Appendix A – Process Control Philosophy

The source of this appendix is the Piñon Ridge Project Basic Engineering Report prepared by CH2M HILL Engineers, Inc., dated February 4, 2009 (CH2M HILL 2009).
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1.0 GENERAL

This document describes the control strategy for the Piñon Ridge Project uranium plant. The plant would be located near Bedrock, CO. This document is to be used as a reference with the latest revisions of the mechanical equipment list, process flow diagrams (PFDs) and process and instrumentation diagrams (P&IDs).

1.1 Reference Documents

This document has been developed using information from the following sources:

1.1.1 Process Flow Diagrams

100-PF-001 Area 100 Ore Handling and Grinding
200-PF-001 Area 200 Pre-leach
200-PF-002 Area 200 Leach Train
300-PF-001 Area 300 Counter Current Decantation (CCD) Thickeners
300-PF-002 Area 300 Tailings Area
400-PF-001 Area 400 Uranium Solvent Extraction (SX) – Feed System and Extraction Train A
400-PF-002 Area 400 Uranium SX Extraction Train B, Scrub and Strip
500-PF-001 Area 500 Uranium Precipitation, Drying and Packaging
600-PF-001 Area 600 Vanadium Oxidation and SX – Extraction Train A
600-PF-002 Area 600 Vanadium SX – Extraction Train B, Scrub and Strip
700-PF-001 Area 700 Vanadium Precipitation
700-PF-002 Area 700 Vanadium Drying and Packaging
800-PF-001 Area 800 Sulfuric Acid, Ammonia and Ammonium Sulfate
800-PF-002 Area 800 Sodium Hydroxide and Sodium Carbonate
800-PF-003 Area 800 Flocculant and Organics
800-PF-004 Area 800 Sodium Chlorate and Hydrogen Peroxide
900-PF-001 Area 900 Water Storage
900-PF-002 Area 900 Boilers and Compressors
900-PF-003 Area 900 Fuel Storage

1.1.2 Piping and Instrumentation Diagrams

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2.0 PROCESS OPERATION

The Piñon Ridge Project is designed to treat 1,000 short tons of ore per day and to produce both uranium in the form of the yellow uranyl peroxide \((UO_4 \cdot nH_2O)\) referred to as \(U_3O_8\) or yellowcake, and vanadium in the form of vanadium pentoxide \((V_2O_5)\).
The ore would be trucked from various pits in the area and stored on a 5 acre stockpile pad. This arrangement is designed to allow toll-milling of ores and optimization of circuit conditions for each ore.

Ore would be ground in a SAG Mill in closed circuit with a vibrating screen. Screen oversize would be returned to the mill and screen undersize passed to the leach circuit.

In the leach circuit, the ore would be mixed with concentrated sulfuric acid and sodium chlorate in a leach train of eight tanks. The uranium and vanadium bearing solutions would be washed from the solids in an 8-stage CCD circuit.

CCD underflow would be pumped to the tailings dam where clear solution would be decanted from the tailings and returned to the plant. The CCD overflow would pass through a pre-leach thickener and clarifier and then to the uranium SX circuit.

The uranium SX feed would be cleaned in one of two polishing filters. Uranium would be recovered from the solution in two parallel solvent extraction circuits. The loaded uranium organic would be stripped to produce a concentrated uranium bearing solution. The uranium would be precipitated as yellowcake (U₃O₈), in the form of uranyl peroxide, filtered, dried and then packed into drums for shipment.

The raffinate from the uranium circuit would pass to the vanadium circuit. The vanadium would be oxidized in a series of six tanks—a three tank adjustment circuit followed by a three tank retention circuit. The vanadium leach liquor would be cleaned in a polishing filter and the vanadium recovered in two parallel solvent extraction circuits. The loaded vanadium organic would be stripped to produce a concentrated vanadium bearing solution. The vanadium would be precipitated, converted, and cast into flakes for packaging and shipment.

The tailings impoundment is designed to consist of a number of tailings cells and evaporation ponds. The areas would be equipped with a leak detection system that would be monitored from the main plant control room.

3.0 CONTROL SYSTEM ARCHITECTURE

The plant would be monitored and controlled from a central control room using a Process Control System (PCS). The PCS would provide automatic control of the circuit, regulatory and supervisory control of the process, configuration of batch processing operations, an operator interface and historical data storage.

3.1 Process Control System (PCS)

The PCS is a complete plant control system. The PCS would be a distributed control network consisting of input/output (I/O), processors, and operator interface. The I/O and processors would be in the main electrical rooms of the plant and therefore the PCS would be divided by process area.

The analog signals would be mostly 4-20 mA with HART protocol and digital I/O would be 24 V DC. Motors and drives would be controlled by intelligent motor control relays and communicate to the Distributed Control System (DCS) through DeviceNet.
Any vendor packages would be fully integrated into the PCS and would communicate using Modbus protocol. Vendor packages that are part of the main process stream— not just services—would require a hardwired interlock signal from the control system to run. All packages must have an active heartbeat to the control system to monitor communications and take action on a loss of control.

3.1.1 Instrumentation Ratings

The solvent extraction area of the plant would be rated Class 1 Div Group D due to flammable vapor from the solvent. This area will require explosion proof instrumentation and barriers for I/O connections. Intrinsically safe equipment would not be required.

3.1.2 Networks

The PCS would use a dedicated network to connect processors, operator interfaces and servers. The plant would have a network (‘plant local area network (LAN)’) for general computing needs and the phone system. The connection between the control and plant LAN networks would be controlled by a firewall. The objective would be to maintain the security and integrity of the control network. The exact structure of the firewall would depend on the PCS vendor’s recommended architecture.

The firewall would only permit access to the data historian from specific clients on the LAN and for remote access to an engineering station. All other access between the networks would be forbidden. There would be no internet or plant LAN access from the control system computers.

3.1.3 Printers

The control network would include a color laser printer in the central control room for operator graphics and diagnostics. A black and white laser printer would be installed with the engineering station for documentation.

3.2 Operator Interface

The plant would be operated from a central control room equipped with three dual-head operator workstations. These workstations give the operators access to real-time and historical data from the process.

There would also be an engineering station that could be used as an operator workstation but would be primarily intended for programming and maintenance. There would be two additional engineering stations added to the system for commissioning.

The functions available at each workstation would be controlled by password access to four levels of security.

- **OPERATOR**: Visualize and operate all areas of the plant.
- **SUPERVISOR**: All OPERATOR rights plus temporary overriding of process interlocks.
- **MAINTENANCE**: All SUPERVISOR rights plus control configuration, tuning and functions related to field devices and hardware.
- **ENGINEER**: Unrestricted rights to the entire system including system configuration.
3.3 **Data Historian**

The data historian would be used by the operators for normal operation of the plant and by the engineering staff for analysis and optimization of plant performance. The historical data would be accessed by client software from computers on the main plant network. A firewall would be configured to only allow traffic between the client software and the historian.

The data historian would be essential for recording and analyzing toll-milling of different ores. The data would be needed for accounting of toll milling batches and optimization of process conditions for different ores. The data will be accessed through an Excel add-in, which would permit the development of any tools and reports required for plant operation.

The data historian should store data based on a user-defined deadband and minimum sampling frequency. The historian must be expandable up to at least 400 GB of compressed historical data and permit archiving of the data to DVD, tape, or equivalent.

The historian client software should have functions for browsing data points, retrieving data interpolated to equal time intervals and summary functions such as average and sum. All data stored in the archive should include the data quality.

3.4 **Closed-circuit Television (CCTV)**

There would be two CCTV systems: process and security, both would be able to watch images from any camera.

The process cameras would be connected over Ethernet to a central matrix in the main control room. The control room operator would have control of any pan-tilt-zoom (PTZ) functions. The CCTV images will be displayed on dedicated monitors in the control room. CCTV software would permit image tiling and automatic scanning. The CCTV matrix would have a network port to make the images available to the plant LAN or control network if required. It would be possible to add a recording device to the CCTV system with cameras connected to the matrix using fiber from the main plant infrastructure.

The security cameras would be a separate CCTV system with its own matrix and controls in the security offices. The process and security CCTV matrices would be connected over Ethernet to permit the exchange of images.

4.0 **CONTROL PHILOSOPHY**

The PCS would be used for monitoring and control of the process and for safe operation of the plant as well as the protection of personnel, equipment and the environment. This section defines the philosophy and terminology used to describe the plant operation.

4.1 Operating Philosophy

The overall operating philosophy of the plant would be that the process is sufficiently instrumented to allow automatic operation under normal, stable conditions. However, the plant would not be fully automated so that switching process streams and similar changes would require manual intervention.
and verification. This means that with the current philosophy, some interlocking of pumps and flows would rely on operator actions in the field without feedback to the control system.

4.2 Operational Modes

The plant would be intended to be operated from the central control room and local control would be provided in the uranium and vanadium packaging areas for their respective systems. The following terms are used to define various types of controls. The mode of a device would be shown on the operator interface. When the device is not in the normal operating mode, this indication would be more noticeable than the normal mode.

4.2.1 Control Source

The control source would be selected from the operator interface.

LOCAL MODE The device would be operated from controls in the field such as pushbuttons. Local mode would be intended for maintenance functions only and would not be the normal operating mode.

REMOTE MODE The device would be operated from the control system through the operator interface or by logic in the controller.

For safety, all stop functions would be active in all modes. A device in local could only be started from the field and a device in remote can only be started through the PCS.

All start signals would be conditioned in the PCS regardless of mode to apply appropriate interlocks.

4.2.2 Device Control Modes

MANUAL The device would be controlled by an operator’s manual actions.

AUTOMATIC The device would be controlled by logic.

A control loop would have the following modes:

MANUAL The loop output would be entered by the operator.

AUTOMATIC The loop set point would be entered by the operator and the output calculated by the control loop.

CASCADE The loop set point would come from the output of another or calculation.

4.2.3 Interlock Types

Interlocks refer to PCS inputs or logic that would be used to control the operation of devices. In general all interlocks must default to a state that would drive the process to a safe state. Any interlocks that are uncertain or have bad quality signals would be assumed to be in the fault state. The system would be intended to make operating with bypassed interlocks inconvenient and noticeable.

HARDWIRED INTERLOCK A signal wired directly to the motor control relay. Hardwired interlocks may be required by construction codes or for fundamental safety. The states of these values would be reported to the PCS for diagnosis.
These interlocks could only be bypassed by inserting jumpers in the field which should never be required.

SAFETY INTERLOCK A PCS input or logic required for the safe operation of a device and equipment protection. These interlocks cannot be bypassed except by changing the control logic.

PROCESS INTERLOCK A PCS input or logic required for the normal operation of a device in the process. In local mode process interlocks could be bypassed. In the transition to remote mode, all process interlocks would be activated.

PERMISSIVE A condition that must be true for a device to change state but when the state has changed it would be ignored. Examples would be a mill motor start permissive of no high temperature alarms or a cyclone valve close permissive of at least the minimum number of cyclones still open.

All interlocks, except permissives, would be latched in the control system and require acknowledgement by the operator. Motor controls would only start on a direct start command and would not be set to trigger when an interlock clears or is acknowledged.

4.3 Motor Control

Motors and drives would normally be controlled from the control system over a DeviceNet link to the control system. If the DeviceNet link is not functioning, the drive could only be operated by a manual override from the motor control relay. This structure ensures that all safety and process interlocking would always be in place during normal operation to provide safe operation and equipment protection.

Motor controls would be built to show the operator the status of all interlocks and permissives. The cause of the last trip would be identified in the logic and displayed on the operator interface and would reset each time the motor restarts.

Motors would typically have only four states:

- NOT AVAILABLE No control power or locked out.
- NOT READY Stopped and not ready to start due to interlock or permissive.
- READY Stopped and ready to start.
- RUNNING Motor running.

4.4 Valve Control

Valves would be controlled by thePCS. All valves would be installed and configured with a fail-safe position in the event of PCS, power, or air failure that drives the process to a safe state. Valve controls would use feedback of actual valve position where possible. The operator interface would display the state of any valve interlocks.
4.5 Sequences

Sequences would be constructed using International Electrotechnical Commission (IEC) 61131-11 compliant Sequential Function Chart (SFC) structures. The sequences would be used where appropriate for frequently repeated series of control actions. All sequences must include feedback for the operator of the current step and status of the sequence. All transitions must be configured with an alternative path in the event of the failure of an action that drives the process to a safe state. Where possible, large sequences should be broken into smaller components that can be activated from a supervisory sequence. For example, if a pump with inlet and outlet valves is part of a sequence, the pump start/stop can be made into a smaller sequence called from the main process sequence.

4.6 Control Loops

Analog control loops must be built to include the following features:

- Output limiting in automatic and optionally in manual mode
- Anti-windup logic
- Parallel proportional-integral-derivative (PID) algorithm
- Output tracking
- Feed-forward inputs
- Process variable filtering
- Controller derivative action on process variable only, not set point
- Set point rate limiting

Cascade loops require the following features:

- Master loop tracking when slaves are not in cascade mode
- Output configurable in the range and units of the slave loop measurement

4.7 Alarm Philosophy

The alarm philosophy would follow the latest Instrument Society of America (ISA) and Engineering Equipment and Materials Users’ Association (EEMUA) guidelines on process control system alarms and include the principles of Abnormal Situation Management (ASM). The alarm philosophy must be applied to the design and configuration of all control logic. A well-structured alarm system would save significant time and money during commissioning and operation. The general principles are:

- Alarms would be items requiring an operator action.
- Alarm saturation should be avoided.
- Unnecessary alarms should be inhibited automatically through control logic.
- Alarms would be prioritized using the following structure:
  - PRIORITY 1 Immediate operator action required to prevent injury or loss.
  - PRIORITY 2 Operator action required to correct an abnormal situation.
  - PRIORITY 3 Operator action required to avoid an abnormal situation.
5.0 FUNCTIONAL DESCRIPTION

This section describes the operation and process controls that would be applied in each area of the plant.

5.1 Area 110 ROM - Coarse Ore Storage and Reclaim

Ore from the Piñon Ridge mine or trucked in from other sources would be stored on a 5-acre ore pad. Trucks would tip ore over a dump wall where a front-end loader would take the ore to the stockpile or mill feed hopper. Dump lights would be used to tell the truck driver if it is permitted to dump. The lights would be red when equipment is present inside the dump pocket or there is a downstream process restriction. The dump wall would be the boundary of the restricted area so that trucks stay outside this boundary and, as a result, do not require decontamination.

A loader would feed ore into a coarse ore hopper that would feed an apron feeder. The hopper design incorporates a grizzly and a mobile rock breaker that would be used to break up large pieces of ore. The apron feeder would discharge onto the SAG Mill feed conveyor and the apron feeder’s speed would be controlled by the SAG Mill feed conveyor weightometer.

5.2 Area 120 SAG Mill Grinding and Screening

Ore would be ground in a fixed speed SAG Mill in closed circuit with two vibrating screens. The screen undersize would be pumped to the leach feed storage tanks.

The SAG Mill usually would be fed at a fixed rate and the SAG Mill bearing pressure and power draw would be monitored. The SAG Mill lubrication system logic would be defined by the mill vendor.

Water would be added to the SAG Mill feed chute in ratio to the feed to the mill to maintain the SAG Mill discharge density at an optimum value to be determined during commissioning (typically in the range of 65–75 percent solids by weight).

The SAG Mill would discharge through a trommel screen. The trommel screen oversize (mill scats) would be directed to a storage hopper that would be emptied periodically. Trommel screen undersize would flow into a sump where water would be added and slurry pumped onto two vibrating screens. The screen feed density and flow would be measured. Process water returned from the uranium and vanadium product filters would be stored in a tank and would be used as sump dilution water and the use of recycled water would be maximized and raw water consumption minimized.

5.3 Area 130 Leach Feed

SAG Mill screen undersize would be pumped,alternately, into the two pulp storage tanks. This way, while one tank is being filled, the other would be used to feed the leach circuit. The leach feed would be sampled and the flow and density measured for metallurgical accounting.
5.4 Area 210 Pre-leach

Leach feed slurry would be mixed with overflow solution from the CCD circuit to recover fast leaching uranium and vanadium. The slurry would flow through two pre-leach tanks; the solids and solution would be separated in a thickener and clarifier. The solution would be pumped to the uranium polishing filters preceding the uranium solvent extraction circuit and the solids would be pumped to the leach circuit.

The hydrogen concentration (pH) in each pre-leach tank would be monitored. Pre-leach Tank 2 would overflow to the Pre-leach Thickener. Flocculant would be added to control the settling rate of solids indicated by the level of the thickener interface. A local control panel would measure the thickener torque and raise and lower the rakes automatically.

5.5 Area 220 Leach Train

Slow leaching uranium and vanadium would be leached from the ore in a series of eight tanks. Slurry from the Pre-leach Thickener underflow would be pumped into the first or second leach tank and then flow by gravity through the remaining tanks. The leached slurry would be pumped to the CCD circuit to wash the leached uranium and vanadium minerals from the slurry and concentrate the values in the solution.

Steam, sodium chlorate, and concentrated sulfuric acid would be added to the first four leach tanks to carefully control the free acid concentration, oxidation/reduction potential (ORP) and temperature. Steam would be added to the other four tanks to control temperature. The ORP would be measured in the last two leach tanks only. Conductivity would be used to infer free acid concentration in the first three leach tanks and control acid flow. The relationship between conductivity would be determined during initial operation.

5.6 Area 310 CCD Thickeners

The leached slurry would be washed in the CCD circuit for solid/liquid separation and recovery of dissolved uranium and vanadium. The circuit would be comprised of eight thickening stages with a wash ratio of 2.3 tons of wash water per tons of solids feed.

The underflow from each thickener would be pumped to the next stage downstream and the underflow from stage eight pumped to the tailings sump. The overflow from each thickener would be pumped to the feed box of the upstream thickener where it would dilute the feed to the thickener and the flocculant. The overflow from the first CCD thickener would be pumped to the pre-leach tanks.

Tailings return water would be added to the last thickener in an operator defined ratio to the mass flow of solids entering that thickener to ensure the wash ratio is maintained at all times and the loss of soluble product would be minimized.

The mass of the bed in each thickener would be measured to show the operator the distribution of solids around the CCD circuit allowing the operator to detect any uneven distribution of solids and make the necessary corrections.

Flocculant would be added to each thickener according to manual settings and underflow pumps would be controlled by the density of the underflow stream.
5.7 Area 320 Tailings Sump and Tailings Pond

The underflow of the last CCD thickener would consist of leached solids with practically all product bearing solution washed out of the slurry and would be pumped to the tailings collection box. The slurry would be sampled and flow by gravity into the tailings sump. These tailings would be pumped to tailings impoundment cells. Water would be recovered from the dam by barge pumps and pumped to the plant return water tank.

The cells would be equipped with a leak collection recovery system designed by others.

5.8 Area 410 Uranium Solvent Extraction Feed

The Pre-leach Clarifier overflow would be filtered in one of two polishing filters to remove any remaining entrained solids before passing to solvent extraction for recovery of dissolved uranium and vanadium.

The filter would use diatomaceous earth (DE) to coat the filter media and remove fine solids. Each filter would operate in an automated cycle. The filter media would be contained inside a pressurized vessel that contains the force to push the filtrate through the filter media (called the 'septum').

The filter would be first coated with a defined thickness of DE. The filter feed would be switched to clarifier overflow dosed with DE to ensure a fresh filter media surface at all times. The filter would run in this mode until the pressure drop reaches a maximum value. At this point the feed would be shut off and the DE discharged from the filter and flushed to the area sump pump to be pumped to the tailings collection box.

5.9 Area 420 Uranium Solvent Extraction Train A

Uranium would be extracted from the leach solution in the solvent extraction circuit.

The filtered uranium-bearing ('pregnant') solution from the polishing filters would be stored in a tank. The solution would be contacted with an organic solvent that would selectively extract the uranium compounds from the solution. The barren solution (raffinate) would be pumped to the vanadium circuit and the loaded organic sent to the stripping circuit. There would be two parallel solvent extraction lines. A common crud handling system would be installed to periodically treat batches of solvent and remove solids accumulations.

There would be four stages of solvent extraction. Each stage would consist of a mixer/settler unit where organic and aqueous phases would be contacted in two mixing chambers—the primary and secondary mixers. The organic and aqueous phases would then be allowed to separate in the settler area where they would flow into separate launders.

Barren organic flows counter-currently to the pregnant solution so that the lowest grade pregnant solution would be contacted with the lowest loaded organic, driving the equilibrium shown below to the right and maximizing extraction.

The SX trains would be controlled to keep the correct organic to aqueous ratio ("O:A") in each unit. This would be controlled manually using a valve that would recirculate organic from the discharge launder to the primary mixer. All the control would be rooted in the feed flow of pregnant liquor. This
would be controlled to an operator defined set point based on the current and expected production level, uranium loading of the leach solution, and the level in the SX feed tank. The flow rate of barren organic to the extraction circuit would be set in ratio to the leach liquor flow and its loading. The circulation of organic and aqueous through the SX and scrub/strip circuits would be controlled to maintain a steady balance in the circuit.

The Piñon Ridge layout would require that organic and aqueous streams be pumped into and out of each section (Figure 1). The flows in and out must therefore be balanced by controlling the speed of the outlet pumps with the level in the overflow launders.

**Figure 1**

**SOLVENT EXTRACTION CIRCUIT**
5.10 Area 430 Uranium Solvent Extraction Train B

The second solvent extraction line would operate in parallel with Train A (Section 5.9) using the same principles of operation.

5.11 Area 440 Uranium Solvent Extraction Loaded Organic

Uranium would be recovered from the organic in the scrub/strip circuit. The organic would be pumped through the scrubber mixer settler to remove impurities and then through the stripper mixer settlers and then back to the barren organic tank.

The loaded organic from both uranium solvent extraction trains would be stored in a tank preceding the scrub/strip mixer settlers. The uranium would be removed from the organic to make a concentrated aqueous solution ("pregnant liquor") by contacting the organic with a carbonate solution at a slightly elevated pH. The barren organic would be returned to the solvent extraction trains. The pregnant liquor would be sent to the uranium precipitation circuit.

The loaded organic would be first scrubbed with dilute sulfuric acid to remove impurities such as iron and silica before stripping. The scrubbing solution would be pumped to the head of the solvent extraction circuit to recover any uranium.

Uranium would then be stripped from the organic. The barren organic would be stored for reuse in the extraction circuit. Careful control of the pH would be essential for effective stripping.

The scrubbing and stripping circuit would be operated to keep the solvent extraction circuit supplied with barren organic without an unnecessary accumulation of loaded organic. The scrub/strip circuit would have a fixed design flow and the amount of loaded organic would depend on how many SX trains are running. The scrub/strip circuit might run intermittently depending on the amount of loaded organic accumulated and amount of barren organic available; this would be dependent on whether one or two extraction trains are running.

Under normal operating conditions, the levels of loaded and barren organic tanks should be stable. Should there be a sustained increase or decrease in levels, the operator would know the stripping flow is not in balance with the solvent extraction flow.

The arrangement of the pumps and flow meters in the circuit is shown in Figure 2. The pumps and mixer speeds would be controlled to keep the mixer/settler interface levels steady and the flows at the design rate. The feed rate of loaded organic to the scrubber would be controlled at an operator defined set point.

The O:A ratio would be controlled in each cell by the recirculation of aqueous from the product launder back to the primary mixer. The speed of the outlet pumps would be controlled by the level in each product launder.
5.12 Area 510 Uranium Precipitation

Uranium would be precipitated as hydrated uranium peroxide from the pregnant liquor using hydrogen peroxide.

Pregnant liquor from the SX circuit would be pumped through a train of five tanks. Sulfuric acid would be used in the first tank to control the pH and eliminate any sodium carbonate left over from stripping. Hydrogen peroxide would be added into the second tank according to the uranium loading of the pregnant liquor.

Approximately 20 percent of the pregnant liquor flow would be pumped to the third precipitation tank. This flow and sulfuric acid would be used to control the pH around 4.2 for optimum precipitation conditions and filterability of the precipitate.

The uranium peroxide precipitate would be sent to a thickener and the thickener overflow would be pumped to the process water tank.
5.13 Area 530 Uranium Drying and Packaging

Uranium peroxide precipitate would be recovered on a belt filter and the filtrate sent to the thickener to recover any remaining precipitate. The filter cake would be washed on the filter and then dried. The drying process would drive off water but would not convert the uranium peroxide. The temperature profile along the dryer and speed of the dryer would be set by the operator to achieve optimum product quality. The product (“yellowcake”) would then be packed into drums by an automated system for shipment. As the material was being packaged, an automated sampler would take “grab” samples to be assayed.

The mass, content, source, and other production data for each drum would be stored in the PCS historian for accounting and process analysis and the drums labeled with the necessary regulatory and shipping information.

The sealed uranium area would be operated with all handling equipment and transfer points well ventilated to prevent uranium dust. The vent gases would be thoroughly scrubbed and monitored before being vented to the atmosphere.

5.14 Area 610 Vanadium Oxidation

Vanadium would be leached from the ore at the same time as uranium. The vanadium would be oxidized to the pentavalent state using sodium chlorate and ammonia to control pH and ORP so the vanadium could then be selectively recovered by solvent extraction.

Raffinate from the uranium solvent extraction circuit would be pumped into the vanadium oxidation circuit at an operator defined flow rate. The oxidation circuit would consist of five agitated tanks in series followed by a storage tank. The ORP would be measured in all five tanks and would control sodium chlorate addition to the first three tanks. The pH would be measured in the first four tanks and would control ammonia gas injection to those tanks. The temperature would be measured in the first three tanks. The control strategy would take into account the feed flow rate and the interaction between pH, ORP, and temperature to provide optimum conditions for vanadium oxidation.

The vanadium bearing solution would be cleaned in a polishing filter and stored in a tank for SX feed. The temperature of the vanadium oxidation tanks would be monitored to ensure the solution is not too hot for solvent extraction.

5.15 Area 620 Vanadium Solvent Extraction Train A

Vanadium would be selectively extracted from the leach solution in the solvent extraction circuit. Each vanadium solvent extraction train would consist of five mixer/settlers and a raffinate settler. The pH would be measured in the aqueous discharge of the first four mixer/settlers and controlled by sparging ammonia gas into the aqueous feed. The pH would be controlled in the fifth mixer/settler by adding sulfuric acid. The barren organic returned from the strip circuit would be alkali and must be neutralized before it could be used in extraction.

The feed flow to each SX train would be set by the operator. The flow of barren organic would be controlled in ratio to the leach solution concentration and flow rate.
Similarly to the uranium SX circuit, the products would be pumped out of the circuit. The levels in the raffinate settler aqueous and organic overflow launders would control the speed of the aqueous and organic pumps respectively.

The vanadium raffinate would be pumped to a storage tank and from there it could be pumped to the polishing filters, evaporation ponds or tailings. The flow to the evaporation pond would be measured for environmental monitoring and reporting.

5.16 Area 620 Vanadium Solvent Extraction Train B

The second vanadium solvent extraction train would be operated in parallel with the first and use the same control philosophy.

5.17 Area 640 Vanadium Solvent Extraction Loaded Organic

Vanadium would be stripped from the loaded organic to produce a sodium decavanadate solution, that would be suitable for recovery of vanadium oxide product.

The loaded organic from solvent extraction would be stored in a tank and pumped through the scrub/strip circuit at an operator defined flow rate. The organic would be first scrubbed with dilute sulfuric acid controlled to a pH of about 2.5 that would remove impurities, particularly dissolved base metals.

The organic would then be contacted with a sodium carbonate strip solution in three stages. An operator defined flow of sodium hydroxide would be injected into the third stage. Sodium carbonate would also be added to the third stage and the flow would be controlled by the pH measured in the first stripping stage. The target pH of the first stage would be about 8.5.

Barren organic would be pumped to a storage tank that could be used in extraction and the striped liquor would be pumped to vanadium conversion.

5.18 Area 710 Vanadium Conversion and Precipitation

Vanadium would be recovered from the strip solution by converting to metavanadate and would be precipitated as ammonium metavanadate.

The strip solution from solvent extraction would be stored in a tank and processed in batches for precipitation. The objective would be to provide the correct chemical and physical conditions for precipitation that would give a product that could be handled easily and with little loss or environmental contamination.

The strip solution would be pumped continuously into the first precipitation tank where steam would be injected to control the temperature at 149°F. Ammonia gas would be injected to neutralize the solution which would convert the decavanadate in the strip solution to metavanadate.

The solution would then be pumped to one of three precipitation tanks where it would be treated in batches. An operator defined quantity of ammonium sulfate solution would be added to each batch and the solution would be allowed to cool. Ammonium metavanadate would crystallize from the solution.
After the batch processing time is complete, the tank agitator would be stopped and the precipitate would be allowed to settle to the bottom of the tank. The solids would drain onto a belt filter and the solution would be decanted off to the process water tank. A fourth tank would be used to blend a bad batch of precipitate with a good batch to allow for good belt filtration.

The precipitation would be operated as a sequence with time and dosage parameters set by the operator.

5.19 Area 730 Vanadium Filtering, Fusion, and Packaging

The ammonium metavanadate precipitate would be dried and then heated to covert it to vanadium oxide that would be melted and cast to produce flakes that would be packaged for shipment.

Vanadium product filtering and packaging would be primarily a batch operation run manually. As each batch of vanadium precipitate is finished, the precipitation tank would be drained onto a belt filter running at an operator defined speed. The filtrate would be pumped to the process water tank and the solids conveyed directly into a dryer. The operator would set the speed and temperature profile of the dryer to give a product that could be easily handled in the conversion kiln.

The dried precipitate would be stored in a hopper that would feed a diesel-fired rotary kiln. In the kiln ammonia would be driven off to produce a vanadium oxide product. Kiln temperature would be controlled by the operator to give complete conversion.

The product from the kiln would be melted in a fusion furnace and then poured onto a water cooled casting wheel to produce flakes which would be fed into an automated packaging system. As the material was being packaged, an automated sampler would take “grab” samples to be assayed.

The mass, content, source, and other production data for each drum would be stored in the PCS historian for accounting and process analysis and the drums labeled with the necessary regulatory and shipping information.

The sealed vanadium area would be operated with all handling equipment and transfer points well ventilated to prevent vanadium dust. The vent gases would be thoroughly scrubbed and monitored before being vented to the atmosphere.

5.20 Area 800 Reagents

The reagent area would be comprised of equipment for receiving and preparing reagents for use in the process. The operation would be primarily manual except where the preparation of fresh batches of reagent from a concentrated feed stock could be automated.

Concentrated sulfuric acid would be received by tanker and stored in storage tanks and the acid would be pumped continuously around a header for use in the plant.

Ammonium sulfate would be delivered as a solid. Batches of ammonium sulfate solution would be prepared automatically as needed.

Ammonia liquid would be delivered to the plant by tanker and stored under pressure. The liquid would be pumped into a vaporizer to provide ammonia gas for the plant. The pressure in the plant header would automatically control the vaporizer and its feed pumps.
Concentrated sodium hydroxide would be added to a storage tank where it would be diluted down to the required concentration for use in the plant.

Sodium carbonate would be delivered to the plant by tanker and put into solution at an operator defined concentration for storage. Batches of dilute sodium carbonate would be prepared automatically as needed.

Flocculant would be prepared by an automated system based on the level in the flocculant storage tank.

Kerosene and organic solvent would be stored in tanks. Fresh solvent would be pumped into the barren organic tanks as required.

Concentrated sodium chlorate would be delivered to the plant by tanker and stored in a stock tank. The solution would be pumped over to a storage tank and diluted to an operator defined concentration for use in the process.

Hydrogen peroxide would be delivered by tanker and stored in a tank for use in the process.

5.21 Area 910 Water

The water system would be designed to consume the minimum amount of fresh water and maximize re-use of process water. Water treatment and storage would be a critical environmental responsibility and would be carefully monitored and controlled.

Raw water would only be used where clean water would be necessary. The water would be stored in a large tank. The top part of the tank would be for raw water storage and the bottom part of the tank for fire water storage that would feed a diesel and a jockey fire water pump.

A water treatment system would be used to treat raw water to produce non-potable water for sinks and showers. Potable water would be supplied from an outside source (vendor).

Process water would be recycled from the tailings dam and used as feed to the CCD circuit. Process water from product belt filters and precipitation would be recycled to the process water tank and used in SAG Mill discharge sump.

5.22 Area 920 Steam

Three automated boiler packages would provide steam for process heating and drying.