



# URM Handling, History, and Preparation

Ryan Bayes

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The URM (umbilical retrieval mechanism) is central to the calibration deployment project. With the requirements for scintillator compatibility and controlling backgrounds, the URM was redesigned with these constraints in mind. The principle difference is that the scintillator URMs are designed to have an isolated nitrogen gas volume to reduce the likelihood of radon ingress to the UI (universal interface) resulting from deploying a source. Specific design elements were also changed to make the isolation of the URM sustainable.

The following document describes the history of commissioning the URM at SNOLAB prior to describing how the URM must be prepared. This covers running the electrical subsystems checks, preparing the umbilical feed-through plate, the umbilical installation, the rope installation, the source connector installation, the cover installation, the source tube and bellows installation, the gatevalve installation, The final umbilical cleaning, the cover gas connection, and a test deployment procedure. The document concludes with a proposed order of operations and scheduling is shown at the end of the document.

## 1 Definitions

- AV: The acrylic vessel. A 12 m diameter acrylic sphere, fabricated for SNO, that currently contains the SNO+ scintillator cocktail.
- PSUP: Photo-multiplier support structure. A geodesic sphere with an average diameter of 17 m, that supports the ~9400 PMTs used to detect light in the SNO+ experiment.
- Umbilical: a 1/2” cable made by potting a HDPE tube surrounded by electrical wires inside a Tygothane tube using SilGel. The umbilical used here has a fibre optic bundle inside the HDPE core.
- Rope: 1/8”, white, braided, Tensylon fibre cord that has been shown to have good strength characteristics while being compatible with LAB. The central rope is installed on the URM while side ropes are made of the same material inside the AV.



Figure 1: The Scintillator URM to be used for the source deployment

- Calibration Source or Source: An item that can be deployed inside the scintillator volume that generates a known signal used to interpret the detector response. A dummy source will also be used which produces no signal, but will be used to test the manipulator system response.
- URM: Umbilical retrieval mechanism. A device containing the umbilical and the central rope equipped with motors to deploy and retract both simultaneously and load cells to monitor the tension on the rope and umbilical. The umbilical is stored on a pair of **blocks** connected to a charged piston that forces the blocks apart as the umbilical is retracted into the system. The rope is stored on a rotating drum.
- UI: Universal interface. A 1.3 m diameter stainless steel vessel designed to contain a nitrogen cover gas over the SNO+ scintillator volume at the top of the AV neck. Equipped with a number of access points to deploy sensors, recirculate scintillator and deploy calibration sources.
- DCR: Deck clean room. A tent on the SNO+ deck with additional HEPA filters to produce a clean environment for preparing calibration sources, or otherwise interaction with the AV interior.
- Source Bellows: A flexible stainless steel structure meant to connect the URM to the UI while allowing for the free movement of the UI. Must be terminated with a

gatevalve.

- URM Hangers: Horizontal beams fixed to the DCR lifting beam. Includes rollers to allow for the limited use of lifting straps as well as turnbuckles to provide partial, semi-permanent support for the URM on rails
- URM Lifting Table: table rated to lift 798 kg with an 80-20 paired frame with an interior hydraulic lifting system to raise the URM an additional 30 cm
- URM Lifting System: Assembly of the URM hangers (specifically the lifting straps and winch) and the URM lifting table. It is essential that these be used in concert for stability when lifting the URM to height.

## 2 History



### 2.1 Arrival at SNOLAB, Cleaning and Testing, February 2017 - March 2019

- **June - August, 2017** URM completely disassembled, cleaned and reassembled URM
- **August - September, 2017** Electrical systems and wiring for motors and sensors setup. Installed a rope to facilitate initial measurements.
- **November 2017** Installed umbilical #5 on URM after wiping down umbilical and URM (there was dust observed on the Umbilical).
- **June - August, 2018** Rope stretch tests in air, UPW and LAB.
- **August, 2018** Umbilical tests including running rope and umbilical together and umbilical slip tests (the umbilical did not slip under tensions up to 200 N)
- **September, 2018** Leak checked internal gas distribution systems
- **November 2018** Expanded the hole in the retraction pulley to accept an M4 eye-bolt
- **January - September 2019** Redo rope stretch tests
- **September 2019** Installed limit switches

## 2.2 Transport Underground, January 2020



See Cindy Lin's document on the preparation of the URM and conclusion of the transport underground, DocDB 6139. The summary is that the URM was disassembled, and all components were triple bagged before being crated up for transport underground. Once underground, the bags were systematically wiped down and removed starting with the outer layer in the outer car-wash, and the middle layer in the inner car wash.

## 2.3 Commissioning Underground to Date, May 2021 - August 2021

- **May 2021** Reassembled URM inside DCR. Some minor test of the electrical systems and reviewing the changes made to the limit switches.
- **July - September 2021** Leak check internal gas distribution components and cover flange. Installed externally flanged VCR ports and vents with gaskets.

# 3 Remaining Procedures

## 3.1 Order of Operations

The following procedures are described in by order of association, and not the practical order. To in fact assemble and commission the URM the processes should be done in the following order.

- 1. Preparation of umbilical feed-through plate; Sec.3.6 (1 shift, machine shop?)
- 2. Remove URM cover (1 shift, 4 workers)
- 3. Electrical systems check; Sec.3.4 (1 shift, 1 worker)
- 4. Install umbilical feed-through plate on umbilical; Sec.3.6 (1 shift, 2 workers)
- 5. Install umbilical on URM; Sec.3.7 (1 shift, 3 workers)
- 6. Install rope on URM; Sec. 3.8 (1 shift, 2 workers)
- 7. Install URM cover; Sec.3.10 (1 shift, 4 workers)
- 8. Transfer URM from cart to lifting table; Sec.3.11 (1 shift, 2 workers)
- 9. Electrical systems check; Sec.3.4 (1 shift, 1 worker)
- 10. Install source tee flange; Sec.3.12.1 (1 shift, 2 workers)
- 11. Install source connector on umbilical; Sec.3.9 (1 shift)

- 12. Install source bellows; Sec.3.13
- 13. Install gate valve; Sec3.13.1
- 14. Purge the URM and connect to the cover gas system; Sec3.15
- 15. Final Umbilical cleaning; Sec3.14 (1 week)
- 16. Connect and clean the dummy source (1 week, 3 workers)
- 17. Connect URM to UI; Sec3.15 (1 shift, 3 workers)
- 18. Field test the manipulator system.; Sec3.16 (1 shift, 3 workers)

The listed time and personnel requirements are estimates to within the nearest shift. Many of these tasks and procedures may take fractions of shifts, but there are few procedures that can be done in parallel; primarily tasks that affect completely different aspects of the URM without overlap.

### 3.2 General Comments

For all of the following procedures workers must keep the following points in mind.

- Workers must use proper PPE for working in the underground clean lab
- All procedures are to be conducted in the DCR.
- Assume that nitrile clean room gloves are to be worn at all times.
- Every effort must be made to maintain the integrity and cleanliness of the DCR.
- When the inner workings of the URM are exposed to the DCR, the dust counts should be monitored. Prior to work beginning, the number of  $0.5\mu\text{m}$  particles must be less than 200 per cubic foot.
- Workers must change coveralls if they work in specific locations prior to conducting work in the DCR including the underground machine shop and the inner car-wash.
- Workers must shower and change clothes if they work in specific locations prior to working in the DCR including the scintillator plant and the outer car-wash.
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### **3.3 Removing the URM Cover**

The first step to the majority of the activities to commission the URM is to remove the cover. The URM has been stored with the cover on to protect it from dust contamination.

- 1. Remove the screws from the electrical and umbilical feed-through plates. Carefully remove the feed-through plates from the URM cover.
- 2. With an M6 hex and crescent wrench, remove the bolts holding the URM cover flange to the base. Store the nuts, bolts and washers so that they can be easily found and used.
- 3. Ensure that the support feet and eye-bolts are secured to the flange at the four corners of the URM.
- 4. With four workers; one at each corner; with an appropriate height assist, lift the URM straight up off of the URM flange until it is clear of the URM backplane.
- 5. Carefully lower the URM onto a area of the floor where it is not likely to get in the way of other activities.
- 6. Check the URM o-ring. Ensure that it remains in its groove with no obvious damage.
- 7. Install the bumpers on the URM flange to protect both the URM flange surface and the o-ring using the same bolts as those that secured the cover to the base.

### **3.4 Electrical Subsystems Check**

It is essential that the electrical systems be checked periodically through this procedure to ensure that there is no loss of function. The 20 pin feed-through is somewhat fragile and is easily put under strain when the cover is removed or replaced. Tests must be conducted with a manipulator control unit, and URM power supplies. Tests should be conducted with the URM cover removed.

- The special cable connecting the 20 pin Amphenol connector to a pair of DB 20 connectors must be plugged into the feed-through plate and connected to the AVR box designated for the URM.
- Install the pair of 6 pin connector cable between the motor drivers and the appropriate [ ] sockets on the feed-through plate. It is important that the cables running to the URM rope and umbilical not be confused, although there is some latitude to debug this prior to installation of the rope and umbilical. The appropriate cables and sockets should be marked.
- Connect the motor drivers to the AVR boxes using the 4 pin connectors.

- Plug in the power supply into the AVR box
- Connect the USB cable for the AVR box into the DCR USB hub on the North side of the UI.
- Go to the Manip computer and check if the appropriate AVR board is connected.
- In manip, connect the URM4rope and URM4umbilical objects to the Laserball source and check if the URM is receiving feedback on the load cells. If not the system must be debugged.
- Run the rope and umbilical by running the motors directly from the manip interface.
- Test the limit switches by moving the retraction block to either end of the track. If the limit switch signals are not detected by the manip interface, the reason must be understood and corrected.

### 3.5 Cleaning the Umbilical

Prior to further handling of the umbilical, the umbilical must be cleaned. For this procedure it is assumed that the following materials are on hand in the DCR

- The umbilical in its original mylar bag
- A spill tray suitable to catch LAB
- A supply of clean LAB
- A supply of UPW
- Nitrile, clean-room gloves

The two workers must take the following steps.

- 1. Put on a double layer of fresh, nitrile clean-room gloves. Rinse the outer gloves with UPW and dry with a lint free cloth.
- 2. Prepare a spill tray by wiping it out with UPW and lint free cloths. Similarly clean the beige working tray and put it to one side.
- 3. Open the top of the umbilical storage bag. Identify the standing end of the umbilical by noting where the end of the optical bundle intended for the connection to the dye laser connects to the umbilical.
- 4. With one worker holding the bag, pull the umbilical from the bag and place it in one corner of the spill tray.



- 5. Wet a lint free cloth with clean LAB.
- 6. Starting from the standing end of the umbilical, wipe the Tygothane surface of the umbilical with the B wetted cloth with multiple passes on each section. Coil the umbilical loosely as you go in the opposite corner of the spill tray.
- 7. Once you get to the running end of the umbilical (the end to be connected to the source), dispose of the cloth used to wipe the umbilical, and change outer gloves to use a new, clean pair.
- 8. Wet a new lint free cloth with clean LAB.
- 9. Starting from the running end of the umbilical, wipe the Tygothane surface of the umbilical with the LAB wetted cloth using multiple passes for each section. Coil the umbilical loosely in the corner of the spill tray opposite to that where it was coiled before as you go.
- 10. Once complete, leave the standing end of the umbilical available for installation on the Umbilical feed-through plate and cover the umbilical loosely with the beige spill tray. Dispose of outer gloves and LAB wetted cloths appropriately.

### 3.6 Preparation of Umbilical Feed-through Plate

A dummy feed-through plate was provided with the URM that has a molded central piece to suggest an umbilical port. It was not milled for an umbilical however and there was no specific plan for securing the umbilical to the URM. It is proposed here to use a Swagelok bulkhead fitting to provide a seal against the URM plate and strain-relief for the umbilical itself. To accommodate this the plate should be milled through with a 3/4" hole and threaded with a 3/4"-20 tap. This hole should be milled through the flat surface rather than the angled cap.

Threading a bulkhead fitting through the feed-through plate and adding o-rings on the inside and outside of the plate, compressed against it with the bulkhead nuts should provide a good seal against leaks. Once the umbilical is fed through the bulkhead it can be swaged to the umbilical on either side with PTFE ferrules to provide a gas seal to the umbilical without damaging the umbilical.

To install the umbilical in this way, a worker must

- 1. Put on a clean pair of clean-room gloves.
- 2. Wipe down the end of the umbilical that is to be secured to the feed-through with lint free wipes and UPW.
- 3. Identify the likely location of the feed-through on the umbilical. Preferably this is near where the Tygothane ends before the bared fiber bundle begins.

- 4. String a Swagelok nut, and ferrule onto the umbilical.
- 5. Add an o-ring onto the bulkhead fitting and push it tight against the fixed nut. Thread the bulkhead fitting into the feed-through plate with the fixed nut side on the outside of the plate. Get the fixed nut as close to the exterior face of the feed-through as possible so that the o-ring is compressed.
- 6. Add an o-ring to the opposite side of the bulkhead fitting and press it against the inside of the plate. Tighten the opposing nut against the o-ring enough so that it is compressed; more is unnecessary and potentially difficult.
- 7. Run the umbilical through the combined bulkhead fitting and feed-through plate. String an additional Swagelok PTFE ferrule and stainless steel nut after the feed-through.
- 8. Place the feed-through on the desired location on the umbilical. This should be determined carefully with enough excess to run the umbilical properly with the URM as it will not be possible to reposition the umbilical after the following step.
- 9. Move the inside ferrule up to the bulkhead fitting. Tighten the inside Swagelok nut onto the ferrule at the bulkhead fitting.
- 10. Move the outside ferrule up to the bulkhead fitting. Check that the umbilical is not experiencing tension or compression when the ferrule is tight against the end of the bulkhead. Tighten the outside Swagelok nut onto the ferrule.
- 11. With two M3 eye-bolts and a piece of wire, suspend the feed-through on the URM from the hanger bar for the duration of the umbilical loading procedure. The feed-through should be placed so it can be reached when the cover is being replaced.

### 3.7 Umbilical Installation

With the feed-through plate installed on the umbilical, the umbilical itself can be installed on the URM. This is a two person procedure. Both workers must wear clean nitrile gloves. The gloves should be rinsed with UPW and dried before working.

- 1. Using a piece of Tensylon rope tie the retraction block at the end of the track to the piston in the closed position.
- 2. Hang the umbilical feed-through plate from the bar supporting the electrical feed-through. Also secure the umbilical to the URM motor backplane.
- 3. With no pressure on the piston, push the retraction block as close to the fixed block as possible.



- 4. Thread the umbilical through the bottom of the pulleys closest to the backplane (in the axis perpendicular to the back plane).
- 5. Pass the umbilical over the top of the first return pulley and over the second pulley of the fixed block.
- 6. Thread the umbilical under the second pulley of the fixed block back under the second pulley of the return block.
- 7. Pass the umbilical over the top of the second return pulley and over the third pulley of the fixed block.
- 8. Thread the umbilical under the third pulley of the fixed block back under the third pulley of the return block.
- 9. Pass the umbilical over the top of the third return pulley and over the fourth pulley of the fixed block.
- 10. Thread the umbilical under the fourth pulley of the fixed block back under the fourth pulley of the return block.
- 11. Pass the umbilical over the top of the fourth return pulley and over the fourth pulley of the fixed block.
- 12. Thread the umbilical under the fifth pulley of the fixed block back under the fifth pulley of the return block.
- 13. Pass the umbilical over the top of the fifth return pulley.
- 14. Place a clean container (spill tray or stainless steel pot) below the URM exit hole.
- 15. Start the umbilical motor at 50 rpm
- 16. Feed the umbilical under the leading, smooth pulley on the motor assembly, over the second smooth pulley. Then under the small, toothed encoder pulley and around the large toothed pulley to go between the bottom toothed pulley and the small, smooth guide pulley. Be mindful of pinch points as the motor must be running through this procedure.
- 17. Once the path of the umbilical is set, allow it to continue running to pay the umbilical through the hole on the bottom of the URM.
- 18. Increase the rate to take up enough slack in the umbilical so that the umbilical is coiled firmly about the fixed and return blocks on the URM. Slow the motor when approaching that point and stop it completely before applying tension to the fixed end of the umbilical.

- 19. Apply pressure to the umbilical piston between 40 and 50 PSI. The pressure should be applied slowly so that the rope is not shocked during the procedure
- 20. Run the motor in the reverse direction to slowly load the umbilical onto the URM.
- 21. Stop the motor with the last meter below the URM.



### 3.8 Rope Installation

The rope should be taken from the supply of Tensylon polymer rope kept in the DCR. This rope has been stored on a spool that is maintained in plastic bag inside the DCR. To spool the rope onto the URM the following steps should be followed

- 1. Clean roughly 40 m of rope with an ultra sonic cleaner, including one cycle with a mixture of nucleon and UPW and two rinse cycles using just UPW.
- 2. Once the ultra sonic cleaning is complete, the rope should be placed loosely in a plastic bag and dried out using a flow of nitrogen.
- 3. Tie a piece of rope from the eye-bolt supporting the sprung pulley to the pulley itself through the center of the spring with enough slack to limit the maximum extent of the spring.
- 4. After the rope is dry the end of the rope must be threaded through the hole at the top of the URM rope drum and the rope tied around the axis of the drum using a folded bow-line (see Fig. ?? for instructions).
- 5. Hold the rope perpendicular to the surface of the drum, start the rope motor running at 50 rpm. Verify that the drum is rotating in the appropriate direction so that the rope loads onto the drum consistent with the right handed screw grooves on the rope drum. Once the direction is verified to be correct, increase the motor rate to between 500 and 1000 rpm.
- 6. When the rope nears the end of the drum, slow down the motor and stop it when the rope is loaded down to the last groove.
- 7. With one person holding the rope tight to the spool, a second person must then string the rope through the pulley system. The running end of the rope should go over the pulley supported by the lead screw down to the rear fixed pulley near the URM bed, over the sprung pulley, back down to the front fixed pulley and up over the load cell pulley. before going down the URM access port parallel to the umbilical.
- 8. The slack between the spool and the pulley mechanism can be removed and a temporary weight tied to the end of the rope to maintain tension on the system.



### 3.9 Source Connector Installation

Assembly of the source carriage requires the cleaned and installed umbilical and central rope. It may be reasonable to conduct a limited pre-assembly of the source pivot well before the final installation. Assembly consists of

- 1. Wet the bottom meter of umbilical with LAB
- 2. Pre-wet all of the screws with LAB
- 3. Install o-rings on the UFO acrylic cylinder, the source connector top and bottom surfaces.
- 4. Thread the umbilical through the pivot
- 5. Thread the umbilical through the pressure plates with appropriate o-rings.
- 6. Thread the umbilical through the top plate of the UFO.
- 7. Ensuring that there is a surplus of umbilical below the top plate of the UFO run the umbilical through the UFO acrylic, steel plate and stainless steel cylinder, and the upper source connector body.
- 8. **Couple the end of the fibre bundle to the source connector plate.**
- 9. Secure the source connector plate to the source upper source connector body with 8 m2 screws.
- 10. Fasten the UFO bottom plate to the top of the UFO steel cylinder.
- 11. Align the acrylic cylinder between the top section and the UFO plate and thread the support rods into the top plate. Once the threaded rod is secured, tighten the UFO assembly together using the appropriate nuts.
- 12. Fasten the UFO steel cylinder to the top of the upper source connector with 8 m3 cap screws.
- 13. Tighten the pressure plates against the top of the UFO assembly using four M3 screws.
- 14. Secure the source pivot pulley support plates to the UFO assembly.
- 15. Tie the central rope to the rotating collar on the pivot assembly using a bowline tight against the barrel of the pivot.

### 3.10 Cover Installation

The following procedures would best be completed with the URM

### **3.10.1 Mount the cover to the URM base**

- 1. Remove the bumpers from the edge of the URM flange.
- 2. Inspect the flange surface for imperfections and remove any traces of residue that may have been left on the surface by wiping with UPW or LAB.
- 3. Check that the o-ring remains properly installed and free of nicks or cuts.
- 4. With four people (one on each corner) lift the cover over the back plane of the URM.
- 5. A fifth person should watch the feed through plates to make sure that they do not get caught on the cover as it descends. The remaining workers may then carefully lower the ~~The~~ motor box cover must go down straight over the back plane.
- 6. The grips of the four workers lowering the cover should shift to use the lifting eye-bolts for the last few centimeters to avoid potential pinch points. The fifth worker should double check the status of the o-rings on the base flange before the cover is fully lowered onto the base flange.
- 7. Bolt the cover flange to the URM base. Each bolt must have a washer on the top and bottom and fastened with a nut. Initially only tighten the nuts to finger tight. There may be some movement in the flange so the best practice is to start from the middle of the URM on both sides and systematically work towards both ends in a staggered pattern.
- 8. With a crescent wrench and M5 hex wrench, tighten the bolts, again starting from the middle and working towards the ends. A third pass (without over-tightening) is encouraged.
- 9. Connect the vacuum leak checker to one of the flange

### **3.10.2 Install the electrical feed-through**

- 1. Pull the o-rings for the electrical feed-through flange out of their storage bag. Check the o-rings for nicks and cuts. If there are any the o-ring must be replaced.
- 2. Wet the o-rings with LAB(?) and place them in the electrical feed-through groove.
- 3. Lightly grease the 26 M4 screws with Super Lube.
- 4. Bolt the feed-through plate to the outer cover. Because the flange is bolted to the inside of the cover using blind holes, it is important to make sure that all of holes are correctly aligned before tightening the flange. Holding the flange against the inside of the cover to reduce the chance of the o-ring falling out, start all of the screws in their blind holes.

- 5. Still maintaining pressure between the plate and the cover, tighten all the screws to finger tight in a star pattern to maintain even pressure on the flange.
- 6. With the appropriate hex wrench, tighten all of the bolts with no more than 2 turns in a star pattern. Once complete, continue the star pattern by an additional half turn or more to tighten the screws without over tightening.
- 7. Connect the helium vacuum leak checker to the VCR ports on the flange. Systematically test the flange with a helium probe. A leak rate greater than  $10^{-7}$  mbar L/s should be treated as a fail. The likely fail case is due to a displaced o-ring; the flange should be disassembled, the o-rings should be inspected and if the o-rings are still considered “good” the flange can be re-assembled. If there are any cuts or deformations in either o-ring, the o-ring must be replaced. Then the flange can be reassembled as before.

### 3.10.3 Install the umbilical feed-through

- 1. Lightly ~~grease~~ the 14 M4 cap screws required for the installation of the umbilical feed-through plate.
- 2. Extract the o-rings for the ~~umbilical feed-through plate~~ from its storage bag and lubricate the o-rings with LAB.
- 3. Pull the umbilical through the o-rings and hold the o-rings near (but not touching) the cover.
- 4. ~~Carefully extract the umbilical feed-through from inside the cover.~~ Install the o-rings while holding the feed-through by the VCR ports.
- 5. Pull the umbilical feed-through plate against the inside of the cover.
- 6. As with the electrical feed-through, start all of the screws in the threaded holes in the plate.
- 7. While maintaining pressure between the plate and the cover, systematically tighten the screws to finger tight.
- 8. Working in a star pattern with a hex wrench, tighten the screws by an equal amount (no more than two turns). Continue the star pattern to ensure that all of the screws are tight without over-tightening.
- 9. Connect the vacuum leak checker to one of the VCR ports on the umbilical feed-through flange. Systematically test the flange with a helium probe. A leak rate greater than  $10^{-7}$  mbar L/s should be treated as a fail. The likely fail case is due to a displaced o-ring; the flange should be disassembled, the o-rings should be inspected

and if the o-rings are still considered “good” the flange can be re-assembled. If there are any cuts or deformations in either o-ring, the o-ring must be replaced. Then the flange can be reassembled as before.

### 3.11 Transfer the URM to the Lifting Table

The URM currently sits on one of the SNO carts in the DCR. This allows the URM to be worked on at a more reasonable height than the resting height of the lifting table. However, once the cover is on the URM should be transferred to the lifting table for all further steps.

- 1. Orient the URM cart and the lifting table so that front of the URM is facing the back (handle side) of the lifting table.
- 2. Lift the URM until it is at the same height as the lowest height of the lifting table.
- 3. Detach the chains securing the URM to the cart.
- 4. Push the URM from the cart to the lifting table. Some rotation might be necessary to avoid snagging the gas manifold. But always ensure that the center of mass of the URM is centered on the cart in some way. The center of mass is shown in Fig. 2a.
- 5. Once the URM is in position secure the URM to the lifting table using the appropriate chains and turnbuckles.
- 6. Connect the wheel mounts to the URM in the appropriate positions using the URM flange bolts to secure the outer sides of the plates. Install the inner, plates with the appropriate hex screws and connector bolts that pass through the URM skid wheel holes. Install the wheels with the bearings through the holes at the bottom of the mounts.

### 3.12 Source Tube / Bellows Installation

This procedure assumes that the bellows cleaning and leak checking is complete. Those procedures are detailed elsewhere. The installation of the bellows is reproduced here for convenience.

Required for this procedure are

- URM with the cover off
- The source tee flange
- Source tee flange bolts (already on the URM)
- 13mm Hex Wrench
- teflon encapsulate viton and viton o-rings

- Source bellows
- Genie lift
- 6 bolts and nuts required for the rotatable flange to bellows connection
- teflon encapsulated viton and viton o-rings for bellows flange surface

### 3.12.1 Source Tee installation

The source tee installation must be conducted with either the umbilical not present or the source connector not installed. The umbilical path hole, while wide for the scintillator URM is not wide enough for the pulley assembly of the source connector. Since the hole on the top of the source tee flange is the same size, eliminating prior installation of the source connector.

- 1. Unwrap source tee flange.
- 2. Wipe all surfaces of the flange with UPW.
- 3. Place o-rings on the top of the source tee using a little vacuum grease on the viton o-ring and LAB on the teflon encapsulated o-ring to ensure they remain in place
- 4. Place the lower end of the umbilical and the weighted rope through the center of the tee-flange.
- 5. Remove the source tee flange bolts from the bottom of the URM.
- 6. With one person to hold the source tee, raise the source tee up to the bottom of the URM, with the port side oriented 60 degrees off of the URM axis. Start all bolts on their threads
- 7. Tighten the bolts in a star sequence so the source tee compresses its o-rings against the bottom of the URM.
- 8. Install the source tee window on the view port of the source tee flange.
- 9. Connect the vacuum leak checker to one of the source tee test ports. Systematically test the edge of the flange against the URM with the helium probe. The leak rate must be less than  $10^{-7}$  mbar L/s. If the test fails the source tee flange must be disconnected and the source of the leak must be identified before re-installing the source tee flange.

### 3.13 Bellows installation

Installation of the bellows should be paused to allow for the installation of the source connector. This will allow for better control of the umbilical and the rope during the bellows installation and it is easier to conduct the source connector installation when the end of the source tube is higher up. Similarly the umbilical soak should be completed prior to the bellows installation.

- 1. Place the Genie lift near the motor box end of the URM 90 degrees to its axis.
- 2. Carefully position the bellows on the Genie lift and move the URM underneath the source tee flange with the **clocking matched between the bellows top flange and the rotatable flange**. Always have one person holding the bellows so that it does not tip.
- 3. Place the o-rings in the groove on the top bellows flange **using vacuum grease** to hold the o-rings in place.
- 4. Slowly lift the bellows into position below the tee flange. When the two surfaces are 1 cm apart, **insert the bolts through** the flanges from the top down. Start threading the nuts onto the bolt s until the bolts are in contact with the lower surface of the flange
- 5. Lift the bellows to allow for the bolts to be tightened by 2 to 3 thread widths. Continue until the bellows makes metal to metal contact with the source tee.
- 6. Tighten the bolts in a star pattern so that the bellows o-rings are compressed.
- 7. **Install turn-buckles and cables between the bellows support rings. Tighten the turn-buckles until the wires are tight between the support rings.**
- 8. Remove the **support struts with bolt cutters** breaking the top welds first and the bottom weld  cond. The strut **is** must be held by a second person so that its movement is controlled.
- 9. Bag the struts and remove them from the DCR at the first opportunity.
- 10. **Connect the vacuum leak checker to one of the top flange VCR ports (with the other blanked off). Test the edge of the flange with the helium probe. The connection fails if the leak rate exceeds  $10^{-7}$  mbar L/s. If there is a failure the source must be identified and the bellows re-installed with a successful leak check.**

#### 3.13.1 Gatevalve Installation

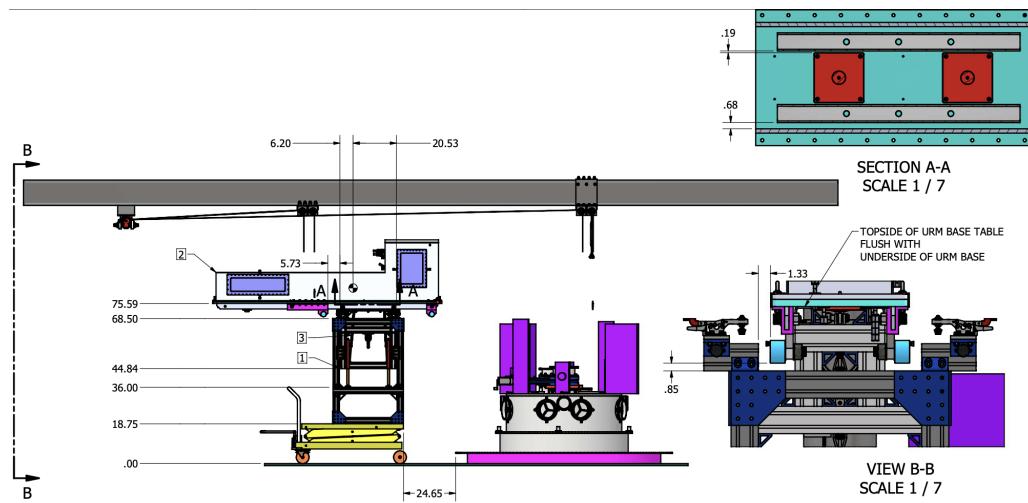
This procedure can be done before or after the bellows is installed on the URM. However it is easier to do so when the bellows is suspended independently, so it is likely better to complete this procedure after the bellows installation.

- 1. Maneuver the Genie lift to the shelf holding the 10 inch gate valve. Transfer the gate valve to the Genie lift.
- 2. Lower the gate valve as low as the Genie lift allows
- 3. Place the gate valve below the bellows.
- 4. Install the o-rings in the groove on the top side of the gate valve.
- 5. Lift the gate valve to the bellows. Adjust the position of the bellows so that the holes on the gate valve matches those on the bellows. The body of the gate valve should be parallel to the URM, with the handle end directly below the stretcher box.
- 6. Bolt the bellows to the gate valve using the appropriate bolts with washers in place. Thread all of the bolts into the gatevalve to finger tight before systematically tightening all of the bolts in a star pattern.
- 7. Connect the vacuum leak checker to one of the bottom flange VCR ports (with the other blanked off. Test the edge of the flange with the helium probe. The connection fails if the leak rate exceeds  $10^{-7}$  mbar L/s. If there is a failure the source must be identified and the bellows re-installed with a successful leak check.

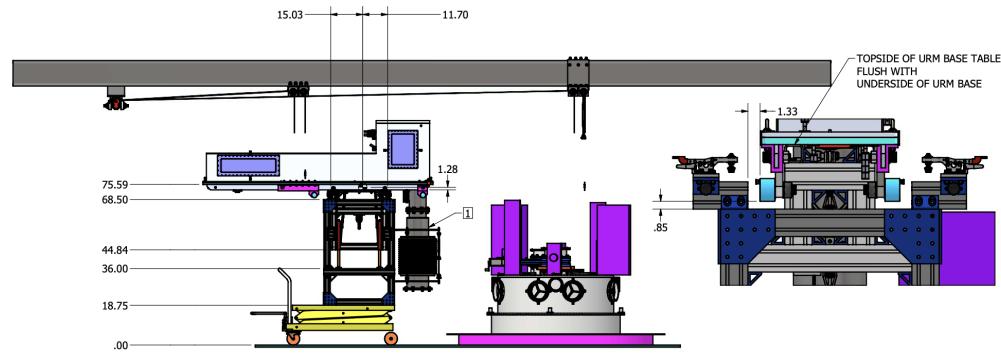
### 3.14 Final Umbilical Cleaning

The Umbilical must be wiped with a LAB soaked lint free cloth during loading. However, it cannot be assumed that all external material was removed from the umbilical from this process. For this reason, soaking the umbilical prior to deployment is considered the optimal method for a final cleaning as it has the potential to remove remaining traces of contamination from the umbilical in an environment comparable to the AV. Assuming that the umbilical is installed on the URM with the source connector blanked off (and the source tee is installed without the bellows) the following procedure can be followed.

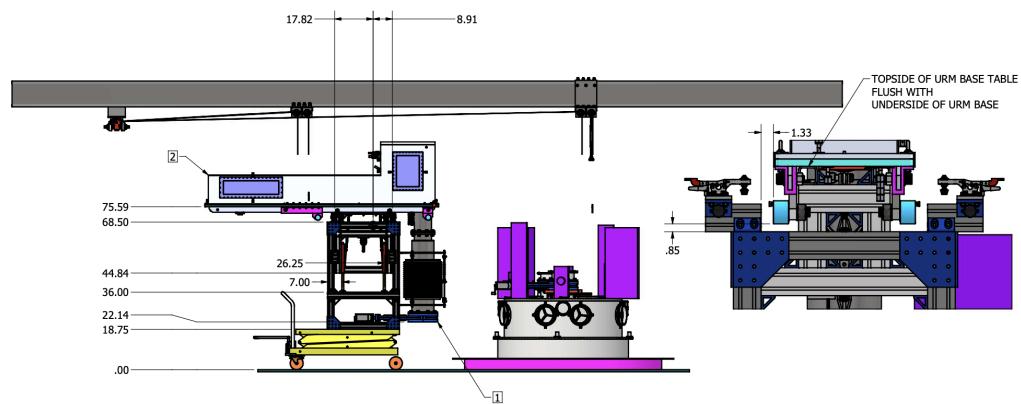
- 1. Clean the umbilical cleaning vessel (stainless steel stock pot) with soap (Sunlight) and water. Rinse inside and outside with UPW twice.
- 2. Fill the pot with 20-30 L of scintillator plant LAB.
- 3. Position the pot under the URM umbilical exit port and lower the source connector into the pot.
- 4. Put the umbilical and rope into constant tension mode with a tension less than the weight of the source connector (20 N on each should be sufficient). Pull the umbilical down from the URM and coil the umbilical in the pot below the scintillator level.



(a) URM on cart prior to bellows installation.

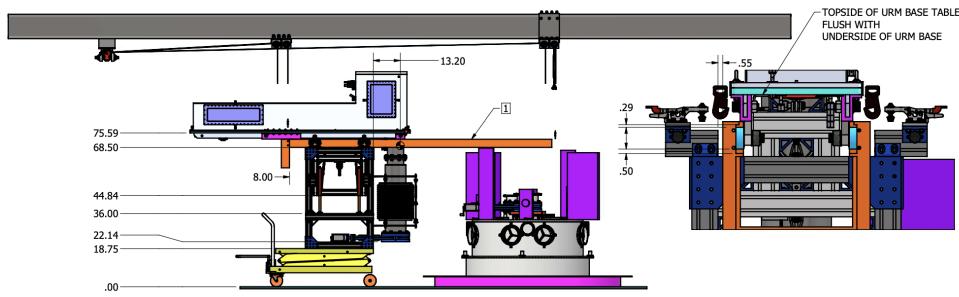


(b) URM on cart with the bellows installed.

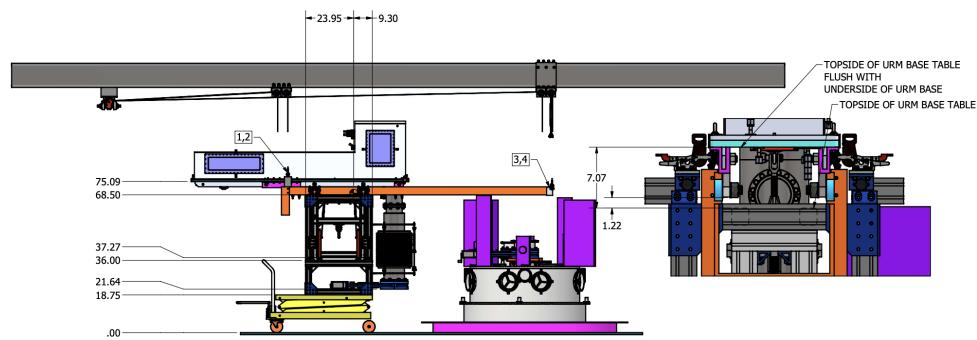


(c) URM on cart with gate valve installed.

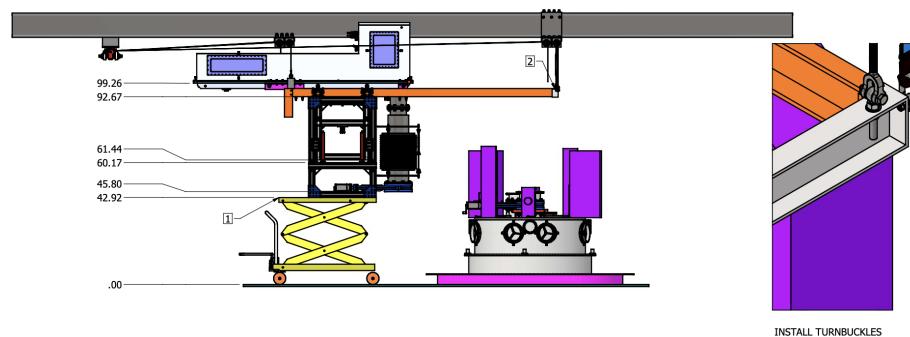
Figure 2: Preparing the bellows and gate valve for use  
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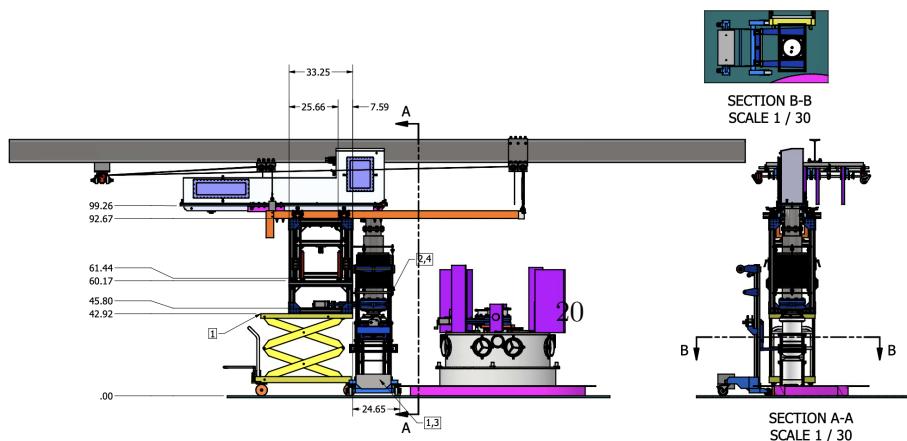
(a) Loading the rails onto the URM prior to lifting



(b) Installing the rail front plate and rear lifting plate



(c) Install the hangers once the URM is lifted to height



(d) Use the source cleaning vessel with the URM at operating height.

Figure 3: Lifting the URM to Operating Height

- 5. Continue pulling the umbilical down until the manip system indicates that the moving block reaches the endpoint of the track. Stop all URM commands. Clear the error and return the rope to constant tension mode with a value less than the connector weight (20 N).
- 6. Using the Genie lift raise the cleaning vessel up to the end of the source tee flange. Ensure that the umbilical settles into the pot while the rope retracts into the URM.
- 7. Close the gap between the URM source tee flange and the umbilical cleaning vessel.
- 8. Leave the umbilical to soak for a week
- 9. Once the soak is complete, check the state of the URM. Ensure that the rope is in constant tension mode. Lower the umbilical cleaning vessel to the floor.
- 10. Put the umbilical into constant tension mode with a value greater than 20 N. The umbilical should retract into the URM at a reasonable rate.
- 11. Watch the umbilical and try to remedy any tangles with a minimal amount of manipulation of the umbilical.
- 12. Allow the umbilical and rope to continue retracting into the URM stop the movement of the umbilical before the source connector assembly reaches the URM base plate.
- 13. Raise the umbilical cleaning vessel back up to the source tee flange to collect the LAB as it drips off of the umbilical and out of the URM.

### 3.15 Cover Gas Connections

Once the umbilical, gatevalve, bellows and cover are installed on the URM, a nitrogen atmosphere must be generated inside the URM. A cover gas bag has been constructed and suspended from a unistrut frame in the DCR. A run of 3/4" piping from the cover gas bag along the frame, up the DCR North wall and across the ceiling to the DCR I-beam is mean to provide a path between the cover gas bag and the URM. At present this is terminated with a valve, but a flexible, stainless steel braided hose was acquired to provide a flexible connection between the URM and the cover gas system. A tee junction has been installed to allow the gas to be transferred using both the end of the stretcher box and the top of the motor box. At the cover-gas bag end, a path has been installed to allow a path to be set to a nitrogen for the case when the URM is open at the bottom of the source bellows with the cover gas bag isolated. The operational cases are

1. URM standing alone (off UI)
1. Nitrogen source valve closed

- 2. Gate valve closed
  - 3. Bag to URM path valve open
2. URM flushing (off UI)
- 1. Nitrogen source valve open
  - 2. Nitrogen source connected and supplying gas
  - 3. URM Gate valve open (possibly not fully)
  - 4. ~~Bag to URM path valve closed~~
3. URM connected to UI before deployment
- 1. Nitrogen source valve closed
  - 2. URM Gate valve closed on top of nipple assembly
  - 3. UI gate valve closed
  - 4. Bag-to-URM path valve open
4. Pump-purge the nipple assembly before deployment
- 1. Nitrogen source valve closed
  - 2. Nitrogen source connected to pump purge board
  - 3. URM gate valve closed
  - 4. Pump purge board input and extraction lines connected to nipple assembly
  - 5. UI gate valve closed
  - 6. Bag-to-URM path valve open
  - 7. To run the pump purge procedure
    - Take note of the pressure on the board gauge for the nipple assembly
    - Pump out the nipple assembly at 5 L/min for 5 minutes
    - Switch the board to purge the nipple assembly using the internal solenoid valve
    - Add nitrogen until the nipple assemblies pressure returns to its initial value
    - Repeat 3 times
5. Deploying the source after pump-purge is complete
- 1. Nitrogen source valve closed
  - 2. Pump-purge board disconnected
  - 3. Bag-to-URM path valve open

- 4. Note the UI to Deck differential pressure on Delta
- 5. Open the URM gate valve
- 6. Open the UI gate valve a crack and monitor the UI to Deck differential pressure on Delta
- 7. If there is no variation in the pressure outside of operating limits open the gate valve completely.
- 8. **If there is a variation close both of the gate valves** and determine how to correct  system to remedy the difference.
- 9. Once the gate valve is open it is expected that variations in mine pressure can be handled by the combination of the URM cover-gas and UI cover gas bags.

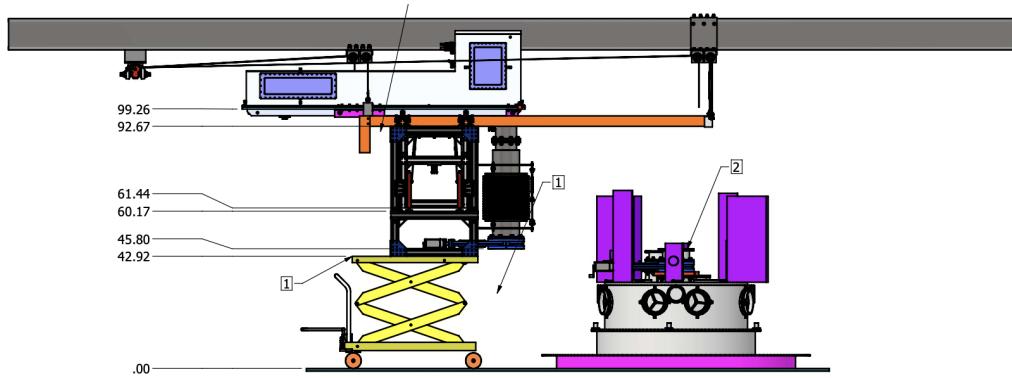
### 3.16 Field Testing the URM

An important activity prior to deploying the source is to deploy a test mass in the AV to ensure that the systems can work in concert properly. For this test it is assumed that;

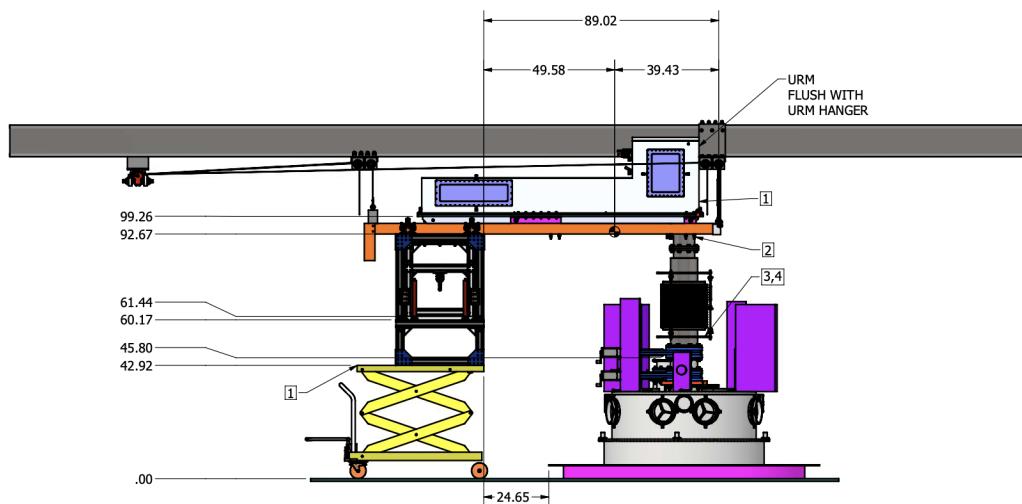
- The umbilical and rope are loaded with the source connector attached to the end of the umbilical
- The cover is on the URM.
- The gate valve and bellows have been installed
- The URM lifting system is working and complete.
- The URM is secured to the lifting cart.
- The nitrogen atmosphere in the URM has been in place for a period not less than two weeks (i.e. four or more radon half lives.)
- The source connector, with an appropriate blanking plate and weight, has undergone **cleaning in the source cleaning vessel.**

To deploy the source the operators must

-  1. Align the URM with the South side URM lifting path.
-  2. Ensure that the URM is chained to the inner table on the lifting cart
-  3. Mount the rails onto the URM. This is done by
  - Raising the inner table of the lifting cart by using the hydraulic crank
  - Sliding the rails onto the URM wheels with the U bend of the rails on the stretcher box side of the URM.



(a) URM prior to connection with the UI



(b) URM mounted on UI after being lifted. Note the URM must be clamped to the rails prior to installing the gate valve.

- Bolt the rail front plate onto the rails using the 1/2" bolts provided.
- Lower the URM on the hydraulic lift by turning the crank counter clockwise.
- Clamp the rails onto the lifting cart with the side clamps.**
- 4. Raise the URM gatevalve so that it is no longer resting on the cart table through the use of the bellows turnbuckles.
- 5. Connect the rails to the lifting mechanism straps using the available eye-bolts on the front and back of the URM.
- 6. With one person on the winch and a second on the cart, lift the URM to operating height. Most of the effort is from the lifting cart; there should never be slack on the winch straps but never so much that it takes all of the URM weight.
- 7. With the URM at operating height, install the turnbuckles installed on the hangers to fix the URM rails into position.
- 8. Undo the turnbuckles chaining the URM to the cart.
- 9. Remove the cover from the 10 inch gatevalve nipple assembly and heck that the requisite o-rings are in place.
- 10. Push the URM into position over the UI.
- 11. Ensure that the gatevalve is aligned with the nipple assembly on the 10 inch gate valve
- 12. Clamp the URM into position on the rails so that the URM can no longer roll freely
- 13. Slowly lower the gatevalve onto the nipple assembly using the bellows turnbuckles. It is essential that the gatevalve lands evenly and without damaging the flanges Start threading bolts into the gatevalve as soon as they can reach.
- 14. Once the bellows gatevalve is supported by the nipple assembly, tighten all of the bolts in a star pattern to ensure that force is distributed evenly across the flange
- 15. Measure the height of the viewport on the URM source tee relative to the height of the UI by aligning the laser level with the viewport. Remove the viewport cover and align the source pivot with the laser level. Note the top of the UI is 1409.63 cm from the center of the AV; locate the source to be the measured difference between the top of the UI and the reference position in addition to 1409.63 cm.
- 16. Pump and purge the space inside the nipple assembly (as described in section ??).
- 17. Open the bellows gate valve

- 18. Check the differential pressure between the UI and Deck using DeltaV
- 19. Slowly open the UI gatevalve. Check the differential pressure between the UI and Deck using DeltaV. If there is a difference that exceeds the operating pressure for the AV, close the gatevalve and determine how to correct the pressure difference (with the expertise of the cover gas expert). If the safe operating pressure is maintained, proceed with opening the gatevalve fully.
- 20. Lower the test mass into the UI. Stop when the test mass is approximately 30 cm below the top of the UI.
- 21. Connect the side ropes to the source carriage. The side ropes will need to be connected to the source in the manip interface as well.
- 22. Lower the test mass into the AV and drive the source to various locations. Efforts should be made to test the limits of motion for the manipulator system given the test mass. Care must be taken to ensure that the drive limits are observed (tensions must remain within limits for the ropes, etc.).
- 23. Retrieve the test mass from the AV. Stop the test mass 30 cm below the UI top to remove the side ropes.
- 24. Raise the source into the bellows. Carefully close the UI gate valve. Then close the bellows gate valve.
- 25. Check the location of the source pivot through the viewport. Compare the source carriage height after the deployment to that value that is predicted by manip using the measurements prior to deployment. Note any changes relative to the expectation in the log book.

## 4 Scheduling

The tasks to be completed prior to source deployment can be placed onto a matrix of weeks of work. Each week is occupied by 5 shifts worth of tasks. Some of the tasks may take less time, but the decision to advance the schedule should only be done as tasks are complete. For reference this block schedule extends beyond the procedures given here to include Laserball deployment. Scheduling an AmBe deployment depends on the outcomes of the Laserball deployment; specifically whether further data collection is required. It is expected that the earliest that the pre-requisites can be fulfilled is the third week of 2025 (week of January 13). This places the end of week 5 as February 14 2025. Thus the Laserball installation and cleaning can take place the following week, starting February 18, with a potential deployment the week of February 24.

Table 1: Block scheduling for the tasks remaining in the assembly of the URM

Week	Task	Personnel
0	<input type="checkbox"/> Preparation of umbilical feed-through plate; Sec.3.6	Machine shop
1	<input type="checkbox"/> Remove URM cover <input type="checkbox"/> Electrical systems check; Sec.3.4 <input type="checkbox"/> Install umbilical feed-through plate on umbilical; Sec.3.6 <input type="checkbox"/> Install umbilical on URM; Sec.3.7 <input type="checkbox"/> Install rope on URM; Sec. 3.8 <input type="checkbox"/> Install URM cover; Sec.3.10	4 workers
2	<input type="checkbox"/> Electrical systems check; Sec.3.4 <input type="checkbox"/> Transfer URM from cart to lifting table; Sec.3.11 <input type="checkbox"/> Install source tee flange; Sec.3.12.1 <input type="checkbox"/> Install source connector on umbilical; Sec.3.9 <input type="checkbox"/> Install source bellows; Sec.3.13 <input type="checkbox"/> Install gate valve; Sec.3.13.1	3 workers
3	<input type="checkbox"/> Purge the URM and connect to the cover gas system; Sec.3.15 <input type="checkbox"/> Final Umbilical cleaning; Sec.3.14 (1 week)	2 workers
4	<input type="checkbox"/> Connect and clean the dummy source with source cleaning vessel	2 workers
5	<input type="checkbox"/> Connect URM to UI; Sec.3.15 <input type="checkbox"/> Field test the manipulator system.; Sec.3.16	3 workers
6	<input type="checkbox"/> Disconnect URM from UI <input type="checkbox"/> Disconnect dummy source and connect Laserball to URM <input type="checkbox"/> Clean Laserball source with source cleaning vessel <input type="checkbox"/> Prepare/optimize Dye-laser for use	3 workers
7	<input type="checkbox"/> Run Laserball deployment program	4-6 workers