium. Such deposits occur in South Africa, China and Russia. Slag from the consumption of iron ore (in steel production) varies from 5% to 25% V₂O₅ contained. Since the slag is essentially free and the cost of extracting the vanadium from it relatively low, this tends to be the lowest cost vanadium source. Not surprisingly, this source supplies the most and has the most capacity to produce vanadium. Very little of the vanadium bearing steel slag being generated is not being utilized.

Production from vanadium ore is in South Africa with a smaller amount of such production in China. Many other vanadium ore bodies exist in Russia, China, Canada, South Africa and Australia --- but high capital costs of new plant and high operating costs of most ore sources make such ventures unlikely to be viable unless vanadium demand climbs above 250MM lbs. V₂O₅ per year (vs. the current c. 200MM)
Oil and coal residues, and spent catalysts make up the balance of current production. The vanadium concentration in these materials varies considerably and, consequentially, so do the production economics.

Production from Uranium ores has just resumed in the U.S.. Initially output will be small, but this could rise to 10-15MM lbs. $V_2O_5$ per year over the next few years – especially if both uranium and vanadium prices remain strong.

**Vanadium Consumption**

Worldwide steel production has risen very strongly over the past three years. (Chart 5)

Extremely strong growth in China has been the main increase, but growth in the Former Soviet Union and Commonwealth of Independent States (FSU/CIS) has been quite strong also.

The overall volume of steel production is the main driver of vanadium consumption, but a shift to production of more high strength steels has further compounded growth in vanadium consumption, again most notably in China. (Chart 6)

During 2004 North America too has seen very strong growth in vanadium consumption due to higher production of high strength low alloy and specialty steels, a rebound in demand from the titanium sector and growth in vanadium chemical application. (Charts 7-10)

**Vanadium Supply**

South Africa is the biggest vanadium producer with three large oxide producing plants, including Stratcor’s Vametco facility. From these facilities, South Africa exports oxide. It also exports ferrovanadium and Nitrovan®vanadium converted from oxide. In addition, large quantities of vanadium-bearing steel slag is exported, primarily to Europe, for subsequent conversion into oxide and ferrovanadium.

China is now the second largest vanadium producing country ---- output there having risen sharply in response to recent strong demand and pricing.

Russia remains a large producer, all production coming from the Kachkanar vanadium-bearing iron ore mine in the Urals, primarily via steel slag generated at the Nishni Tagil steel mill.

The U.S. remains a significant vanadium producer, the biggest oxide facility being Stratcor’s Hot Springs, Arkansas facility.
Comparing worldwide production and consumption over the past six to seven years, it can be seen that there was a long period of excess production between 1999 and 2003. This occurred as a direct result of unneeded uneconomic capacity being installed in Australia – a consequence of the 1998 price spike.

This in turn led to a large buildup in worldwide vanadium inventory (Chart 12) and historically low prices (Chart 1).

During this period, almost every vanadium producer was losing money, capital spending on plant and equipment was minimal and no new capacity was installed.

This led, inevitably, to the closure of some facilities, the Australian production plant was closed and so was a large oxide plant in South Africa.

As a result, worldwide vanadium production – and capacity – both dropped sharply even though consumption was steadily rising. (Chart 11).

Then, during 2004, a very strong surge in vanadium demand occurred – increased demand for high strength steels in China, record U.S. consumption (in steel and titanium), and a resurgence of usage in the “Eastern Block” countries.

The large market inventory helped fill the gap between soaring demand and reduced production, but the vanadium market price still rose very sharply due to the time required to convert oxide to (mostly) ferro vanadium and the time needed to move finished product to where it was to be used. The “pipeline” was too long and too thin to keep up with demand.

Early in 2005, surplus stocks were exhausted and prices rose still further. Panic buying and trader speculation added fuel to the fire, leading to the unprecedented market spike. (Charts 12 and 2)

Meanwhile, production from existing sources climbed strongly—just not strongly enough or fast enough to meet demand during the second quarter of 2005 (Chart 11).

During the third quarter, however, demand began to soften due to a combination of substitution in steelmaking (substitution of vanadium with niobium), de-stocking of vanadium-bearing grades of steel, and de-stocking of consumer and trader vanadium inventories. This led to the recent price collapse as supply once again began to exceed demand (Chart 11).

**What Next?**

Despite some substitution, it seems likely that future demand for vanadium will be strong. The strong growth in demand for high strength steels is likely to continue over at least the next five to ten years, driven initially by China but likely to be followed by India, other Asia countries and the former “Eastern Block” countries.
Production of vanadium from existing sources has risen sharply and will continue to rise as and when demand requires it. In addition, as in 1998, we again have speculative moves to generate new capacity (mostly from vanadium ore sources). These ventures tend to need relatively high vanadium prices to survive, but historically the extra (usually unneeded) production that they create is usually enough to drop the market price below what they need to stay in business.

This suggests that the vanadium market is likely to be rather volatile over the next five to ten years. Strong consumption and strong supply result in a steady market if they are reasonably well synchronized. Unfortunately, strong supply will only occur if market conditions (i.e. price) are conducive. Periodic over supply leading to prices below production cost works against this – as we have seen in the 2004-5 market.

The current level of vanadium production from existing sources is around 200MM lbs. V₂O₅ per year. Generation of vanadium bearing slag is increasing strongly in both China and South Africa (with a 30% increase projected at Highveld). Extraction from lower grades of oil and coal ashes and residues is also climbing and likely to increase still further. Extraction of vanadium from uranium ores has recently resumed in Colorado and is likely, with current strong uranium prices, to continue to rise. The combined potential increase from these existing sources is likely to enable production to increase from the current 200MM lbs. V₂O₅ per year level up to around 240 MM over the next couple of years if the market needs it – this should be more than adequate to meet my likely increase in demand above the current (instantaneous) level of around 180-190 MM lbs V₂O₅.

This should be adequate time for both consumers and producers to assess the need for investment in new capacity – most likely from vanadium ore sources.

**Vanadium and the Titanium Industry**

High quality vanadium is a critical material for titanium alloy production, there is no substitute. The titanium industry consumes only a small (less than 4 percent) proportion of worldwide usage.

The steel industry on the other hand, consumes more than 90% of worldwide vanadium usage and buys it as if it were a commodity, expecting below-cost prices if that is where the “market” is and suffering damagingly high prices in any market shortfall – as recently.

Titanium alloy producers must have vanadium product and this product must be assured to be of extremely high chemical and physical quality. This being the case, it is most important that the titanium industry has a thorough understanding of the issues vital to the production of vanadium oxide and of the vanadium–bearing master alloys that they buy. One is no good without the other. It is also important to recognize that the vanadium product used by the titanium industry is far removed physically, chemically, and commercially, from the product used by the steel industry.
The titanium world should not be treating vanadium as a commodity – the product they use is not a commodity.

My advice, therefore, would be that the titanium industry should work to strengthen long-term relationships with their vanadium suppliers, and that this relationship should also include contractual and technical ties to the source of oxide, not just the master alloy. I am not going to belittle the key role that masteralloy producers play, but vanadium-bearing masteralloys cannot be made without suitable vanadium oxide – this is where most of the capital investment in the vanadium supply chain lies.

Long-term contracts would best serve the needs of both titanium alloy producers and vanadium producers, but it is most important that such arrangements include the source of oxide as well as the conversion to masteralloys.

Summary and Outlook

I would like to be able to say that the historic pattern of low pricing followed by spike, crash and burn has ended in the world of vanadium. Unfortunately, given the abundant availability of vanadium sources, this is unlikely to be true.

I suspect, perhaps wishfully, that strong new demand from rapidly developing countries such as China and India will tend to pull up average vanadium pricing in the future, to somewhat higher levels than has been the historic norm in the long price dips.

I also think that a price spike of the magnitude seen in early 2005 is unlikely in the foreseeable future, due to the mobilization of extra production from traditional sources over the last year or so.

The speculators are out there again trying to raise money to build new vanadium capacity. If successful, such new capacity will likely lead to oversupply --- and history has shown that unless such capacity has very low capital and start-up costs, as well as low extraction costs, this new capacity will be the first to fail in the future periods of low pricing.

Such supply and pricing uncertainty for the future is not helpful to the titanium world. The best defense for the titanium industry is the further development of closer long-term arrangements with vanadium sources. These arrangements, both technical and commercial, should include both masteralloy manufacture and vanadium oxide production.