Molybdenum and Vanadium Market Fundamentals

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1.0 Molybdenum

1.1 Molybdenum Supply

Slightly more than half of current Molybdenum production is based on processing Molybdenum bearing secondary materials generated by copper smelters in North and South America and other regions of the world. Slightly less than half of Molybdenum production today is based on processing ores from primary Molybdenum mines in North America and China.

Today China accounts for about 40% of global Molybdenum production. North American production accounts for about one third of the global total, and about 20% of current production occurs in South America. Total Molybdenum production in 2012 is projected at about 234,000 MT Molybdenum contained.

1.2 Molybdenum Consumption

China accounts for about one third of global Molybdenum consumption today. Europe follows closely at about 30% of global consumption. Japan, North America and other countries each account for about 12% of global Molybdenum consumption.

Looking at first use by application for Molybdenum, carbon steel production consumes about 40% of Molybdenum production today. Stainless steel production consumes about one fourth of global Molybdenum production, while chemical applications account for about 15% of demand. Cast Iron, special alloy steels and Molybdenum metal production each consume approximately 7% of global Molybdenum production. Titanium alloys and super alloys consume about 3% of global Molybdenum production today.

1.3 Molybdenum Suppl/Demand Balance History and Projection

Looking now at the supply demand balance in recent years we can see that the Molybdenum market has moved from a state of oversupply in 2009 to a balanced situation in 2012.
Global Molybdenum demand growth will be driven primarily by the growth in carbon and stainless steel production rates, as well as changes in the intensity of use of Molybdenum in these steels. Molybdenum demand is projected to grow at 4.5% CAGR 2011-2017.

There are several significant Molybdenum by-product expansions already under construction that will be coming on stream in the western world in 2015-2016. For example Sierra Gorda and Codelco will each bring new supply of about 23,000 MT Molybdenum per year in the near future. In addition to these massive projects there are several others that cumulatively will add another 20-30,000 MT Molybdenum per year to market in the next few years.

In China Molybdenum production is almost exclusively based on primary mine production. Given the projected oversupply of Molybdenum outside of China and the resulting impact on prices it is conceivable that China Molybdenum mines could reduce production in the future and China could become a net importer of Molybdenum.

The most likely outcome is a rationalization of relatively high cost primary Molybdenum mining in the future. It is projected regardless that the market could reach a state of oversupply by 2014.

2.0 Vanadium

2.1 Vanadium Supply

Roughly 70% of current V production is based on the processing of V bearing slag resulting from steelmaking processes using V rich iron ores in China, Russia, South Africa and New Zealand. About 20% of current V production is based on processing V bearing residues and spent catalysts resulting from processing of V bearing oil primarily from Venezuela, Mexico and Kuwait. Approximately 10% of current V production is based on processing primary vanadium ores in South Africa, China and most recently Australia.
China accounts for approximately 45% of global vanadium production today. South Africa supplies about 20% of total vanadium production not including a significant amount of vanadium slag generated in South Africa but processed into vanadium final products in Europe.

Russia accounts for about 13% of current vanadium production, followed by Europe (9%) and North America (7%).

2.2 Vanadium Demand

It is estimated that China will consume about one third of all V production in 2012. Europe is anticipated to account for about 19% of global demand, followed by North America at about 14%. Japan and CIS countries each consume about 8% of global V production. About 16% of global consumption occurs in other countries including Korea, SE Asia, the Middle East.

About 60% of V production today is used in the production of high strength low alloy carbon steel. Special high alloy steels like tool and high speed steels consume about 30% of global V supply today. Titanium and super alloy production accounts for about 4% of global V consumption. Chemical applications and cast iron each account for approximately 3% of global V demand.

2.3 Vanadium Supply/Demand Balance History and Projection

Looking and V we see a situation where global supply has surpassed production from 2005 through 2010 but this situation seems to have reversed in 2011-2012.

Vanadium production in China during the first half of 2012 was lower than in 2011 as the majority of stone coal processors have stopped production in the face of market prices below cash costs. The majority of vanadium production in China is a result of steel mills processing vanadium bearing magnetite ores. There is a possibility that these important sources of vanadium could be impacted by the current weak situation in the Chinese steel industry.

In the meantime vanadium consumption in China continues to rise as a result of an increasing specific vanadium consumption rate in the Chinese steel industry.
Since 2006 vanadium production in the world ex China has been in excess of production outside of China, and the gap between supply and demand ex China has grown in recent years.

If we look at the total supply/demand balance outside of China we a situation where production outside of China plus Chinese exports have not supplied demand outside of China since 2008. This would suggest a drawdown in global vanadium inventories outside of China began in 2009.

From a global perspective including China total inventories started moving down in 2011 after growing for several years. Cumulative inventory change globally grew from 2001 through 2010 but began to decline in 2011. If we look at this same data in terms of months of inventory rather than absolute units we see that the global inventories expressed in months of consumption are similar today to what we last saw in 2003.

Similar to Molybdenum, vanadium demand growth will be driven by changes in global steel production levels as well as changes in the intensity of use of V in carbon steel applications. Strong economic drivers leading to the substitution of HSLA steel for carbon steel have lead to double digit growth rates in vanadium consumption over the past few years.

Given that about 70% of V supply is based on steelmaking slag from Russia, China and South Africa, future changes in vanadium supply will be closely related to steel production from V bearing iron ores in these countries. There are numerous primary V mining projects being touted today but with the exception of the Windimurra project in Western Australia which commenced production this year none of these potential projects will contribute to global supply in the next 2 years.

Looking at the projected inventory change we can see that we anticipate further global inventory drawdown to occur in the coming years.

Given double digit demand growth and limited supply increases in the next few years, upward pressure on current vanadium market prices is anticipated.
3.0 Molybdenum and Vanadium Markets and the Titanium Alloy Industry

Titanium and super alloy production accounts for 3% and 4% of Molybdenum and V consumption respectively – the Titanium alloy industry is not a major driver for Molybdenum and V demand. Approximately 80% of Molybdenum and 90% of V is consumed by the steel industry. Molybdenum and V production capacity is designed to meet the quality requirements of the steel industry.

Molybdenum and V consumed by the titanium and super alloy industry are consumed in the form of master alloys with very stringent quality requirements. High purity Molybdenum and V oxides are required to produce these master alloys. There is a limited amount of capacity to produce high purity Molybdenum and V oxides required for master alloy production. Demand for high purity V oxides will potentially be further strained in the future by growing use of V in energy storage systems. There are very few producers of master alloys qualified to supply critical applications for titanium alloy production.

4.0 Conclusions

Molybdenum supply is anticipated to grow at 9% and demand projected to grow at 4.5% CAGR over the next few years leading to an oversupply situation. Expanded byproduct Molybdenum production will make for challenging times for primary Molybdenum mines.

V demand will continue to grow at double digit rates. V supply growth is highly dependent upon changes in steel production in China, Russia and South Africa, and other than the Windimurra project there is little chance to see additional primary V production in the next few years.

Molybdenum and V industries are driven by the steel industry in terms of market supply/demand balance and resulting prices, as well as in terms of quality requirements.
The master alloy supply chain is fragile. There is limited availability of high purity V and Molybdenum oxides. There is a very limited number of qualified master alloy producers. Future supply of high purity V oxides may be further strained by growing use of V in energy storage applications.
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Agenda

**Molybdenum**
- Production
  - By Raw Material Source
  - By Region
- Consumption
  - By Region
  - By Application
- Supply/Demand Balance
- Market Projection and Implications

**Vanadium**
- Production
  - By Raw Material Source
  - By Region
- Consumption
  - By Region
  - By Application
- Supply/Demand Balance
- Market Projection and Implications

• Implications for the Ti Alloy Industry

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Slightly more than half of Mo production today is based on processing ores from primary Mo mines in North America and China. Just less than half of current Mo production is based on processing Mo bearing secondary materials generated by copper smelters in North and South America and other regions of the world.
Today China accounts for about 40% of global Mo production. North American production accounts for about one third of the global total, and about 20% of current production occurs in South America. Total Mo production in 2012 is projected at about 234,000 MT Mo contained.
China accounts for about one third of global Mo consumption today. Europe follows closely at about 30% of global consumption. Japan, North America and other countries each account for about 12% of global Mo consumption. Total consumption in 2012 is projected at about 235,000 MT Mo.
Looking at first use by application for Mo, carbon steel production consumes about 40% of Mo production today.

Stainless steel production consumes about one fourth of global Mo production, while chemical applications account for about 15% of demand.

Cast Iron, Special alloy steels and Mo metal production each consume approximately 7% of global Mo production.

Titanium alloys and super alloys consume about 3% of global Mo production today.
Looking now at the global supply demand balance in recent years we can see that the Mo market has moved from a state of oversupply in 2009 to a balanced situation in 2012.
If we look at the world outside of China demand is anticipated to grow at 4.2% CAGR 2011-2017

There are several significant Mo by-product expansions outside of China already under construction that will be coming on stream in the western world in 2015-2016. For example Sierra Gorda and Codelco will each bring new supply of about 23,000 MT Mo per year in the near future. In addition to these massive project there are several others that cumulatively will add another 20-30,000 MT Mo per year to market in the next few years. Production of Mo outside of China is anticipated to grow at a 7.8% CAGR 2011-2017.
Within China Mo consumption is expected to grow at 6.3% CAGR from 2011-2017.

Mo production in China is almost exclusively based on primary mine production. Given the projected oversupply of Mo outside of China and the resulting impact on prices it is conceivable that China Mo mines could reduce production in the future and China could become a net importer of Mo.
Global Mo demand growth in the future will be driven primarily by the growth in carbon and stainless steel production rates, as well as changes in the intensity of use of Mo in these steels. Global Mo demand is projected to grow at 4.9% CAGR 2011-2017.

Given the situation the most likely outcome is a rationalization of relatively high cost primary Mo mining in the future. Assuming significant reductions in primary Mo mining in China (scenario C) global supply is projected to grow at 7.2% CAGR leading to a state of oversupply by 2014.
Roughly 70% of current V production is based on the processing of V bearing slag resulting from steelmaking processes using V rich iron ores in China, Russia and South Africa. About 20% of current V production is based on processing V bearing residues and spent catalysts resulting from processing of V bearing oil primarily from Venezuela, Mexico and Kuwait. Approximately 10% of current V production is based on processing primary vanadium ores in South Africa, China and most recently Australia.
2012 global V production is estimated at 69,000 MTV.

China accounts for approximately 49% of global vanadium production today. South Africa supplies about 21% of total vanadium production not including a significant amount of vanadium slag generated in South Africa but processed into vanadium final products in Europe.

Russia and Europe each account for about 10% of current vanadium production, followed by North America (%) and other countries (Japan, Taiwan, Korea, India) which supply roughly 4% of global production today.
Global consumption of V in 2012 is estimated at 82,000 MTV

China is projected to account for about 34% of 2012 V consumption. Europe is anticipated to account for about 19% of global demand, followed by North America at about 14%. Japan and CIS countries each consume about 9% of global V production. About 14% of global consumption occurs in other countries including Korea, SE Asia, the Middle East and India.
About 60% of V production today is used in the production of high strength low alloy carbon steel.

Special high alloy steels like tool and high speed steels consume about 30% of global V supply today.

Titanium and super alloy production accounts for about 4% of global V consumption.

Chemical applications and cast iron each account for approximately 3% of global V demand.
Looking at the historical vanadium supply/demand balance we see a situation where global supply has surpassed production from 2005 through 2010 but this situation seems to have reversed in 2011-2012.
Since the vanadium price spike of 2004-2005 Chinese V production has grown rapidly through 2011. Vanadium production in China during the first half of 2012 was lower than in 2011 as the majority of stone coal processors have stopped production in the face of market prices below cash costs. The majority of vanadium production in China is a result of steel mills processing vanadium bearing magnetite ores. There is a possibility that these important sources of vanadium could be impacted by the current weak situation in the Chinese steel industry.

In the meantime vanadium consumption in China continues to rise as a result of an increasing specific vanadium consumption rate in the Chinese steel industry.
Since 2006 vanadium consumption in the world ex China has been in excess of production outside of China, and the gap between supply and demand ex China has grown in recent years.
If we look at the total supply/demand balance outside of China we a situation where production outside of China plus Chinese exports have not supplied demand outside of China since 2008. This would suggest a drawdown in global vanadium inventories outside of China began in 2009.
Looking at the global picture in 2011 total inventories started moving down after growing for several years. Global inventory reductions in 2003-2004 lead to a significant increase in vanadium prices in 2004-2005. Although the magnitude of global inventory drawdown which has occurred during 2011-2012 is much larger than what was seen in 2003-2004 thus far there has been no price reaction in the market.
If we look at the cumulative inventory change global since 2001 we see a situation where inventories grew significantly through 2010 but began to decline in 2011. Global inventories at the end of 2012 are projected to be similar to 2005 but trending down.
If we look at this same data in terms of months of inventory rather than absolute units we see that the global inventories expressed in months of consumption are similar today to what we last saw in 2003.
Similar to Mo, vanadium demand growth will be driven by changes in global steel production levels as well as changes in the intensity of use of V in carbon steel applications. Strong economic drivers leading to the substitution of HSLA steel for carbon steel have lead to double digit growth rates in vanadium consumption over the past few years. Vanadium demand is anticipated to grow at a CAGR of 8.4% 2011-2017.

Given that about 70% of V supply is based on steelmaking slag from Russia, China and South Africa, future changes in vanadium supply will be closely related to steel production from V bearing iron ores in these countries. There are numerous primary V mining projects being touted today but with the exception of the Windimurra project in Western Australia which commenced production this year none of these potential projects will contribute to global supply in the next 2 years.

Global supply of vanadium is expected to grow at CAGR of 8.9% from 2011-2017 assuming all of the announced expansions in China and elsewhere occur relatively on currently announced schedules.
Looking at the projected inventory change we can see that we anticipate further global inventory drawdown to occur in the coming years. Although projected V production rates are slightly higher than projected V consumption growth rates 2011-2017, the large deficit in production compared to consumption which has developed during 2011-2012 will take some time to rebuild. As a result global inventories as measured by months on hand will continue to decreased through 2017. Eventually global V inventories are projected to reach a critical level resulting in a market reaction.
Mo and V Supply Chain Issues for Ti Alloy Industry

- Titanium and super alloy production accounts for 3% and 4% of Mo and V consumption respectively – the Titanium alloy industry is not a major driver for Mo and V demand.
- Approximately 80% of Mo and 90% of V is consumed by the steel industry. Mo and V production capacity is designed to meet the quality requirements of the steel industry.
- Mo and V consumed by the titanium and super alloy industry are consumed in the form of master alloys with very stringent quality requirements. High purity Mo and V oxides are required to produce these master alloys.
- There is a limited amount of capacity to produce high purity V oxides required for master alloy production.
- Demand for high purity V oxides will potentially be strained by growing use of V in energy storage systems.
- There are very few producers of master alloys qualified to supply critical applications for titanium alloy production.

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Summary

- Mo supply is anticipated to grow at 9% and demand projected to grow at 4.5% CAGR over the next few years leading to an oversupply situation. Expanded byproduct Mo production will make for challenging times for primary Mo mines.
- V demand will continue to grow at close to double digit rates. V supply growth is highly dependent upon changes in steel production in China, Russia and South Africa, and other than the Windimurra project there is little chance to see additional primary V production in the next few years.
Summary

- Mo and V industries are driven by the steel industry in terms of market supply/demand balance and resulting prices, as well as in terms of quality requirements.
- The master alloy supply chain is fragile:
  - There is limited availability of high purity V oxide.
  - There is a very limited number of qualified master alloy producers.
  - Future supply of high purity V oxides may be further strained by growing use of V in energy storage applications.
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