

Operations & Maintenance Manual

Mt. Taylor Mine/Rio Grande Resources Corp.
Mine Water Treatment Unit (MWTU) – Uranium IX and
Molybdenum/Selenium Treatment Facility

LNV Project No. 130040/150092



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MT. TAYLOR URANIUM IX AND MOLYBDENUM/SELENIUM TREATMENT PLANT OPERATING MANUAL

I. Background Information

Rio Grande Resources (RGR) plans to re-open the Mt. Taylor mine located outside of Grants, New Mexico. The existing mine has to be dewatered to enable access to the ore. To dewater the existing mine works and operate the mine in the future, an extensive water management system must be run in combination with a Mine Water Treatment Unit (MWTU) to remove uranium (U), Molybdenum (Mo), and Selenium (Se) from the mine water to enable discharge to an NPDES-permitted outfall north of the mine.

The water treatment will be operated in two main phases:

Phase 1 - Mine de-watering phase:

- Flow 8,000 -10,000 gallons per minute (gpm)
- U 0.07 parts per million (ppm) trend increasing
- Mo 0.2 ppm trend increasing
- Se 0.001 ppm trend increasing
- TDS ~ 400 ppm

Phase 2 - Mine operation:

- Flow 4,000 -5,000 gpm
- U about 1 ppm (previous mining conditions, late phase)
- Mo 0.530 ppm
- Se 0.090 ppm
- TDS 800 ppm

Discharge requirements:

- 30 parts per billion (ppb) U (human health standard in 20.6.2.3103.A(12)NMAC)
- 50 parts per billion (ppb) Se (human health standard in 20.6.2.3103A(10)NMAC)
- 100 parts per billion (ppb) Mo (Standards for Irrigation Use in 20.6.2.3103C(4)NMAC)

RGR considers U removal by ion exchange (IX) using the existing IX plant at the site as the primary option. IX loaded resin will be transferred to an off-site facility, duly licensed by the Nuclear Regulatory Commission (NRC) or an Agreement State, to be regenerated. The stripped resin will then be returned for reuse at the IX Plant.

RGR has put together a U removal system utilizing a proven IX process to meet the drinking water standard discharge requirements. The system will incorporate IX trains each consisting of two IX columns in series. Each IX column will have a load capacity of 400 cubic feet (ft³) of IX resin with a maximum loading capacity of 0.09 pounds of U per cubic foot of resin. Each train has been designed to handle a maximum flow rate of 1,650 gpm and will be operated at a nominal flow rate

of 1,429 gpm. The IX columns are designed to transfer the resin in the lead IX column when it reaches a loading of about 0.06 pounds of U per cubic foot, to prevent discharge exceeding 30 ppb U. The loaded resin from the lead IX column will be transferred to one of two loaded resin storage tanks and then will be off loaded to a resin tanker. The resin tanker will transport the loaded resin to an off-site facility for regeneration.

Each of the IX columns will be operated in an up flow mode with safeguards to prevent resin leakage between IX columns or resin spills. Each of the IX columns will have safety devices to prevent resin spills as follows: 1) resin screens in the overflow of each column, 2) a level control system that will reduce the input flow rate to the lead IX column; and 3) a bypass on the tail column to reroute bypass fluid to an overflow storage tank. The fluid sent to the overflow storage tank will be recycled back to the main supply wet well where it will be fed to the lead IX column.

To remove Mo and Se from the mine water, RGR has put together a Mo and Se removal system utilizing MAR Systems' Sorbster® media technology. MAR, which stands for Mercury Arsenic Removal, "was founded in 2006 to develop a patented, proprietary process to remove mercury, selenium, arsenic, and other metal contaminants from water." The Sorbster® is an enriched alumina media which adsorbs soluble metals. The system will include 14 treatment trains each consisting of two media columns in series. Each treatment train will be operated at a nominal flow rate of 715 gpm. The individual trains will be sampled and assayed from each lead and tail column to ensure that the discharge water will not exceed the discharge limits for U of 30 ppb, Se of 50 ppb, and Mo of 100 ppb.

II. Plant Function

The Mt. Taylor IX Plant is designed to treat 10,000 gpm of mine water for removal of U. The ion exchange process for recovering U from mine water utilizes a quaternary amine incorporated onto a porous styrene divinylbenzene bead. The amine has the ability to give up anions in exchange for anions in solution, in this case, U. When loaded to 0.06 pounds U per cubic foot the resin will be transported to an offsite facility to be regenerated with a concentrated brine solution in a split elution cycle. The regenerated resin will be returned to Mt. Taylor to be reused.

The effluent of the IX Train is sent to the MAR Sorbster® Media system, housed in a new stand-alone building, for removal of Mo and Se prior to discharge. The MAR Sorbster® Media system consists of two adsorbent medium, Sorbster® Si-1 and Sorbster® Se-1. The Sorbster® Si-1 media is effective in the removal of silica from water and acts as a pretreatment process for the Sorbster® Se-1 media which is highly functionalized to remove Se as well as Mo and other metals. The pH is adjusted with H₂SO₄ to a pH of 6.27, which was determined from prior bench scale testing to be the optimal pH for Mo and Se adsorption, prior to the Sorbster® Media. The pH is subsequently raised after passing through the Sorbster® Media to a pH of 7 required for discharge. Once the adsorption capacity of the media is reached, the media is disposed of in a non-hazardous waste landfill after passing EPA TCLP testing and replaced with new media.

The following drawings should be referred to in conjunction with this Operation and Maintenance Manual (O&MM):

Drawing No.	Description
2	Symbols & Legend (Sheet 1 of 2)
3	Symbols & Legend (Sheet 2 of 2)
4	Uranium Ion Exchange Equipment Layout Plan
5	Uranium Ion Exchange Foundation Containment Plan
6	Uranium Ion Exchange Miscellaneous Details
7	Uranium Ion Exchange Process Flow Diagram
8	Molybdenum and Selenium Process Flow Diagram
9	Uranium P&ID – Mine Water Wet Well
10	Uranium P&ID – IX Columns (Trains 1 &2)
11	Uranium P&ID – Resin Storage and Transfer
12	Molybdenum and Selenium P&ID
13	Molybdenum and Selenium Building Layout

III. Facility Description

Refer to Drawing Numbers 4 – Uranium Ion Exchange Equipment Layout Plan and 13 – Molybdenum and Selenium Building Layout for the location of the various items described below. The Mt. Taylor IX Plant consists of five mine water pumps, four operating and a spare, seven IX trains with two IX columns each (14 columns total), two loaded resin storage columns, one overflow storage tank and two resin transfer water storage tanks. All of the above U IX equipment except the mine water pumps are enclosed within the IX building. Also housed inside of the IX building are a motor control center (MCC), office, control room and restroom. The MAR Sorbster® Media system for Mo and Se removal consists of 28 media columns all housed within a new building as shown on Drawing Number 13.

A. Mine Water Pumping

Mine water gravity flows from the treatment lagoons to a wet well located adjacent to the IX building on the south side. The wet well has dimensions of 30 ft. x 6 ft. x 8 ft. The mine water wet well is covered by a platform which supports the five mine water transfer pumps (MWP-1, 2, 3, 4, and 5). Each mine water pump has a capacity of 2,500 gpm. For the plant's capacity of 10,000 gpm, four pumps are operating with one full spare.

B. Ion Exchange

The IX portion of the facility is located within the IX building and consists of seven trains of two IX columns each (14 columns total). Each train has a capacity of 1,650 gpm or one-sixth the total plants flow. The IX trains are arranged so that water will gravity flow from the first (lead) column (IX-1, 3, 5, 7, 9, 11, and 13) in each train to the second (tail) column (IX-2, 4, 6, 8, 10, 12, and 14). Water from the

tail column in each train will then gravity flow to a sump that will contain seven (7) submersible pumps. Each submersible pump will have a design flow rate of 1450 gpm and will be driven by a variable frequency drive to provide the necessary pressure for the Mo/Se media columns. Each IX column is provided with overflow screens to prevent resin loss. Each column has a diameter of 12 ft with a 12 ft straight sidewall, and is loaded with approximately 400 ft³ of resin.

C. Resin Transfer

The resin transfer system consists of two resin transfer water storage tanks (T-2A/2B), a single process water pump (P-2), and two loaded resin storage tanks (T-3A/3B). The resin is transferred as a slurry with water and will incorporate the use of eductors at each vessel. Eductors are a type of device that uses liquid pressure as a motive force to effectively convey granular solids or slurries over relatively short distances. The eductors are supplied with process water from a 200 gpm centrifugal pump which is sufficiently sized for transferring resin from one vessel at a time.

Once the resin has been loaded with U in the IX columns, the resin from a given column will first be transferred to one of two loaded resin storage tanks, each capable of holding 1,000 ft³ of resin. The purpose of the loaded resin storage tank is to temporarily hold loaded resin while it awaits transport to the offsite facility for regeneration. The loaded resin will then be transferred to a resin tanker that can hold up to 1,500 ft³ of resin. This resin tanker will transport the loaded resin to the regeneration facility and then return regenerated resin back to Mt. Taylor to be put back into service.

Facilities are provided for hydraulic transport of the resin between the IX columns, loaded resin storage tanks, and resin tanker. To reduce water consumption, water used to transport resin throughout the facility will be recycled and stored in the resin transfer water storage tanks.

D. MAR Sorbster® Media

The Sorbster® Media columns are located within the Mo/Se building and consists of 14 trains. Each train consists of 2 columns in series for a total of 28 Sorbster® Media columns. Each train will operate at a flow rate of 715 gpm. Flow from the IX trains will be pumped to the Sorbster® Media trains. The Sorbster® Media trains are arranged so that water will flow from the first (lead) column (Sorbster® Media-1, 3, 5, 7, 9, 11, 13, 15, 17, 19, 21, 23, 25, and 27) in each train to the second (tail) column (Sorbster® Media - 2, 4, 6, 8, 10, 12, 14, 16, 18, 20, 22, 24, 26, and 28). Water from the tail column in each train will then gravity flow to the plant discharge. Each column is provided with internal screens to prevent media loss.

MAR recommends an Empty Bed Residence Time (EBRT) of 15-30 minutes with a flux range of 1 – 6 gpm/ft². The media columns are 12.5 ft. in diameter with a 12 ft side wall and are loaded with approximately 1473 ft³ of Sorbster® Media for a

flux of 5.86 gpm/ft² and an individual and combined EBRT of 15 and 30 minutes respectively.

The Sorbster® Media within each media column is made up of two MAR media components, Sorbster® Si and Sorbster® Se, at a 1 to 1 volume ratio. The Sorbster® Si is primarily used as a silica removal media while the Sorbster® Se reduces the Se and Mo concentration of the water. The inclusion of Sorbster® Si allows the system to remove nearly 99% of the silica in the system which will minimize the media change-out frequency by optimizing the Se and Mo removal performance of the Sorbster® Se. Further details of the Sorbster® Si and Sorbster® Se media are shown in Appendix B.

E. Instrumentation

The control system that RGR proposes to install in the IX Plant will be a computer-based system. It will incorporate an active screen for each process and will display real time activities of tank levels and process flow rates. This system will have input from flow transmitters and level transmitters. The IX system will be monitored by operators and a Programmable Logic Controller (PLC) located in the control room.

F. Plant Utility

The following utility services are provided at the IX Facility: electricity, potable water, process water and instrument air. A 13.8 kV line delivers primary power from the Mt. Taylor Mine to a transformer for conversion to 440/220 volts. Distribution to plant users is through the MCC. Potable water is delivered to the IX Facility through an underground line originating at the Barium Chloride Building. Process water is provided at appropriate locations at a pressure of 60 pounds per square inch (psi). Filtered and dried instrument air is supplied by a 23.5 actual cubic feet per minute (ACFM) compressor at 100 psi for operation of pneumatic controls.

G. Support Facilities

Forced air heating is provided for the entire IX building. The office, MCC and restroom are air conditioned.

IV. Plant Operation

A. Mine Water Pumping

Refer to Drawing 9 – Uranium P&ID - Mine Water Wet Well

- 1) The mine water wet well is equipped with an inlet line from the mine water ponds and a bypass line that can in emergency situations feed excess water to the radium removal system.
- 2) Under normal operations Valves V901 and V902 are fully open and the Isolation Valve V903 is closed.
- 3) The mine water pumping system is designed so that four of the five mine water transfer pumps will provide the necessary capacity. The fifth pump provides backup capacity.
- 4) Before starting the mine water pumps, the operator should select the desired wet well level for the level indicator controller (LIC located in the control room).
- 5) Two IX trains will be valved open to accept mine water flow and one mine water pump will be turned on. The operator will adjust fluid flow through both IX trains prior to placing a second pump and any additional trains in service. This procedure will be followed until the desired water flow is obtained.
- 6) The mine water wet well is provided with level control which will automatically maintain a constant level within the wet well. This is accomplished through the use of Variable Frequency Drive (VFD) on each mine water pump (MWP-1, MWP-2, MWP-3, MWP-4 and MWP-5). The level controller is set at a predetermined elevation that will adjust the VFD accordingly to maintain this level set point. The level device will be installed in the wet well to cover the operating level range. In the event that the level continues to increase, the operator must manually reduce the incoming fluid to the mine water wet well. If the level drops below the low-low setting, the pumps will sequentially turn off to protect the pumps from insufficient fluid level.
- 7) To shut off the flow of water to the IX Plant, the following sequence should be observed:
 - Open Valve V903

- Close Valves V901 & V902

The IX Plant will now be bypassed and all mine water will flow from the settling ponds to the Barium Chloride Treatment Facility.

8) To initiate flow of mine water to the IX Plant, the following sequence should be observed:

- If Closed, Open Valves V901 & V902
- Close Valve V903

The operator should visually observe the water levels in the mine water wet well at the IX Plant to ensure that no obstructions are impeding the flow of water.

B. Ion Exchange

Refer to Drawing 10 – Uranium P&ID - IX Columns (Trains 1 & 2)

The IX Plant will utilize seven identical trains. Each train will have a capacity of 1,650 gpm and will consist of two (2) 12-foot diameter columns in each train. The operation of one train is described below as an example. The components and functions will be identical for the remaining trains.

Feed water is delivered by the mine water transfer pumps to the main plant header. This 24-inch diameter header is located above the IX columns. A mag meter (M-MW) is located in the header with a flow recorder (FR-MW) and low flow alarm (FAL-MW) is located in the control room.

Prior to initiating flow to the IX columns, the operator should check the resin drain Valves V211 and V212, located below the IX column tank, to ensure that they are both closed. Valves V112 and LCV-2 should be closed. Valve V110 should now be opened. The flow control valve (FCV-1) will regulate the flow to the IX train.

To begin flow to the Lead IX column, open Valve V110, check to make sure V112 and LCV-2 are closed and set FCV-1 to 25 percent of desired flow rate. Check the resin depth in the column and make sure flow has been established throughout train number one. Repeat this on train number 2 and then start increasing the flow rate through both trains by adjusting the VFD on the mine water pump and FCV to the desired flow rate.

The IX trains are designed with the capability of bypassing both the lead and tail IX columns. The FCV or LCV (LCV for tail column and FCV for lead column) will maintain a constant level in the IX column by opening and closing depending on observed levels and flow rates. If the LCV or FCV fails and the level increases past the first set point the operator will be notified by the level alarm high (LAH). In the event that the LCV still cannot control the flow, the level will continue to increase to the second set point. At this point, the operators will place the spare IX train in service which will receive flow diverted from the upset IX column. If the

spare train is not ready to receive flow, the level alarm high will sound and the bypass valve will open automatically. This will divert flow from the upset Tail IX column to the overflow storage tank.

C. Resin Transfer

Refer to Drawing 7 – Uranium Ion Exchange Process Flow Diagram

Refer to Drawing 10 – Uranium P&ID - IX Columns (Trains 1 & 2)

Refer to Drawing 11 – Uranium P&ID - Resin Storage and Transfer

When the resin in the lead column of an IX train is loaded to about 0.06 pounds/ft³ with uranium, a resin transfer cycle will begin and proceed in the following order.

1. The resin will first be transferred from the lead IX column to the loaded-resin storage tanks.
2. The partially loaded resin from the tail IX column will then be transferred to the lead IX column.
3. Stripped (regenerated) resin will be transferred from the resin tanker to refill the tail IX column.
4. Loaded resin will be transferred from a loaded resin storage tank to the resin tanker.

The loaded resin will be removed from the lead IX column(s) (IX-1, 3, 5, 7, 9, 11, 13) by an eductor, where it is fluidized by the resin transfer water and conveyed through a 4" steel pipe at 200 gpm to the loaded resin storage columns. The transfer lines between each IX column have a clear inline sight glass so that the operator can determine when all of the resin has been removed. The inline sight glass will also allow the operator to ensure that the resin is in fact moving out of the IX column. The loaded resin storage columns (T-3A and T-3B) are located in the northeast quadrant of the building and are 8 ft in diameter by 20 ft high. The resin transfer water pump (P-2) will provide water from the resin transfer water storage tanks (T-2A and T-2B) at the necessary flow rate and pressure to fluidize the resin and transport it through the resin transfer cycle.

The partially loaded resin will then be removed from the tail IX column by an eductor and hydraulically transported to the lead IX column. This process will begin immediately after the loaded resin has been removed from the lead IX column.

The regenerated ion exchange resin will be transferred hydraulically from the resin tanker to the tail IX column(s) (IX-2, 4, 6, 8, 10, 12, or 14). This process will begin immediately after the partially loaded resin has been removed from the tail IX column, and transferred to the lead IX column.

The loaded resin will then be transferred from either T-3A or T-3B to the resin tanker. The resin transfer volume from the loaded resin storage tanks to the resin

tanker is determined by the level indicator controller. The operator will open the resin tanker compartment hatch and drop the resin transfer hose into the designated receiving compartment. Once this is complete, the resin transfer water pump (P-2) and the resin outlet valve for either of the resin storage tanks will open. The “resin out” valve will close when the level indicator controller reaches a predetermined level change equal to 400 ft³. Excess water drained from the resin tanker during the resin transfer process will be picked up by a sump (SP-1), and pumped through a filter (F-1, F-2, or F-3) prior to being sent back to resin transfer water storage tanks (T-2A or T-2B). The reason for filtering and recycling is to minimize water consumption. The hose connection from the tanker to the resin eductor will have a “no-spill” check valve and a clear sight glass. The purpose of the sight glass will be to provide the operator with a view of the media being transferred, enabling the operator to determine when all of the resin has been transferred. The no-spill check valve will prevent water and/or resin from spilling during connection and disconnection.

D. Instrumentation

1. Mine Water Sump and Pumps

Mine Water Transfer Pumps will have local start-stop switches with a stop only switch located in the control room. In the event of low level in the mine water sump, the level indicator controller (LIC-MW) will adjust the pump speed and activate the level alarm low (LAL-MW) in the control room. Further reduction in level by 12 inches will trip level alarm low low (LALL-MW) and all pumps. The mine water wet well will also be provided with an overflow line to prevent the sump from overtopping. This sump overflow will go directly to the radium removal system.

Mine Water transfer pumps should hold a discharge pressure of at least 10 psi for proper operation of flow control valves at the IX columns.

The 24" diameter mine water header flow will be monitored downstream of the process water take-off. A recorder and low flow alarm will be provided in the control room. The low flow alarm point will be set at 2500 gpm.

2. Lead IX Columns

The control system proposed for the IX facility will display real time activities of tank levels and process flow rates by receiving input from transmitters and indicators throughout the plant. The instrumentation, placement, and function of the controls system is described below.

Flow of mine water to each IX column will be controlled either at the valve or in the control room as described below. Local flow readout will be provided for manual control.

Primary Control

The first magnetic flow meter (mag meter) monitoring each train will be placed on the common header. The mag meter (M-MW) will measure the total flow being delivered to the IX process by the pumps. The mag meter output signal will be transmitted through the flow indicator transmitter (FIT-MW) to the flow recorder (FR-MW) and the flow alarm low (FAL-MW). The FR-MW will record the real time flow and store it digitally for record keeping. The flow alarm low (FAL-MW) will activate or deactivate if the flow is below the pre-determined set point. FAL-MW will be an audible and visible alarm to alert the operator and other personnel of an inadequate flow rate. Downstream of M-MW the flow will enter a common header and be divided into the seven trains.

Each of the seven lead IX columns will be equipped with a mag meter (M-1, 3, 5, 7, 9, 11, 13) located on the supply line to each of the seven trains. The mag meter will be upstream of the flow control valve (FCV-1, 3, 5, 7, 9, 11, 13) and the lead column. The mag meter will measure the flow being delivered to each IX column. The mag meter output signal will be transmitted through the flow indicator transmitter (FIT-1,3, 5, 7, 9, 11, 13) to the flow indicator controller (FIC-1, 3, 5, 7, 9, 11, 13) and flow recorder (FR-1, 3, 5, 7, 9, 11, 13), both of which will be located in the control room. The flow recorder will digitally record data for recordkeeping. The flow indicator controller will be programmable so that the operator can set it to maintain a desired flow rate. The flow indicator controller will send a signal to a flow control valve which will open and close to maintain the desired flow rate set on the flow indicator controller. The flow indicator controller will also activate or deactivate the flow alarm high (FAH-1, 3, 5, 7, 9, 11, 13). The flow alarm high will be an audible and visible alarm whose set point can be determined and programmed by the operator.

Secondary Control

Each of the seven lead IX columns will be equipped with a sonic level sensor, located in the column tank, which will send its output signal to a level indicator transmitter (LIT-1, 3, 5, 7, 9, 11, 13). The level indicator transmitter will transmit a signal to the level indicator controller (LIC-1, 3, 5, 7, 9, 11, 13). The level indicator controller will be located in the control room and display the water level in each lead column in real time. The level indicator controller will also be programmable to maintain a certain set point level. The purpose of the level indicator controller is to monitor tank levels and to ensure that the levels are not high enough to overtop the tanks and cause a spill. The level indicator controller will communicate to the lead column flow control valve (FCV-1, 3, 5, 7, 9, 11, 13), the level alarm high (LAH-1, 3, 5, 7, 9, 11, 13), and the level alarm high high (LAHH-1, 3, 5, 7, 9, 11, 13). In the event that the first level set point has been reached the level indicator controller will activate the level alarm high to notify the operator. The level indicator controller will also adjust the flow control valve appropriately to maintain the programmed set point and prevent a

spill. In the event that the level indicator controller is not able to resolve the abnormally high water level by manipulating the flow control valve and the second set point is reached, the level indicator controller will activate the level alarm high high and the operator will be able to manually divert the entire flow around the high level column to the tail IX column. The tail IX columns will have the ability to divert excess flow from the lead IX columns to the overflow storage tank (T-1).

3. Tail IX Columns

Each of the seven tail IX columns will be equipped with a sonic level sensor, located in the column tank, which will send its output signal to a level indicator transmitter (LIT-2, 4, 6, 8, 10, 12, 14). The level indicator transmitter will transmit a signal to the level indicator controller (LIC-2, 4, 6, 8, 10, 12, 14). The level indicator controller will be located in the control room and display the water level in each tail column in real time. The level indicator controller will also be programmable to maintain a certain set point level. The purpose of the level indicator controller is to monitor tank levels and to ensure that the levels are not high enough to overtop the tanks and cause a spill. The level indicator controller will communicate to the tail column level control valve (LCV-2, 4, 6, 8, 10, 12, 14), the level alarm high (LAH-2, 4, 6, 8, 10, 12, 14), and the level alarm high high (LAHH-2, 4, 6, 8, 10, 12, 14). In the event that the first level set point has been reached the level indicator controller will activate the level alarm high to notify the operator, the level indicator controller will also adjust the level control valve appropriately to maintain the programmed set point and prevent a spill. In the event that the level indicator controller is not able to resolve the abnormally high water level by manipulating the level control valve and the second set point is reached, the level indicator controller will activate the level alarm high high. When the level alarm high high is activated the level control valve will be closed 100% and all flow to the tail IX column will be diverted to the overflow storage tank (T-1).

E. Quality Control of Discharge Fluids

1. Sampling of Discharge Fluids

- a. Composite sampling will be performed for all IX Tail columns, total discharge stream of the IX system, all Mo/Se Tail Columns, and the total discharge stream leaving the facility.
- b. This composite sampling will be on an eight (8) hour schedule and will incorporate a duplicate sample bottle for third party assay.
- c. The operator will grab samples every eight (8) hours from each lead and tail IX column to determine when resin transfer must occur to keep the system discharge stream below the 30 ppb standard for U and from each lead and tail Mo/Se column to determine when the Sorbster® Media is

spent to ensure the discharge stream is below 50 ppb for Se and 100 ppb for Mo.

2. Test Method

- a. The test method for U will follow the ASTM D5174 Standard. This test method for trace U in water uses Pulsed-Laser Phosphorimetry analyzed by a KPA (Kinetic Phosphorescence Analyzer). This analyzer achieves highly specific analysis for U down to 0.01 µg/L with an analytical range of over 500,000 µg/L.
- b. The test method for Se will follow EPA Method 200.8. This test method for Se uses an ICP-MS with CRC detector and achieves analysis for Se to 0.25 µg/L.
- c. The test method for Mo will follow EPA Method 200.7. This test method for Mo uses an ICP-AES and achieves analysis for Mo to 10 µg/L.
- d. The third party assay laboratory will be a NELAC-certified laboratory.

APPENDIX A



DOWEX 21K 16/20

A High Efficiency, Large Bead, Strong Base Anion Exchange Resin for Mineral Processing Applications

Product	Type	Matrix	Functional group
DOWEX* 21K 16/20	Type I strong base anion	Styrene-DVB, gel	Quaternary amine

Guaranteed Sales Specifications		Cl ⁻ form
Total exchange capacity, min.	eq/L	1.2
Bead size distribution		
Thru 20 mesh, max.	%	10
Thru 25 mesh, max.	%	2

Typical Physical and Chemical Properties		Cl ⁻ form
Water content	%	50 - 58
Whole uncracked beads	%	90 - 100
Total swelling (Cl ⁻ ⇒ OH ⁻)	%	20
Particle density	g/mL	1.08
Shipping weight	g/L lbs/ft ³	690 43

Recommended Operating Conditions

- Maximum operating temperature:
 - OH⁻ form 60°C (140°F)
 - Cl⁻ form 100°C (212°F)
- pH range 0 - 14
- Bed depth, min. 800 mm (2.6 ft)
- Flow rates:
 - Service/fast rinse 5 - 50 m/h (2 - 20 gpm/ft²)
 - Backwash See figure 1
 - Co-current regeneration/displacement rinse 1 - 10 m/h (0.4 - 4 gpm/ft²)
- Total rinse requirement 3 - 6 Bed volumes
- Regenerant:
 - Type NaCl/Carbonate
 - Temperature Ambient or up to 50°C (122°F) for silica removal
- Organic loading, max. 3g KMnO₄/l resin

Typical properties and applications

DOWEX 21K 16/20 type I strong base anion resin has excellent kinetics, excellent regeneration efficiency and outstanding physical stability. This enhanced-porosity gel bead product is made by a special process giving enhanced resistance to organics and fast equilibrium rates. The DOWEX 21K family of resins is specially suited for mineral processing and groundwater remediation applications. DOWEX 21K 16/20 type I strong base resin is suited for fluidized-bed and Resin-in-Pulp applications.

Packaging

5 cubic foot fiber drums

Figure 1. Pressure Drop vs. Flow Rate

For DOWEX 21K Resins, Cl, 77 deg. F

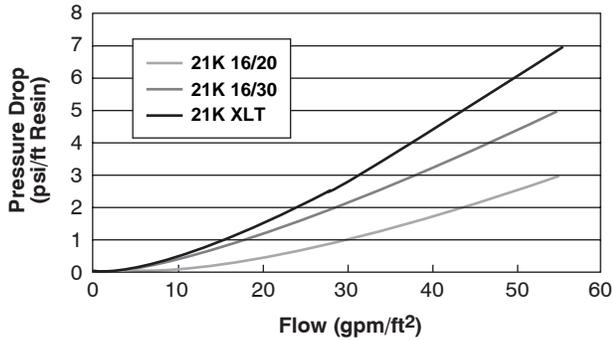
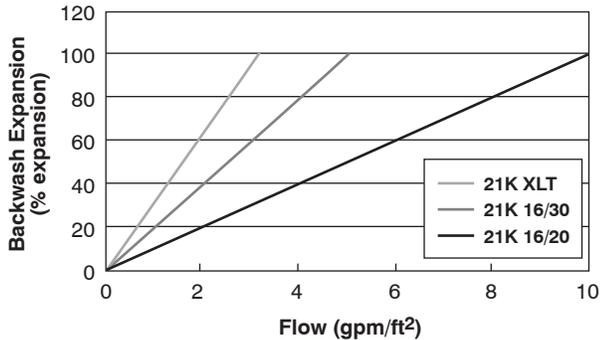


Figure 2. Backwash Expansion vs. Flow Rate

For DOWEX 21K Resins, Cl, 77 deg. F



DOWEX Ion Exchange Resins
For more information about DOWEX resins, call the Dow Liquid Separations business:

North America: 1-800-447-4369
Latin America: (+55) 11-5188-9222
Europe: (+32) 3-450-2240
Pacific: +60 3 7958 3392
Japan: +813 5460 2100
China: +86 21 2301 9000
<http://www.dowex.com>

Warning: Oxidizing agents such as nitric acid attack organic ion exchange resins under certain conditions. This could lead to anything from slight resin degradation to a violent exothermic reaction (explosion). Before using strong oxidizing agents, consult sources knowledgeable in handling such materials.

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APPENDIX B



Product Bulletin Sorbster® Si-1

Sorbster® Si-1

Adsorbent Media for Silica Removal

Description

Sorbster® Si-1 media is effective for the removal of silica from industrial water. Reactive silica in water bonds to the high surface area of the media for rapid removal. Sorbster® Si-1 has a 20-30 weight percentage capacity for silica. Reduction of other anions in water, such as fluoride, may also be achieved by Sorbster® Si-1

- Sorbster® Si-1 is uniformly active throughout the media, resulting in excellent chemisorption kinetics across a wide variety of water conditions
- Sorbster® Si-1 can be an effective pre-treatment media for in-process water streams and other removal systems
- Sorbster® Si-1 is an effective pre-treatment when cooling tower cycles of concentration need to be increased to reduce chemical and make up water costs

Features and Benefits

Temperature*: 32° F to 150° F

Total Dissolved Solids: No Limit

Total Suspended Solids*: Recommended <15mg/L

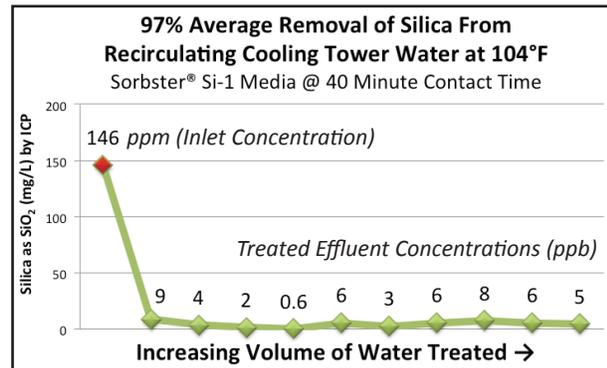
Total Organic Carbon*: Recommended <15mg/L

Free Oxidants*: Not Present



Product Specifications

Particle Size	Nominal 1/8" pellet
Bulk Density (lbs/ft ³)	45
Moisture Content	<10%
pH Range	6-9.5
Flux Rate	1-5 GPM/ft ²
Empty Bed Contact Time	10-60 minutes
Back Wash Bed Expansion	10%-15% of total bed height



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Product Bulletin Sorbster® Se-1

Sorbster® Se-1 Adsorbent Media for Selenium Removal

Description

Sorbster® Se-1 is a highly functionalized, enriched alumina media that covalently bonds soluble selenium and other trace contaminants to its active sites. It is suitable for use across a broad range of water qualities.

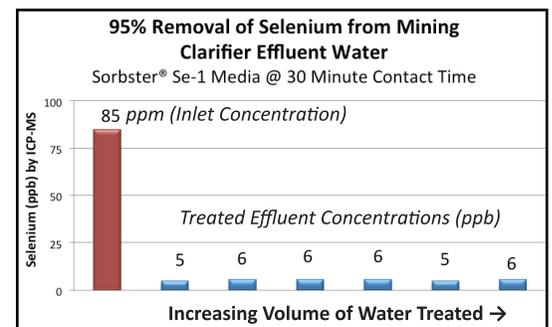
Features and Benefits

- Effectively removes soluble selenite, selenate and selenocyanate in a wide range of process streams
- Can lower selenium concentrations to less than 1 ppb in a single pass
- Produces no ancillary water streams that require additional treatment, handling or disposal
- Media passes the EPA TCLP test and allows for non-hazardous disposal options, reducing total cost to treat
- Requires fewer changeouts than competing media, maximizing ROI
- Active and diverse chemistry allows it to selectively capture and chemisorb selenium in both the oxyanion and cation forms, eliminating expensive process steps required by some competitive solutions
- Does not support bacterial growth
- May be used as a polishing media to reach ultra low-level concentrations where existing solutions cannot perform to new permits
- Also removes Molybdenum, Mercury, Arsenic, Selenite, Copper, Fluoride, Selenate, Cadmium, Thallium, Silica, Tin, Barium, Hexavalent Chromium, Antimony, Cobalt, Vanadium, Lead, Zinc, Boron, Nickel and Cyanide.



Product Specifications

Particle Size	Nominal 1/8" pellet
Bulk Density (lbs/ft ³)	50–52
Moisture Content	<10%
pH Range	3–10
Flux Rate	1–5 GPM/ft ²
Empty Bed Contact Time	20–120 minutes*
Back Wash Bed Expansion	5%



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Date	Title	Client	Contact
1/22/2015	Mt. Taylor: Sorbster® Sorbent Studies for the Removal of Selenium and Molybdenum	Rio Grande Resources	Lupe Rocha Chief Engineer

GOAL: Removal of selenium and molybdenum from a mine shaft dewater project at Mt. Taylor uranium mine in New Mexico to allow mine startup. The project is projected to initially process 10,000 GPM for two years, then 5,000 GPM for several years. Objectives of treatment program are to remove selenium and molybdenum to drinking water standards. The EPA enforceable limit for selenium is 50 ppb maximum in drinking water. Molybdenum is not regulated in drinking water however, the State of New Mexico has a groundwater enforcement standard of 40 ppb and some states have an interim health advisory level for molybdenum at 90 ppb, so the MAR target was < 40-90 ppb. In the water sample, molybdenum was found to be present, measured at 530 µg/L. However, selenium was found at less than 1 µg/L which is far below the historical data provided to MAR for the site. In order to accurately gauge the treatability of the water, selenate, approximately 90 µg/L, was added to be consistent with average concentrations provided by Rio Grande Resources. Selenate is typically the most difficult selenium species to remove and is typically the species form in mining water. The selenate spiked sample was pumped through columns of Sorbster media at a 30 minute contact time to evaluate removal performance.

EVALUATION CONDITIONS:

Two column studies completed January 6-7, 2015 using Mt. Taylor water sample after spiking with selenate.

Column Conditions	Test 1: MAR column with Sorbster® Si-1. Spiked with Selenate and Treated at pH 9.70	Test 2: MAR column with Sorbster® Si-1. Spiked with Selenate and Treated at pH 6.27
Column Dimensions	1" diameter x 36" high	1" diameter x 36" high
Media 1: Sorbster® Si-1	Lot # M-SA158J074	Lot # M-SA158J074
Media 1: Sorbster® Se-1	Lot# M-829128	Lot# M-829128
Inlet pH	9.70	6.27
Media Volume	461 cm ³ per media type	461 cm ³ per media type
1 Empty Bed Volume	461 mL per media type	461 mL per media type
Flow Rate	15.3 mL/minute	15.4 mL/minute
Bed Volumes Treated	17.4 (8000 mL)	17.4 (8000 mL)
Empty Bed Contact Time per media Column	30.1 minutes per media type	29.9 minutes per media type
Water Pretreatment	Water was analyzed for Se content and then spiked (1/5/2014) with 2.28 mL of 1000 ppm selenate standard* into 20 L of water sample	Same Water as Test 1 with HCl added to reduce pH to 6.27 prior to treatment. 3.5 mL of concentrated HCL* was added to 10 L of water

*Selenate standard is from Ricca Chemical Company (Catalog No R6699000-1A)

*Hydrochloric Acid is 34-37% and from VWR/BDH Aristar® Plus (Catalog No 87003-253)

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MAR SYSTEMS

Send Us Your Water Study

WATER SAMPLE DESCRIPTION:

- Water was received at MAR Labs on 12/23/2014
- pH: 9.77 (before addition of selenate standard)
- pH: 9.70 (after addition of selenate standard)
- Total alkalinity: 328 mg/L as CaCO₃
- Reactive silica: 8.2 mg/L
- Specific conductivity: 576 µmhos/cm (method E120.1)
- Metals (measured after spiking with selenate; ICP Method E200.7) by Precision Analytical, Cleveland OH
 - Al: 19.3 µg/L
 - Ca: 926 µg/L
 - Cu: 14.6 µg/L
 - Fe: 76.6 µg/L
 - Mg: 303 µg/L
 - Mn: 6.2 µg/L
 - Mo: 539 µg/L
 - K: 1400 µg/L
 - Silica (from ICP Si): 6.09 mg/L (as SiO₂)
 - Na: 139 mg/L
 - Zn: 195 µg/L
 - Se: 0.574 µg/L by ICP-MS with CRC (before spiking with selenate standard)
 - Se: 89.6 µg/L by ICP-MS with CRC (after spiking with selenate standard)
- Anions (Ion Chromatography Method E300.0) by Precision Analytical, Cleveland OH
 - Chloride: 10.1 mg/L
 - Fluoride: 5.04 mg/L
 - Nitrate: Not Detected
 - Ortho-phosphate: Not Detected
 - Sulfate: 21.6 mg/L

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PERFORMANCE GRAPHS AND RESULTS:

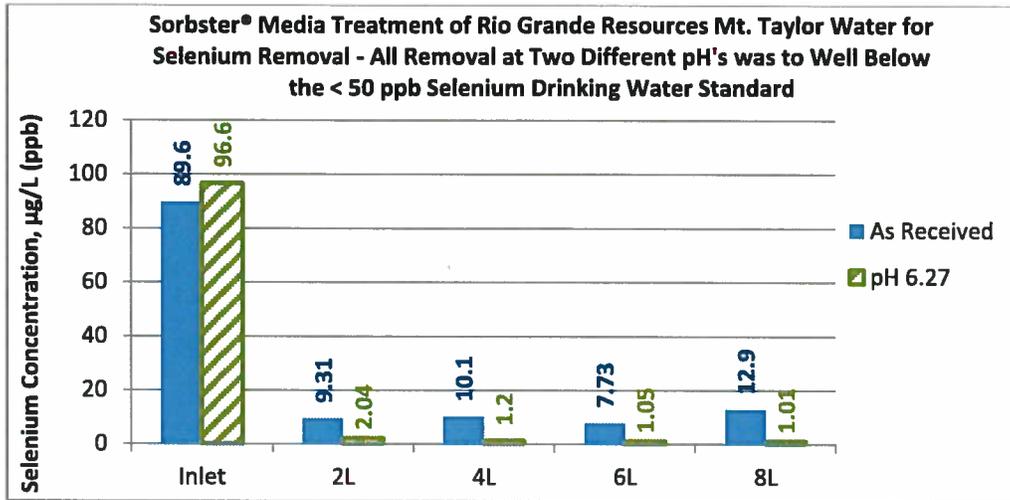


Figure 1: Selenium Concentrations in Sorbster Treated Mt. Taylor Water with pH Adjustment Averaged 1.4 ppb (98% Removal Rate). The Average Selenium Level for Non-pH Adjusted Water was 10 ppb (89% Removal Rate). Sorbster Media Provided Very Strong and Sustained Selenium Removal.

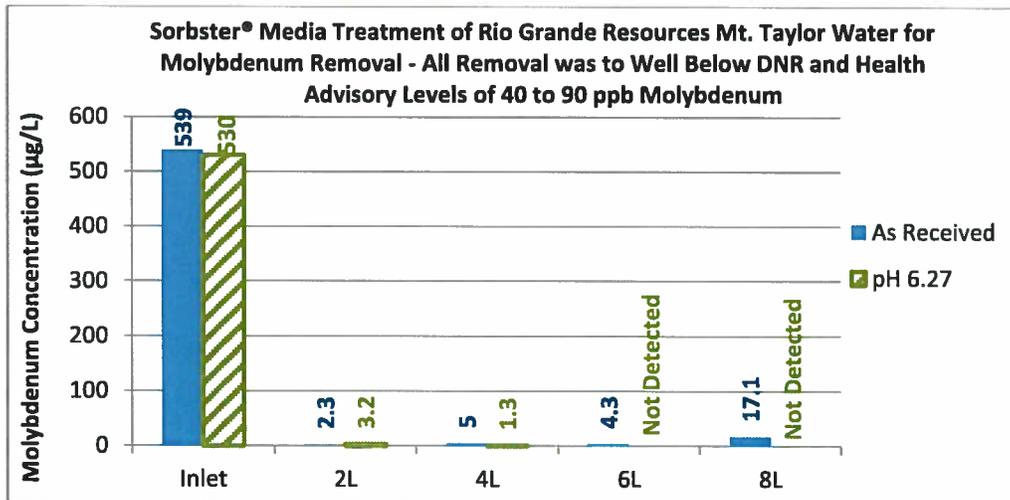


Figure 2: Molybdenum Concentrations in Mt. Taylor Water with pH Adjustment Averaged 3 ppb (99% Removal Rate). The Average Molybdenum Level for Non-pH Adjusted Water was 7 ppb (98% Removal Rate).

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Table 2: Performance Summary of Sorbster Media for Tests Performed on Mt. Taylor Water Spiked with Selenate.

	Concentrations; $\mu\text{g/L}$ (% removal)					
	Inlet Test 1	Average	at 8L	Inlet Test 2	Average	at 8L
Molybdenum	539	7.2 (98.7%)	17.1 (96.8%)	530	1.1 (99.8%)	ND (~100%)
Selenium	89.6	10.0 (88.8%)	12.9 (85.6%)	96.6	1.3 (98.6%)	1.01 (99.0%)
Silica	6.1	-	0.01 (99%)	6.0	-	0.05 (99.0%)

Comments and Recommendations:

- The Sorbster® Si-1 + Sorbster® Se-1 media system was found to be highly effective in treating Mt. Taylor water for selenium and molybdenum removal. Selenium (selenate) was reduced to 1.3 ppb and molybdenum to 1.1 ppb when the pH was reduced to 6.27. This removal was sustained throughout the 17 empty bed volumes treated, which is a good indicator of removal rate trend and high media capacity.
- pH adjustment to 6.27 provided the maximum removal. Removal efficiency for the water “as received” without pH adjustment was also very high at an average selenium reduction of around 89% and an average molybdenum reduction of around 98%.
- In all cases, selenium was removed by Sorbster to well below the drinking water standard of 50 ppb and molybdenum was removed to well below the State of New Mexico and health advisory levels of 40 to 90 ppb.
- The silica in the system was removed at 99% from the influent making the inclusion of Sorbster Si-1 pretreatment likely to be beneficial in extending the change-out rate/capacity of the metals removal media for selenium performance.
- MAR recommends a 500 GPM (or a flow rate representative of the total treatment flow) field demonstration to validate the results (when/if the State of New Mexico requires this step) with the following goals:
 - Optimize contact time required to meet treatment goals – System could potentially be scaled smaller.
 - Establish a media lifetime/capacity for this water to determine change-out frequency
 - Optimize the pH needed to meet treatment goals – System could potentially be operated at a higher pH in order to reduce the amount of acid needed. Acid demand in this water sample would equate to around 3.5 gallons of concentrated acid required per minute to reduce 10,000 GPM to a pH of around 6.3. If operated 24/7, this equates to ~1.84 M gallons/yr of concentrated acid
 - Optimize the ratio of Sorbster® Si-1 to Sorbster® Se-1 volumes to minimize media costs and change out frequency – This test operated at 1 to 1 volume ratios whereas a system with reduced Sorbster® Si-1 might perform as well and minimize cost without increasing the Si-1 change out frequency.
- MAR recommends organizing a meeting to discuss Sorbster® Technology, establish treatment criteria and define project scope/timeline

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