The Vertically Integrated Primary Vanadium Producer
Site Visit
31 January 2019
Bushveld Minerals Experienced Leadership Team

Fortune Mojapelo
Chief Executive Officer

- Co-founder and Chief Executive Officer (CEO) of Bushveld Minerals
- Co-founder and director of VM Investment (Pty) Ltd, a principal investments and advisory company focusing on developing mining projects in Africa
- Founding CEO of Bushveld Minerals Limited where he has played a lead role developing and executing the company’s vanadium strategy
- Played a leading role in the origination, establishment and project development of several junior mining companies
- His corporate career started at McKinsey & Company as a strategy consultant

Mikhail Nikomarov
Chief Executive Officer of Bushveld Energy

- Co-founder and Chief Executive Officer of Bushveld Energy, an energy storage solutions company, part of AIM-listed Bushveld Minerals, an integrated vanadium company
- Chairman of the South Africa Energy Storage Association (SAESA)
- Chair of the Energy Storage Committee of Vanitec, the global non-profit organisation of vanadium producers
- Previously worked for McKinsey & Company in Russia and across Africa, focusing on the power sector and economic development

Lyndon Williams
Vametco Chief Operations Officer

- Previously Vametco General Manager until promotion to COO role in 2015
- Has held a range of roles with Highveld Steel & Vanadium including Metallurgist, Superintendent Vantra, Assistant Manager Steel Plant, Manager Vanchem Manager Steelmaking, Manager Ironmaking, Works Manager Steel and Vanadium, and global Vanadium sales and marketing
- Is a qualified Metallurgical Engineer
- Over 35 years’ experience in the extraction of vanadium as well as vanadium slag production and processing

Tania Mostert
Vametco Chief Financial Officer

- CFO since April 2011 with overall responsibility for Financial & Management Accounting and Procurement
- Worked within the Financial and Internal Audit Functions of Highveld Steel & Vanadium
- Various roles previously held at Highveld Steel & Vanadium include Senior Internal Auditor, Section Manager Management Accounting and Unit Manager Financial Accountant
- Is a Certified Professional Accountant
- Over 21 years’ experience in management and financial accounting

William Steinberg
Vametco Works Manager

- Works manager since March 2012
- Formerly Manager for Iron Plant 2 at Highveld Steel & Vanadium (“HSV”)
- Prior positions at HSV include Project Manager Furnace 7 rebuild, Iron Making Technologist, Production Manager Iron making, Shift Manager Steel Making, EIT Steel Making
- Holds a Master’s degree in Metallurgical Engineering from the University of Pretoria, with a thesis in EAF control
- Also has a Diploma in Organisational Management from the Moscow School of Business
- Over 10 years’ experience in iron, steel, vanadium processing and management
Company Overview
A Leading, Low Cost, Vertically Integrated Primary Vanadium Mining And Processing Platform

A growing, low cost, vertically integrated primary vanadium producer
- High grade ore for primary vanadium mining & processing
- Largest primary V resource base in the world

The Group is targeting a 10,000 mtV production in the medium term

An energy storage project developer and component manufacturer
- Electrolyte manufacturing
- Co-location in Vametco process => significantly lowering costs
- VRFB Assembly & manufacturing
- MW scale energy storage project development
- Deployment models include PPAs, leasing models

Targeting initial 200MWh of electrolyte p.a.
Targeting 1,000 MWh opportunities by 2020

Source: Bushveld Minerals analysis, Citi Group, Roskill, TTP Squared
• Bushveld Energy recognises that electricity in Africa intersects paramount potential for social transformation with an immense commercial opportunity

• The Company is focused on developing and promoting the role of vanadium in the growing global energy storage market through application in VRFBs

• Its strategy is to install several Vanadium Redox Flow Battery systems (“VRFB”) as part of its longer term vision to become a significant electricity storage provider in Africa by 2020, meeting the demand for utility scale energy storage in Africa by leveraging South Africa-mined and beneficiated vanadium

• Bushveld Energy is commissioning a VRFB with a peak power of 120kW and peak energy of 450 kWh into Eskom’s Research Testing & Development (“RT&D”) facility

• Bushveld Energy, together with the Industrial Development Corporation of South Africa, is currently establishing the manufacturing of vanadium electrolyte in South Africa
I. Manufacture electrolyte

II. Vanadium electrolyte rental

III. VRFB assembly

IV. Sell and install VRFB systems

v. Develop and invest in MW scale energy storage projects

**Bushveld Energy's focus**

- Electrolyte manufacturing
- Scope to co-locate in Vametco process => significantly lowering costs
- VRFB assembly & manufacturing
- MW scale energy storage project development
- Deployment models include PPAs, leasing models

Source: Bushveld Energy
How A Vanadium Redox Flow Battery Works
The VRFB Is The Simplest And Most Developed Flow Battery In Mass Commercial Operations

• The flow battery, unlike conventional batteries, uses a liquid vanadium electrolyte to store energy in separated storage tanks, not in the power cell of the battery

• During operation these electrolytes are pumped through a stack of power cells, or membrane, where an electrochemical reaction takes place and electricity is produced. Since vanadium can exist in four different states, it allows for a single element to be used

• Energy capacity is determined by the volume of electrolyte and the power rating is determined by the active area of the electrodes

• Energy capacity can be increased simply by scaling up the size of the electrolyte tanks and replacement of the electrolyte instantly recharges the battery

Source: Vanadium: Global Industry, Markets and Outlook, 2017. Roskill
Advantages of VRFB technology

1. **Long lifespan cycles**: Ability to repeatedly charge/discharge over 35,000 times for a lifespan of over 20 years.

2. **100% depth of discharge**: Without performance degradation is unique to VRFBs.

3. **Lowest cost per kWh**: When fully used at least once daily makes VRFBs today cheaper than Li-ion batteries.

4. **Safe**: With no fire risk from thermal runaway.

5. **100% of vanadium is re-usable**: Upon decommissioning of the system.

6. **Scalable capacity**: To store large quantities of energy (MW-range).

7. **Flexibility**: Allows capture of the multi-stacked value of energy storage in grid applications.

8. **Very fast response time**: Less than 70ms.

9. **No cross-contamination**: Only one battery element, unique among flow batteries.

Applications of VRFB technology

1. **Assist Government with limited grid capacity**
   - At present, electrification in sub-Saharan Africa is only 33%.
   - Coupling a VRFB with solar or wind generation can provide high quality, round-the-clock electricity to unconnected consumers.

2. **Assist off-grid communities in three ways**
   - Bring quick, lower cost electricity and provide a 24 hour, 100% renewable energy solution.
   - Deliver a simple “plug and play” solution in a matter of months and cut CO₂ emissions by up to 100%.
   - Reduce risk of theft of fuel or batteries and eliminate the noise created by generator engines.

3. **Shift time of electricity supply**
   - Allow less generation capacity to be built and increase load factors of base plants.
   - Allow increased penetration of renewable generation, such as wind and solar, to be added stably and safely to the grid.
   - Delay or reduce the need to build new power lines and reduce transmission and distribution losses of existing power lines.

4. **Lower operating costs for remote large energy-intensive operations (e.g. mines)**
   - Substitute on-site, thermal-powered spinning reserve with rapid response VRFB systems.
   - Serve as emergency response power source for ventilation and hoisting in underground mines.
   - Reduce back-up generator use in unstable grid environments, allowing for fuel savings of 40-80%.
   - Improves reliability of the power supply and reduce impact of weak grids in its site location evaluation process.
### Specifications Of Eskom R&D Centre

Evaluating The Values Of A VRFB Is A Major Component Of Our Current Project With Eskom

<table>
<thead>
<tr>
<th>Specifications</th>
<th>Details</th>
</tr>
</thead>
<tbody>
<tr>
<td><strong>Peak Power</strong></td>
<td>120kW AC</td>
</tr>
<tr>
<td><strong>Maximum Energy Discharge</strong></td>
<td>450kW AC</td>
</tr>
<tr>
<td><strong>time</strong></td>
<td>1h, 3.5h, 5h</td>
</tr>
<tr>
<td><strong>Power</strong></td>
<td>120kW AC, 90kW AC, 80kW AC</td>
</tr>
<tr>
<td><strong>AC (Roundtrip) Efficiency</strong></td>
<td>≈70%</td>
</tr>
<tr>
<td><strong>Voltage</strong></td>
<td>400VAC - 15% to 480 VAC + 10%</td>
</tr>
<tr>
<td><strong>Current THD (IEEE 519)</strong></td>
<td>&lt;5% THD</td>
</tr>
<tr>
<td><strong>Response Time</strong></td>
<td>&lt;100ms</td>
</tr>
<tr>
<td><strong>Reactive Power</strong></td>
<td>+/- 90kVAR</td>
</tr>
<tr>
<td><strong>Humidity</strong></td>
<td>95% RH noncondensing</td>
</tr>
<tr>
<td><strong>Footprint</strong></td>
<td>160ft² (14.9m²)</td>
</tr>
<tr>
<td><strong>Envelope</strong></td>
<td>20' [L]x8' [W]x9.5' [H]</td>
</tr>
<tr>
<td><strong>Total weight</strong></td>
<td>80,000 lbs (36,300kg)</td>
</tr>
<tr>
<td><strong>Cycle and Design Life</strong></td>
<td>Unlimited cycles over the 20 year life</td>
</tr>
<tr>
<td><strong>Ambient Temp.</strong></td>
<td>-4°F to 120°F (-20°C to 50°C)</td>
</tr>
<tr>
<td><strong>Self Discharge</strong></td>
<td>Max 2% of stored energy</td>
</tr>
</tbody>
</table>

### Source
UniEnergy Technologies

- In 2018 Eskom identified the need for potentially up to 2,000MW of additional, daily balanced energy storage within the existing grid.
- The project was developed by Bushveld Energy and IDC.
- The Integration is performed by Bushveld Energy, with VRFB from UniEnergy Technologies.
- Eskom’s operational objectives for the VRFB:
  - Minimum load shifting
  - Wind smoothing
  - Solar smoothing
  - Improved power quality
  - Micro-grid black-start
  - A combination of the above (including cannibalisation)
  - Other applications, as to be determined.
• South Africa is the largest host of high-grade primary vanadium resources, with grades in-situ ranging between 0.5% to 1.4% in magnetite V₂O₅.

• As a leading primary vanadium producer and exporter, South Africa serves as the logical base for VRFB manufacturing. This includes multiple steps of mineral beneficiation, including converting vanadium into electrolyte and assembling VRFBs locally.

• In South Africa, demand for energy storage systems continues to rise with more and more enquiries for provision of single-acid vanadium electrolyte and direct projects that require energy storage for at least four hours per day.

• Bushveld Minerals and Bushveld Energy are bringing the energy storage value chain to South Africa in order to leverage South Africa-mined and beneficiated vanadium, through the development and operation of a vanadium electrolyte production plant to supply South African and international VRFB projects.

• The new government in South Africa and the renewal of investor confidence has brought encouraging signs of increased regulatory clarity over the treatment of energy storage, the deployment of renewable energy and the direction of the country’s energy policy as published in the Department of Energy’s Integrated Resource Plan.
440 Mt Quality Resource In The Bushveld Complex

Our Resource In The Bushveld Complex, The “Pilbara” of Vanadium Production, Provides The Group Significant Potential To Expand Production To More Than 10,000 mtV

1. Vametco
- Low cost primary vanadium producer
- CY19e production volume > 2,560mtV (2018), guidance to be provided in Q1 2019 operational update
- 26 Mt reserve average in-magnetite grade of 1.96% V₂O₅
- 142.4 Mt Resource with average in-magnetite grades of 1.96% V₂O₅

2. Brits Vanadium
- Outcropping, strike extension of the Vametco mine
- Drilling confirms vanadium grades similar to Vametco (1.5 – 2.0% V₂O₅ in magnetite)
- Mineral resource estimate expected Q2 2019

3. Mokopane Vanadium
- 298 Mt JORC, outcropping reserve and resource
- Vanadium in-magnetite grades of 1.75% V₂O₅
- Positive PFS completed January 2016: 25% IRR, US$300m capex, V price $33/kgV for 5,500mtV per annum production
- Expect to be granted a New Order Mining Right

KEY
- V-bearing titaniferous magnetite
- Main Road
- Railway
Stratigraphy of Vametco Mine & Brits Vanadium Project

<table>
<thead>
<tr>
<th>UNIT</th>
<th>LOG</th>
<th>DESCRIPTION</th>
</tr>
</thead>
<tbody>
<tr>
<td>Overburden</td>
<td></td>
<td>Magnetite Seam</td>
</tr>
<tr>
<td>Upper Seam</td>
<td></td>
<td>1.70 % V₂O₅ in magnetite &amp; 1.4 % V₂O₅ in Situ</td>
</tr>
<tr>
<td></td>
<td></td>
<td>Average 60% Magnetite</td>
</tr>
<tr>
<td>Internal Waste (Magnetite Gabbronorite / Anorthosite - &lt;15 % Magnetite)</td>
<td></td>
<td>Average Grade 1.85 % V₂O₅ in magnetite</td>
</tr>
<tr>
<td>Intermediate Seam</td>
<td></td>
<td>Average 30% Magnetite</td>
</tr>
<tr>
<td></td>
<td></td>
<td>Disseminated to semi massive magnetite Seam</td>
</tr>
<tr>
<td>Internal Waste (Magnetite Gabbronorite / Anorthosite - &lt;15% Magnetite)</td>
<td></td>
<td>Main Ore Seam comprising of 8 sublayers</td>
</tr>
<tr>
<td>Lower Seam</td>
<td></td>
<td>Average 1.96 % V₂O₅ in magnetite &amp; 2.00 % in situ</td>
</tr>
<tr>
<td></td>
<td></td>
<td>Average 30% Magnetite</td>
</tr>
<tr>
<td>Footwall Anorthosite</td>
<td></td>
<td></td>
</tr>
</tbody>
</table>

- Vanadium grade in the Bushveld complex is higher in the lower portions of the stratigraphy than in the upper section, hence vanadium in magnetite is higher in the lower seam, and lower in the overlying layers i.e. intermediate & upper seam
- Magnetite % does not have a linear correlation with vanadium grade
Stratigraphy of Mokopane Vanadium Project

- Main Ore Seam comprising of 2 sublayers: MML Upper (MAG3) & MML Lower (MAG4)
- Average 1.48% V₂O₅ in situ & 1.75% in magnetite
- Over 60% Magnetite

Drill core showing a complete MML Intersection: MML Upper, parting & MML Lower
Vametco’s Geographic Location

• Vametco is an integrated mining and processing plant situated 8km to the north-east of Brits

• Vametco operates an open pit mine supplying ore to its vanadium processing plant located on the same properties

• CY19e Production volume > 2,560mtV (2018)

• 26 Mt reserve average in-magnetite grade of 1.96% V₂O₅

• 142.4 Mt Resource with average in-magnetite grades of 1.96% V₂O₅
Vametco History
The Mine And Processing Facilities Have Been In Operation Since 1967

1967
Mine started on Krookodilkraal and Uitvalgrond farms in Brits. Known as UCAR Minerals, owned and operated by Union Carbide (USA).

1986

2004
Submitted application for conversion from Old Order to New Order mining rights

15-Jun-05
EVRAZ purchase controlling stake in SMC, becoming the ultimate holding company

2007

2011

Apr-2017

Dec-2017

Sep-2018
Bushveld Minerals increases effective interest to 74% through a series of transactions

Bushveld Minerals increases effective interest to 59%

Mine taken over by SMC. Name changed to Vametco Minerals Corporation. Acted as a branch of the US Holdco

BEE Co acquired 15% in Vametco:
- AKA – 11.25% (paid for in cash)
- Community Trust – 3.75%

Company names changed to EVRAZ Vametco Holdings, Alloys and Properties

Bushveld Minerals acquires 27% effective interest in Vametco.
Company name changed to BUSHVELD Vametco Holdings,

Company names changed to EVRAZ Vametco Holdings, Alloys and Properties

Bushveld Minerals acquires 27% effective interest in Vametco.
Company name changed to BUSHVELD Vametco Holdings,
Vametco Overview

Vametco Enjoys A Significant 3% Market Share Of The Global Vanadium Market With Expansion Plans Underway Increase Its Footprint

- Open-pit mine along 3.5km strike with in-magnetite V grades of c.2% V₂O₅, among the highest in the world
- Reserve of 26 Mt, 26.79% magnetite, 1.96% V₂O₅. Resource of 142.4 Mt resource, 29.44% magnetite, 1.96% V₂O₅
- Utilises well-established salt roast processing method to produce refined vanadium in the form of Nitrovan™ and Modified Vanadium Oxide (MVO)
- 450 employees (including contractors)
- Management with over 100 years of combined vanadium mining and processing experience in South Africa

Source: Company records
Bushveld Vametco Operational Update  
Vametco Generated Healthy Cash Flows In CY18, Supported By A Strong Vanadium Price

• Production capacity
CY19e production volume > 2,560mtV (2018), guidance to be provided in Q1 2019 operational update

Expansion project to grow Vametco’s share of global market in the near term
➢ The Company commenced an Operational Transformation programme to enhance Vametco’s production and efficiencies

• Vanadium Price
Strong price performance trading at ~US$76/kgV YTD¹
➢ Vametco's realised price is based on the prior month's average price

<table>
<thead>
<tr>
<th>Bushveld Vametco results² (100%)</th>
<th>CY18</th>
<th>CY17</th>
<th>CY16</th>
<th>CY15</th>
</tr>
</thead>
<tbody>
<tr>
<td>Vanadium produced (mtV)</td>
<td>2,560</td>
<td>2,649</td>
<td>2,856</td>
<td>2,419</td>
</tr>
<tr>
<td>Vanadium sold (mtV)</td>
<td>2,573</td>
<td>2,721</td>
<td>2,810</td>
<td>2,340</td>
</tr>
<tr>
<td>FeV LMB price US$/Kg V</td>
<td>81.2</td>
<td>32.6</td>
<td>18.5</td>
<td>18.6</td>
</tr>
<tr>
<td>USD/ZAR exchange $=ZAR</td>
<td>13.2</td>
<td>13.3</td>
<td>14.7</td>
<td>12.8</td>
</tr>
<tr>
<td>Revenue US$’m</td>
<td>192.2</td>
<td>79.1</td>
<td>51.7</td>
<td>49.2</td>
</tr>
<tr>
<td>EBITDA US$’m</td>
<td>107.5</td>
<td>23.9</td>
<td>3.3</td>
<td>1.3</td>
</tr>
<tr>
<td>Underlying costs³ production US$/kgV</td>
<td>19.7</td>
<td>16.6</td>
<td>12.9</td>
<td>14.6</td>
</tr>
</tbody>
</table>

1. Year to date (YTD) as at 24 January 2019
2. Following the completion of the acquisition of the remaining 55% share in BVL in December 2017, Bushveld’s net attributable interest was 59.1%, this subsequently increased to 74% in September 2018, through a series of transactions
3. Excludes depreciation, royalties, selling, general and administrative expenses, and impact from production stoppages.

Source: Bloomberg, Company records
Nitrovan™ Allows Steel Mills To Achieve High Strength More Efficiently

- Nitrovan™ is a vanadium-nitrogen ("VCN") product that strengthens steel more efficiently than ferrovanadium. This strengthening mechanism allows steelmakers to use less vanadium in high-strength low alloy steels and reduce vanadium costs by as much as 40%

- By replacing ferrovanadium with Nitrovan™, steelmakers can achieve high strengths more efficiently and at lower costs

- Cost-conscious steelmakers around the world have saved well over US$100 million dollars by using Nitrovan™ vanadium

### Obtaining Equivalent Yield Strengths With Less Vanadium

<table>
<thead>
<tr>
<th>ALLOY USED</th>
<th>VANADIUM USED</th>
<th>VANADIUM SAVINGS PER METRIC TON OF STEEL USING NITROVAN™ Vanadium instead of Ferrovanadium</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>VANADIUM ADDITION Per Metric Ton</td>
<td>VANADIUM CONTENT In Steel</td>
</tr>
<tr>
<td>NITROVAN™ VANADIUM</td>
<td>0.60kg (1.35 lbs)</td>
<td>0.06%</td>
</tr>
<tr>
<td>80% FERROVANADIUM</td>
<td>1.0kg (2.25 lbs)</td>
<td>0.10%</td>
</tr>
</tbody>
</table>
Vametco currently produces only Nitrovan™, selling to steel mills across the world. Nitrovan™ is used for the production of the following High-strength low-alloy steel:

- Reinforcing Bars
- Forgings
- High-Strength Sheets
- High-Strength Plates
- High-Strength Bars
- High-Strength Structural Steel

Bushveld Vametco’s Global Customer Base

Vametco Sells Majority Of Its Product To The US

Bushveld Vametco’s Global Customer Base (CY18 Sales)
Substitution Consideration

Niobium Substitution Threat

Factors working against substitution
- Replacement of vanadium requires technical adjustments to steel production, to ensure that product specifications and quality are not compromised
- Vanadium is generally considered to require lower rolling pressures and temperatures than niobium to give equivalent steel properties
- Less energy is thus consumed in the production process when vanadium is used
- Niobium supply significantly more concentrated – CBMM controls >80% of supply with significant additional capacity

These factors combined mean that substitution is normally not considered for short-term changes in market conditions because of the considerable effort needed to implement the changes

Factors supportive of substitution
- Sustained high vanadium prices
- Vanadium price volatility – substitution occurs when the V price is 2-4x higher than Nb
- Long term niobium contracts provide reasonable price stability for steel plants
- Concentration in niobium supply means supply response better coordinated

Recent data
- China imported 45% more FeNb in 2018 compared to 2017 (35,737mt in 2018 compared to 24,644mt in 2017)
- Much of the substitution is price elastic and will be reversed as the Vanadium price normalises

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Source: Bushveld Mineral analysis, Roskill

![FeV and FeNb L12M prices graph](image)
Brits Vanadium Project Update
Large High-grade Primary Vanadium Resource Base

- Outcropping, strike extension of the Vametco mine
- Second phase of the exploration programme completed. The aim is to delineate a maiden Mineral Resource Estimate
- Positive results from a soil geochemical sampling programme and ground magnetic survey has led to several drilling targets being delineated
- Q2CY18 results indicated vanadium grades in magnetite of 1.54-2.09% $V_2O_5$

Ore body extends West to East and dips in northerly direction at 20 degrees

Brits Vanadium Project’s Strike Confirmed by Ground Magnetics & Drilling Results
Vametco Employs The Standard Salt Roast And Leach Process To Produce Nitrovan™
**Bushveld Vametco Processing Steps**

1. **Mining**
   - The processing plant at Vametco is fed ore from the co-located Vametco mine. The Vametco mine is an open pit mine along a 3.5km strike running west to east and dipping at about 20 degrees in a northerly direction. Vametco employs the standard salt roast and leach process to produce a trademark vanadium carbon nitride (VCN) product called Nitrovan™.

2. **Concentration**
   - The ore is passed through a three-stage crushing and milling circuit to produce a product sizing suitable to liberate the gangue materials in the ore, typically 20% passing 75 microns and passed through a low intensity magnetic separation circuit to produce a magnetite concentrate product.

3. **Salt Roasting**
   - The concentrate is roasted with sodium carbonate and sodium sulphate in a rotary kiln at temperatures of up to 1,150°C to form watersoluble sodium vanadates. Solids exiting the rotary kiln are discharged directly into a rotary cooler that cools the solids sufficient for conveying to the leaching circuit.

4. **Leach Milling & Purification**
   - The cooled calcine is fed to a wet ball mill which grinds the agglomerated material for improved leaching and also acts as the first stage of leaching. The mill discharge slurry is pumped to belt filters to separate the vanadium rich solution and calcine tailings. The vanadium rich solution is pumped to thickeners where desilication and concentration of the vanadium-bearing leach liquor takes place. Calcine tailings are conveyed to the tailings disposal facility.

5. **AMV precipitation**
   - Ammonium sulphate is added to the vanadium-bearing leach liquor which allows for the precipitation of vanadium in the form of ammonium metavanadate (AMV).

6. **Modified Vanadium Oxide Production**
   - The AMV filter cake is dried in a rotary dryer and thereafter transferred to the MVO Rotary Calciners to produce Modified Vanadium Oxide (MVO).

7. **Nitrovan™ shaft furnace**
   - Nitrovan™ production – the MVO is mixed with carbon and a binder which is briquetted and fed into an induction shaft furnace under a nitrogen atmosphere to produce Nitrovan™.

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**Mining Bushveld Vametco Processing Steps**

<table>
<thead>
<tr>
<th>Step</th>
<th>Description</th>
</tr>
</thead>
<tbody>
<tr>
<td>1</td>
<td>Mining</td>
</tr>
<tr>
<td>2</td>
<td>Concentration</td>
</tr>
<tr>
<td>3</td>
<td>Salt Roasting</td>
</tr>
<tr>
<td>4</td>
<td>Leach Milling &amp; Purification</td>
</tr>
<tr>
<td>5</td>
<td>AMV precipitation</td>
</tr>
<tr>
<td>6</td>
<td>Modified Vanadium Oxide Production</td>
</tr>
<tr>
<td>7</td>
<td>Nitrovan™ shaft furnace</td>
</tr>
</tbody>
</table>
Vametco operates an open pit mine supplying ore to its vanadium processing plant located on the same properties. The open pit mine is approximately 3.5 kilometres long in a west-east direction. The ore body is well defined, continuous and dips in a northerly direction at approximately 20 degrees. The mine is based on a JORC resource of 142.4 Mt, including 26.12 Mt reserves with in-magnetite vanadium grades averaging 1.96% $V_2O_5$. 
Breaks up large boulders to a maximum size of 150mm, the ore is screened (grizzly) the oversize is +40mm to -150mm in size, and goes to the 150mm stockpile (coarse stockpile). This ore is fed to the secondary crusher. The undersize of the grizzly goes to the screens in the screen house together with the undersize from the secondary crushers.
In the milling section the 10mm ore is pulverized in ball mills and then fed to magnetic separators where the magnetic portion is separated from the gangue. The first concentrate from the magnetic separators are fed to the secondary mills where it is further grinded down and finally separated in a magnetic separator. The concentrated magnetite is then fed to the kiln section and the slimes and gangue is pumped to tailing slimes dams and the water is recovered and recycled in the plant.
Measured amounts of magnetite, sodium sulphate and sodium carbonate are mixed and fed to the pulverised coal fired rotary kiln. The mixture is roasted at about 1,150 degrees celcius, rendering the Vanadium water-soluble. Kiln off-gases are scrubbed in a venturi scrubber prior to release to atmosphere. The solids in the scrubber liquor are settled in a thickener, dewatered over a belt filter and returned to the Kiln feed. The thickener overflow is pumped to lined scrubber dams for further settling before being reused in the scrubbing circuit.
The kiln product is water-leached. The solids are wet milled, and washed in a counter current process over a large belt filter. The magnetite tailings are disposed of on a tailings dump. Aluminium Sulphate and a flocculent are used to desilicate and clarify product liquor called pregnant (preg.) solution.

The Vanadium-bearing liquor (the principal components of which are Sodium Sulphate and Sodium Metavanadate) is pH adjusted with Sulphuric Acid before being pumped to the Precipitation Plant. Some Ammonium Metavanadate (AMV) sludge is re-dissolved in this plant with the use of Caustic Soda.
Vanadium in the Pregnant Solution is precipitated with Ammonium Sulphate to form Ammonium Metavanadate (AMV). This is then dried in a rotary calciner at a temperature that will not drive the Ammonium off. In the AMV the Vanadium is in the +5 oxidation state. The dried AMV is then forwarded to the MVO section for conversion. The Vanadium depleted solution called the Barren Solution is pumped to the Sulphate Recovery Plant (SRP).
The function of the MVO section is to reduce the AMV to Modified Vanadium Oxide (MVO). In this product the Vanadium is in the +3 oxidation state with the formula V$_2$O$_3$. The MVO is drummed and sealed when cool to prevent re-oxidation. The product is Black in color with some variation to brown. A bright Blue color is an indication that the product had been exposed to Oxygen before being cooled off sufficiently. MVO is the Feed Stock for Nitrovan™, Electrolytes.
The MVO is mixed with the required quantity of Carbon in the Mix Plant to produce the various Grades of Nitrovan™, i.e. Nitrovan 12% and 16%. Under controlled conditions Nitrogen is purged into the furnace to substitute the Carbon and dependent on the quantity of Carbon this results in the required grades of Nitrovan™. Vanadium in these products are in the reduced state with a minute quantity tied to Oxygen. Elements are in a solid solution state.

<table>
<thead>
<tr>
<th>Grade</th>
<th>Vanadium</th>
<th>Nitrogen</th>
<th>Carbon</th>
<th>Aluminum</th>
</tr>
</thead>
<tbody>
<tr>
<td>Nitrovan 12</td>
<td>76-81%</td>
<td>10-14%</td>
<td>10% max.</td>
<td>0.15% typical</td>
</tr>
<tr>
<td>Nitrovan 16</td>
<td>76-81%</td>
<td>14-19%</td>
<td>6% max.</td>
<td>0.15% typical</td>
</tr>
</tbody>
</table>