MIDWEST VANADIUM PTY LTD

WESTERN AUSTRALIA

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Definitive Study – Scope of Work for Refinery De-Bottlenecking Project

Midwest Vanadium Pty Ltd ABN 65 113 874 712

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1. GENERAL

1.1. Introduction

The Midwest Vanadium Pty Ltd (MVPL) Windimurra plant is located approximately 80 km by road from Mt Magnet and produces ferrovanadium and iron ore. Following a fire in the Beneficiation Plant that stopped all production, the plant has been reviewed for capacity at a high level to determine what equipment needs to be modified in order to sustainably achieve a throughput of 4800tpa of vanadium (contained in FeV).

This Definitive Study - Scope of Work (SOW) is for the review of a number of key process and pieces of equipment in the Refinery to ensure they are capable of meeting MVPL production requirements of 400 tonnes per month (tpm) of vanadium (contained in FeV).

The objective of this study is to complete definitive level engineering that will allow high confidence level (+/-15%) capital and operating cost estimates, detailed project implementation schedule and a comprehensive set of documents to enable an EPCM tender for project execution.

2. SCOPE OF WORKS

2.1. General

The Consultant works shall be performed and completed in accordance with the latest issue of all relevant Australian Standards, Codes, Acts and Regulations of statutory authorities and MVPL Refinery Site Specifications. Supporting documentation shall be provided to the MVPL Company Representative upon request at no cost to MVPL.

2.2. Drawings and Documentation Requirement

The Consultant shall provide all documentation, drawings and any of the key deliverables as specified in Appendix H, in native format, PDF, 3D models in native and Navisworks format (.nwd) and all calculations in native format to MVPL Company Representative upon request at no cost to MVPL.

2.3. Key Deliverables and Review Process

The key deliverables can be seen in Appendix H.

The following steps are recommended for the review process
1. Consultant to canvass all possible solutions
2. Final option list will be presented to MVPL based on consultant and MVPL discussions
3. Consultant to conduct a pre-feasibility level analysis of solution on the final option list
4. A preferred option list will be decided based on consultant and MVPL discussions
5. Consultant to provide the deliverables as itemized in Appendix H

There will be 2 working business days for MVPL to review documents and return to the Consultant.

MVPL personnel shall have full access (in relation to this SOW) to Consultant offices. MVPL engineers/personnel will be embedded in the Consultant team.

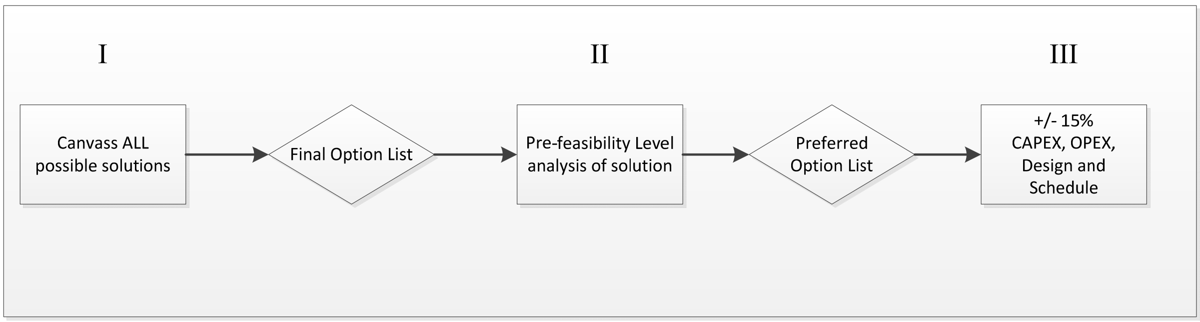

Figure 1 Recommended Review Process

2.4. Areas of Interest

The key deliverables in Section 2.3 shall be completed by the Consultant for all the areas as specified below:

i. Areas 19 and 20 – Roasting Circuit
ii. Area 25 – Leaching Circuit
iii. Area 30 – Desilication Circuit
iv. Areas 35 and 36 – AMV Precipitation, Filtration and Flash Drying
v. Area 41 – V_2O_3 Production Circuit

Details for each area are listed in Section 3.

The Process Design Criteria 6033-G-00-F-001 referenced in Schedule 9 of Invitation to Tender Package 10-306-PR-TEN-0001, and a Refinery Stage Recovery document has been included in the Refinery Library for this Scope of Work. The figures/recoveries in the Refinery Stage Recovery document takes precedence over the Process Design Criteria 6033-G-00-F-001.

The characteristics of the magnetic concentrate which serves as the feed to the refinery section will change from the 2013 operations. The change in composition as specified by the new beneficiation plant process design criteria is defined in the Kiln Feed Characteristics Rev 1.

3. AREAS

3.1. Area 19 and 20 - Roasting Circuit

3.1.1. Scrubber Bleed Pumps/ Piping Blockage Fix

Background Information

The Scrubber Bleed pumps (19PPC501) feed the slurry from 19TNK501 to the Dirty Preg Tank (30TNK510) in the Desilication Area. From operation, it has been apparent that after a period of service, the flow rate of the slurry would be restricted to significantly lower than the capability of the pumps.

Upon inspection, it was noticed that scale had built up inside the pipe and was causing a restriction on the flow rate of the pumps. There are a number of pipe sections that form dead-legs and accumulate solids, causing blockages in the line.

Existing and Potential Issues

It is imperative that the Scrubber Bleed Pumps are reliable as the roasting kiln cannot be started and stopped quickly, thus the kiln and its associated equipment's reliability and maintainability are very important for the continuous operation of the plant. The pump capabilities need to be reviewed for system capability.

Area Critical Success Factors

1. Reliability of the scrubber bleed pumps system must exceed kiln reliability
2. Ability to clean the lines if solids settling cannot be eliminated

Potential Solution

1. CIP system
2. Duty/standby line

3.1.2. Feed Hood and Feed Screw System Rectification

Background Information

The Roasting Kiln feed system and feed hood consists of a mixing screw, feed screw, an over flow chute and supporting mechanical equipment and instrumentation. The kiln mixing screw (19MXR501) receives magnetic concentrate via a conveyer (19CVR501). The mixing screw discharge then feeds the kiln feed screw (19FDS502) which in turn feeds the roasting kiln (20KLN501). The roasting kiln back-spill overflows into the kiln feed hood and dust hopper (19FH501) at the feed end of the kiln, which discharges into the skip bin via a double flap valve (19DFV501).

The wear life of the original bis-alloy feed screw flights was quite low prompting MVPL to work closely with Bulk Materials Handling (BMH) to improve the feed screw performance and identify additional modification opportunities.

There has been a continuous problem regarding ring formation at the feed end of the kiln and the inability of the kiln to draw material in, leading to excessive back spill in the feed hood.

An audit conducted on the roasting kiln by FLSmidth on October-November 2013 highlighted numerous issues and provided potential solutions for the issues identified.[1]

Hatch conducted a Refinery Debottlenecking Review on June 2014, identifying potential bottlenecks and providing high-level recommendations to achieve 400tpm and 500tpm V (contained in FeV).[2]

The kiln, in addition to all the mine site regulations, is a gas system that is required to follow the gas laws and regulations for WA.

Existing and Potential Issues

The kiln has considerable back spillage from the feed end of the kiln into the overflow chute 19FH501, approximated to be about 7% during the FLSmidth audit.

Large agglomerations of product that are unable to pass through the double flap valve cause the chute to block and build up with material. This can lead to seal damage, compromise of structural integrity and additional load on the kiln drive and thrusting mechanism. This leads to extensive downtime to un-block the chute and repair the damage.

The feed screw undergoes significant wear after a reasonably low amount of throughput. The screw design prevents an efficient screw change-over.

The screw shafts are considerably worn and have an increased chance of failure as the shaft has a welded joint.

The mixing screw is difficult to maintain due to its position within the kiln feed structure. The mixing screw is foreseen to be an unnecessary complication to the feed system.

The hot dust return from the cyclones to the paddle mixer was determined to be potential issue for the feed screw based on the FLSmidth audit. When the dust is mixed with the soda ash and the magnetic concentrate in the paddle mixer, it is suspected that this mixture hardens and affects the feed screw. It was recommended to return the dust directly into the kiln, bypassing the mixer.

Area Critical Success Factors

1. Eliminate back-spill of the product into the feed hood and feed end build-up.
2. Minimise complexity and improve maintainability of the feed system.
3. Removal of the recycle of the cyclone dust to the mixer.
4. Feed system should be able achieve a production of 400tpm V (contained in FeV). This is equivalent to a concentrate feed rate of ~118tph on a dry basis (excluding moisture, soda ash and dust recycle) at 90% availability.

Possible Conceptual Solutions

1. Feed hood and dust hopper re-design (19FH501) – refer Appendix A
2. Kiln feed spirals – refer Appendix B
3. Drytech Offgas System Documentation – refer Appendix E
4. Drawings of Kiln Feed Hood – refer Appendix F

[1] FLSmidth, *Windimurra Vanadium Australia Kiln Audit*, 06 November 2013
[2] Hatch, *Capacity Constraints and Suggestions for Debottlenecking to 400tpm and 500tpm V, June 2014*

3.1.3. Burner and other instrumentation upgrade for the roaster

Background Information

The roasting kiln burner (20BUR501) supplies heat to the entire roasting kiln process, receiving gas and primary air though the nozzle and secondary air through the cooling tubes.

An audit conducted on October 2013 on the kiln by FLSmidth highlighted numerous issues with the current burner and provided potential solutions to improve the performance of the installed burner. The two holes cut into the primary air nozzle to allow new scanners to monitor the flame were partly closed to improve the distribution of primary air and improve the flame shape. However, the repair to the primary air nozzle was insufficient to provide the required primary air value due to the damage to the primary air nozzle. It has been recommended by FLSmidth to install a new Uniflow burner that has the capacity to handle the planned increase in production. Alternatively, a Duoflex burner can be installed in the kiln to allow for better flexibility in adjusting the flame.

FLSmidth recommended the installation of a dam ring in the discharge end of the kiln to keep the material longer in the reaction/hot zone, especially in the case of the existing burner.

Hatch performed modeling of the kiln on June 2014. It has been suggested that a more sophisticated burner will be required to achieve proper recovery at a feed rate of 107.5tph (dry basis). When modelling a low dust generation scenario, a kiln feed rate of 117tph (dry basis) may be possible.

A kiln feed rate of ~118tph (dry basis) is necessary to achieve 400tpm V (contained in FeV) at an overall recovery to FeV of 75%.

It has been recommended to replace the existing Uniflow burner with a different burner, such as the Duoflex burner recommended by FLSmidth, or a custom made burner from the likes of FCT in Adelaide

Existing and Potential Issues

The modifications to the primary air nozzle for the new flame monitors adversely affected the burner, making it impossible to obtain a good flame shape and achieving the required throughput in the kiln to reach the 400tpm V production (contained in FeV). The burner is also damaged and bent.

Based on the modeling conducted by Hatch, it may be possible to achieve a feed rate of ~117tph (dry basis) if low dust generation is achieved in the kiln. A more realistic feed rate is 107.5tph (dry basis), with focus on improving equipment, instrumentation and kiln combustion in order to achieve the required residence time at temperature of 1hr at 1150ºC.

Area Critical Success Factors

1. Achieve a sustainable process at ~118tph (dry basis) magnetic concentrate feed at a minimum of 86% vanadium conversion in the kiln. The kiln should able to process the equivalent throughput necessary for the production of 400tpm V (contained in FeV).
2. Enable control room monitoring and recording of (as a minimum):
    a. Kiln shell temperature.
    b. Bed and flame temperature.
    c. Gas supply control.
3. BMS optimization and provision of BMS instruction manual
4. Reliability of the burner to exceed that of the kiln

Possible Conceptual Solutions

1. Duoflex Burner from FLSmidth or a custom made burner from FTC
2. Mirion Pyrometer Camera (M555/M215)

3.1.4. Roaster Discharge System (Improved Reliability)

Background Information

The roasting kiln (20KLN501) discharge drag chain conveyer (20CVR501) transports the roasting kiln discharge to the bucket elevator prior to the quenching vessel and the Leaching Vats.

The excessive wear on the mechanical components of the drag chain conveyor including the manganese wear strips and sprocket cleaner has caused multiple breakdowns on the discharge drag chain conveyor.

Existing and Potential Issues

It is imperative that the roasting kiln discharge conveyor is reliable and any imminent failure is detectable so that feed to the roasting kiln can be stopped and the remaining products run through while the kiln continues to rotate and cool down.

Area Critical Success Factors

1. Kiln discharge system reliability must exceed kiln reliability. The kiln discharge system should not drive planned shutdown critical path.
2. Eliminate potential for catastrophic failures.

Possible Conceptual Solutions

Magaldi EcoBelt as per Appendix C

3.1.5. Roasting Kiln Cowl (Discharge End) Support Structure and Concrete Remediation

Background Information

An ad-hoc brace has been installed to support the roasting kiln discharge hood. The brace has been anchored into the existing concrete slab, which is not designed to sustain the loading imposed upon it by the brace. As a result, the concrete has sustained damage.

Existing and Potential Issues

The concrete slab that is supporting the brace has been damaged and cracks have formed, exposing the reinforcement bar to the ingress of air and water and possibly compromising the integrity of the structure.

Area Critical Success Factors

1. Ensure the kiln discharge hood is adequately supported and the integrity of the structure is maintained.
2. Damaged structure and concrete are remediated, removed or replaced

3.1.6. Roasting Kiln Retaining Wall Concrete Remediation/Demolition

Background Information

The roasting kiln retaining wall adjacent to the roasting kiln exhibits damage to the concrete structure. It appears the walls have been subjected to impact and cyclic loads throughout the lifetime of the structure. This was possibly from thermal expansion/contraction as the wall is located adjacent to the roasting kiln. The area is now unused.

Existing and Potential Issues

The wall reinforcement bar is exposed and the wall shows signs of further deterioration.

Area Critical Success Factors

Modification/remediation of the wall to prevent further deterioration, without compromising the integrity of the surrounding structure.

3.2. Area 25 - Leaching Circuit

Background Information

Three leach vats are provided with a capacity of ~2,400 tonnes of calcine each. The base of each vat is fitted with a network of support steel upon which grid mesh and media are positioned. The calcine slurry is discharged into the vat, and as the vat fills with quenched calcine, the level of the solution in the vat rises and the excess is bled to the slug dose tank. Filtrate from the vat passes through the media and is chanelled through the support structure to the discharge suction pumps.

Existing and Potential Issues

The existing filter media used in the leach vats came from the filter belt. This may not be fit for purpose, but was used as a temporary solution during operations. This is suspected to contribute to the leach vats not reaching the process design criteria of 53 hours cycle time and only achieving a 90% soluble vanadium recovery in the plant.

Area Critical Success Factors

1. Eliminate leach vat underflow blockages and failures.
2. Achieve processing of 400tpm V (contained in FeV) at 90% availability.
3. Achieve soluble vanadium recovery of at least 96%.

3.3. Area 30 - Desilication

3.3.1. Sulphuric Acid and Aluminium Sulphate System Rectification

Background Information

The refinery sources its sulphuric acid and aluminum sulphate from the purpose built storage tanks and bund facilities.

Existing and Potential Issues

Key equipment in the sulphuric acid and aluminum sulphate systems are either inoperable, damaged or their integrity has been compromised. The current sulphuric acid storage and distribution facility needs to be reviewed, remediated and/or redesigned to increase safety, reliability and to ensure that the facility meets standards for loading/unloading and storage.

Area Critical Success Factors

1. Remediation/redesign of the sulphuric acid system to comply with environmental and safety requirements.
2. Sulphuric acid onloading system to be upgraded to Coogee standards (refer Appendix G).
3. Sufficient aluminium sulphate storage system to limit deliveries to a maximum of once every 7 days.
4. Aluminium sulphate delivery system upgraded to achieve soluble silica removal efficiency of >99%, with the ability to split the aluminium sulphate addition to two desilication tanks.
5. Ability to control pH in the circuit to reduce corrosion and maintain solution pH at 8.3 (range between pH of 8-8.5), with the ability to split the sulphuric acid addition to two desilication tanks.
6. Re-instatement of the acid line to provide the required flow rate to the V_2O_3 scrubber system.

3.3.2. Desilication Filter Optimization

Background Information

The slurry from the last desilication tank gravity feeds the desilication filter feed tank (30TNK503). The slurry is pumped on a batch basis to the desilication filter press (30FTP501). Although not currently installed, the desilication facility allows for the future installation of a pre-coat system that is designed to coat the filter cloth with a diatomaceous earth to avoid very fine silicate solids from washing through the filter and prevent the occurrence of blinding of the filter cloth due to precipitate growth within the cloth.

High downtime hours and high losses in the desilication circuit were contributing factors to the low vanadium production in the refinery in 2013. Internal investigations and reviews showed that the filter cake produced in the desilication filter press average 30-45mm, with the design being 25mm.

A vendor visit/audit conducted on August 2013 has mainly focused on the safety and operational aspect of the filter press, with no focus on the automation of the system.[3] Internal reviews and trials to improve the operation and to automate the system were not completed due to the beneficiation plant fire in February 2014.

[3] Filtration Systems Ltd, *Midwest Vanadium Desilication Filter Press Review, 12 August 2013*

Existing and Potential Issues

The filter press can only operate correctly when the chambers are filled evenly at a steady rate – this is not achieved with the current set-up. Uneven distribution of the cake and uneven washing of the cake contribute to high vanadium losses in the circuit and higher batch time for filtration. Higher batch times can contribute to the desilication filter press becoming a bottleneck to the production of 400tpm V (contained in FeV).

Damages to the filter cloths will also result in excessive downtime hours associated with changing out the filter cloths.

The feed rate required to fill the press needed to be maintained on the front end by the input of the desilication feed material. If the feed was not of the same value, the overflow from the first tank into the second and subsequently third will stop, allowing in turn the feed tank to reach a low level and the desilication filter feed to drop off significantly. This process operating philosophy does not allow the filter to fill completely and results in the press being “trickle fed” for the remainder of the time until such time that the operators deem it necessary to operate.

It is believed that there is an inherent flaw in the process design and the control philosophy for the filter press, preventing a complete cycle to be processed. The whole system will need to be reviewed in detail.

The filtrate quality is monitored using an inline turbidity meter. The nature of the filtrate is such that scaling occurs on the turbidity analyzer and causes the reading to be inaccurate.

The filter cake is removed by a bobcat from the filter press floor and brought to the leaching vats. This practice poses safety issues to the operator. A solution for transporting the filter cake to the final destination, based on the best area for disposal/additional recovery of vanadium needs to be determined.

Area Critical Success Factors

1. Desilication filter is fully automated for all cycles and able to be run from the DCS instead of the local PLC, at the same time increasing safety, reliability and efficiency.
2. Desilication filter sustainably achieves <0.5% soluble vanadium losses.
3. Safe and effective filter maintainability to achieve 90% availability.
4. Devise a cloth changing station that shall reduce cloth changing time to 10 minutes per plate.
5. Process achievement of 400tpm V (contained in FeV) through the filter press.
6. Early detection of solids breakthrough in the clear pregnant liquor.
7. Eliminate contamination of filter cake solids in the clear pregnant liquor.
8. Eliminate/reduce manual handling of the filter cake from the filter cake floor to a recommended final destination.

3.4.Area 35 and 36 - AMV Precipitation, Filtration and Flash Drying

3.4.1. AMSUL Loading Facility

Background Information

The Amsul mixing facility is a batch operation based on two mixing tanks (35TNK511, 512), each with 12hrs storage capacity of Amsul solution. A front end loader is used to reclaim Amsul from either the storage bunker or the unloading bunker and deposited into the Amsul receival hopper (35HO503). The Amsul conveyor transfers the reagent at a fixed speed to the selected mixing tank via a drag chain conveyor. The required mass of Amsul is calculated via an algorithm and is displayed on the DCS along with the estimated number of loader buckets required.

The mass of Amsul added, the strength of the barren solution and the active mixing tank's level is used in an algorithm in the DCS to calculate the strength of the concentrated Amsul solution.

Existing and Potential Issues

Inaccurate measurement of Amsul solution strength has led to high vanadium losses in the precipitation circuit during operations in 2013. The concentration of Amsul is measured by hydrometer which relies on specific gravity of the solution. Due to higher vanadium and corresponding contamination levels in the barren solution during that period, the barren solution strength was over reported by as much as 150g/L, which resulted in lower overall Amsul solution strength and resulted in low AMV precipitation.

The drag chain conveyor is believed to be undersized for the duty required to make up the Amsul solution, requiring operators to monitor the process during the batching sequence. Issues have also been encountered with the weighing system, which leads to operations estimating the buckets of Amsul that needs to be added to the mixing tank.

Area Critical Success Factors

1. Upgrade the conveying and weighing system to provide sufficient make up solution for the production of 400tpm V (contained in FeV) through the AMV circuit.
2. Efficient method of making up concentrated Amsul solution
3. Accurate measurement of the Amsul concentration

3.4.2. AMV Precipitation and Filtration

Background Information

Clear pregnant solution from the desilication circuit is pumped into three x 90m^3 capacity, mechanically agitated, ammonium metavanadate (AMV) precipitation tanks (35TNK501, 502, 503), configured in series. Ammonium sulphate is pumped into the first AMV tank to precipitate out the insoluble AMV crystals. The slurry flow between the tanks is driven by the head difference between interconnecting launders.

During operations in 2013, significant downtime was associated with the bogging of AMV solids in the precipitation tanks. A custom-built, temporary transfer system was installed to allow the transfer of solids from one tank to the next.

It was also identified that the crystal structure of the AMV produced by MVPL is small with multiple inclusions in comparison to the large, clean crystal structures produced by another vanadium producer, Hot Springs. A scope of work for the conversion of the existing AMV precipitation system was prepared by MVPL personnel in 2013. The proposed re-design includes the installation of pumps between the AMV tanks to enable solids transfer from one tank to the next.[4]

The addition of the baghouse slurry to the AMV circuit has also contributed to the inclusions seen in the AMV crystals, as well as in the blinding of the AMV belt filter. A temporary solution of bagging the V_2O_3 baghouse dust prevented this issue from causing issues in the AMV filter belt.

Existing and Potential Issues

The motors used for agitation in the first two AMV tanks have been changed out from 3kW to 7.5kW. These are meant to keep the solids in suspension, but have been proven to be insufficient during operations.

Blinding of the AMV filter with the finer V_2O_3 powder from the reduction circuit will cause downtime hours and prevent the production of 400tpm V (contained in FeV).

The barren solution tank (35TNK506) silts up with material, which in turn causes bogging of the pumps that extract the barren solution for various processes through the plant.

Area Critical Success Factors

1. Efficient solids transfer from one tank to the next downstream tank.
2. Eliminate contamination of AMV with V_2O_3.
3. Ability to control the solution temperature from 90ºC to 35ºC and pH to 8.3.
4. Availability of the heat exchanger to exceed 90%.
5. AMV conversion of >97% - vanadium losses to barren should be <3%.
6. Eliminate belt filter spillage.
7. Achieve <20% moisture in the AMV filter cake to the flash dryer.
8. Achieve AMV production rate > 400tpm V (contained in FeV) at 90% availability
9. Prevention of solids build-up in Barren Liquor Tank 35TNK506.
10. Accurate measurement of AMV production

Possible Conceptual Solutions

1. Conversion of precipitation tanks to crystallizers.
2. Permanent solution for the removal of the addition of V_2O_3 powder to the AMV circuit.

3.4.3. AMV Flash Drying

Background Information

AMV containing up to 20-25% moisture is discharged from the AMV filter into a back mixer (36MXR502) where it is mixed with warm, dry AMV to produce a free flowing, friable product. The warm, dry AMV is mixed with the wet feed to reduce the possibility of blockages in the system due to caking. The combined AMV feed contains a moisture content of 8-12%.

The product is discharged to the disintegrator (36DI501) via the backmixer discharge chute. The disintegrator is fed with AMV from the back mixer and hot gas from the dryer combustion chamber. The AMV is then dried in a vertical hot air column (36FC501) and the dried product collected from the gas stream by cyclones and bag filter plant (36DEX501). The bag filter is a fully automatic reverse pulsed type baghouse. The dried AMV collected from the cyclones and baghouse are discharged into the AMV silo. A bin vent on the AMV silo prevents dust emission.

[4] F Cabalteja, *Scope of Work for Converting the Precipitation Tanks into Crystallizers,* Dec 2013

Existing and Potential Issues

Excessive downtime hours in the AMV circuit during operations in 2013 were associated with blockages in the backmixer and the disintegrator. The disintegrator also pulverizes the AMV, which counteracts the large crystal structure that needs to be maintained for the AMV.

There are occasions when airborne AMV is present within the flash drying and AMV silo section. This is suspected to be coming from issues within the baghouse and the AMV silo vent. A short visual inspection conducted by Marc Technologies on Oct 2013 highlighted some issues with the cleaning circuit which were addressed by maintenance, however, dust emissions continued to be a recurring problem in the circuit.

Area Critical Success Factors

1. Elimination of disintegrator/mixer blockages.
2. Elimination of airborne AMV in circuit.
3. Dried AMV at <0.5% moisture from the AMV flash dryer
4. Maintain large crystal structure from the precipitation circuit.
5. Improved accessibility of the AMV bin
6. System that requires minimal level of interaction

Possible Conceptual Solution

1. Installation of a reversible conveyor or screw that will prevent feeding wet slurry to the back mixer

3.5. Area 41 - V_2O_3 Production

3.5.1. V_2O_3 Kiln Feeder Upgrade

Background Information

There are two reduction kilns in the V_2O_3 production area – Line 1 and Line 2. Each line is fed from a reduction kiln buffer silo which is positioned on load cells to give an indication of the weight in the bin and the mass flow of AMV withdrawn from the bin via the discharge screw feeder. The discharge screw is variable speed and controlled to a mass flow set point.

The kiln screw speeds have been changed in 2013 from 50Hz to 60Hz in order to increase the feed to the circuit.

Existing and Potential Issues

It has been proven in the plant in short periods of time that the kiln screw feeders (individually) are able to achieve >1000kg/hr AMV feed rate, which is greater than the design AMV throughput of 750kg/hr. However, this has not been proven on a continuous basis due to different issues (lack of feed, other downtime causes). The inherent inaccuracy of measuring the amount of AMV to the kilns through change in bin weights and the speed of the screw also makes it difficult to determine accurately how much AMV is fed to the kiln.

Area Critical Success Factors
1. Achieve the required AMV through each kiln to produce the equivalent 400tpm V (contained in FeV). Target is >1000kg/hr AMV to provide catch up capacity when one kiln is down.
2. Accurate mass measurement of AMV fed to the kilns

3.5.2. Reduction Kilns

Background Information

The two reduction kilns (41KLN501 and 41KLN502) consist of an externally gas fired rotating tube within a muffle furnace. The rotary tube is heated up to 950ºC from the outside by six natural gas burners. In the kiln, solid AMV dissociates into V_2O_5, nitrogen gas and hydrogen gas. The hydrogen gas reduces the V_2O_5 to V_2O_3.

Maintaining a seal on the reduction kilns is of paramount importance due to the low melting temperature of V_2O_5. It is imperative that a reducing atmosphere is maintained within the reduction kilns to prevent the production of V_2O_5, which will melt in the kiln and consequently cut through the stainless steel shell.

Start up of the kilns require nitrogen purging to eliminate V_2O_3 reacting with oxygen until the process becomes self sustaining through generation of its own reducing atmosphere.

Each kiln is supplied with a main and standby drive (41KLN501A/B, 41KLN502A/B). The drive for the second motor has been removed.

Existing and Potential Issues

The capacity of the reduction kilns was reviewed by Hatch and deemed to be adequate, but marginal, for the throughput required for 400tpm V (contained in FeV). The installed burner capacity is 6 x 318kW burners for a total thermal input of 1.91MW, and the required burner capacity for 400tpm V (contained in FeV) based on an 80% duty is 1.83MW.

Area Critical Success Factors

1. Reinstatement of a main/standby drive
2. Ability to isolate burners in the reduction kiln
3. Achieve the required V_2O_3 through the reduction kilns to produce 400tpm V (contained in FeV).
4. Maintain a reducing atmosphere in the reduction kiln

3.5.3. V_2O_3 cooler, discharge screw, transfer system

Background Information

The reduction kilns' (41KLN501/502) discharge cooling screws (41FDS502/504) convey V_2O_3 product from the kiln discharge chutes via a rotary valve (41ROV502/504) to the V_2O_3 product bin (41BIN504).

There were a number of operation changes to the system during the operations ramp-up in 2013, which include:

- By-passing the thermocouple sensors within the kiln discharge chute (41CHU502/501) due to their inability to consistently determine the material level in the chutes.
- The speed of the cooling screws were increased and controlled manually.
- Cooling water was removed from the cooling screw jackets.
- A nitrogen injection line was placed at the discharge end of the screws.
- The compensators at the discharge chute end were removed and replaced with a solid chute.

Some cooling screw failures include:

- The rotary valve becoming blocked and in turn causing the screw shaft to bore a hole in the feed end cap.
- Cracking along the welds of the cooling jacket (during the time where the cooling water was offline).
- The screw feeder is sometimes unable to start after shut down (with product in the screw).

Existing and Potential Issues

The cooling jacket does not contain an expansion joint, thus differential expansion of the kiln screw shell and the water jacket lining shell causes mechanical damage at the welds.

Maintenance and thickness testing of the cooling screw inner jackets is difficult to achieve and require excessive man-hours.

The inlet of the screw feeder is supposed to be choke fed into the screw feeders to prevent ingress of air, however, the level sensing devices are unable to consistently detect the level in the discharge screws. The speed of the screws needs to be re-evaluated and adjusted accordingly. The cooling performance of the screw is unknown.

The discharge rotary screw becomes blocked with material and causes mechanical damage to the discharge screw and the valve itself if the screw continues to run.

There is no compensator built into the discharge end of the discharge screw and the condition of the feed end discharge screw's compensators is unknown.

Access for cleaning the chute is quite limited.

There is a large amount of external damage to the discharge screw discharge chute.

Area Critical Success Factors

1. Cooling screw design to achieve the required cooling of product from ~800ºC to <100ºC at the required production rate of 400tpm V (contained in FeV).
2. Ease of maintenance and inspection of the cooling screw components and shells.
3. Reliability of the cooling system exceeds the reliability of the kiln.
4. Ensure a gas seal is maintained at the discharge of the kiln discharge chutes (41CHU502/501) at all times.

Possible Conceptual Solutions
Replace cooling screws with another cooling device.

3.5.4. V_2O_3 Baghouse

Background Information

The filter baghouse (41DEX501) receives cooled off-gas from the reduction kilns (41KLN501/502) and a damper valve that is open to atmosphere. The filter baghouse separates the solids from the gas and discharges the solids through a rotary valve (41ROV505) into a slurry tank (41TNK501) via a gravity fed chute. The gas passes through the pulse cleaned filter bags and into the scrubbing tower (41SBR502).

Existing and Potential Issues

Many components including the filter bags have disintegrated from the exposure to conditions outside of their specifications. The baghouse internals, especially the shell walls, are showing signs of corrosion.

From a review conducted by Marc Technologies and by Donaldson Torrit Australia in Oct-Nov 2013, it has been determined that the current baghouse is not suitable for the process characteristics.

The baghouse is situated over the reduction kilns, hindering the removal of the kilns for maintenance. A location review needs to be conducted to enable the continued operation of a kiln when the other is being removed for maintenance.

The discharge of the baghouse hopper becomes blocked with material. The discharge rotary valve (41ROV505) is not always able to convey the product.

The kiln and air inlet dampers are not operating correctly, their automation has been removed and the damper valves have become blocked with product build-up.

Condensation are forming on the walls of the baghouse and ducting before entering the scrubber. This will cause material to stick on the walls of the baghouse and ducts over time. This may also cause build-up on the filter bags, preventing their operation.

Area Critical Success Factors

1. Baghouse reliability to exceed the kiln reliability.
2. Delivery of a robust baghouse that is suitable for the operation characteristics, requirements and maintainability.

3. Eliminate chute blockages in the baghouse.
4. Ability to monitor baghouse operations and process parameters from the control room to enable quick troubleshooting.

3.5.5. Replacement of BIN 504 rotary valve with discharge screw and trommel

Background Information

The V_2O_3 storage bin (41BIN504) receives V_2O_3 from the reduction kilns (41KLN501/502) via the kiln discharge cooling screws (41FDS502/504). The bin is vented via the reduction kiln product dust filter (41DEX504).

Material handling properties of V_2O_3 has been tested by TUNRA.

Paul Ingleson from Bulk Materials Handling has developed a concept to resolve most of the foreseen problems with the V_2O_3 hopper.

Existing and Potential Issues

V_2O_3 powder builds up on the sides of the walls and is difficult to clean/remove. When large deposits of build-up dislodges from the walls of the hopper it can cause blockages in the rotary valve or further downstream. The discharge isolation valve is externally damaged and may cause the chute to block or the valve to malfunction.

Area Critical Success Factors

1. Eliminate blockages from the kiln shell all the way to the FeV tower
2. Accurate mass measurement of V_2O_3 production
3. Eliminate or reduce wear issue from V_2O_3 transfer
4. Eliminate airborne V_2O_3

Possible Conceptual Solutions

Bulk Materials Handling (BMH) concept and general arrangement. Refer to Appendix D.

3.5.6. V_2O_3 Packaging

Background Information

MVPL is investigating options to sell vanadium as V_2O_3 instead of, or in addition to FeV. This option will necessitate the bagging of V_2O_3, which the plant currently has no provisions for.

Existing and Potential Issues

There is no existing equipment, infrastructure or location designated for the collection and storage of bagged V_2O_3.
Personnel may be exposed to the V_2O_3 dust particles during bagging operations.

Area Critical Success Factors

1. Bagging and packaging system for 400tpm vanadium (contained in FeV) in 500kg or 1000kg bag (to be confirmed).
2. Airborne V_2O_3 is eliminated.
3. Design for zero spillage.
4. Automated sampling system that will eliminate operator interaction with V_2O_3 product.

3.5.7. Reduction Kiln Tube Maintenance Access Review

Background Information

There are two reduction kilns (41KLN501/502) on site; both are fed from the feed buffer silos (41BIN501/502) and their corresponding screw feeder (41FDS501/502). Each kiln is heated via 6 burners along its length. The kilns discharge into a chute where product is removed by a discharge cooling screw feeder (41FDS502/504).

The capacity of the reduction kilns was reviewed by Hatch and deemed to be adequate, but marginal, for the throughput required for 400tpm V (contained in FeV).

Existing and Potential Issues

The kilns are difficult to remove and replace. A substantial amount of structural disassembly is required for the removal of Kiln 2, with Kiln 1 requiring more disassembly.

The kiln's discharge mechanical gas seals are difficult to maintain without substantial structural disassembly. The design allows ingress of product into the seal and compensator arrangement. Product builds up in the seal and causes wear. The lubrication system for the seal is unknown for the kilns which may be exacerbating the problems.

The reduction kilns compensators allow ingress of product, thus over time causing the compensator to malfunction due to product build-up.

The current Kiln 2 shell is worn and needs to be replaced. The refractory/cladding on the inside of Kiln 2 has been damaged by product leaking out of the damaged kiln shell.

Area Critical Success Factors

1. Downtime associated with replacing a kiln shell shall not exceed 24h.
2. Maintenance free kiln seal.
3. Positive pressure maintained in the reduction kiln during operations.

Possible Conceptual Solutions

1. Positive pressure compensator and seal arrangement.
2. Custom monorails that will allow a kiln to be removed from the building while avoiding existing equipment.

4. MVPL FLIGHTS AND SITE FACILITIES

MVPL operates scheduled flights from Perth to Mount Magnet and return, and a bus service from Mount Magnet airport to site and return. A scheduled bus service also conveys personnel from the camp to the mine site at the start and finish of each day. These services will be made available free of charge for movement of Consultant's personnel required for the performance of work under the contract or as otherwise approved.

The MVPL Company Representative will provide the Consultant all necessary meals and accommodation in the existing camp as free issue. Existing camp rules will apply, a copy of which is available upon request.

Telecommunications (mobile phone) - there is no reception at the mine site for this service; however, the MVPL Company Representative will provide an internet connection and desk phone connection to the Contractors on site. There is a very limited Wi Fi and mobile phone reception at the Village.

APPENDIX A - FEED HOOD AND DUST HOPPER (19FH501)

APPENDIX B – KILN FEED SPIRALS

APPENDIX C – MAGALDI ECOBELT

APPENDIX D – BIN 504 DISCHARGE SCREW AND TROMMEL

APPENDIX E – KILN SCRUBBING SYSTEM

APPENDIX F – DRAWINGS OF KILN FEED HOOD

APPENDIX G – COOGEE CHEMICALS REQUIREMENTS

APPENDIX H - DELIVERABLES

Deliverable	Format
3D models	Native documents and pdf
General arrangement drawings	Native documents and pdf
Equipment datasheet and specification for procurement	Native documents and pdf
Updated PFDs, mass balance, process design criteria and P&IDs	Native documents and pdf
Material Take Off (MTO) lists for civil, structural, mechanical, piping, electrical and instrumentation	Native documents and pdf
Final report with recommendations on the best approach or solution, incorporating technical risks and commercial justifications (to include CAPEX and OPEX deltas)	Native documents and pdf
Project Execution Plan	Native documents and pdf
+/- 15% cost estimate based on the proposed solution with breakdown for detailed design, shop detail drawings, procurement, fabrication, construction management and installation, and broken down by discipline	Native documents (excel file) and pdf
Cash flow forecast	Native documents
High Level Risk Assessment	Native documents and pdf
Gantt Chart with breakdown for detailed design, shop detail drawings, procurement, fabrication and installation	Native documents and pdf
Weekly progress report that will include an S-curve for cost and schedule, a high-level summary of the work done and any risk associated with the completion of the work, and weekly man-hour forecast. Refer to Schedule 10 of Invitation to Tender Package 10-306-PR-TEN-0001.	Native documents and pdf