Vanadium Supply and Demand Trends

(or, why the World Needs Windimurra)

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Slide 1 – Disclaimer

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Slide 2 – Title "Vanadium Demand and Supply Trends"

Slide 3 – Presentation Overview

In the past, the world vanadium industry has been hard to analyze. The largest producer, Highveld, didn't publish separate figures for steel and vanadium and a significant portion of world production and consumption was concealed behind the iron and bamboo curtains. The US Bureau of Mines publishes estimates, but withholds US figures. Only in recent years have Highveld and Evraz opened up, and Chinese producers listed on the stock market, revealing detailed information.

I will talk about the use of vanadium and developing markets, key factors underlying the long-term demand outlook, an overview of key suppliers and factors that may restrict future supply.

Shortages of vanadium in the last few years since the Windimurra mine last operated have been met by growth in high cost co-production, substitution by other metals and a plethora of small environmentally unsustainable, high cost producers in China.

Future demand cannot be met in this way, and you will see that there is a likelihood of demand growing at a rate faster than supply, clearly establishing the need for substantial, sustainable, environmentally responsible new production.

Lastly therefore, you will hear how, whether existing producers welcome the fact or not, Windimurra must, and will, meet that growing demand.

The World needs Windimurra!

Slide 4 - Vanadium Demand

Vanadium is indeed a 20th century miracle metal. As mankind strives to make products stronger, lighter, and safer and more fuel efficient there will be ever increasing demand for the metal and the need for gradual increases in sustainable, cost effective vanadium production.

Unlike other metals whose markets are fully developed, commercial production of vanadium only arose in the 1960s, and so new applications continue to be found for the metal's useful chemical and physical properties.

Its principal use is as a strengthening addition to carbon steel and high strength steels in structural applications, oil and gas pipelines, buildings and cars. Tool steels and stainless steel use are also important.

Titanium aluminium vanadium alloys are used in aircraft components, air frames, rocket motors and gas turbines. Non-steel uses include superalloys, welding and hard-facing, magnets and alloys used in nuclear engineering and superconductors. Vanadium chemical catalysts are used in the manufacture of sulphuric acid, maleic anhydride, EPDR rubber and desulphurization of sour gas and oil.

Steel will remain the key end-use market, although growth in aerospace alloys and the emergence of new uses for titanium-vanadium will see this sector grow the fastest.

Slide 5 – Steel is Driving Vanadium Demand

The graph illustrates the clear historic link between vanadium demand and steel demand, as reflected in prices.

The lower chart illustrates how historically the Asian countries have added less vanadium to their steel than the world average. However, the maturing of the Chinese and other emerging steel markets will result in an increase in the intensity of use. The forecast growth of vanadium use is therefore higher than the forecast growth in steel consumption alone.

Slide 6 – China is Driving Steel Demand

Vanadium in construction steels (particularly "rebar") adds significantly to load-bearing strength. In 2003, Chinese construction authorities required the use of vanadium-added rebar for use in earthquake-affected areas.

Chinese consumption of engineering and alloy steel has also grown over the last few years as an increased proportion of manufacturing is for higher-value, more complex machinery.

In the first six months of 2006 China's production of specialty steels which contain vanadium grew by 22.5%[1], far outpacing growth in total crude steel production.

This trend is projected to continue for an extended period, on a global level, as emerging economies (China, India and others) continue to industrialise.

Macquarie Bank forecasts[2] total world steel production to grow at an annual 5.8%, with China increasing her share to 40% by 2010.

Increasing intensity of use, coupled with increasing steel production, will see vanadium consumption in steel use grow by at least 7% per year.

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[1] Chinese Govt Chian *Metallurgical Newsletter*, July 2006
[2] Macquarie Bank Limited, Research, *Commodities Outlook*, October 2006

Slide 7 - Titanium Vanadium Alloys Soar

In most uses, titanium is alloyed with vanadium, most often at a 5% – 6%. Used extensively in the aerospace sector, this alloy imparts strength and improves performance at sustained high temperatures.

The drive to produce aircraft that are lighter, longer range and more fuel efficient is driving greater use of light weight alloys, dominated by vanadium and titanium.

Each generation of new aircraft uses increasing amounts of titanium / vanadium alloy as shown in the graph. The new generation of aircraft led by Boeing's 787 Dreamliner and Airbus' 380 contain almost 100t of alloy in each; more than double that for a 747.

An excellent paper by John Monahan at the Titanium 2006 Conference[3] predicted the doubling of titanium vanadium alloy consumption over the next 10 years.

The makers of titanium alloys require a stable source of high purity vanadium pentoxide to meet demanding quality standards. Windimurra was previously the largest producer of high purity material, and was widely used in this sector. The standard Windimurra process fulfils this demanding premium grade, due to a competitive advantage in the use of natural gas to roast the ore, which introduces fewer impurities than does the coal used by competitors.

Now let me turn to the supply side of the vanadium equation.

Slide 8 - Vanadium Production Sources

The majority of vanadium is sourced from the small proportion of iron ores that are vanadiferous magnetites. Low levels of vanadium are also found with carbon either in coal or oil. Some vanadium is recovered from oil residues and uranium ores.

While occurrences of vanadium-bearing minerals are relatively plentiful, reserves of economically recoverable vanadium are not. Several publicised potential vanadium resources suffer from poor access to ore, high strip ratios, low grade, unweathered ore resulting in high mining costs, or a combination of these.

There are three major groups of vanadium producers, plus a group relying on substitution. An understanding of these is important to an understanding of the vanadium industry.

- **Primary Producers** – extract vanadium directly from vanadiferous titanomagnetite, mined only for this purpose.
- **Co-Producers** – produce a vanadium-containing slag as a co-product of making iron from vanadiferous titanomagnetite.
- **Recyclers** – extract vanadium from wastes such as fly ash, oil residues or spent catalysts.

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[3] Commercial Aerospace Outlook for Titanium, John Monahan, VSMPO, Titanium 2006 Conference 1 – 3 Oct 2006

- **Substitution** – users substitute ferroniobium or produce larger quantities of "weaker" steel not containing vanadium.

In discussing each group of producers, I will comment on some of the leaders in each field in order to draw conclusions on likely trends in those fields. It is not possible or necessary to cover all producers, and I mean no offence by leaving any out of the discussion, or by stating frank views.

Slide 9 – Vanadium Primary Producers

Magnetite ore containing vanadium is crushed and ground, beneficiated by magnetic separation, roasted in a rotary kiln with a sodium flux until the vanadium is leached out. This "salt-roast water-leach" process is used by all primary producers. The vanadium is produced as either vanadium pentoxide or vanadium trioxide and is then "converted" (reduced) by aluminothermic reduction to ferrovanadium.

Rhovan mine hard-rock titanomagnetite ore for two-stage crushing and milling before upgrading by magnetic separation to a magnetite concentrate containing around 2% vanadium. The plant was built in 1997 originally with a capacity of 4,800t of vanadium pentoxide. Since closing Windimurra and exhausting Vantech's ore in 2003, Xstrata has pushed production at Rhovan to a maximum 9,300t of V_2O_5.

Rhovan has booked solid profits of US$31.1m in 2004 and US$181.1m in 2005. Xstrata are considering an expansion of Rhovan, but have not yet committed to do so. The current plant is producing at maximum capacity with any further increases in production costing up to US$100m, including the building of a new rotary kiln.

Highveld's Vanchem plant is a primary producer because most of the vanadium it produces comes from fine magnetite ore (<6mm) from the Mapochs mine, mixed with 20% vanadium-bearing slag produced from the steel making plant. The three rotary kilns have a total capacity of 11,000 tpa V_2O_5 from both ore and slag. However, production has been around 10,000 tpa V_2O_5 due to low plant availability.

Vametco is a subsidiary of Strategic Minerals Corporation of USA (Stratcor). It produces Nitrovan (a nitrated vanadium alloy) at its facility in Brits, South Africa. Vametco is not able to meet all its ore needs from its own mine due to depletion of economic ore. Slag from Highveld is used to "sweeten" the ore. Production in 2005 was 6,300t tonnes of V_2O_5 of which 1,300t were from slag and 5,000t from ore. Vametco's output is currently limited to this level by the unavailability of ore or more slag.

Russian steel producer Evraz acquired 73% of the Stratcor business in 2006 and later an interest in Highveld. Common ownership may allow a rationalisation including the treatment of more Highveld slag at Vametco, with less slag available for treatment by others.

"Backyard" producers in China numbering more than 200 have sprung up in the last three years of high prices, extracting over 6,000 t of vanadium from magnetite and stone coal in 2005. There is growing pressure from the Chinese central government to close down these backyard operators as part of a programme to rationalise much of the country's mineral and metal production and to reduce rampant pollution. China imposed a new resource tax on primary vanadium mines in

September 2006, in what the government said was an attempt to prevent "irrational" mining. The tax of US$1.50 per tonne of ore has added over US$1 per pound to the cost of vanadium pentoxide.

We believe these producers would struggle to survive at prices below US$5/lb V_2O_5.

Being larger scale and vastly more efficient, Windimurra will be able to assume at least part of the market left by these small producers as they close down.

Slide 10 - Vanadium Co-Producers

There is a popular myth that the co-producers get their vanadium as a free by-product from the process of making steel. They are in fact, relatively high cost steel **and** high cost vanadium producers.

These steel makers use as a source of iron, very low (iron) grade titanomagnetite that also contains vanadium and titanium. The vanadium is removed in a slag as part of the iron making process. The titanium is partly removed either during the beneficiation stage (Pangang and Chenggang), or removed in a titanium slag waste, during iron making (Highveld).

The vanadium bearing slag is processed through the same salt-roast – water-leach process used on ore by primary producers.

There are only five relatively small steel plants worldwide producing steel from these ores, because they are a very low grade source of iron (15% - 30% Fe), compared to the more common 60 -68% Fe haematite. Plus the titanium content is harmful to steel-making plant, and the huge volume of slags generated compared to using high grade haematite, blows out energy costs.

Not surprisingly, less than 2.5% of global steel was produced from titanomagnetite containing vanadium. These small steel producers lack the economies of scale of their competitors. They nevertheless account for more than half of current vanadium production.

Steel Production of Vanadium Co-Producers –2005

Steel and Vanadium Co-Producer	Region	Ore Type	In situ Iron Grade	Annual Steel Production	In situ Vanadium Grade (% V_2O_5)
Chengde Xinxin (Chenggang)	Hebei Province, China	Vanadiferous Titanomagnetite	31% Fe	2.42 Mt	0.3%
Panzhihua Iron and Steel Group	Sichuan province, China	Vanadiferous Titanomagnetite	31% Fe	6.0 Mt	0.3%
United Metallurgical Chusovskoy	Permsky region, Russia	Vanadiferous Titanomagnetite	15% Fe	13.85 Mt	0.13%
Vanadii Tula (Nishni Tagil)	Kachkannarsky, Russia	Vanadiferous Titanomagnetite	16% Fe	5.5 Mt	0.14%
Highveld Steel & Vanadium Corp	Witbank, South Africa	Vanadiferous Titanomagnetite	38% Fe	0.87 Mt	0.40%
New Zealand Steel (Chenggang)	Waikato North Head, New Zealand	Vanadiferous Titanomagnetite sands	57% Fe (in concentrate)	0.59 Mt	0.40% (in concentrate)
Total Vanadium Co-Producers steel output				**29.23 Mt**	
Total World Steel output				**1,150.00 Mt**	

Plants that do use these low grade iron sources and produce vanadium as a co-product, were built in the 1960's in Russia, China and South Africa, during times when imports of haematite were not possible. No new plants of this kind have been built since. The easing of international boundaries, the opening up of these domestic economies to overseas competitors, and availability of enormous tonnages of high grade iron ore (not "contaminated" with titanium) from new mines in Australia, Brazil and South Africa have allowed a 35% growth in steel production in 5 years, but without attendant growth in vanadium co-production.

Slide 11 – Co-Producers (Cont.)

Highveld Steel and Vanadium Corporation Limited produces around 70,000 tpa of slag grading 22% V_2O_5 making Highveld the world's largest vanadium producer.

Around 14% of the slag goes to Stratcor's Vametco plant, where it is processed to produce Nitrovan. Another 14% goes to Highveld's Vantech primary vanadium plant to "sweeten" the ore blend, and the remainder shipped all the way to the Treibacher facility in Austria.

Highveld has enjoyed good profits in the last two years due to record vanadium and steel prices, with almost all the profit made from vanadium rather than steel. Over the 20 year life of the operation Highveld has done little better than break even, with average annual profit from 1996 to 2003 of just US$9m. Steel production has remained constant, and vanadium slag production has slowly fallen over time, even in the recent years of high prices.

Highveld's first half 2006 profit was 60% down on the previous year due to relatively "low" vanadium prices despite the price being double the long-term average. The group was cash flow negative in the same period and output of vanadium actually fell[4].

Panzhihua Steel Group is a very astute and technically competent Chinese producer who mines local low grade titanomagnetite. Their iron ore must be blended with higher quality haematite ore at a ratio is 7 t to 3 t, imported principally from BHP in Australia. Pangang is located in a mountainous region in the south west of China and rail costs from the port to Pangang are a significant impost at USD32 – 40 per tonne.

Despite their high efficiency, Pangang did little more than break even in the quarter end December 31, 2005[5] during a period of historically high steel and vanadium prices.

Tulachermet (Vanady Tula) is a major pig iron producer in Russia that extracts vanadium from slag purchased mostly from Evraz' Nizhny Tagil steelworks, but does not mine any ore itself. Its ability to expand is limited by its ability to buy more vanadium-bearing slag.

[4] Highveld Steel and Vanadium Corporation Limited, Interim Report June 2006
[5] *China Daily* February 15, 2006

Evraz Group is a successful Russian integrated steel producer who benefits from being 80% self sufficient in raw materials, having steel production sites located close to its mines, and a robust local steel market. At Kachkanarsky (KGOK) and Vysokogorsky (VGOK) Evraz mine a vanadiferous titanomagnetite grading 16% Fe and 0.13% - 0.14% vanadium pentoxide. The vanadium bearing slag from this ore, treated at Nishny Tagil Steelworks, is the feedstock for Tulachermet.

Vanadium production does not contribute significantly to Evraz' revenue, with sales of Russian slag returning $83m in the first half 2006, for 2.2% of revenue[6]. Any increase in Russian slag, and hence vanadium production is likely to relate more to the economics of mining and steel making at Nizhny Tagil, than demand for vanadium.

Evraz have recently acquired an interest in Highveld and Stratcor giving them access to the finished vanadium market and technical know-how. They have stated their intent of becoming a leading vanadium producer through down-stream integration. This is an exciting development for the industry and may lead to more consolidation and stability in the industry.

Unfortunately for the co-producers, the price of vanadium and the price of steel are very closely correlated. When vanadium is low, steel is typically not high enough to absorb the costs of production. Past data suggests that when the ferrovanadium price is below US$20kg, historically corresponding with steel prices below USD275 t, co-producers are sub-economic.

Whilst co-production of vanadium from steel-making slag is likely to remain an important source of vanadium, it is not likely to grow significantly in the future as vanadium prices retreat to long term historical levels. More likely is a rationalisation, where the producers of slag such as Highveld and Evraz themselves treat more slag to remove vanadium, rather than selling it to others.

Slide 12 - Vanadium Recyclers, and Substitution

Vanadium catalysts used by petrochemical and chemical industries that have reached the end of their useful life, can be recycled to remove the vanadium and other metals. The burning of vanadium-containing fuel oil such as the Venezuelan product Orimulsion® produces a fly ash containing vanadium which can be treated.

A number of small, again high cost, high polluting processors of spent catalysts and oil residues have sprung up in China in the last three years to meet the vanadium shortage. These produced over 3,000t in 2005, but are unlikely to be sustainable in the long term.

Strategic Minerals Corporation (Stratcor) is the leading US supplier of vanadium products including a wide range of chemical as well as ferrovanadium for the steel and alloys sector. Capacity at Hot Springs is approximately 5,500t pa V_2O_5 equivalent.

[6] Evraz Group SA Interim Results 2006

The high price of vanadium in recent years and more stringent environmental regulations preventing burial of spent catalysts and other wastes, has meant that almost all potential feedstock is already being utilised limiting the ability to expand production.

Substitution of niobium can take place at very high vanadium prices, or alternatively, a greater quantity of (weaker) non vanadium-containing steel may be used.

The high price of ferrovanadium from 2003 saw Chinese steel makers substitute Brazilian ferroniobium, principally in high grade re-enforcing bar. In Jan – May 2006 China imported 4,164.74 t of ferroniobium, 40% up on the same period in 2005 and equating to 10,000 t for a full year.

Ferroniobium is only 60% effective when compared to ferrovanadium. Consequently, in 2005 9,000 t of ferroniobium in effect displaced approximately 6,000 t of FeV. This substitution is likely to end (i.e. FeV will be re-substituted for FeNb) when the price of ferrovanadium is below the substitution price of around USD25/kg FeV.

The market price of ferroniobium climbed in 2006 for the first time in several years, further increasing the likelihood of steelmakers returning to vanadium.

The elimination of substitution alone could absorb all of Windimurra's planned output.

Slide 13 – Vanadium Supply/Demand Balance

A summary of our discussion of supply and demand outlook comes together in this graph.

The long term growth in steel production and in titanium alloy consumption fell back in 2000 and 2001 just as vanadium supply increased, resulting in a surplus, and falling prices. Over 15,000 t of vanadium was built up in inventory in slags in South Africa, and by traders that held the material. A number of ill-considered closures were undertaken, just as demand increased strongly again from 2004. The traders were able to sell the inventory into the higher-priced markets in 2004/05

The market remains in a tight supply situation at present due to continued strong demand and limited short-term ability to increase supply.

Demand is forecast to grow 5% - 7% per year over 2006 - 2015 due to steel production growth, increasing intensity of use in steel and a buoyant aerospace market. Demand may again outstrip supply, causing short term shortages and price hikes.

Slide 14 – Windimurra Video

Slide 15 – Windimurra Closure and Rebirth

Windimurra was prematurely closed in 2004 due to low vanadium prices, flaws in the original design of the plant and differences between the owners.

This has been resolved with a strong marketing agreement with Noble Group, which underwrites the operating costs for the life of mine; ensuring temporary pullbacks in the vanadium price will not cause short term cash flow problems. Noble is an ideal partner for us, with huge penetration into the rapidly growing Chinese steel industry. Noble is not a competitor to Windimurra, unlike our former partner, and is absolutely committed to the success of the mine.

The project has been completely re-engineered, drawing on the experience of three years operating the mine, addressing past operating constraints.

Work has begun at site on the rebuilding of the operation, and long lead capital items have been purchased or ordered, ensuring that we will be able to meet our commitments to customers.

Slide 16 – Windimurra, a Vast World Resource (fly-through)

The world-class Windimurra Vanadium deposit is located in the heart of one of Western Australia's fastest growing mining provinces - the Mid West

The enormity of the vanadium mineralisation at Windimurra is hard to comprehend. 26km long, the deposit is so large it can be seen from space, within a massive system of vanadiferous titanomagnetite protruding from the earth.

Only 15% of the deposit has ever been drilled, giving what is already the world's largest Proven Ore Reserve of vanadium.

The extent of the current known Ore Reserve is shown in green - the entire zone averaging half percent vanadium. Remarkably, it can be seen that every hole drilled at Windimurra has proven ore, with no barren holes. Drilling now underway, will extend the deposit in all directions.

A small open pit exists at Windimurra from which 7 million tonnes was mined in the early 2000s. Note the absence of waste rock dumps – every tonne mined was processed. Uniquely, the ore lies at the surface with no mining of barren rock required. The new Windimurra mining operation will be at a much larger scale….

Mining will extend along the entire 6 kilometre drilled reserve and, in future, well beyond.

At 350 metres thickness, the Windimurra orebody is two hundred times thicker than the world's largest operating vanadium mine, and it lies on the surface, waiting to be exploited.

Slide 17 – Windimurra, Key Advantages

Windimurra vanadium deposit is different from any other. While the vanadium is contained in a vanadiferous titanomagnetite, this is where the similarities end.

The Windimurra deposit is only one in the world that is **oxidised**. This is because it lies in the West Australian archean shield, within the oldest known part of the earth's surface. Chemically it is the same as ores mined in the Bushveld, Russia and China and those found in Canada and is the same or better grade. But physically it is very different, in that nature has already done a lot of the work, oxidising the ore to a depth of 40 meters. Consequently the ore is soft and cheap to mine, to crush and to grind.

The major process reagents, a sodium flux and ammonium sulphate, are available as waste products of the local alumina and nickel industries. PMA owns Australian and South African patents for the use of sodium oxalate which is available for almost nothing in WA. Competitors have to purchase expensive sodium carbonate.

The Windimurra kiln will again be fired by natural gas rather than coal, which has advantages in kiln availability, operating cost and product purity and enable it to employ heat recovery that reduces consumption by 30%.

A 365km gas pipeline has already been built to the Windimurra mine to supply natural gas.

Slide 18 - Key Process Enhancements

Windimurra ore was mined between 2000 and 2003, with more than 7mt treated. Windimurra engineers have identified process improvements from this experience, which will exploit the high-grade soft ore. These range from dozens of de-bottlenecking measures, to process improvements costing tens of millions to implement, which ensure that Windimurra will remain the most advanced vanadium mine in the world.

Production will be increased form the previous 12 mlbs per year to 20mlbs V_20_5 per year equivalent, reducing per unit costs.

A new external flash dryer utilising free waste heat from the existing kiln has been purchased to and pre-heat and dry the magnetite feed. Detailed computer modelling shows this will reduce kiln gas consumption by at least 25%.

Power will be generated by three gas turbines, now fitted with flash evaporators to concentrate the liquor, dramatically cutting reagent consumption.

PMA has placed orders for facilities by which AMV powder will be processed into vanadium trioxide (V_20_3) then reduced to ferrovanadium (FeV) in an electric arc furnace. Reduction of trioxide to FeV uses approximately 38% less aluminium than does reduction of pentoxide, due to the lower oxygen content.

Slide 19 – A Noble Alliance

Earlier this year, we cemented a strategic alliance with one of the world's leading commodities and supply chain managers, Hong Kong-based Noble Group Limited.

The Alliance includes a sales and marketing agreement whereby Noble has agreed to purchase the entire output of the Windimurra at prevailing market prices. During the first seven years of production, Noble will pay the higher of the current market price or the actual cash cost of production, guaranteeing cash costs are met.

Noble has taken a 10% stake in the Windimurra mine, underpinning the operation with $21.7 million in funding, and gaining a 10% holding in PMA.

Noble will exclusively market and handle all distribution logistics for Windimurra vanadium through their international network of offices.

This strong, long-term alliance will ensure the development of Windimurra as a competitive long-life, world-class operation producing high-quality vanadium at a sustainable cost.

Slide 20 – Precious Metals Australia Limited (ASX code PMA)

PMA is based in Perth Western Australia, home of the world's strongest growing mining economy. GDP growth was 14% last year, eclipsing even China!

The company's technical team is very strong, drawing its members from around the world, from competitors and former Windimurra personnel.

The company's largest shareholders are UK and Australian institutions who are very supportive of the Company and its development.

Slide 21 - Summary

Vanadium consumption will continue to grow strongly. Because of the cost and resource constraints of existing supply sources, I believe we will see a significant and growing supply shortfall emerge over the coming years.

Shortages of vanadium have in the recent past been met by growth in high cost co-production, substitution by other metals and a plethora of environmentally unsustainable, high cost producers in China.

There are a number of potential sources for increased production, but only increased primary production from a new or expanded mine is feasible for the scale and timing required.

Of the possible new mines, Windimurra is the only one already under construction.

Windimurra hosts a significant and unique, world-class vanadium deposit and will support, at a sustainable cost, a processing operation that will produce the high-quality vanadium products needed for the long term.

The World Needs Windimurra!