

# URM Handling, History, and Preparation

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Version 3

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 pulley 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

General comments about the handling: all operations with the URM were conducted in a cleanroom setting after the URM was placed in the SNOLAB cleanrooms and it was not removed from the cleanroom until after it was disassembled and bagged prior to being shipped underground. General guidelines were that the URM was never handled without cleanroom gloves on the hands of the workers and that the URM was cleaned after every interaction with UPW and Kimwipes.

- **June - August, 2017** URM completely disassembled, cleaned and reassembled. All large pieces were completely wiped with UPW. Screws were ultrasonically cleaned.
- **August - September, 2017** Electrical systems and wiring for motors and sensors setup. Installed a rope to facilitate slipping and stretching measurements.
- **November 2017** Installed umbilical #5 on URM after wiping down umbilical and URM with kim wipes and UPW (there was dust observed on the Umbilical).
- **June - August, 2018** Rope stretch tests in air, UPW and LAB. The contaminated rope was removed and never retracted into the URM.
- **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 to exclude leak rates above  $10^{-8}$  mbar L/s.
- **November 2018** Expanded the hole in the retraction pulley to accept an M4 eye-bolt.

- **January - September 2019** Redo rope stretch tests in air.
- **September 2019** Installed limit switches at either end of the URM track.

## 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 before storage in the DCR.

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

- **May 2021** Reassembled URM inside DCR. Surface cleaned parts by hand with Kimwipes and UPW. Some minor test of the electrical systems and reviewed 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.3.9 (1 shift, machine shop?)
- 2. Remove URM cover; Sec.3.4 (1 shift, 4 workers)
- 3. Electrical systems check; Sec.3.5 (1 shift, 1 worker)
- 4. Clean the umbilical; Sec.3.6
- 5. Clean the surfaces of the pulley blocks and drive pulleys; Sec.3.7
- 6. Install umbilical on URM; Sec.3.8 (1 shift, 3 workers)
- 7. Install umbilical feed-through plate on umbilical; Sec.3.9 (1 shift, 2 workers)
- 8. Install rope on URM; Sec. 3.10 (1 shift, 2 workers)

- 9. Install URM cover; Sec.3.11 (1 shift, 4 workers)
- 10. Transfer URM from cart to lifting table; Sec.3.12 (1 shift, 6 workers)
- 11. Electrical systems check; Sec.3.5 (1 shift, 1 worker)
- 12. Install source tee flange; Sec.3.13 (1 shift, 2 workers)
- 13. Epoxy the fibre bundles at both ends of the umbilical;
- 14. Install source bellows; Sec.3.15.1
- 15. Install gate valve; Sec.3.16
- 16. Install source connector on umbilical; Sec.3.14 (1 shift)
- 17. Purge the URM and connect to the cover gas system; Sec.3.17
- 18. Final Umbilical cleaning; Sec.3.15 (1 week)
- 19. Connect and clean the AmBe source (?) (1 week, 3 workers)
- 20. Connect URM to UI; Sec.3.17 (1 shift, 3 workers)
- 21. Field test the manipulator system.; Sec.3.18 (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.
- When working on the interior workings of the URM
  - Double gloves must be worn. Inside and outside gloves should be rinsed with UPW after they are donned.
  - After handling lubricants or oils, the outer gloves must be removed and replaced.
- 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.

### **3.3 Personal Protective Equipment: Donning Gloves**

The general glove cleanliness protocol requires that operators exercise extreme care when handling equipment that will come into contact with the detector scintillator.

- 1. Thoroughly wash and dry hands.
- 2. Put on a pair of clean room nitrile gloves.
- 3. Spray with UPW and rub hands together.
- 4. Rinse with UPW.
- 5. Dry with Kimwipe.
- 6. Put another pair of clean room nitrile gloves.
- 7. Spray UPW on the clean room gloves and rub hands together.
- 8. Rinse with UPW.
- 9. Dry with Kimwipe.

### **3.4 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 cover.

- 4. Prepare an area out of the way of other activities to place the URM with a piece of plastic suitable to be wrapped over the URM cover.
- 5. With four workers; one at each corner; with an appropriate height assist, lift the URM cover straight up off of the URM flange until it is clear of the URM backplane.
- 6. Carefully lower the URM cover onto the prepared plastic sheet. Wrap the sheet over the URM cover..
- 7. Check the URM o-ring. Ensure that it remains in its groove with no obvious damage.
- 8. 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.

### 3.5 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.

Running the electrical system requires

- A Special paired cable connecting to a single 20 pin Amphenol connector at one end and a pair of DB-15 bus connectors on the others
  - A AVR control box shown in fig. 2
  - Two Motor power supply boxes; each must have a power cable and a 6 pin Amphenol connector terminated output cable integrated into the box.
  - Two four pin motor control cables
  - One AVR power supply
  - An extension sufficient to reach the Manip computer in the DCR garage
  - The URM with the cover off.
- Connect the components as shown in Fig. 4.
- The Rope and Umbilical sense cables attach to the URM via the 20 pin socket mounted to the electrical feed-through plate,



Figure 2: The box containing the AVR controller boards that are to be used with URM4

- the DB-15 ends of the Rope and Umbilical sense cables connect to the AVR Unit via the appropriate socket. Convention has the Umbilical on the bottom and the rope on the top connector, but this should be verified with the Manip configuration on the Calibration Computer.
- The 6 pin Amphenol terminated control cables connect to 6 pin sockets, when looking at the feed-through plate from the outside, the umbilical motor control cable should be connected to the right feed-through socket and the rope connected to the left feed-through socket.
- The two four pin motor control cables run between the AVR control unit and the the motor power supply units.
- Connect the USB cable to the Manip computer USB extension, usually kept on the Northwest side of the UI.
- Plug the motor power supplies and the AVR power supply into an extension cable. Ensure that the fan is running on the AVR power supply. Make sure that the power switches on the motor supplies are set to on and the red LED lights are illuminated.
- Connect the AVR box to the computer power supply via the bus cable connector on the top of the AVR box. Ensure that the fan still runs after connecting the power supply and that the green LED light inside the AVR box is illuminated.
- Go to the Calibration computer and check if the appropriate AVR board is connected.

- Open a terminal and navigate to the **AVR32** directory
- Run the command **manip**
- At the **manip** command prompt run **init**
- Check the list of connected AVR's. Ensure that the AVR connected to URM4 appears in the list.
- Run the command **show laserball** on the command prompt. Disconnect URM2rope and URM2umbilical from the Laserball using the **laserball disconnect** command if necessary.
- 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 will need to be debugged, starting with ensuring that the correct AVR connects to the the URM4rope and URM4umbilical objects in the **WIRING.dat** file in the **AVR32** directory
- 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.

### 3.6 Cleaning the Umbilical

The umbilical to be used is the 8th scintillator umbilical assembled at Queen's in 2016. This is the only umbilical synthesized with a fiber optical bundle. The umbilical was wiped once with acetone, then with methanol in the Queen's clean lab and stored in a clean bag inside of a nitrogen filled mylar bag. From 2017 to 2024 the umbilical in its bag in the bottom of a cabinet in SNOLAB cleanroom A. It was moved from the cleanroom as the Diol still commissioning ramped up and is sitting on a desk with two additional plastic bags over the mylar bag. Prior to further installing the umbilical on the URM, 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

### Electrical connections

#### Conector 6 pins (Step Motor)

Pin	description
A	Pole A+
B	Pole A-
C	Pole B+
D	Pole B-



#### Conector 20 pins (electronic)

Pin	description
U	Encoder RopeMechanism GND
V	Encoder RopeMechanism Canal A
M	Encoder RopeMechanism Canal VCC
N	Encoder RopeMechanism Canal B
P	RopeMechanism Load Cell Signal +
Q	RopeMechanism Load Cell GND
R	RopeMechanism Load Cell Signal -
S	RopeMechanism Load Cell VCC
T	Switch Normal Open
L	Switch Normal Close
B	Switch Commun
C	Not Connected
D	HoseMechanism Load Cell VCC
E	HoseMechanism Signal -
F	HoseMechanism Load Cell GND
G	HoseMechanism load Cell Signal +
H	Encoder HoseMechanism Channel B
J	Encoder HoseMechanism VCC
K	Encoder HoseMechanism Channel A
A	Encoder HoseMechanism GND

18-12†  
6#16  
A

#### 20 Contacts

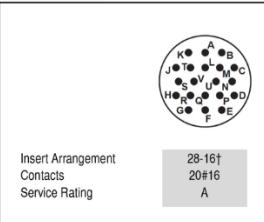


Figure 3: Pin out diagram for the URM as of August 2017. One minor revision made to incorporate the limit switch circuits in 2021.

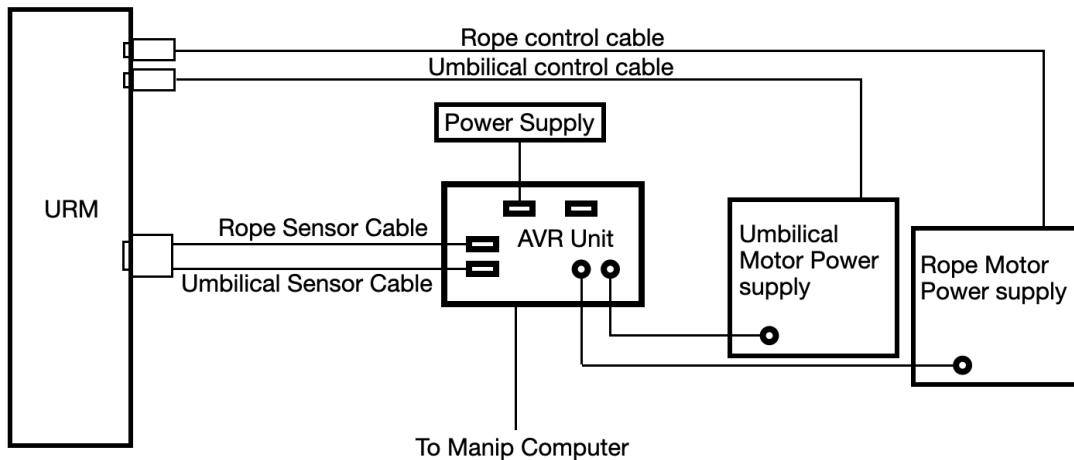


Figure 4: Diagram of AVR controller setup for URM.

- poly gloves
- fisher-brand, Poly-cellulose cleanroom wipes (should start with an unopened pack)
- Two clean plastic bag suitable made from pink static resistant plastic (inside the DCR).
- A heat sealer
- A nitrogen source (using a standard bottle on deck) with a regulator and a flow meter.

Cleaning the umbilical is to be done in a two step process. This should be done between three workers; two to handle the umbilical and one to provide additional help or go for additional items if needed. The first step provides an initial starting point for the cleanliness of the umbilical, while the second step prepares the umbilical for loading on the URM. To initially clean and evaluate the state of the umbilical

- 1. 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.
- 2. Don clean-room gloves using the procedure in section 3.3
- 3. Open the top of the umbilical storage bag.
- 4. With one worker holding the bag, pull the umbilical from the bag and place it in one corner of the spill tray.
- 5. Inspect the outside of the umbilical for damage.
- 6. Pick out one end of the umbilical. Shine a light into the one end of the umbilical and look for the light at the other end. The light should be visible at the ends of the fibers on the opposite end, even though the bundle is not yet complete. Count and record the illuminated fibers.
- 7. Designate one end of the umbilical as the standing end. This will be the end of the umbilical that will be secured to the URM umbilical feed-through. Both the standing end and the running end of the umbilical (the end to which the source will be connected) are identical and the fibre bundles will need to be terminated after loading onto the URM (the procedure of which will be communicated elsewhere).
- 8. Protect the ends of the umbilical. This can be done by wrapping the end in plastic wrap, or a plastic sleeve held in place with a zip tie. It is expected that the ends of the fibers are flush with the ends of the umbilical at this time, so this will mostly protect the fibers as they flex during installation. Cap the standing end of the umbilical with a different colour sleeve relative to the running end.

- 9. Wet a lint free cloth with UPW.
- 10. Starting with the running end, wipe the umbilical in strokes towards the standing end with UPW. Coil the umbilical in the opposite side of the spill tray. Be sure to keep an eye out for kinks and possible surface damage to the umbilical throughout this process.
- 11. Once the entire umbilical has been wiped down transfer the umbilical to a clean pink plastic bag.
- 12. Insert an open line to the nitrogen source into the bag with an outlet line. Seal the plastic bag with the heat sealer so the inlet and outlet lines are contained. Open the valve to the nitrogen supply with an output pressure on the order of 20 psi at a flow rate of 5 L/min. This will dry out the umbilical in a contained way. Leave the umbilical in this configuration overnight.
- 13. After drying the umbilical completely, open the bag and place the umbilical in the spill tray. Take tape lifts from various locations along the length of the umbilical and submit the tape lifts for XRF analysis.
- 14. Return the umbilical to the plastic bag. Fill the bag with nitrogen and heat seal the bag.
- 15. Store the umbilical in a bin to protect the bag until use.

A second cleaning procedure should be followed immediately prior to loading the umbilical onto the URM; ideally in the same shift. Again this procedure should be completed by two workers with a third in reserve to handle. The two workers must take the following

- 1. 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.
- 2. Don clean-room gloves using the procedure in section 3.3
- 3. Open the top of the umbilical storage bag.
- 4. With one worker holding the bag, a second should pull the umbilical from the bag and place it in one corner of the spill tray.
- 5. Inspect the umbilical again. Pick out one end of the umbilical. Shine a light into the one end of the umbilical and look for the light at the other end. The light should be visible at the ends of the fibers on the opposite end, even though the bundle is not yet complete. Count and record the illuminated fibers.
- 6. Wet a lint free cloth with clean LAB.

- 7. Identify the running and standing ends of the umbilical
- 8. Protect the ends of the umbilical. This can be done by wrapping the end in plastic wrap, or a plastic sleeve held in place with a zip tie. It is expected that the ends of the fibers are flush with the ends of the umbilical at this time, so this will mostly protect the fibers as they flex during installation.
- 9. Starting from the running end of the umbilical, wipe the Tygothane surface of the umbilical with the LAB wetted cloth with multiple passes on each section. Coil the umbilical loosely as you go in the opposite corner of the spill tray.
- 10. Once you get to the standing end of the umbilical, Store the cloth used to wipe the umbilical for particle counting analysis, and change outer gloves to use a new, clean pair.
- 11. Wet a new lint free cloth with clean LAB.
- 12. Flip the coil of umbilical over to access the running end again and, 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 as you go.
- 13. Once complete, leave the standing end of the umbilical available for installation on the URM and cover the umbilical loosely with the beige spill tray. Store the outer gloves in a bag for appropriate disposal. Store the LAB wetted cloth for particle counting analysis.

### 3.7 Cleaning the URM (prior to umbilical installation)

At each stage of the URM assembly, disassembly, movement underground and reassembly, the components of the URM have been cleaned with UPW and cleanroom wipes. The last opportunity to clean the URM before source deployment will be after the URM cover is removed and before the umbilical is installed. To clean the URM two workers will require

- a fresh supply of UPW
- two spray bottles
- a fresh pack of Fisherbrand, Poly-cellulose cleanroom wipes
- supply of cleanroom gloves.

To clean the URM the workers must

- Don clean room gloves using the procedure in section 3.3.

- Remove the front and rear pulley blocks, The umbilical motor assembly, the rope encoder pulley, and the sprung rope pulley.
- Disassemble the front and rear pulley blocks, the rope encoder pulley, and the sprung rope pulley. Remove the guide and drive pulleys from the umbilical motor assembly. Submit the parts for ultra-sonic cleaning.
- Clean the umbilical motor assembly with UPW and clean room wipes.
- Reassemble the front and rear pulley blocks, the rope pulleys, and the pulleys on the motor assembly. N.B. URM5 is physically identical to URM4, so the pulleys and their support systems have already been cleaned ultrasonically, so the blocks, and rope pulleys can just be replaced. In contrast the umbilical motor assembly from URM5 was never tested, so the pulleys on the URM4 motor assembly should be replaced with the clean ones from URM5.
- Mist the remaining surfaces of the URM and wipe the surface with the cleanroom wipes until the surface is again dry. This should include the URM backplane, support braces, bed, piston, and retraction pulley. Special care should be taken to wipe the bottom rope pulleys with UPW as it is extremely difficult to remove those pulleys from the system for ultrasonic cleaning without removing the back plane.
- Wipe down the surfaces of the rope drum and the traveling pulley with UPW and clean room wipes.
- Replace the ultrasonically cleaned rope and umbilical pulley blocks, and motor assembly on URM4.

### 3.8 Umbilical Installation

This is a three person procedure; two workers handling the umbilical and a third to run commands on the manip system. Both workers handling the umbilical must wear clean nitrile gloves. The gloves should be rinsed with UPW and dried before working. For the installation the workers need

- to have the URM setup to run with commands from the manip system
  - the cleaned umbilical sitting loosely coiled in a spill tray
  - to ensure that the ends of the umbilical are protected, neatly, so that the ends of the umbilical will not catch on the
- 1. If not already done, remove the cover over the umbilical exit port at the base of the URM. Replace the bolts afterwards to keep the interior reinforcing ring in place.

- 2. Using a piece of Tensylon rope tie the retraction block at the end of the track to the piston in the closed position. A long piece of rope will be required for this as it will need to span the 1.2 m distance between the umbilical retraction block and the retraction pulleys mounted to the pneumatic piston at least twice, so make sure that 3 m of rope is available when securing the system.
- 3. With no pressure on the piston, push the retraction block as close to the fixed block as possible.
- 4. Start the URM motor at a constant 50 rpm. This should be with the supervision of a calibration expert first by executing the command `avr3 m1 on 1` followed by `avr3 m1 dir 1` and `avr3 m1 ramp 50`. Ensure that the motor direction will retract the umbilical as it is fed through the system by checking the direction of the drive pulleys. One worker must monitor the system constantly and be in communication with the other workers who will be manipulating the umbilical, as there may be the need to start and stop the system at any time, or to otherwise change the motor rates when necessary.
- 5. Both umbilical workers should don gloves according to the procedure in section 3.3.
- 6. Identify the standing end of the umbilical. Insert the umbilical into the exit port of the URM and carefully thread it between the first smooth guide pulley and the first toothed wheels of the motor mechanism. Be mindful of pinch points in the mechanism. Both workers will need to co-operate for this task as the gap between the toothed pulleys is held shut with a spring arm.
- 7. Continue to guide the umbilical end around the large toothed pulley and under the encoder pulley.
- 8. While one person continuing to guide the umbilical end over the remaining smooth guide pulley, the second will increase the motor revolution rate to 500 rpm.
- 9. Once the umbilical end is clear of the motor pulley system, start feeding the umbilical over the pulley in line with the motor system on the fixed block and the return block. Bend the umbilical over the return block with one worker guiding the umbilical end and one to collect the umbilical end on below the block while protecting the running end.
- 10. Continue guiding the standing end of the umbilical under the first pulley of the fixed block. Between two workers, bend the umbilical up and over the first pulley on the block. Continue guiding the umbilical over the second pulley of the return block and under the second pulley of the fixed block. Continue through the third, fourth, fifth and sixth pulley pairs.

- 11. After bending the umbilical under the sixth pulley of the fixed block allow the motor to run long enough to provide an additional 3.5 meters of umbilical. Then stop the motor. The umbilical feed-through plate may now be installed on the standing end of the umbilical 3 meters from the end. The 7.075 m of umbilical currently on the URM and the additional 4 meters above that will never exit the URM after installation is complete.
- 12. Connect a nitrogen gas bottle to the gas port at the bottom of the URM that connects to the piston at the motor box end through a pressure regulator and a ball valve. Set the regulator to output a pressure between 45 and 60 psi. Ensure that the bottle internal pressure is greater than 500 psi to start and replace it otherwise.
- 13. One worker must hold the standing end of the umbilical firmly. Apply pressure to the piston by opening the ball valve carefully.
- 14. One worker must hold the umbilical at the standing end. The second worker will return to the Calibration computer, reverse the URM4 motor direction, and start the motor running again at a rate of 500 rpm. This will retract the umbilical onto the URM. Stop the umbilical once it the end is less than 1 meter below the base of the URM, but more than 30 cm while waiting for further steps.

### 3.8.1 The Required Umbilical Length and the Feed-through Location

The minimum distance between the pulley blocks is 216 mm. The diameter of the pulleys are 205 mm. With 6 coils, a minimum length of 6.46 m will be stored on the URM blocks. The distance between the front block and the main drive pulley is 295 mm and the diameter of the drive pulley is also 205mm. Given that the drive pulley is 230 mm above the bed of the URM and that the umbilical does not follow a direct path through the guide and encoder pulleys, the minimum length of 7.303 m will be contained in the URM when the umbilical is fully deployed. These dimensions are depicted in Fig.??.

The expected distance between the URM and the gate valve is 1.357 m, based on Fig.12b, while the distance between the gate valve and the bottom of the AV is 14.43 m (as determined from measurements recorded by Peter Skensved in the “Calibration Log Book #6” contained in the DCR. This means that the total length of umbilical required when the umbilical is deployed (ignoring the source length) is 23.09 m. Therefore 7 m of surplus umbilical (given the manufactured length of 30 m) are available after loading. The 23.09 m can be comfortably stored on the URM given that when the blocks are at their maximum extent the URM can hold 29.2 m. The placement of the feed-through plate should be done so that there is an additional length of at least 2 m on the end of the umbilical to accommodate the consolidation of the fibre bundle and the installation of the source; more is likely better as having a length of 3 m (suggested) will allow the end of the umbilical to be comfortably manipulated for the sealing of the fibre bundle ends while

5 m could allow the umbilical to reach the dye laser without the use of an additional patch cable. The position of the umbilical ends is dictated by the position of the feed-through plate. To consolidate the fibers at the end going to the laser, at least 3 m will be required so that the work can be done on a comfortable surface adjacent to the URM cart, so three meters is given as the minimum length of umbilical that should be outside of the URM. Any difference in distance between the end of the umbilical and the laser must be made up with a fiber optic patch cable.

### 3.9 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 and strain-relief for the umbilical itself. Incorporating teflon material between the bulkhead and the plate at either end with washers and teflon tape through the run of the threads should make this leak tight. 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 angled cap with the edges milled down to allow a flat surface for the bulkhead nuts with space to connect the backing nuts on the bulkhead. Once the umbilical is fed through the bulkhead fitting, 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. A mockup of the umbilical feedthrough plate, with the umbilical, is shown in Fig.6.

Tests have shown that the bulkhead fitting, when secured to the umbilical using the two nuts and ferrules, does not move along the umbilical when the umbilical was put under tension.

To conduct this procedure the following items are required

- Cleaned, installed umbilical
- 1/2" through-bore bulkhead fitting (ultra-sonically cleaned)
- Two 3/4" ID FFKM o-rings
- Two 1/2" Swagelok nuts (ultra-sonically cleaned)
- Two 1/2" Swagelok teflon ferrules
- Spray bottle of fresh UPW
- Supply of Fisherbrand, Poly-celulose cleanroom wipes

To install the umbilical in this way, a worker must

- 1. Put on a double layer of clean-room gloves using the procedure in section 3.3.

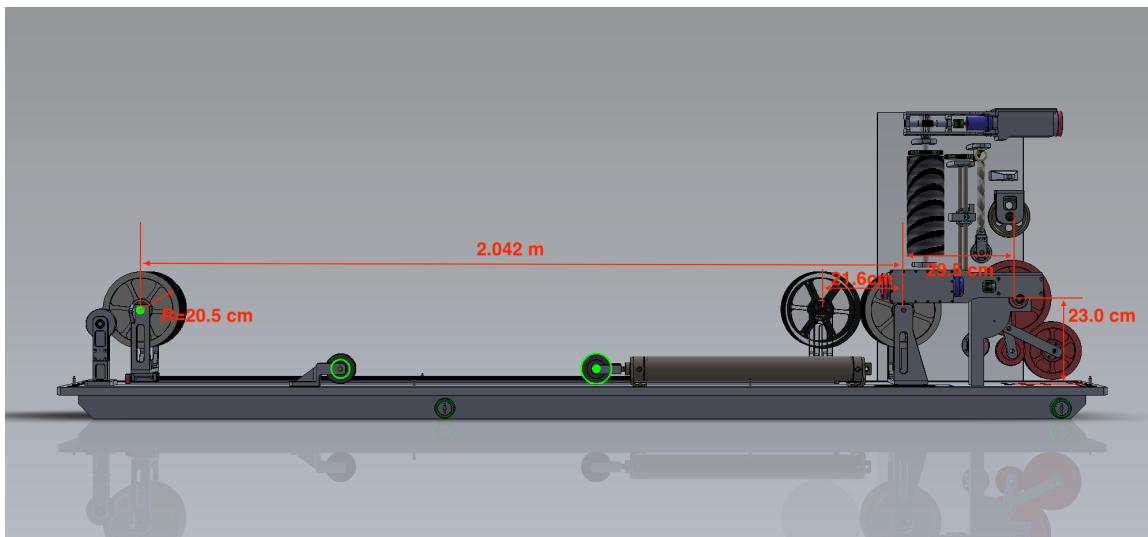
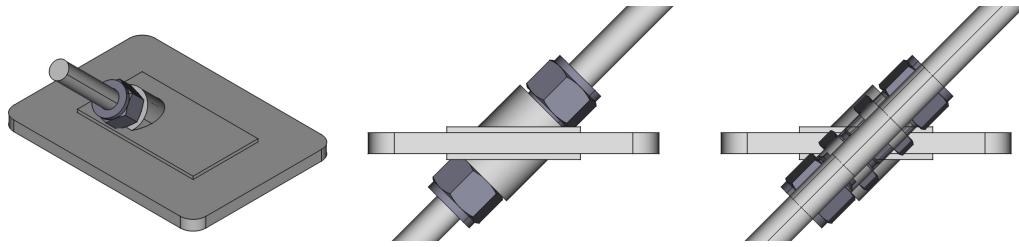


Figure 5: URM with the cover removed showing the minimum and maximum distance between the pulley blocks. The dimensions shown set the minimum and maximum umbilical lengths contained in the URM during deployment and after full retraction.



(a) Orthographic view of the feedthrough plate      (b) Sideview of feedthrough plate      (c) Cutaway view through the bulkhead and umbilical

Figure 6: A representation of the feedthrough plate. Measurements are estimated, but the dimensions of the bulkhead fitting are correct. This shows the degree of milling required to incorporate the bulkhead fitting.

- 2. Wipe down the end of the umbilical that is to be secured to the feed-through with cleanroom wipes and UPW.
- 3. Identify the location of the feed-through on the umbilical. This should be 3 meters from the end of the umbilical to provide space to produce the fibre bundle on the standing end of the umbilical and the same on the running end of the umbilical while allowing enough length to reach the bottom of the AV.
- 4. String a Swagelok nut, and ferrule onto the umbilical oriented to secure in the direction of the standing end.
- 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 oriented so that the nut can tighten against the bulkhead fitting.
- 8. Place the feed-through on the umbilical at 3 meters from the end of 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. Note: there is a difference of 6 meters between the capacity of the URM and

the total length of umbilical required to reach the bottom of the AV so additional length can be taken if necessary.

- 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 (already in place) 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.

### 3.10 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. Workers must don cleanroom gloves before handling the rope. A first pair must be rinsed with UPW before donning a second pair which must also be rinsed.
- 2. Collect roughly 40 m of Tensylon rope from the spool in the DCR. Fold the rope into a plastic bag to avoid knotting.
- 3. Clean the rope in an ultra sonic cleaner with a set of stainless steel weights and hooks. Cleaning will include one cycle with a mixture of nucleon and UPW and two rinse cycles using just UPW.
- 4. Once the ultra sonic cleaning is complete, the rope should be folded loosely in a plastic bag and dried out using a flow of nitrogen.
- 5. Tie a 30 cm segment of the cleaned rope from the eye-bolt supporting the sprung pulley to the pulley itself through the center of the spring. This will limit maximum extent of the spring.
- 6. Thread the rest of the cleaned rope through the hole at the top of the URM rope drum and secure the rope around the axis of the drum using a folded bow-line (see Fig. 7b for instructions).
- 7. 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.

- 8. 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.
- 9. With one person holding the rope tight to the spool so that it does not fall off, 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.
- 10. The slack through the rope system must be removed by tying cleaned rope hook to the rope and hanging a cleaned weight from the hook to maintain tension on the system until the source connector is secured to the rope.

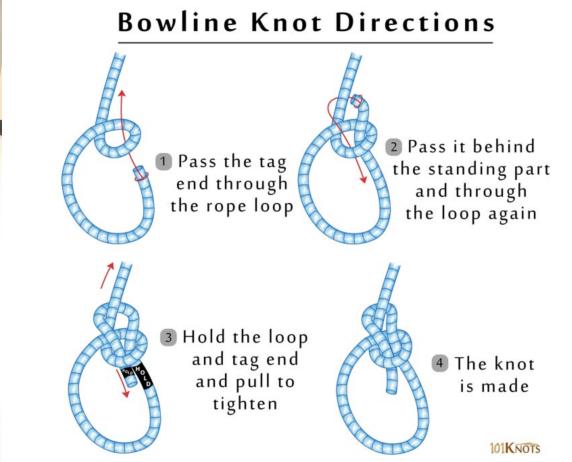
### **3.11 Cover Installation**

The following procedures to be completed with the URM in the following state

- The URM on the URM cart.
- The URM cleaning is complete.
- The umbilical and rope are installed on the URM.
- The electrical and gas distribution systems have been checked and are in working order.

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

- 1. Wipe the inside of the URM cover with UPW and clean room wipes.
- 2. Remove the bumpers from the edge of the URM flange.
- 3. 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.
- 4. Check that the o-ring remains properly installed and free of nicks or cuts.
- 5. Insert the standing end of the umbilical (the one on the outside of the feed-through plate) into the appropriate opening in the URM cover from beneath (it is likely that this will be easier if the URM is on its side after cleaning).



(b) Instructions for the knot to be used to secure the URM rope. Note a slightly easier method

(a) Rope system for a side rope motor in this context is to tuck the standing end back box using a URM spring to support the through the loop at step one to make a bight sprung pulley. The URM rope system is Then the running end is passed through the bight identical except that the umbilical exit and the loop can then be placed in the desired port on the URM is in the location of location before the standing end is pulled tight to the final pulley on the rope box. recreate the loop in step 3, above.

Figure 7: Details for the rope installation

- 6. With four people (one on each corner) lift the cover over the back plane of of the URM.
- 7. A fifth person should watch the feed through plates to make sure they do not get caught on the cover as it descends. A sixth person should pull the umbilical out of the URM cover as it is lowered so that the fibre is not in risk of kinking. The remaining workers may then carefully lower the URM cover by the flange to provide an appropriate angle. It must be stressed that the motor box cover must go down straight over the back plane or it will get hung up.
- 8. 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.
- 9. 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.
- 10. 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.
- 11. Connect the vacuum leak checker to one of the flange VCR ports connecting to the inter o-ring space. 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, using the o-ring from URM5. Then the flange can be reassembled as before.

### 3.11.2 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. This is done so that they will stick in the o-ring grooves when the plate is held vertically. The operator should hold the plate by the feed-through and inter o-ring VCR ports against the inside of the cover once the o-rings are placed to ensure that they do not have a chance to leave the groove. Every effort should be made to avoid letting the

o-ring drop into the URM cover as it will be extremely difficult to retrieve it. The best way to achieve this is to always keep a grip on the electrical feed-through and maintain pressure against the cover.

- 3. A second operator should slightly grease the threads (only) of the 26 M4 screws with Super Lube. That operator must change outer gloves after the screws are greased to reduce cross contamination.
- 4. The second operator will 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. While the first operator holds the flange against the inside of the cover to reduce the chance of the o-ring falling out, the second operator must start all of the screws in their blind holes, but not tighten them.
- 5. With the first operator still maintaining pressure between the plate and the cover, the second operator must 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 by 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. The first operator can now release the plate.
- 7. Connect the helium vacuum leak checker to one of the VCR ports on the flange connecting to the inter o-ring space. 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.

### **3.11.3 Install the umbilical feed-through**

- 1. One operator must lightly grease the 14 M4 cap screws required for the installation of the umbilical feed-through plate with Super Lube. Change outer gloves.
- 2. A second operator must extract the o-rings for the umbilical feed-through plate from its storage bag and lubricate the o-rings with LAB. Hold the o-rings so they do not touch any other surfaces.
- 3. The first operator must pull the umbilical through the o-rings while the second operator carries the o-rings towards (but not touching) the URM cover.

- 4. The first operator must carefully extract the umbilical feed-through from inside the cover. The second operator must install the o-rings while the feed-through is held by the VCR ports by the first operator. The second operator should change outer gloves after the o-rings are in place
- 5. The first operator must pull the umbilical feed-through plate against the inside of the cover to keep the o-rings in place.
- 6. The second operator must start all of the screws in the threaded holes in the plate.
- 7. While the first operator maintains pressure between the plate and the cover, the second will 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. The first operator can now release pressure on the plate.
- 9. Connect the vacuum leak checker to one of the VCR ports on the umbilical feed-through flange connecting to the inter o-ring space. 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.

### 3.12 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. This is a six person task led by a calibration expert.

- 1. Wrap the gas outlets on the bottom of the URM with plastic encapsulated foam to cushion any contacts with the gas manifold through the following procedure.
- 2. Two workers orient the URM cart with respect to the lifting table so that front of the URM is facing the back (handle side) of the lifting table.
- 3. Lift the URM until it is at the same height as the lowest height of the lifting table.
- 4. Engage the breaks on the lifting table and the URM cart. Two workers must brace the lifting table so that it does not move through the next steps.
- 5. Detach the chains securing the URM to the cart.

- 6. Push the URM from the cart to the lifting table. Two workers should hold the URM cart and push the URM forward while two more workers guide the URM onto the lifting table.
- 7. The workers holding the cart must be sure to stop the forward motion of the URM before the gas connections reach the URM cart. The URM center of mass should be over the lifting table at this point.
- 8. The rear workers must hold the URM back end up while the two workers steady the lifting cart remain in place. The two remaining workers should lower the URM cart and remove it from the working area.
- 9. The rear workers and the free workers must finish moving the URM onto the lifting cart, while the workers holding the lifting table stay in place. The final location for the center of mass is shown in Fig. 9a.
- 10. Once the URM is in position secure the URM to the lifting table using the appropriate chains and turnbuckles.
- 11. 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.

### 3.13 Source Tee Installation

The bellows and associated hardware arrived in the SNOLAB underground lab in March of 2022. They were cleaned in the control room, double bagged (using large clear plastic bags) and stored in the DCR over the course of two nights.

The source tee installation must be conducted before the source connector is installed. The umbilical path hole, while wide relative to that for the water URMs is not wide enough for the pulley assembly of the source connector. The source tee cannot be installed until the URM has been moved to the URM lifting table.

Required for this procedure are

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

- 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. Carefully place the lower end of the umbilical and the weighted rope through the center of the tee-flange. Avoid getting any of the lubricant on either the rope or the umbilical.
- 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. Orient the tee 60 degrees from the backwards direction of the URM to the right, so that the view port will face in the SSW direction when the URM is mounted. 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 inter o-ring 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.

### 3.14 Source Connector Installation

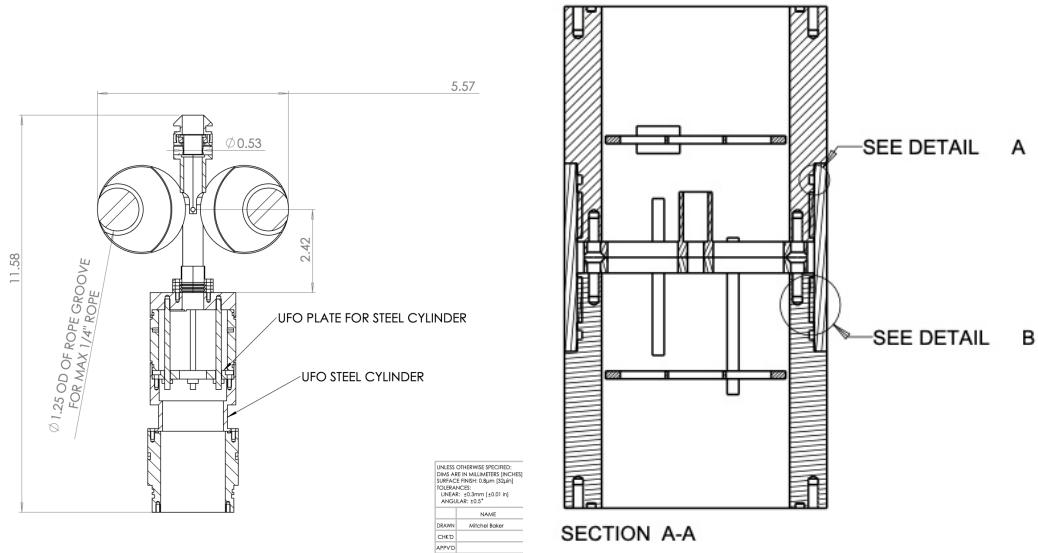
Assembly of the source carriage requires the cleaned and installed umbilical and central rope. The source connector was machined and electro polished at U of A before it was sent to Sussex for the UFO construction and testing. It was then sent to Queen's with the Laserball source before coming to Sudbury when the Laserball fill tests began. It was cleaned with all of the Laserball parts prior to the initial fill.

A limited assembly test showed that the source carriage design that included the UFO would not work because the acrylic piece had warped, so that the diameter of the lip on both sides would not admit the top and bottom plates. For this reason, a new top plate has been designed that provides a platform to clamp onto the umbilical which can be bolted to the source connector and the rope pivot. The following installation procedure assumes the installation of the new plate.

The procedure also assumes that the fibre bundle has been consolidated in an epoxy filled pipe, the procedure of which will be described elsewhere and should be done by

specific laserball experts. The procedure of producing that fibre bundle involves sanding the end so steps must be taken to protect the URM interior during that process and clean the umbilical after. The procedure can in principle be completed without the fibre bundle in place in preparation for AmBe source deployment, but the end of the umbilical must be left free.

- 1. Wet the bottom meter of umbilical with LAB
- 2. Pre-wet all of the screws with LAB
- 3. Install o-rings on the upper source connector body
- 4. Thread the umbilical through the pivot
- 5. Thread the umbilical through the three pressure plates with a teflon o-ring following each one.
- 6. Thread the umbilical through the top plate of the source connector.
- 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. If the fibre bundle has been completed there should be 3 cm of Tygothane cladding below the top plate followed by 10 to 30 cm of fibre bundle. If the fiber bundle is not complete there should be 5 cm of Versilon clad fibre bundle.
- 8. Couple the end of the fibre bundle to the source connector plate if the fibre bundle is complete. Connect the wires to the further electrical feedthroughs on the source connector plate.
- 9. Secure the source connector plate to the source upper source connector body with 8 M3 screws.
- 10. Fasten the upper source connector plate to the top of the upper source connector body using 8 M3 screws. These screws must include holes for retaining wire. The retaining wire should be installed at this time.
- 11. Tighten the pressure plates against the top of the source connector top plate. using six #4-40 1 inch length screws until there is an equal gap less than 1 mm between all of the plates. The mounting screws must have a hole for a retaining wire, and that wire should be installed after
- 12. Secure the source pivot pulley support plates to the UFO assembly using four M3 screws. Retaining wire should be strung between the screws, which should also be equipped with holes to accommodate the wire.



(a) The source pulley assembly with the UFO and top source connector.

(b) The source connector

Figure 8: The original plan to terminate the umbilical includes the source pulley assembly, a umbilical flasher object and a source connector as shown

- 13. Tie the central rope to the rotating collar on the pivot assembly underneath the rope groove using a bowline tight against the barrel of the pivot. This should be done using the alternative method of tying the knot described above and should be tied so that the knot cannot go above the edge of the rope groove on the barrel.

### 3.15 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. Clean again with Nuclean and water in a 1:50 dilution. Rinse inside and outside with UPW twice. Wipe clean with UPW and lint free wipes.

- 2. Fill the pot with 20-30 L of scintillator plant LAB. Retain a sample for liquid particle count for reference.
- 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.
- 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. **The umbilical cannot be released until the URM stop command is issued.** 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 so that all of the umbilical that can be deployed into the AV will be exposed to the LAB
- 8. Leave the umbilical in the LAB for 1 hour.
- 9. When the umbilical cleaning is complete, ensure that the rope is in constant tension mode. Lower the umbilical cleaning vessel to the floor.
- 10. Submit a sample of the LAB for liquid particle counting. If the count does not conform to the particle standard relative to the reference sample, remove the LAB from the cleaning volume using a peristaltic pump and fill the cleaning volume with clean LAB and soak the umbilical for an additional hour.
- 11. Connect the URM LAB drain ports to a vessel to collect the LAB as it drips off of the umbilical.
- 12. 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.
- 13. Don PE gloves over the clean-room gloves. Watch the umbilical and try to remedy any tangles with a minimal amount of manipulation of the umbilical.
- 14. 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.
- 15. 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.

### **3.15.1 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.

The bellows was transported with three support struts welded onto the support ring at the top and the bottom of the o-ring. These support struts were painted yellow by the manufacturer. The paint can be rubbed off with effort so there is concern that it could spread in the DCR. For this reason the struts were wrapped with JamMek plastic to prevent such contamination during storage. The struts will have to be removed to allow the bellows to be used, but will be kept through installation for stability.

For installation of the source bellows the following items are required

- 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
- 1. Clean and install the Genie lift plate on the forks of the Genie lift if is not already there.
- 2. Place the Genie lift near the motor box end of the URM 90 degrees to its axis.
- 3. Cut and secure a piece of plastic onto the plate to prevent damage to the the bottom flange sealing surface.
- 4. Carefully position the bellows on the Genie lift and move the bellows underneath the source tee flange with the holes lined up between the bellows top flange and the rotatable flange. Always have one person holding the bellows so that it does not tip.
- 5. Place the o-rings in the groove on the top bellows flange.
- 6. 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 and washers onto the bolts until the bolts are in contact with the lower surface of the flange.
- 7. 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.
- 8. Tighten the bolts in a star pattern so that the bellows o-rings are compressed.

- 9. Install turn-buckles and cables between the bellows support rings. Tighten the turn-buckles until the wires are just tight between the support rings. These turnbuckles are intended to support the gate valve once it is installed.
- 10. Connect the vacuum leak checker to one of the top flange inter o-ring 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.
- 11. Remove the support struts with bolt cutters or a hack saw breaking the top welds first and the bottom welds second. The strut must be held by a second person so that its movement is controlled. If a hack saw is used the bottom of the bellows must be blanked off to protect the interior of the URM and a vacuum cleaner must be run next to the hack saw blade to limit the spread of dust in the DCR.
- 12. Bag the struts and remove them from the DCR at the first opportunity.

### 3.16 Gatevalve Installation

The gate valve arrived from the supplier in the fall of 2019. It was subsequently sent underground in the shipping packaging in the summer of 2021. Standard car wash procedures were followed when the gate valve entered the lab including a full cleaning after removing the packaging and swipe tests to confirm that surface contamination was removed. Following that it has been stored in the DCR and wiped clean several times.

This procedure can be done after the bellows is installed on the URM.

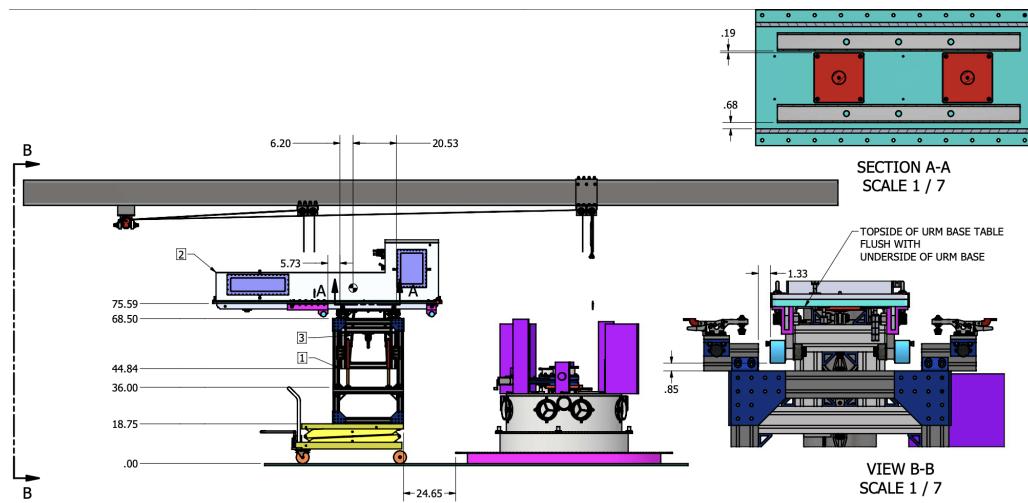
- 1. Clean and install the Genie lift plate on the forks of the Genie lift if is not already there.
- 2. Cut and secure a piece of plastic onto the plate to prevent damage to the the bottom flange sealing surface.
- 3. Maneuver the Genie lift to the shelf holding the 10 inch gate valve. Transfer the gate valve to the Genie lift.
- 4. Lower the gate valve as low as the Genie lift allows
- 5. Place the gate valve below the bellows.
- 6. Install the o-rings in the groove on the top side of the gate valve.
- 7. 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.

- 8. 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.
- 9. Connect the vacuum leak checker to one of the bottom flange inter o-ring VCR ports (with the other blanked off). Open the gate valve before starting the vacuum cycle on the leak checker. 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 gate valve re-installed with a successful leak check.

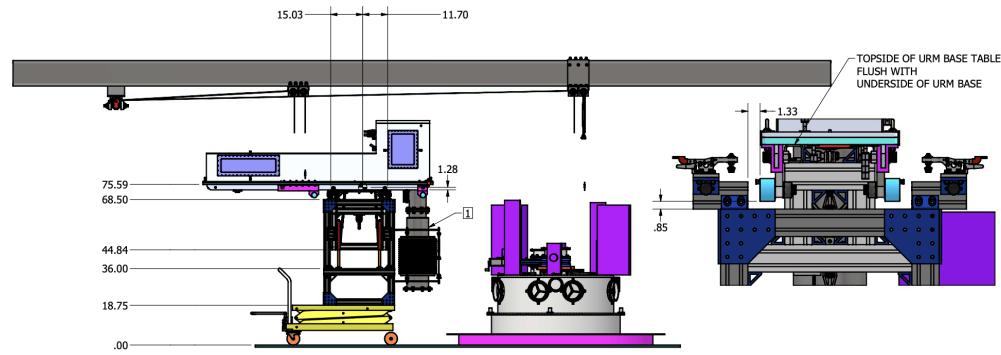
### 3.17 URM Gas Connections

Once the umbilical, gatevalve, bellows and cover are installed on the URM, a nitrogen atmosphere must be generated inside the URM. A 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 meant 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

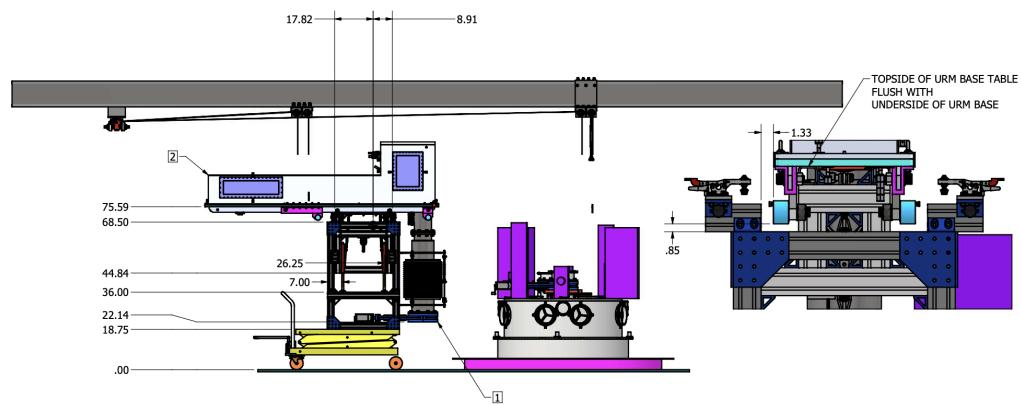
1. URM standing alone (off UI)
  - 1. Nitrogen source valve closed
  - 2. Gate valve closed
  - 3. Bag to URM path valve open
2. URM flushing (off UI)
  - 1. Nitrogen source valve open
  - 2. Nitrogen source connected and supplying gas
  - 3. URM Gate valve open
  - 4. Bag to URM path valve closed
3. URM connected to UI before deployment
  - 1. Bag-to-URM path valve open
  - 2. Nitrogen source valve closed



(a) URM on cart prior to bellows installation.

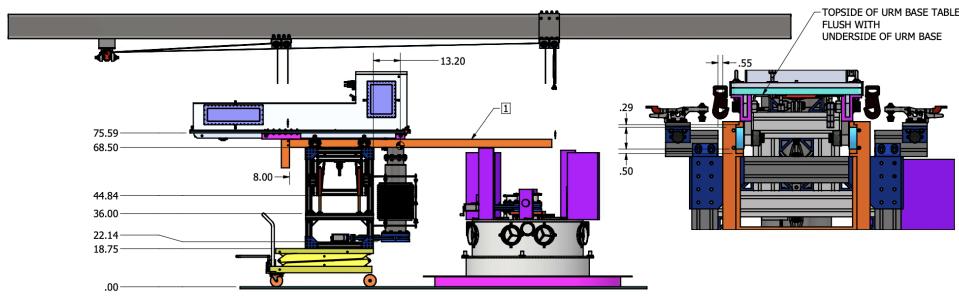


(b) URM on cart with the bellows installed.

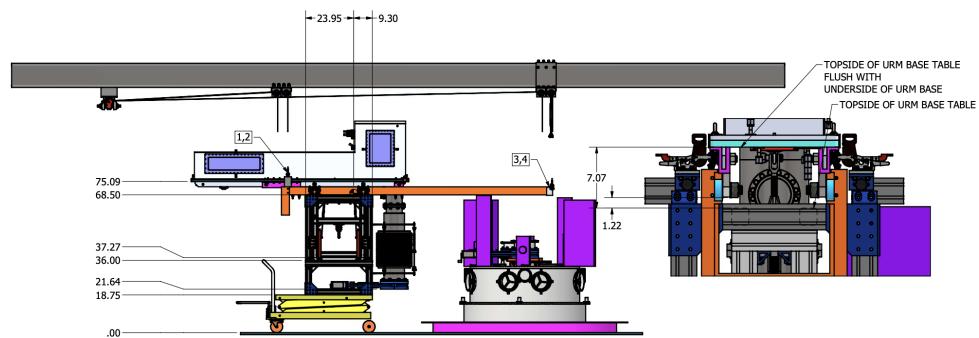


(c) URM on cart with gate valve installed.

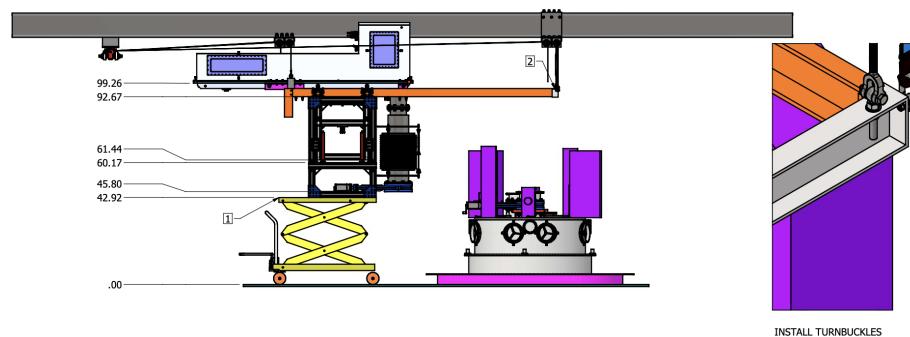
Figure 9: Preparing the bellows and gate valve for use



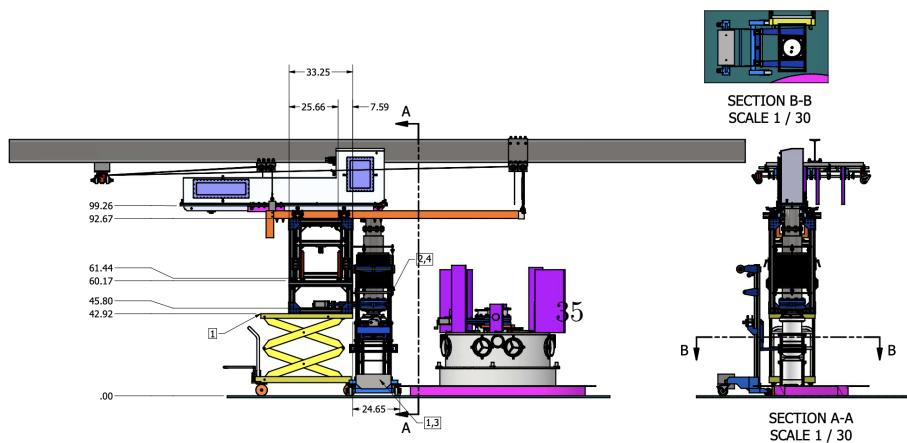
(a) Loading the rails onto the URM prior to lifting



(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 10: Lifting the URM to Operating Height

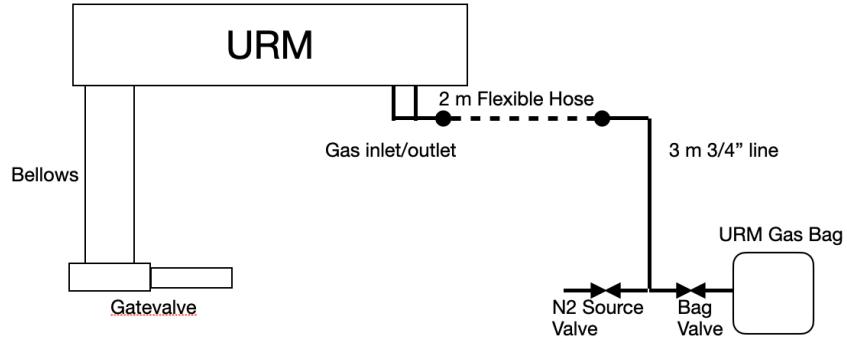


Figure 11: Flow diagram for the URM gas connections

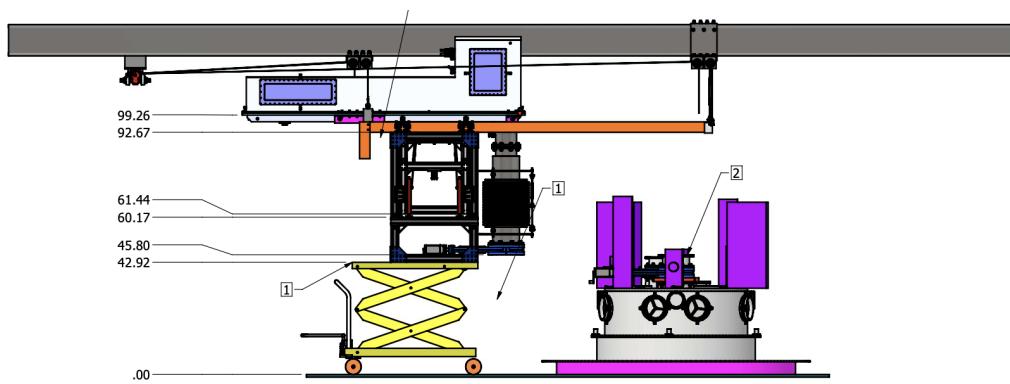
- 3. URM Gate valve closed on top of nipple assembly
- 4. UI gate valve closed
- 4. Pump-purge the nipple assembly before deployment
  - 1. Bag-to-URM path valve open
  - 2. Nitrogen source valve closed
  - 3. Nitrogen source connected to pump purge board
  - 4. URM gate valve closed
  - 5. Pump purge board input and extraction lines connected to nipple assembly
  - 6. UI gate valve closed
  - 7. To run the pump purge procedure on the nipple assembly volume between the gate valves before they are opened;
    - Take note of the pressure on the board gauge for the nipple assembly
    - Double check that the gate valve state indicators are consistent with the gate valve being closed.
    - Open a VNC instance into a DeltaV computer to monitor the UI dp.
    - Pump out the nipple assembly at 5 L/min for 5 minutes. Continue monitoring the UI dp to check for anomalies and stop if there is an unexpected drop in pressure. Resume if the change is determined to be unrelated to the pumping procedure.
    - 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.  
Continue monitoring the UI dp for pressure excursion
  - Repeat 3 times
5. Deploying the source after pump-purge is complete
- 1. Bag-to-URM path valve open
  - 2. Nitrogen source valve closed
  - 3. Pump-purge board disconnected
  - 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 carefully determine why the variation occurred. Further review will be necessary.
  - 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.

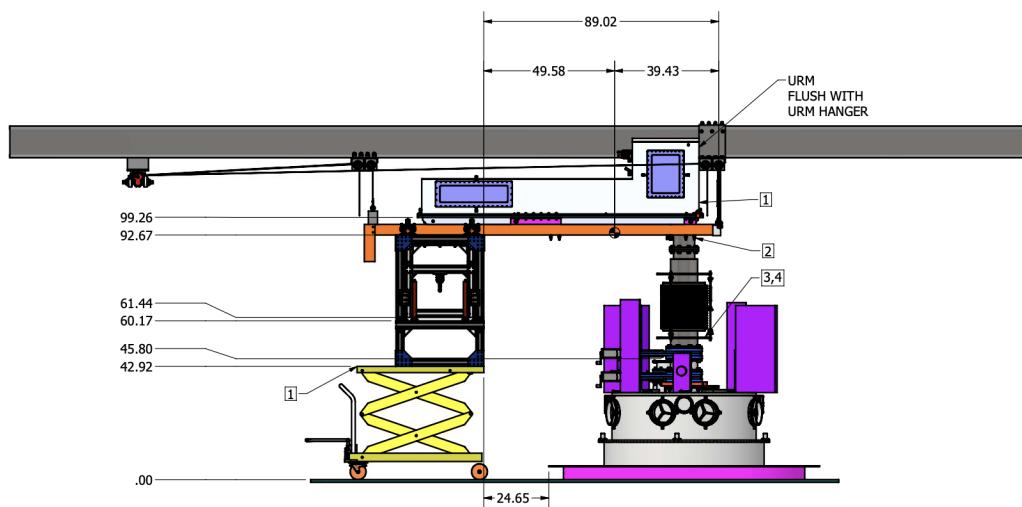
### 3.18 Field Testing the URM

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.



(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.

Figure 12: URM Deployment positions

To deploy the source the operators must follow the engineer approved lifting and hanging procedure as follows;

- 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 to its maximum height 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.
  - Bolt the rail front plate onto the rails using the 1/2" bolts provided.
  - Lower the URM so that it is supported on the rails by its wheels by turning the crank counter clockwise. Lock the inner table to the outer table using the eight yellow levers.
  - Clamp the rails onto the lifting cart with the four 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. Set the safety stop bars in place at the base of the table.
- 8. Undo the turnbuckles chaining the URM to the cart. Unlock the inner table and lower it until it is flush with the surface of the outer table.
- 9. Remove the cover from the 10 inch gatevalve nipple assembly and check 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 3.17).
- 17. Open the bellows gate valve
- 18. Check the differential pressure between the UI and Deck using DeltaV
- 19. Slowly open the UI gatevalve. Actively monitor the differential pressure between the UI and Deck using DeltaV. If there is a change in the differential pressure for between the deck and the AV, close the gatevalve. Check that the cover gas bag for the URM is connected and responding to changes and that the UI cover gas bag also responding within their nominal operating range. Once those checks have been completed with the participation and approval of a cover gas expert, and all of the systems are behaving properly, resume opening the gate valves. 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.

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.3.9	Machine shop
1	<input type="checkbox"/> Remove URM cover; Sec.3.4 <input type="checkbox"/> Electrical systems check; Sec.3.5 <input type="checkbox"/> Install umbilical feed-through plate on umbilical; Sec.3.9 <input type="checkbox"/> Install umbilical on URM; Sec.3.8 <input type="checkbox"/> Install rope on URM; Sec. 3.10 <input type="checkbox"/> Install URM cover; Sec.3.11	4 workers
2	<input type="checkbox"/> Electrical systems check; Sec.3.5 <input type="checkbox"/> Transfer URM from cart to lifting table; Sec.3.12 <input type="checkbox"/> Install source tee flange; Sec.3.13 <input type="checkbox"/> Final Umbilical cleaning; Sec.3.15 <input type="checkbox"/> Install source connector on umbilical; Sec.3.14 <input type="checkbox"/> Install source bellows; Sec.3.15.1 <input type="checkbox"/> Install gate valve; Sec.3.16	6 workers
3	<input type="checkbox"/> Purge the URM and connect to the cover gas system; Sec.3.17	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.3.17 <input type="checkbox"/> Field test the manipulator system.; Sec.3.18	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