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MIDWEST VANADIUM PTY LTD

WINDIMURRA VANADIUM PROJECT

PROCESS PLANT DESCRIPTION

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C O N T E N T S

1.0 TREATMENT PLANT LAYOUT

The proposed site was selected based on the existing infrastructure from previous operation of the plant. The plant is based on suitably flat terrain and within close proximity of the mining operations. The main process plant including the ROM pad, crushing, grinding, beneficiation, roasting, leaching, desilication, AMV precipitation, de-ammoniation, FeV plant, reagents, concentrate handling, administration offices, workshop, stores, powerhouse and fuel storage are all situated in a 500 metre square block. Therefore, all parts of the plant are easily accessible from one another.

The crushing, grinding and beneficiation areas of the plant are situated to the extreme south of the operating plant. The beneficiation area ends with a radial stacker and magnetite concentrate stockpile.

The magnetite is reclaimed via a 60 metre conveyor system ready for roasting. Kiln off gas is handled at the feed end of the kiln and is situated to the immediate west of the kiln feed end. The rotary kiln is 102 metres in length and is orientated in a north easterly direction. The material exiting the kiln continues in a north easterly direction through the hot screen and jaw crusher. The screen and crusher discharge is transferred to the drag chain conveyor which heads in a south easterly direction.

The leaching section of the plant contains the quench vessel, leach vats, tanks associated with the leaching process, and the calcine dump. The quench vessel feeds the vats which lie north east, south east and south west of the slewing mechanism. Slug dose and pregnant liquor is pumped from the vats to the slug dose and pregnant liquor tanks situated to the south west and adjacent to the rotary kiln. The calcine tailings are excavated from the vats and trucked to the calcine dump, situated in the extreme north west of the plant.

The pregnant liquor from the leaching section is pumped a short distance west to the evaporator situated at the feed end of the kiln.

Desilication contains the dirty pregnant tank, precipitation tanks, a filter press, and aluminium sulphate, and sulphuric acid storage facilities. The dirty pregnant tank receives the concentrated liquor from the evaporator at the feed end of the kiln. The liquor is then transferred to the precipitation tanks a very short distance east. The resulting solution from precipitation is transferred to the filter feed tank and subsequently fed to the desilication filter press. The clear pregnant solution from the filter is gravity fed to the clear pregnant tank, while the solids are transferred to the silicates bunker and are trucked to the calcine dump.

The aluminium sulphate storage area is situated 20 metres to the north east of the desilication area to allow access to road train tankers. The sulphuric acid storage area is situated 50 metres south east of the aluminium sulphate storage area.

The AMV precipitation part of the plant contains the precipitation tanks, thickener, belt filter and ammonium sulphate storage and handling areas. The clear pregnant solution is pumped 40 metres to the AMV precipitation tanks. The resulting slurry is gravity transferred to the thickener which is in close proximity to the precipitation tanks. The underflow of the thickener is pumped a short distance north east to the AMV filter belt and filtered to produce a relatively dry filter cake. The barren solution from the thickener and the filter belt is transferred to the barren solution tank and subsequently pumped to the barren liquor evaporation dam, which is situated to the extreme south of the plant, beyond the main tailings facility.

The ammonium sulphate storage facility is situated between the desilication and AMV filter areas of the plant. This provides easy access to road trains required to unload the crystalline ammonium sulphate reagent. Ammonium sulphate is transferred to the mixing tank and mixed with barren solution. The ammonium sulphate is transferred to the first AMV precipitation tank at a ratio to the clean pregnant solution flow.

The AMV drying, de-ammoniation and V_2O_5 packing facilities lie a short distance north west of the AMV areas. The FeV plant lies south east of the AMV area.

The potable water plant is situated to the extreme north east of the process plant and provides clean water to the areas that require it, such as safety showers throughout the plant.

All wet process and reagent areas have been supplied bunds to contain any spillage that may occur. Each of the bunded areas will be provided with a sump pump to return the spillage back to the process or for discharge to the tailings system.

The plant layout has been designed with significant access corridors to permit access to all process equipment with a large mobile crane for significant maintenance activities. The administration building, stores, laboratory and workshop are all located 50 metres to the east of the plant to keep commercial and light vehicles away from the immediate process area. The powerhouse and fuel yard are situated on the extreme south eastern side of the plant.

2.0 AREA 19 – MAGNETITE

Ref (6033-19-F-1001, 6033-19-F-1002)

2.1 Kiln Feed System

Concentrated magnetite ore from the beneficiation plant is stockpiled via a radial arc stacker conveyor (BOOT plant), with the northern end of the radial arc stacked above the vanadium processing plant table feeder. This provides the flexibility to continue stockpiling whilst the table feeder is offline, but provides a small live stockpile capacity with the remainder of the stockpile mobilised via mobile equipment to the magnetite table feeder inlet. A camera (19CAM501) is provided to monitor and manage the stockpile utilisation.

The ore is fed to the magnetite conveyor (19CVR501) via a table feeder (19FDR501) at a nominal rate of 131 dry tonnes per hour. A sampler (19SAM501) provides a belt cut sample of the magnetite concentrate prior to the addition of the soda ash reagent and is composited in a drum by the side of the conveyor.

Soda ash at a ratio of 3.9% by weight of the magnetite feed rate, nominally 5.11 tonnes per hour is added dry from the 500m^3 storage silo to the magnetite conveyor via the soda ash feeder (19FDB501). The magnetite concentrate and soda ash mixture is discharged to the kiln mixing screw (19MXR501). Recovered dust from the kiln off gas cyclones (19CYC501A-D) is also discharged to the kiln mixing screw and the mixture transferred to the kiln feed screw (19FDS502).

This mixture passes through the kiln feed screw and is subsequently transferred to the rotary kiln (20KLN501).

2.2 Kiln off Gas Treatment

Off gas from the rotary kiln is used to evaporate pregnant solution and is cleaned before emission to the atmosphere. Kiln exhaust gas which has been cooled to approximately 450°C by contact with ambient feed solids entering the kiln, is drawn from the kiln feed inlet chamber (19FH501) by a variable speed induced draft (ID) fan (19FAN501) and directed through a duct to four Buell type 435 refractory lined cyclones (19CYC501A-D). The cyclones separate approximately 90% of the dust from the gas stream. The cyclone underflow dust reports to the drop out boxes from where it is returned to the kiln via rotary valves (19ROV501 A-D), kiln mixing screw (19MXR501) and kiln feed screw (19FDS502). The gas passes out the cyclone overflow and continues via a duct to the venturi scrubber (19SBR501).

Pregnant liquor, grading approximately 50 grams per litre of V_2O_5 equivalent, from the leaching section of the plant is pumped (25PPC505 A/B) to the suction of the scrubber circulation pumps (19PPC502 A/B) and utilises the heat in the kiln exhaust gas to evaporate water and increase the concentration to approximately 100 grams per litre of V_2O_5 equivalent. The scrubber circulation pump (19PPC502 A/B) transfers the scrub solution to the pre-quencher section of the venturi scrubber (19SBR501) to saturate the gas stream with water vapour. The acceleration and then deceleration of the saturated gas stream across the venturi throat produces a pressure drop which causes the separation of solids from the gas stream. The solids and scrub solution exit the scrubbing tower (19SBR502) and gravitate into the agitated 20m^3 scrubber circulation tank (19TNK501).

The saturated gas is drawn through the Scrubber Tower (19SBR501) and sequentially through the following sections within the scrubber:

- through the Chevron demister, which by initiating sudden multiple changes in gas direction ensures the removal of the majority of fine particulates and entrained V_2O_5 mist,

- through chimney tray which separates the lower drop out section from the gas wash section,

- through valve tray which is flooded with water and acts as a polishing stage,

- through a second Chevron demister to minimise mist carryover.

The cleaned gas, depleted of solids, mist and hazardous gases, passes through the kiln ID fan and exits to atmosphere via the main kiln stack (19STK501). Water is circulated through the wash tray section at nominally 370m3/hr. A purge is ensured by the addition of raw water at approximately 4.1m3/hr to the water circulation pump inlet (19PPC503A) which results in an overflow from the wash tray section to the scrubber circulation tank.

Excess scrub solution, namely the concentrated pregnant liquor, is pumped via the scrubber discharge pumps (19PPC501 A/B) to the dirty pregnant liquor tank (30TNK510), ahead of the desilication process. A dedicated gland water system is provided to pump raw water to the gland seals of the scrubber discharge pumps.

Any spillage is handled by a sump pump (19PPS504) with the resulting solution pumped to the scrubber circulation tank and ultimately to the dirty preg tank.

Start-up of the rotary kiln (20KLN501) following commissioning or a prolonged shutdown requires the kiln to be heated to prevent thermal shock and failure of the refractory lining. The heating schedule for a cold kiln to reach operating temperature is approximately 4-6 days, and requires the kiln off-gas system to be operational. After a prolonged shutdown of the kiln, the heating requirement is half an hour of heating for every hour of downtime. Extended operation of the kiln off-gas scrubbing circuit in closed circuit increases the concentration of salts in the scrub solution. To prevent scaling or precipitation of solids within the scrubbing system, a bleed of scrub solution is required and raw water or alternatively if available, dilute pregnant solution added as makeup to balance the evaporative losses and the bleed.

2.3 Sodium Carbonate Storage and Dosing

Sodium carbonate solids are received onsite from road train tanker delivery. The tanker is equipped with a blower to pneumatically transfer the soda ash to the soda ash silo (19BIN501). The silo has a capacity of 400 tonnes which is equal to approximately 3 days consumption at the average feed rates. A concrete apron is provided at the unloading facility.

The soda ash silo is equipped with a reverse pulsed bag filter (19DEX501), which pulses on a timed sequence, to prevent the emission of dust to the environment. The bag filter operates automatically (by PDAH195116) when unloading and is also initiated by the driver from a local control panel. A level switch (LS195102) mounted in the silo provides a light alarm on the local panel to warn the driver to stop pumping and an audible alarm on detection of a high weight (WAH195101) that indicates over-filling of the silo is imminent. Load cells (WE195101) mounted on the soda ash silo measure and indicate the weight of soda ash in the silo.

A local control panel is provided at the unloading point to give the driver a local high level alarm, local “start loading” button and display of the bin weight (WI195101). Although unloading is locally initiated by the driver, the local control panel is not operable until authorisation has been provided from the CCR, including confirmation that an earth has been successfully achieved between delivery chassis and loading pipeline. Telephone communication shall be initiated by the driver to the CCR operator if loading valve is still inhibited.

A belt weigh feeder (19FDB501) is employed to transfer the sodium carbonate material from the storage silo to the magnetite conveyor (19CVR501) as required. In order to allow for variations in the feed rate of the magnetite concentrate, sodium carbonate addition is controlled using a ratio controller, which automatically adjusts the reagent feed rate in order to maintain an operator alterable dosing ratio of 3.9% weight of sodium carbonate to weight of magnetite. The ratio calculation is on a dry solids basis, therefore there is a facility for an operator enterable input into the DCS algorithm for the magnetite moisture content correction.

3.0 AREA 20 – ROASTING

Ref (6033-20-F-1001, 6033-20-F-1002)

3.1 Rotary Kiln

The mixed magnetite concentrate, soda ash and recovered dust enters the 4.75 metre diameter by 102 metre long, refractory lined, rotary kiln via a kiln feed screw feeder (19FDS502). Natural gas and primary air (20FAN501) are introduced at the discharge end of the kiln as fuel for the kiln gas burner (20BUR501), which on combustion generates a maximum solids temperature of approximately 1200°C in the hottest part of the kiln. The design residence time of the material in the kiln is approximately 5.5 hours, which includes a period of over an hour in the hottest zone. The vanadium in the magnetite concentrate reacts with the sodium in the soda ash to produce a water soluble sodium vanadate. Kiln gases are drawn through the kiln, along with secondary air drawn through the planetary cooler tubes, by the kiln ID fan.

The rotary kiln is supplied with two parallel and synchronised variable speed main drive trains and can reach a maximum speed of 1 rpm. A barring drive is installed on each main drive to ensure kiln rotation can continue in the event of a failure of the main drives, albeit at a much lower rotational speed. Since the optimal kiln operation occurs at a constant material bed depth within the kiln, the speed of the kiln will need to be altered proportional to the feed into the kiln. The barring drives are connected to the standby diesel emergency generator which starts automatically when power is lost.

The kiln is supported in five tyres, each tyre sitting on two rollers, with each roller supported in two oil lubricated and water cooled bearings. Each bearing is equipped with a thermocouple and cooling water line with a sight glass, gate valve and ball valve to regulate flow. The kiln bearing temperature is monitored from the CCR and can be manually controlled by the adjustment of the manual ball valve located on the respective bearing's cooling water line.

The kiln is inclined at a two percent slope to facilitate the movement of feed stock towards the discharge end of the kiln. As the kiln heats up and rotates, thermal expansion forces the kiln to grow in length about a single horizontal thrust station. The thrust station comprises of a hydraulically actuated (via a pump and ram) thrust roller that allows the kiln to move up and down its horizontal axis by approximately 50mm. The hydraulic pump (25KLN501J), which provides motive power to the thrust system to move the kiln "uphill", is powered up when the thrust roller carrier activates a lower limit position switch (ZS205224), When an upper limit position switch (ZS205223) is activated, the hydraulic pump stops and the kiln, under gravity and over a period of several hours, will move back down hill and commence the cycle again. If the upper limit position switch fails, a higher limit switch (ZS205222) will be activated as a back-up to prevent the kiln from being pushed from its rollers. Similarly the lower limit position switch has a back up to activate the hydraulic pump to prevent the kiln running down hill off its rollers.

The thrust system carries approximately 30% to 40% of the total kiln longitudinal load, with the rollers at each tyre station being “skewed” from parallel to take up the rest of the load. The purpose of this continuous up hill and down hill movement is to distribute wear across the full face of the tyre/roller contact and to spread the wear contact area of the feed end and discharge end seals.

The kiln feed hood is equipped with temperature indication (TI195316) and pressure indication (PI195317). An emergency water spray system is activated on the detection of a high temperature alarm to protect the cyclones and connecting duct work from thermal damage. The pressure controller controls the speed of the kiln ID fan (19FAN501) to maintain a -0.5kPag operating pressure in the kiln and a 5% oxygen concentration in the off-gas as measured by the online gas analyser.

The kiln primary air fan (20FAN501A) is equipped with a variable speed drive (SC205209) and is controlled as part of the burner management system. This fan provides approximately 10% of the air required for combustion and this air serves two distinct purposes. During normal operation the primary air provides momentum to the gas/air mix and generates turbulent pre mixing of the natural gas at the burner tip. This is necessary for complete mixing of the fuel with the pre-heated secondary air from the cooler tubes, to ensure a short hot flame and to burn off all combustible gases. During kiln trips, the primary air fan should continue to run (gas will have been shut off under most circumstances) and provides cooling air to the burner tube to offset the radiant heat from the material charge. In the event of a power failure or motor failure of this fan, a back up diesel driven fan (20FAN501B) will automatically start to provide air for either of these functions.

The burner tunnel cooling fans (20FAN503A/B) circulate air through the burner tunnel to prevent it reaching excessive temperatures.

The kiln interior CCTV (CAM205228) provides a visual inspection of the charge and flame in the kiln. The position of the charge up the inside wall of the kiln is a good indication of optimum roasting conditions. A high position at approximately 2 o’clock indicates optimum recovery in similar vanadium kiln operations. A low position is a possible indication of insufficient flux or a low material temperature. The CCTV is air cooled and automatically retracts on the loss of plant air or power to protect the camera from thermal damage.

The kiln is equipped with an optical pyrometer (TE205227) to measure the temperature in the hot zone of the kiln. The pyrometer is air cooled using plant air and will automatically retract on the loss of plant air or power to protect the instrumentation from thermal damage.

A kiln gun is provided for the specific use of knocking down build up within the kiln. Firing a large bore zinc slug into such a ring is likely to remove a section of the ring, causing total collapse of the build up. The kiln gun is mounted on a tripod to prevent recoil injury to operators.

The calcine produced in the kiln passes through a set of parallel planetary coolers, which consists of nine cooler tubes, each 2.1 metres in diameter and 15 metres long, through which secondary combustion air is drawn. The heat transfer between the cold air and hot calcine material results in the calcine exiting at approximately 450 °C with the incoming air heated to over 600°C. Any spillage around the kiln area is pumped away by the roasting spillage sump pump 20PPS502 on the discharge end and 19PPS501 at the feed end.

A 1 megawatt cooling tower (20CTR501) provides cooling water to cool the kiln support roller bearings and to also cool the jaw crusher bearings. Cooling water is pumped (20PPC502 A/B) from the cooling tower to the kiln support roller bearings and the jaw crusher and the resulting hot water is returned to the cooling tower. Potable water is supplied as makeup water for the cooling tower. The circulating cooling water is dosed continuously with a combination anti-scalent / corrosion inhibitor (initially Cleantec CW760), in addition to routinely alternating between one of two biocide reagents (initially Cleantec Bio812 and Bio820) to ensure bacterial resistance to the biocide is not established. Reagents are dosed via the package water treatment unit (20WTP501).

A sump pump (20PPD507) is installed within the kiln cooling water bund to transfer the cooling tower blowdown water which reports to the bund and cater for any spillage that may occur.

3.2 Calcine Handling

The calcine material passes through a 250mm static grizzly at the entry port of the cooler tubes. The calcine discharged from the kiln is then passed over a 4.3 x 1.2m hot vibrating screen (20SN501) with a 60mm diameter aperture punched plate screen deck to separate the calcine lump from the fine material. The fine material passes through a discharge chute (20CHU502) to the drag chain conveyor (20CVR501). The oversize calcine lumps are transferred to the calcine jaw crusher to reduce lump size to a size more amenable to leaching (set to produce a product of -60mm). An emergency diverter gate allows screen oversize to be diverted away from the crusher into a concrete bunker when experiencing problems with the jaw crusher. The emergency stockpile can be reclaimed by a bobcat for transfer to the calcine dump. The lumps would have cooled prior to reclaiming which would result in lower thermal stresses during any quench process and consequentially lower fracture rates resulting in suboptimal leach recovery. For this reason there is no facility to return the oversize lumps to the main ore stream.

The crusher product passes through a discharge chute (20CHU506) onto the drag chain conveyor. The crushed product combines with the hot screen undersize and is conveyed via drag chain conveyor to a bucket elevator, which in turn feeds the quench vessel (25VSL501) for quenching prior to transport to the leaching vats.

Transfer points from the kiln to the hot screen are under a slight negative pressure from the kiln ID fan. The drag chain conveyor, jaw crusher and bucket elevator transfer points are under a slight negative pressure from the quench scrubber fan.

4.0 AREA 25 – LEACHING

Ref (6033-25-F-1001, 6033-25-F-1002)

4.1 Calcine Quench System

The hot, fine / crushed, calcined material at approximately 450^{o}C discharges from the bucket elevator, enters the quench vessel feed chute (25CHU502) and is quenched with process liquor which directs the calcine slurry into the 1.53m diameter 5.1m high quench vessel (25VSL501). Liquor from the vats is recycled to quench the hot calcine material via the leach vat recycle pump (25PPC513 A/B). The calcine material experiences thermal shock when contacted with the recycle solution and fractures, which aids leaching of sodium vanadate ($NaVO_3$). The slurry from the quench vessel is discharged via a slewing chute (25CHU501) into one of three leach vats (25TNK506, 507, and 508). The recycle pumps (25PPC513 A/B) are fed from the leach vat overflow launders.

The quenching of hot calcine generates significant volumes of steam and dust. These are drawn from the quench vessel discharge hood and through to the quench scrubber (25SBR501). The air/steam/dust mixture is scrubbed of particulates and fine droplets via a combination venturi vessel / cyclonic separator scrubber before being discharged to the atmosphere by the quench scrubber ID fan (25FAN501) and stack (25STK501). The scrubber effluent is discharged into a tank (25TNK510) and pumped (25PPC512 A/B) back to the quench vessel.

4.2 Leach Vat Operation

The leach vat process operates on a batch system with each batch designed to take a total of approximately 52.9 hours to complete. The process comprises of the following steps:

- Slug dose transfer (4 hours)
- Fill vat with calcine (17.6 hours (including 4 hours for slug dose transfer))
- Pump out pregnant liquor and wash calcine (25.3 hours)
- Discharge calcine from vat (10 hours)

Three leach vats are provided with a capacity of 2,400 tonnes of calcine each. Each vat is 10 metres wide, 25 metres in length, and 5.6 metres deep. The base of each vat is fitted with a network of support steel upon which grid mesh and media are positioned. Filtrate from the vat passes through the media and is channelled through the support structure to the discharge pump suctions. The walls of the vat and the base above the filter membrane are protected by rails.

The vat leaching process commences with the transfer (25PPC502 A/B) of slug dose from the slug dose tank (25TNK502, 503) to the relevant vat overflow launder. The leach vat recycle pumps (25PPC513 A/B) transfers the majority of the slug dose from the launder to the quench vessel and scrubber. The excess slug dose gravitates into the vat taking approximately 4 hours to fill the vat and give a continuous overflow.

The liquor filters through the filter media in the base of the vat and is recirculated by the vat discharge pump (25PPC507 A/B, 508 A/B, 509 A/B) to the vat. All the time, overflow from the vat is continuously recycled to the quench vessel.

As the calcine slurry is discharged into the vat, it must be spread to ensure that a relatively even layer of calcine is attained within the vat. This is achieved by the slewing drive mechanism (25CHU501A) of the transfer sluice, which traverses continuously along the 25 metre length of the vat. As the vat fills with quenched calcine, the level of solution in the vat rises and the excess is bled to the slug dose tank via the leach vat discharge pumps.

The act of quenching the calcine and the continuous recirculation of filtrate results in the dissolution of the water soluble sodium vanadate present in the calcine. By the time the vat has been completely filled with calcine, the recirculating solution has dissolved the soluble vanadium to give a concentration of approximately 50 grams per litre of V_2O_5.

The leach vat discharge pump (25PPC507, 508, 509) transfers a set volume of liquor to the pregnant liquor storage tank (25TNK505). When the solution level in the vat reaches the calcine level, a preset volume of wash water from the leach wash tank (25TNK501) is pumped (25PPC501) into the vat. This wash water is used to carry out a displacement wash of the calcine. When the liquor transfer to the pregnant liquor tank is complete, the remaining liquor is transferred to the slug dose tank in preparation for the next batch.

The leached and washed calcine, with 8.5% moisture, is dug out of the vat by the excavator and transported to the calcine dump (25DAM501) via dump trucks. Upon the completion of the discharging of calcine tailings, the vat is again available to accept the next batch of calcine.

4.3 Calcine Dump Operation

Barren calcine from the leach vats is discharged by excavator and transported to the calcine tailing dump via dump trucks, in addition to filter cake from the desilication process and FeV slag. The desilication material is stockpiled on the dump separate to the calcine and a bulldozer is utilised to spread the calcine evenly across the dump. A truck wash down pad is provided to facilitate the wash down of any vehicle which has been working with the calcine dump area and needs to move to a clean area. Wash down slurry is pumped (25PPS504) back to the calcine dump.

The calcine tailings dump is constructed with the calcine solids being placed over a HDPE membrane. Low saline water is sprayed over the calcine tailings via the calcine dump dust suppression system (25DSN501). Solution that permeates through the dump is drained out and collected in the calcine dump pond from which it is pumped by a pontoon pump (25PPS505) to the leachate return pond. The continuous drenching of the dump is necessary to avoid wind dispersion of dust. The excess solution is analysed for V_2O_5 and pumped back to the leach wash tank.

The facility has been designed to enable the entire vat wash water requirement to be added to the calcine dump and then transferred to the leach wash tank to maximise the recovery of soluble vanadium in the calcine dump, and render the remaining calcine benign.

5.0 AREA 30 – DESILICATION

Ref (6033-30-F-1001, 6033-30-F-1002, 6033-30-F-1003)

5.1 Desilication Precipitation

Concentrated pregnant liquor, at a concentration of approximately 100 grams per litre V_2O_5 equivalent is pumped to the 320m^3 capacity, agitated dirty pregnant liquor tank (30TNK510) from Area 19 off-gas scrubbing system. The purpose of the new dirty pregnant liquor tank is to provide surge capacity to decouple the desilication area from upstream areas of the plant.

The concentrated liquor is pumped (30PPC509 A) through the 22m^2 SAF2205 Alfa Laval spiral desilication feed cooler (30HEX501) to the first of two agitated and fully enclosed desilication precipitation tanks in series (30TNK501, 502). The desilication process requires the addition of concentrated sulphuric acid for pH modification consequently a significant amount of heat is generated across the process. The purpose of the feed cooler is to reduce the temperature of the concentrated feed liquor, such that the exiting desilication slurry has a temperature below the maximum operating temperature of the filter press. Sulphuric acid addition rate is controlled by a single pH probe (AE305113) installed in the first desilication tank.

Aluminium sulphate at 42% $Al_2(SO_4)_3$ is added to the process to precipitate out soluble silica as a desilication product (commonly formed in Bayer liquors). The addition rate of aluminium sulphate is dependent on the concentration of soluble silica in the dirty preg solution. Routine sampling and analysis of the dirty preg solution is carried out by operations personnel to determine the soluble silica concentration in the dirty preg solution, and this value is an input at the OIS. Together with the desilication feed flow rate, an algorithm in the DCS calculates the flow rate of aluminium sulphate required and this is the set point for the aluminium sulphate controller.

The slightly alkali pH (ph 8.3) of the desilication liquor causes excess alum to precipitate out as a solid aluminium hydroxide. If the pH of the liquor is too high then the silica and aluminium may redissolve as soluble hydroxide complexes. For this reason sulphuric acid is added to maintain pH such that excess alum is consumed and that soluble hydroxides are not allowed to form. The basic reactions that govern precipitation reactions are given below.

$$2SiO_{2(aq)} + Al_2(SO_4)_{3(aq)} + 8NaOH_{(aq)} \rightarrow Na_2O.Al_2O_3.2SiO_2.2H_2O.3Na_2SO_{4(s)} + 2H_2O_{(l)}$$

$$Al_2(SO_4)_{3(aq)} + 6NaOH_{(aq)} \rightarrow 2Al(OH)_{3(s)} + 3Na_2SO_{4(aq)}$$

$$2NaOH_{(aq)} + H_2SO_{4(aq)} \rightarrow Na_2SO_{4(aq)} + 2H_2O_{(l)}$$

All reagents and liquor are added in the first desilication tank due to the large residence time. The liquor is then fed to the second desilication tank by a launder that exits the top of the first tank and feeds to the well agitated zone of the second tank. This modified launder is used to ensure that short circuiting of liquor is minimised. Each tank has a capacity of 90 m³, which represents a residence time of approximately 7 hours each.

The tanks, agitators and interconnecting lines are coated in acid resistant butyl rubber.

5.2 Desilication Filtration

The ensuing slurry from the last precipitation tank gravity feeds the agitated desilication filter feed tank (30TNK503). The slurry is pumped (30PPC501 A) on a batch basis to the desilication filter press (30FTP501), with an area of 600 m^2. The Latham International 2000mm Membrane Filter Press runs in batch operation. Consequently much of the control surrounding the filter press is the sequencing of various stages of each batch cycle.

Although not currently installed, the desilication facility allows for the future installation of a pre-coat system should this be deemed necessary during operation. The pre-coat system is designed to coat the filter cloth with a pre-coat of diatomaceous earth to avoid very fine silicate solids from washing through the filter and to prevent the occurrence of blinding of the filter cloth due to precipitate growth within the cloth.

Raw water is used as the filter wash water. The wash water tank (30TNK504) has a capacity of 10 m³, which is enough for over 12 hours of operation. Wash water from the tank is pumped (30PPC502) to the filter as required during the batch filter cycle.

The solid material produced from the filter press is dumped into a cake bunker (30BKR501). The resulting stockpile of alumina silicates is transferred to the calcine dump (25DAM501) via a truck or trailer. The concentrated pregnant solution containing the valuable vanadium is collected from the filter press and pumped to the agitated, clear pregnant liquor storage tank (30TNK506). This tank has a capacity of 320 m³, which holds enough solution for over 24 hours of production. The solution is continuously pumped (30PPC504 A) from the tank to the pregnant liquor cooler (35HEX501) before AMV production and precipitation.

5.3 Aluminium Sulphate

Aluminium sulphate is required to precipitate out all of the silica associated with the concentrated pregnant liquor produced from leaching.

Aluminium sulphate liquid is delivered to site in road train tankers. On arrival, the road tanker driver reports to the central control room (CCR) operator to obtain authorisation to enter the plant area. A concrete apron is provided at the unloading facility and any spillage is collected and hosed into the aluminium sulphate spillage pump (30PPS503).

The unloading facility includes an unloading pump (30PPC508). A local control panel is provided at the unloading facility to give the driver a local high level alarm, local “start loading” button and display of storage tank high high level alarm. Although unloading is locally initiated by the driver, the local control panel is not operable until authorisation has been provided from the CCR, including confirmation that an earth has been successfully achieved between delivery chassis and loading pipeline. Plant communication shall be initiated by the driver to the CCR operator if loading valve is still inhibited.

The aluminium sulphate is pumped (30PPC508) from the road tanker to the aluminium sulphate storage tank (30TNK508). The storage tank is equipped with level indication alarmed at high and low level. The tank is equipped with a high high switch that, when triggered, activates a siren (SIR305323) and inhibits the offloading pump.

A duty and standby aluminium sulphate dosing pump is provided (30PPC506A/B) to ensure there is a constant flow of Alum to the desilication circuit. A flow meter fitted to aluminium sulphate feed pump discharge pipe line provides an instantaneous and totalised readout of volumetric flow. The pump discharge is fitted with a bleed line incorporating a restrictive orifice plate (RO305324) to prevent the damage to the pump should the pump be accidentally dead headed.

The aluminium sulphate storage area is equipped with a sump pump (30PPS503). The pump automatically operates on detection of a high level and stops at a low level.

Two combination deluge and eye wash safety showers (30SHS505, 506) have been provided, one located outside the bund near the unloading facility and the other inside the bund.

5.4 Sulphuric Acid

Sulphuric acid is used to control pH for silicate precipitation. Concentrated Sulphuric Acid is delivered to site in road train tankers. On arrival, the road tanker driver reports to the central control room (CCR) operator to obtain authorisation to enter the plant area. A concrete apron is provided at the unloading facility and any spillage is collected in the sulphuric acid spillage pump (30PPS502).

The unloading facility includes an unloading pump (30PPC507). A local control panel is provided at the unloading facility to give the driver a local high level alarm, local “start loading” button and display of storage tank high high level alarm.

Although unloading is locally initiated by the driver, the local control panel is not operable until authorisation has been provided from the CCR, including confirmation that an earth has been successfully achieved between delivery chassis and loading pipeline. Plant communication shall be initiated by the driver to the CCR operator if loading pump is still inhibited.

The sulphuric acid is pumped (30PPC507) from the road tanker to the sulphuric acid storage tank (30TNK507). The storage tank is equipped with level indication, alarmed at high and low level. The tank is equipped with a high high switch that, when triggered, activates a siren (SIR305303) and inhibits the offloading pump.

Located outside the bund is local control panel for the operation of the acid dosing pumps and isolation valves. Duty and standby acid dosing pumps are provided (30PPC505A/B). The duty standby arrangement is that one pump will stop before the other starts; this is to reduce the possibility of fluid surging, especially due to the hazardous nature of sulphuric acid. The operator must open the suction valve (HV305305, HV305306) to the selected pump before the pump can be started. The suction valves are fail closed and fitted with proximity switches to indicate valve position. The proximity switches are interlocked to the operation of the respective pump.

The sulphuric acid feed pump discharge is fitted with a bleed line incorporating a restrictive orifice plate (RO305340) to prevent the damage to the pump should the pump be accidentally dead-headed.

The sulphuric acid storage area is equipped with a sump pump (30PPS502). The sump is alarmed at high level to inform the operator the there has been a spillage of sulphuric acid in the bund. The operator must start the pump from the local control panel. The dirty preg tank discharge pump also interlocks with the sulphuric acid addition such that the sump cannot operate unless the dirty preg tank discharge pump is operating to avoid excessively low pHs in the desilication circuit.

Two combination deluge and eye wash safety showers (30SHS503, 504) have been provided, one located outside the bund near the unloading facility and the other inside the bund.

6.0 AREA 35 – AMV PRECIPITATION

Ref (6033-35-F-1001, 6033-35-F-1002, 6033-35-F-1003)

6.1 Pregnant Liquor Cooling

Clean pregnant solution from the storage tank (30TNK506) is pumped (30PPC504 A) at a nominal rate of approximately 15 m³/hr through an APV plate heat exchanger (35HEX501), where the liquor is cooled from 88°C to 35°C. Cooling water is supplied from the services area cooling tower (50CTR501).

6.2 AMV Precipitation

The cooled pregnant liquor is directed into the first of three, 90 m³ capacity, mechanically agitated, closed, AMV precipitation tanks (35TNK501, 502, 503), configured in series. Amsul solution is pumped into the first AMV tank to precipitate ammonium metavanadate (AMV) crystals. Either the online analyser or a lab analysed result of the incoming vanadium in solution coupled with the incoming flowrate provides the inputs for the DCS ammonium sulphate dose rate algorithm. The residence time across the precipitation process tanks is in excess of 18 hours. Due to the speed of the precipitation reaction and the large residence time available, there is currently no facility for seed recycle.

The slurry produced from the last precipitation tank gravity feeds a discharge hopper (35HO502) and is pumped (35PPC510 A) to 7 metre diameter high-rate Outotech thickener (35THK501). The AMV thickener is designed as a clarifier so as to thicken the AMV solids but primarily, to minimise losses of solids to the thickener overflow stream. Clarified barren liquor overflows the thickener directly to the barren solution tank (35TNK506). The barren solution tank feeds the area 41 scrubber and bag house slurry tank (35PPC507), filter belt/cloth wash (35PPC516) and delivers barren solution to the Amsul mixing tanks (35PPC509). Overflow from the barren solution tank reports to the Barren solution overflow hopper (35HO501) from which it is pumped (35PPC503A) to the Barren Liquor storage facility.

A vertical spindle sump pump (35PPS501) is provided to the area to maintain the precipitation area free of spillage. All spillage that is produced will be pumped back to the first AMV precipitation tank, with optional bypass lines to the second precipitation tank or the thickener.

The AMV precipitation area includes a safety shower (35SHS501).

6.3 AMV Filtration

The thickened 35% solids is pumped (35PPD504 A) from the thickener to the Larox Pannevis RB-SV AMV belt filter (35FTB501) at a nominal rate of 3.6 m^3/hr. The belt filter comprises 24 m^2 of filtration area and is equipped with a three stage filtration process to facilitate the efficient removal of residual barren solution from the AMV filter cake. The first stage is a dewatering stage, following by the product wash stage where a wash ratio of 1.11:1 (m^3 / t_{solid}) is utilised to obtain the required cake washing efficiency, and finally an air drying stage where air is drawn through the cake to minimise the final moisture content.

Potable water is used as AMV product wash water to remove soluble sodium and other soluble salts present in the precipitation liquor. Process water cannot be used due to contamination risks from dissolved salts that may be present. A separate solution stream of barren solution is used as belt wash water, and this is utilised to provide belt lubrication over the stationary sections of the filter structure and post process belt and filter roller washing.

The filtrate and product washings are collected in the filtrate receiver (35RCP501) and pumped (35PPC508) back to the first precipitation tank (35TNK501) to recover any soluble vanadium. Belt wash solution is collected in the belt wash return hopper (35HO504) and pumped (35PPC511) to the AMV thickener.

The belt filter is equipped with a dedicated vacuum pump (35PPV501), moisture trap (35RCP04) and seal water return tank. Seal water to the vacuum pump and gland water to the primary filtrate pump (35PPC508) is supplied (35PPC506) from the seal and gland water tank (35TNK507). Recovered seal water is collected in a hopper (35HO505) and returned to the seal and gland water tank. The seal and gland water is cooled in an APV plate heat exchanger (35HEX502) to maintain the circulating solution temperature below the solution flash point.

Washed AMV product filter cake, with a moisture content of approximately 20%, is discharged to the AMV flash dryer. The filter belt speed and consequently the cake thickness can be varied; this coupled with the feed slurry density and feed particle size will be large determinants in the final moisture achieved.

A barren solution sump pump (35PPS502) maintains the area free of spillage, with the recovered solution pumped to the thickener feed tank.

6.4 Ammonium Sulphate Storage and Mixing

Ammonium sulphate (Amsul) is supplied to site by side tipping triple trailer road train. The ammonium sulphate unloading facility is under cover and accommodates sequential tipping of the trailers into a receival system. The receival system comprises of an unloading bunker with a front end loader required to move the Amsul to the adjacent storage bunkers.

The ammonium sulphate mixing facility is a batch operation based on two mixing tanks (35TNK511, 512), each with approximately 12 hours storage capacity of Amsul solution. The mixing process is initiated when the offline mixing tank has been filled with barren solution. A front end loader is used to reclaim Amsul from either the storage bunker or the unloading bunker and deposit into the Amsul receival hopper (35HO503) which contains a rotating Amsul lump breaker (35FDS501). The Amsul conveyor (35CVR501) transfers the reagent at a fixed speed to the selected mixing tank via an impact weigher (35WII501) and reversible screw feeder (35FDS502). The impact weigher records the weight of Amsul added to the mixing tank and when the required weight of Amsul has been added to the mixing tank activates a green indicator light. The system is not interlocked when the final weight is reached such that the conveyors, feed screw and hopper can be run out. An algorithm is present to calculate solution strength, with the option of using a laboratory assay instead.

When the operating mixing tank is at a low level, the reserve tank is brought on line to ensure an uninterruptable flow of Amsul solution to the first AMV precipitation tank (35TNK501). The addition of the Amsul solution to the precipitation circuit is controlled to maintain an acceptable excess of ammonium sulphate of approximately 90 g/L $(NH_4)_2SO_4$ in the barren solution.

The area is supplied with an Amsul storage sump pump (35PPS505) and an Amsul mixing sump pump (35PPS506). The resulting spillage is returned to the Amsul Mixing Tanks.

The area also contains a safety shower (35SHS505) for the Amsul storage and mixing area.

7.0 AREA 36 – AMV DRYING

Ref (6033-36-F-1001)

AMV containing approximately 20% moisture is discharged from the AMV filter into a back mixer (36MXR502) and then into the AMV flash dryer (36DI501). The flash dryer is guaranteed to be capable of drying 2500kgs per hour of AMV exiting the belt filter, which is equivalent to minimum 35 tons V_2O_5 per 24 hours.

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 between 8-12%. The product is discharged to the disintegrator (36DI501) via the back-mixer discharge chute which is fitted with a blocked chute switch and alarm to alert the operator of any obstructions.

The disintegrator is fed with AMV from the back-mixer and hot gas from the dryer combustion chamber. The rotation of the disintegrator and the configuration of the blade arrangement pulverises the AMV and disperses it in the hot gas entering the drying column. The disintegrator is fitted with amperage indication and associated alarms to alert the operator of any potential overload situations. A high high amperage alarm will stop the wet feed to the drier.

The flash column (36FC501) is a large diameter duct in which the moisture in the product is removed or flashed off. The inlet temperature to the flash column is approximately 500 C and the exit temperature is around 150 C. The product is therefore exposed to high temperatures for a very short period, which volatilises the moisture into vapour form, removing it from the solid AMV, whilst ensuring it is retained at a relatively low residual temperature. The gas temperatures after the flash dryer must be maintained above 110 C to ensure no moisture remains in the product and to prevent condensation of water vapour in the dryer system but below 135^{o}C to avoid equipment damage.

The Flash Dryer column is thermally insulated with a 100 mm thick layer of mineral wool (120 kg/m^3) and is fitted with temperature indication and high and low alarms to ensure the AMV is dried without damaging the product or the equipment. The temperature of the stream is again measured in the duct entering the primary cyclone (36CYC501) and is fitted with a high temperature alarm to help prevent damage to the cyclone liners.

The dried AMV collected from the gas stream by the cyclones reports to the bag filter plant (36DEX501). The cyclone installation consists of a large single primary cyclone (36CYC501) followed by smaller secondary cyclones (36CYC503 A/B). The bag filter is a fully automatic reverse pulsed type bag house. The dried AMV collected from the cyclones and the bag house is discharged into the AMV silo (36BIN501).

A bin vent (36BV501) installed on the AMV silo prevents dust emission whilst the bin activator (36ACT501) and air pads prevent bridging of solids and assist in the discharge of dry AMV into the air slide (36ASL501) via a rotary valve (36ROV509).

The AMV silo feeds the air slide (36SL501) where the AMV is fluidised by the air slide blower (36BL501) and split between two rotary valves. The air slide back mix rotary valve (36ROV506) is connected to a variable speed motor (SC365115) and provides an operator input mass flow of dry AMV to a feed screw (36FDS501) that feeds back to the back mixer. The air slide transfer rotary valve (36ROV509) transfers the remainder of the dry AMV to the secondary air slide (36SL502). Each of the rotary valves' are fitted with under speed alarms to give warning as to problems with the valves' shafts or motors.

The secondary air slide feeds a leg that separates to feed the two reduction kilns, that also allows for the addition of a feed line to a deammoniator area in the future. The feed lines for reduction kilns 1 and 2 are fitted with rotary valves (36ROV505/506) each with under speed alarms to give warning as to problems with the valves' shafts or motors.

8.0 AREA 40 – V_2O_5 PRODUCTION (FUTURE)

Ref (6033-40-F-1001, 6033-40-F-1002)

8.1 De-Ammoniator

When operating, around 10% of the dried AMV product will be used in the de-ammoniation process.

The AMV product transfer blower suctions AMV from the air slide (36ASL501) via a cyclone equipped with a bin vent (40BV501). AMV is discharges the cyclone underflow via a rotary valve (40ROV501) into the deammoniator buffer silo (40BIN501). Exhaust air discharges the cyclone via the bin vent to prevent dust emission.

AMV is discharged from the deammoniator silo (40BIN501) via a rotary valve (40ROV501) and screw fed (40FDS501) into the de-ammoniator (40KLN501) where it is thermally decomposed to produce V_2O_5 powder. The de-ammoniator is an externally gas fired rotating tube, within a muffle furnace. The external temperature of the rotating tube is controlled close to 600°C, giving an inside material temperature of around 400°C. Gas flow is counter current, with excess air being allowed into the tube from the discharge end. Under these conditions the AMV disassociates predominantly into V_2O_5 and NH_3.

Due to the oxidising nature of the reaction in the de-ammoniator, significant quantities of air are required to be drawn through the de-ammoniator shell. Air required for the process is drawn from the scrubber extraction blower (40FAN502) and the combustion off gases is exhausted through an accompanying stack (40STK501).

The V_2O_5 is discharged from the de-ammoniator and transferred to a screw feeder (40FDS502). The V_2O_5 product is transferred to the V_2O_5 bin (40BIN502) ready for fusion via a transfer screw (40FDS503).

8.2 De-Ammoniator Off Gas Scrubbing

The off gas from the de-ammoniator is drawn through a dust cyclone (40CYC502) and bag filter (40DEX503) to remove entrained vanadium bearing solids from the gas stream ahead of the scrubbing tower (40SBR502). Recovered V2O5 from the cyclone and bag filter are discharged to the deammoniator feed screw via individual rotary valves (40ROV503, 506)

The main de-ammoniation reaction results in the removal of ammonia from the AMV feed. Most of the ammonia is decomposed via the action of high temperatures in the presence of catalytically active vanadium; however, some ammonia is present in the off gas and must be removed in the absorber tower (40SBR502) prior to the gases being exhausted to the atmosphere via the stack (40STK504). Ammonia is scrubbed from the gas stream using sulphuric acid, which is dosed into the second stage recirculation pump discharge (40PPC507) via an inline mixer (40MXR501). Sulphuric acid reacts with the ammonia present in the gas to form a water soluble ammonium sulphate which remains in solution in the recirculating scrubber liquor. This solution is returned (40PPC504) to the dilute Amsul mixing tank (35TNK513).

A safety shower (40SHS501) is supplied with this area of the plant.

8.3 V_2O_5 Flake Production and Handling

V_2O_5 powder is discharged from the V_2O_5 powder hopper (40BIN502) via a variable speed drive screw feeder (40FDS504) and fixed speed furnace screw feeder (40FDS505), into the V_2O_5 fusion furnace (40FRN501) where it is melted.

The fusion furnace consists of a refractory lined steel chamber with a water cooled base. Temperature within the furnace is controlled at 900°C via the combustion of natural gas. To avoid excessive dust generation, the furnace is designed to avoid flame impingement on the fresh V_2O_5 powder entering the furnace by using radiant heat as the main method of heating and melting the V_2O_5 powder feed.

Water cooling of the furnace base is utilised to extend the life of the furnace refractories by the creation of a crust of solidified V_2O_5 over which a molten stream of V_2O_5 product flows. The molten V_2O_5 discharges from the furnace water cooled spout onto a rotating flaking wheel (40CWH501). Cooling water is supplied from the process cooling tower (50CTR501) and after utilisation, is collected in the cooling water return tank (40TNK505) and returned (40PPC506) back to the cooling tower.

The molten V_2O_5 is re-solidified on the flaking wheel to produce vanadium pentoxide flakes, approximately 1 – 3 millimetres in thickness. The flakes are continuously scraped from the wheel and discharge onto a hot pan conveyor (40CVR501) for transfer to the product packing area.

The hot V_2O_5 fused flakes rapidly cool on the hot pan conveyor before being discharged into a 25 tonne storage bin (40BIN503). The incoming fused flakes are discharged from the conveyor through a roll crusher (40CRR501), which breaks the oversize flakes.

A dust extraction system is provided in the fusion and flake handling facilities due to the hazardous nature of vanadium pentoxide. Any dust generated from the dust extraction hoods (40DEH501 – 503) are joined with the fusion furnace off gas to a bag filter (40DEX502). The particulate free air is discharged to the atmosphere by an induced draft fan (40FAN504) and an accompanying stack (40STK503). The dust produced is returned to the V_2O_5 powder hopper via a screw feeder (40FDS506) and re-processed through the fusion furnace.

Flakes are discharged from the storage bin into either one tonne bags, or 250 kilogram steel drums and packed for export. The de-ammoniator has been guaranteed by the supplier to have capacity to produce 15 tons V_2O_5 per day. The furnace and flaking wheel system will not be as operated in the original plant, where a record daily production of in excess of 30 tons V_2O_5 was produced.

9.0 AREA 41 – V_2O_3 PRODUCTION

9.1 Reduction Kilns

Ref (6033-41-F-1001)

AMV is discharged from the air slide (36ASL502) outlet via the rotary valves (36ROV505, 506) to the reduction kiln buffer silos (41BIN501, 502) ahead of the reduction kilns (41KLN501, 502). The reduction kiln buffer silos are vented to the AMV silo. The AMV, from the buffer silos, is transferred to the kiln via screw feeders (41FDS501, 503), which double as an air seal to the kiln.

The reduction kilns are essentially identical and each has a nameplate capacity of 14 t/d V_2O_3. The kilns consist of an externally gas fired rotating tube within a muffle furnace. The rotary tube is heated to 900 C from the outside by six natural gas burners. In the kiln, solid AMV disassociates into V_2O_5, nitrogen gas and hydrogen gas. The hydrogen gas reduces the V_2O_5 to V_2O_3. The V_2O_3 produced, in actual fact, has a chemical composition of approximately $V_2O_{3.6}$. The V_2O_3 discharges from the tube via gas tight water cooled screw (41FDS502, 504) and transferred to the V_2O_3 silo for storage and future ferrovanadium processing. The cooled water screw lowers the temperature of the V_2O_3 to minimise the potential for oxidation back to V_2O_5.

The venting system for the tube is co-current flow with the off-gas and any entrained dust leaving the system at the discharge end of the reduction kiln. Off gas from the two reactors are combined before cleaning in the scrubbing circuit. The kiln operates under a slight positive pressure (50 Pa) protected by specialized and proven dust/gas seals to prevent the ingress of air. This seal is one of the key fundamental designs of the plant which ensures the reduction process is controlled and that maximum conversion of AMV to V_2O_3 is achieved.

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. Introduction of air or other oxidising substances may lead to the production of V_2O_5 which will melt in the kiln and consequently ‘cut’ through the stainless steel shell.

The combusted natural gas, from each set of kiln burners, is vented to separate stacks (41STK501, 502).

V_2O_3 discharges the kiln via a cooling screw feeder (41FDS502, 41FDS504) and rotary valve (41ROV502, 504). Cooling of the V_2O_3 to below the 120 C prevents the oxidation of the V_2O_3 to V_2O_5. Cooling water is provided via a 5 MW evaporative cooling tower serving the entire vanadium processing plant.

Start up of the reactors requires nitrogen purging of the rotating tube to prevent V_2O_3 reacting with oxygen and the steel alloy of the reactors until the process becomes self sustaining through generation of its own reducing atmosphere.

9.2 Reduction Kiln Off Gas Scrubbing

Ref (6033-41-F-1002)

The Off gas Scrubbing system is designed to remove dust and ammonia vapours in the Reduction Furnace Off Gas before it is released to atmosphere. An acidified barren liquor solution is used to scrub the gas, producing a barren stream fortified with ammonium sulphate which is recirculated through the Scrubber by the recirculation pumps.

The off gas from the reduction kilns is drawn through a bag filter (41DEX501) to remove entrained vanadium bearing solids from the gas stream ahead of the scrubbing tower (41SBR502). Recovered V_2O_3 from the bag filter is discharged to the slurry tank (41TNK501) to which barren solution is added in a semi batch process. This slurry is transferred back to first precipitation tank (35TNK501) to ensure all vanadium is recovered.

Off gas from the Reduction kilns enters the off gas Scrubber, (41SBR502), and is quenched by a spray of recirculated barren liquor. This step both cools the gas and removes the bulk of the ammonia. The cooled gas then passes through two separate scrubbing stages, each fed by separate recirculating barren liquor streams. In the first scrubbing stage, liquor is recirculated through the lower half of the column, via the First Stage Recirculation Pumps, (41PPC505). The gas then passes into the second scrubbing stage, where liquor is recirculated through the top section of the column via the Second Stage Recirculation Pumps, (41PPC507). These two recirculating streams are separated within the Scrubber by chimneys allowing only gas to pass through.

The pH of both recirculating streams is measured via dedicated pH pots. The pH in the first stage recirculation is controlled to a pH of 6.8 by injecting concentrated sulphuric acid into the system, via an acid mixing tee, (41MXR501). The sulphuric acid is injected at the discharge of the Second Stage Recirculation Pump, (41PPC507), thus the final scrubbing stage has the lowest pH and serves as a polishing stage, operating at 2-3 g/l free sulphuric acid.

To prevent the accumulation of ammonium sulphate in the system, a constant barren liquor purge stream is pumped by the Bleed Pump, (41PPC504). The purge is taken from the first stage recirculation at the base of the scrubber as this has the highest dissolved solids concentration and lowest free acid, i.e. a pH of approximately 6.8. This solution sent back to the precipitation circuit to maximise recovery.

The liquid level at base of the Scrubber is automatically controlled via the addition of fresh barren liquor into the system. The barren liquor is fed into the suction of the Second Stage Recirculation Pump (41PPC507).

The top section of the Scrubber is fitted with a demister, which eliminates droplet entrainment into the outlet vapour. A wash manifold is provided to routinely wash the demister. Cleaned vapour discharges from the top of the Scrubber to the Scrubber ID Fan, (41FAN503), and to atmosphere via the stack.

A safety shower (41SHS501) is supplied with this area of the plant.

10.0 AREA 45 – FERROVANADIUM PRODUCTION

Ref (6033-45-F-1001, 6033-45-F-1002, 6033-45-F-1003, 6033-45-F-1004, 6033-45-F-1005, 6033-45-F-1007)

10.1 Raw Material Handling

10.1.1 Aluminium

Aluminium is added to the DC arc furnace and reduces the V_2O_3 to V ($3V_2O_3 + 6Al \rightarrow 3Al_2O_3 + 6V$) and in the process the Al_2O_3 combines with lime (CaO) to form a calcium aluminate slag.

Aluminium is delivered to site in cubic meter bags and is pneumatically vacuumed to the aluminium storage silo (45BIN505) via a bag splitter and feeder arrangement. The pneumatic vacuum transfer system comprises of a blower (45BL503) and a cyclone (45CYC503) equipped with a bin vent (45BV501) to prevent fines discharge to atmosphere.

10.1.2 Lime

Lime is used as a flux in the DC arc furnace in the ferrovanadium production process.

Lime is delivered to site in one cubic metre bags which are emptied in a bag splitter (45BS501) and then transferred to the bucket elevator (45BE501) via a vibrating feeder (45FDV510). The bucket elevator transfers the lime to the lime storage silo (45BIN507).

10.1.3 Scrap Steel

Steel is required in the DC arc furnace to alloy the vanadium to produce the ferrovanadium. Steel is delivered to site in drums.

The steel charging system consists of a feed bin (45BN501) and a vibrating feeder (45FDV510) to load the skip hoist (45EL501). The required weight of steel is weighed in the skip and transferred to the tube feeder (45FDV504) via the hoist.

10.1.4 V_2O_3

V_2O_3 is pneumatically vacuumed from the reduction kiln product bin (41BIN504) to the V_2O_3 silo (45BIN503). The pneumatic vacuum transfer system comprises of a blower (45BL504) and a cyclone (45CYC502) equipped with a bin vent (45BV502) to prevent fines discharge to atmosphere. The V_2O_3 is discharged from the cyclone via a rotary valve (45ROV502) to the V_2O_3 silo (45BIN503).

10.2 FeV Production

Al, lime and V_2O_3 are transferred from their respective weigh bins to the furnace feed bin (45BIN510) to create a feed mixture to be charged into the furnace. The addition rates of these raw materials are controlled to produce a reasonably consistent mix within the bin.

The tube vibrating feeder (45FDV504) transfers all raw materials to the furnace. Iron is charged to the furnace before the Al, lime and V_2O_3 mix to help produce an arc in the furnace. Power is supplied via a single carbon electrode into the mix, resulting in the reduction of V_2O_3 to vanadium with aluminium ($3V_2O_3 + 6Al \rightarrow 3Al_2O_3 + 6V$). The iron melts at the reaction temperature (1800°C) and combines with the vanadium to produce ferrovanadium. The Al_2O_3 formed in the reduction of V_2O_3 is fluxed with the lime to form a liquid calcium aluminate slag. Each batch will produce around 2.5 tons of 80% V ferrovanadium, and will require a power input equivalent to 1,400 kW/tonne FeV produced.

At the end of the reaction the electrodes are lifted out of the furnace, and the furnace tilted to tap out the metal slag mixture into a tapping pot (45PT501). The pot is allowed to cool, resulting in the heavy FeV settling to the bottom of the pot, with the slag above it. When solidification is complete the pot is inverted, and a metal FeV button separates from the solid slag. The slag is transported to the calcine dump.

10.3 FeV Crushing

Ref (6033-45-F-1005, 6033-45-F-1006, 6033-45-F-1007,)

The metal button is transferred to the ferrovanadium handling and packing plant by fork lift and allowed to cool before handling.

The FeV button is broken using a mechanical hammer (rock breaker) (45RB501) over a static grizzly (45SN501) until the entire button passes the grizzly aperture. A vibrating feeder transfers the broken FeV metal onto the primary conveyor (45CVR502). The primary conveyor transfers the FeV metal to the primary jaw crusher (45CRJ501) with an appropriate closed side setting and the crusher product conveyed (45CVR503) to the secondary conveyor discharge screen (45SN503).

Oversize from the screen is crushed using a jaw crusher (45CRJ502) with an appropriate closed side setting and the crusher product conveyed by the recirculating conveyor (45CVR504) back to the secondary conveyor to be re-fed to the screen. Screen undersize is directed to the tertiary conveyor (45CVR505) where it is transported to the packaging plant (by others).

The batching plant, furnace, and alloy crushing system have been guaranteed for a capacity of at least 9,072 tons V_2O_5 equivalent per annum.

11.0 AREA 50 – PLANT SERVICES

Ref (6033-50-F-1001, 6033-50-F-1002, 6033-50-F-1004, 6033-50-F-1005, 6033-50-F-1006, 6033-50-F-1007, 6033-50-F-1008, 6033-50-F-1009, 6033-50-F-1010)

Plant Services incorporates all equipment required to reticulate services essential to the process facilities operation.

These services include:

- Plant Air – Sourced from compressors at 10 bar the plant air is filtered and then reticulated through the plant at 7.5 bar servicing the process and hose points.
- Instrument Air – Sourced from the compressors at 10 bar, instrument air is filtered, dried and then refiltered before being reticulated through the plant at 7.5 bar.
- Raw Water – Raw water is sourced from the bore field and is reticulated around the plant servicing the process and hose points.
- Fire Water – Fire water is sourced from raw water and is reticulated around the plant via a ring main.
- Potable Water – Potable water is received from the RO plant and is reticulated to areas requiring high purity water.
- Safety Shower Water – Safety shower water is supplied from the potable water line to a head tank. Line pressure is maintained via the head tank and safety shower pumps.
- Cooling Water – Cooling water is circulated through plant in a closed circuit and is cooled via a 5MW cooling tower
- Natural Gas - Natural Gas is sourced from the Mid-West Pipeline Trust
- Nitrogen – Compressed nitrogen is reticulated at 7 bar and services the reduction kilns
- Oxygen – Compressed oxygen is reticulated at 7 bar and services the oxygen lance

11.1 Plant Air

Plant air for process and maintenance use is provided to a receiver (50RCP501) from a dedicated compressor station with two air compressors (50CMP501A/B). These compressors come equipped with fault alarms (YA505109/110). The plant air receiver is equipped with constant pressure indication (PI505102) and alarms at low pressure (PAL505102) indicating leakage or rupture. A relief valve (PRV505101) opens at high pressure to avoid damage to the receiver. Air from the receiver reports to the plant air filter (50FTS501) and the instrument air circuit.

The plant air is filtered and a differential pressure indicator (PDI505103) detects the pressure drop over the filter so that a blockage may be detected and cleared. After filtration the plant air reports to the required destinations throughout the plant.

The desilication filter press has two receivers (50RCP503/508). Restricting orifices ensure a fixed supply of air to the two receivers. The receivers are equipped with pressure indication (PI505157/158), local gauges (PI505104/106) and relief valves (PRV50105/107).

Air is supplied to the two desilication filter press receivers at 1000kPa and reticulated throughout the rest of the process facility at 750kPa. This reduction in pressure is achieved by the use of a pressure regulating valve (PCV505149). In the event of failure of this valve a pressure relief valve (PRV505148) has been located downstream to protect all downstream lines and equipment from the higher pressure.

The air pressure leaving the desilication receivers is also reduced to 750kPa by PCV505150/153 and PRV505151/152 providing back-up protection.

11.2 Instrument Air

Prior to accumulating in the receiver (50RCP504) the instrument air is filtered (50FTS502) then dried (50DRY501) then filtered again (50FTS503). Differential pressure indicators over the two filters (PDI505201/202) indicate pressure drops through the filters so any blockage can be detected and cleared. The dryer is equipped with a fault alarm (YA505207). Temperature indication (TI505261) will be fitted after the drier with a high temperature alarm (TAH505261) that excessive heat is being generated through the desiccant drier. The filters and drier are all provided with by pass lines.

The instrument air receiver (50RCP504) is equipped with constant pressure indication (PI505204) that alarms at a low pressure (PAL505204), and a local pressure gauge. The receiver is also equipped with pressure relief valve (PRV505203). An additional receiver (50RCP505) exists in the kiln area as a failsafe to maintain pressure to the kiln instruments. This receiver is also equipped with pressure indication (PI505206) and relief (PRV505205).

The air is stored in the two receivers at 1000kPa, which is then reduced to 750kPa by pressure regulating valves (PCV505210/260). Pressure relief valves (PRV505211/259) downstream of the PCVs provide protection against over pressurisation in the instance of the PCV failing.

11.3 Raw Water

Low saline water, supplied from the shallow bore field east is received into the plant at the raw water tank (50TNK501). The tank is equipped with level control (LIC505601) that alerts the operator to high (LAH505601) and low (LAL505601) levels. The raw water is reticulated to the process by the raw water pump (50PPC501A) with a standby pump (50PPC501B) present in case of failure. The pump discharge lines are equipped with pressure relief valves (PRV505603/604) to protect the pump in the event the pump is accidentally dead headed. The pressure relief valves, when activated, send the water back to the raw water tank. The raw water header is equipped with a pressure transmitter (PT505602) that is displayed in the control room and alerts the operator of low pressure (PAL505602).

11.4 Fire Water

Low saline water is provided by MRL from the BOOT plant to the fire water ring main. Electric and diesel powered pumps can be utilised with an electric jockey pump providing extra support to maintain line pressure. The ring main is equipped with a pressure transmitter (PT505233) that is displayed in the control room and comes with high (PAH505233), low (PAL505233) and low low (PALL505233) pressure alarms. The main (electric) pump is started automatically when a hydrant is opened, through a pressure switch by the lowering of pressure in the system.

11.5 Potable Water

The potable water system services the domestic needs of both the accommodation village and the plant including all the safety showers. It also provides water to the AMV filtration washing process where high quality water is stipulated and to the cooling water circuit. The potable water production and distribution is part of the infrastructure scope of work and this feeds the vanadium plant as required.

The potable water is distributed to the following systems:

- The power station
- Area 45 cooling water system
- Plant cooling water system
- AMV wash water tank
- Kiln cooling water system
- Safety shower head tank.

Supply of water to all these systems is controlled by float operated valves located within each destination tank.

11.6 Safety Shower Water

Safety shower water is supplied from the safety shower head tank. The tank is fitted with level indication (LI505402), high and low level alarms (LAH/LAL505402). The level of the tank is maintained by potable water addition to the tank via a float valve.

The water is pumped (50PPC512A/B) throughout the plant to maintain pressure in the lines, with a duty/standby arrangement ensuring continuous supply. A by-pass line around the pumps is in place to allow supply to the majority of the showers in the event of a complete power failure (only showers above the height of the head tank will not receive water). A return line to the head tank, fitted with an orifice plate, is provided to prevent dead heading the pumps when all showers/eyewashes are closed.

All safety showers are fitted with position switches on eyewash and deluge handles. This raises an alarm in the control room when either of the handles is activated.

11.7 Cooling Water

Cooling water is constantly circulated through the plant. Before returning to the cooling tower the water reports to the return tank (50TNK509). The tank discharge is equipped with temperature indication (TI505902). The variable speed pump (50PPC511) is controlled by the level (LIC505901) of the tank and pumps the water back into the cooling tower (50CTR501). To account for evaporative and other losses, makeup water is drawn from the potable water system and the addition is controlled by float valve. The cooling tower is equipped with low level alarm (LAL505903). Before being pumped to throughout the plant the water passes through an in line strainer which will be manually inspected and cleaned daily. Cooling water pumps (50PPC508A/B) pump the water throughout the plant. These pumps are equipped with recycle streams fitted with restricted flow orifices to ensure they are not dead headed. The main discharge line is fitted with high temperature alarm (TAH505906) that is activated when the cooling water is greater than 35^{o}C, pressure indication (PI505907) and low flow alarm (FAL505908).

Cooling water for the following process areas is supplied from a cooling tower (50CTR01) by cooling water pumps (50PPC08A/B) to the following areas:

- Desilication
- AMV Production
- AMV Filtration
- V_2O_5 Production (Future)
- V_2O_3 Production
- FeV Production

The cooling tower is a forced draught unit with a cooling capacity of 5000 kW. The Cooling water services all the plant except the rotary kiln, which has a dedicated cooling water system, and operates in a closed circuit with make up water supplied from the potable water system.

The circulating cooling water is dosed continuously with a combination anti-scalent / corrosion inhibitor (initially Cleantec CW760), in addition to routinely alternating between one of two biocide reagents (initially Cleantec Bio812 and Bio820) to ensure bacterial resistance to the biocide is not established. Reagents are dosed via the package water treatment unit (50WTP501).

11.8 Natural Gas

Natural gas is provided to site by Mid West Pipeline Trust and reticulated to the following plant equipment:

- Rotary kiln
- AMV Flash Dryer
- De-ammoniator (Future)
- V_2O_5 Fusion Furnace (Future)
- Reduction Kilns
- Tapping Pot Preheating

The natural gas line is fitted with nozzles which allow for individual line nitrogen purging. The nozzles are closed with a screw thread plug during normal operation and require the manual transport and connection of nitrogen to each point to facilitate purging during shut downs.

11.9 Nitrogen Supply

Nitrogen is supplied to the plant by BOC Gases in the form of a KAY Pack which holds 15 nitrogen cylinders. The nitrogen is utilised to purge the reduction kilns in area 41 prior to use, as well as a safety measure to purge the natural gas lines for maintenance.

The pressure of the nitrogen packs deliver nitrogen at a pressure of approximately 25,000 kPa. The nitrogen is regulated (PCV505931) to 700 kPa before being piped through the plant. The piping after the regulator is fitted with a pressure relief valve to protect the line, pressure indication and a low pressure alarm to warn if there have been problems with nitrogen supply.

The nitrogen supplies to the reduction kilns are fitted with actuated flow valves (FV505934/935) with proximity sensors to indicate whether the valve is opened or closed. The flow of nitrogen to the kilns is controlled (FIC505933) by opening the selected kilns flow valve (FV505934/935) to allow a volume (FQ505933) of approximately 40 Nm^3 of nitrogen. The opening and closing of the valves is an operator task and is not automated.

11.10 Oxygen Supply

Oxygen for the oxygen lance is provided from BOC in the form of a MAN Pack. The oxygen is piped through the plant at a pressure of approximately 700 kPa and the line is equipped with a pressure control valve (PCV505981) and pressure gauge (PI505982) both at the pack and at the lance itself.