Siderope O-ring Remediation

Ryan Bayes

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1 Introduction

The side rope boxes are a part of the SNO+ calibration system consisting of four large motor boxes each containing the rope spools coupled to an external motor, and connected to the UI through a 1/2 inch tube by way of one of four load cell boxes. As such, they are integrated into the SNO+ UI cover gas space. Two of the motor boxes, the North Motor box and East Load Cell box seals have not shown leaks with a vacuum leak checker in excess of 10^{-4} mbar L/s where the expectation is that the leak should be less than 10^{-7} mbar L/s. Problems have also been observed in both the South motor box and load cell boxes. The results of the previous leak checking campaigns are shown in table 1. The North motor box, East load cell box and South siderope system o-rings have been replaced. Of these the North Motor box and the South Load cell box show leaks. It is suspected that the North Motor box issues are due to a warped flange or cover, and so it is unlikely that further improvements beyond activly feeding nitrogen through the flange. Some residue was observed on the flange of the South load cell box when those o-rings were replaced, so the goal at this time is to remove this residue and replace the o-rings on this box a second time before replaceing the cover and leak checking the motor box.

The measures taken during the previous seal remediations were demonstrated to be successful at suppressing radon to well below DCR background levels. This procedure is described in section 4.1. Figure **??** shows the radon monitor data collected between April and July of 2025. For reference Deck air injected into the radon monitor directly will produce a rate of 1.3 Hz, whereas the expected operation produced an increase in rate of approximately 0.01 Hz; more than a factor of 100 reduction.

2 Definitions

- **AV**; Acrylic Vessel - The centre of the SNO+ detector containing the active scintillator volume
- **AV neck** - A 7 metre long cylinder that connects to the spheroidal main body of the AV.

Table 1: Summary of previous leak checking campaigns as applied to the calibration side rope systems

Feature	Status	Leak (mbar L/s)	Date
East and west motor box	good	$< 2 \times 10^{-8}$	June 2023
West load cell box seal	good	$< 10^{-10}$	June 2023
South motor box outer seal	pass	5×10^{-7}	June 2023
South motor box inner seal	pass	1.4×10^{-7}	July 2024
South exten. box outer seal	fail	3×10^{-5}	June 2024
South exten. box inner seal	pass	2×10^{-9}	July 2023
North motor box	fail	$> 10^{-4}$	May 2023
North load cell box	pass	$< 10^{-9}$	June 2023
East load cell box seal	fail	$> 10^{-4}$	Oct 2019

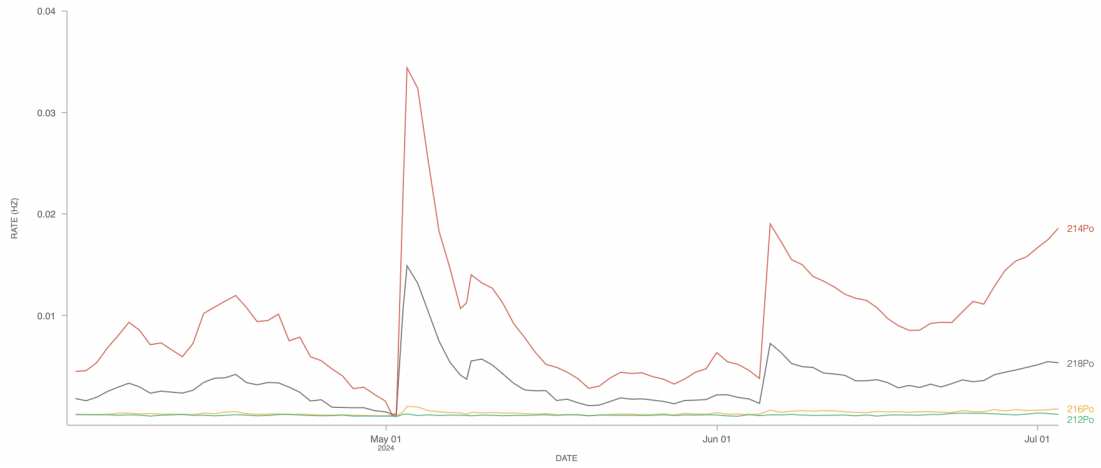

Figure 1: Radon Monitor data collected between April and July of 2024, showing the first siderope remediation procedure (May 1, 2024) and the second (June 5, 2024). The second is closer in scope to the procedure proposed here.

- **UI**; Universal interface - The cap on the top of the AV neck consisting of the lower UI through which tubes for recirculation and extracting samples from the AV are connected, and the upper UI through which ports for gas lines, level sensors and calibration equipment exist.
- **DCR**; Deck clean room - a tent in the centre of the SNO+ deck to isolate activities about the UI that may introduce contamination into the experiment from the rest of the lab. Is equipped with multiple hepa filters to circulate and clean the air that passes into the facility.
- **Bubblers** - Three gas lines that run into the UI through a bubbler flange which use gas pressure to determine the fluid level in the AV.
- **Neck tubes** - PMTs installed on the UI to veto events suspected of appearing in the neck. Contained in steel top-hats with a coaxial electrical feedthrough on top.
- **Radon monitor** - A 3 m^3 vacuum vessel used to measure levels of radon daughters in the cover gas volume. It is connected to the UI cover gas through a 1" diameter bellows hose.
- **Side rope motor box** - One of four boxes cantilevered off of the UI. Used to adjust the tension on the ropes used to guide sources in a 2-dimensional plane in the UI (either XZ or YZ). Necessarily connected to the UI cover gas through a 1/2" tube containing the side rope. All four motor boxes are equipped with quick connects to facilitate a clean connection to the UI cover gas space.
- **Side rope load cell box** - One of four boxes used to align the side rope with a feed through to enter the UI. So called because the original design called for a load cell to be included to provide a secondary measurement of the rope tension. The load cell is not connected into the manipulator system, however. Each load cell box is connected to the siderope motor box via a 1/2" inch tube with VCR connections on both ends. Each is further connected to the UI cover gas through the rope feedthrough. Two load cell boxes (East and South) are equipped with valves to allow for clean connections to the UI cover gas.

sectionPersonnel

- Task Lead: Ryan Bayes
- Second: Matt Depatie
- Cover gas expert: Aleksandra Bialek
- Cover gas monitor: Clara Dima (training required)

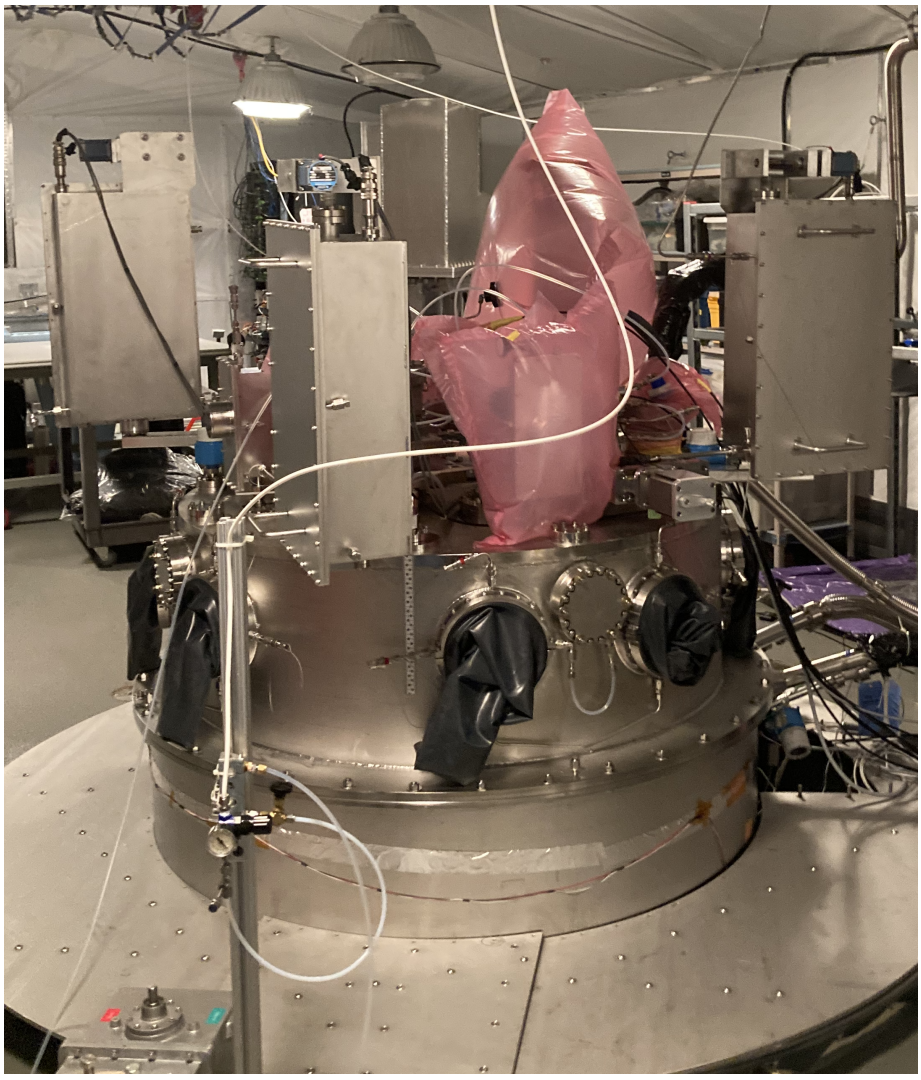

Figure 2: The UI with pink plastic nitrogen bags installed on the UI over the North Motor Box and the East Load cell box.

Figure 3: One of the motor boxes with an acrylic window installed to see the interior mechanisms.

3 Parts and Equipment List

- 2× TEV o-ring; 604mm × 2.6 mm
- 2× TEV o-ring; 596mm × 2.6 mm
- 2× TEV o-ring; 456mm × 2.6 mm
- 2× TEV o-ring; 449mm × 2.6 mm
- 88 hex cap screws for Motor box replacements 20mm × 1/4", ultrasonically cleaned
- 1 (or more) 3/16" Allen key
- 1 ratchet with 3/16" hex bit
- 1 1/4" torx hex bit (for removing stripped cap screws)
- 1 vice grip
- 1 mallet
- Helium leak checker
- Helium spray bottle (filled)
- Nitrogen source
- Flow meter
- Nitrogen regulator

4 Risks and Mitigation

The risk to workers through this procedure is extremely low. Workers should conduct themselves with the following considerations

- A potential oxygen deprivation hazard due to exposure to the cover gas. This can be mitigated by ensuring that workers keep their faces well away from open ports to the UI at all times (low risk, low severity)
- Workers must be aware of pinch points as the purpose of the activity requires sealing heavy metal steel surfaces against each other. (medium risk, low severity)
- The lids to the motor boxes are heavy, so steps to prevent musculo-skeletal distress should be taken (get help as required and potentially using mechanical assistance if necessary). (medium risk, low severity)

4.1 Radon Mitigation

The primary risks with these procedures are to the detector itself through radon ingress. The solution to this is to set up a monitored UI flushing path. This involves

1. Connect one of the load cell gas ports (the valve on the South or East load cell boxes) to a nitrogen source (preference is for a nitrogen bottle) through a regulator and a flow meter with a shut-off valve inside the DCR.

2. Connect an outflow line using a quick connect, a 1/4" teflon line and a 1/4" check valve and a pump.

3. Start monitoring the cover gas bag size and UI dp using Delta V. This should be done by a user not directly doing the work on the UI with a laptop situated in the DCR garage.

4. Start the nitrogen flow into the UI with a pressure less than 10 psi, and a flow less than 5 L/min

5. Match the nitrogen inflow with the pump outflow pressure. The UI dp must be in a range of $\pm$ 0.05 psi as read out on delta V using DPT-005. Adjustments to the dp should be made by using the valve before the flow meter to throttle the gas flow.

6. Continue monitoring the UI dp through the UI procedures.

7. The nitrogen flow should continue for 30 minutes after the motor box is closed and sealed.

8. Turn off the nitrogen flow followed by the pump in close sequence.

9. Disconnect the pump from the motor box and move to the next motor box.

To reduce the volume that can be exposed to contamination the radon monitor and UI cover gas bags should both be valved off. Both valves are metal seated valves, the operation of which requires a properly set and calibrated torque wrench as part of the closing procedure. The specifications for both are recorded on the valves themselves.

5 Procedure

5.1 Pre-Requisites

To conduct this procedure the environment must be prepared. This includes

- The DCR must be well cleaned. This includes vacuuming the floors, wiping down the DCR walls, and wiping down surfaces including shelves and UI

- Pass swipe tests on surfaces in the DCR such as the UI, shelving, and URMs.
- A benchmark of fewer than 200, 0.5μm dust counts per m^3 per second must be achieved in the DCR air.
- Prepare all tools for use in a secure location away from the UI, preferably on a trolley for ease of access. This includes wiping down all tools to reduce the chance of dust getting into the UI, ensuring that the required machine screws are available, and wiping down the o-rings.

These cleaning activities and tests must be done on the days prior and the day of the procedure. If at any point the tests fail, cleaning should be redone, and the tests should be done again.

On the day of the o-ring replacement, the o-rings themselves should have a liberal amount of vacuum grease applied to help them stick in the o-ring grooves during installation.

5.2 Emergency Procedures

If there is an all stations call with a side-rope box open

- Place a cover (the remnants of the North box nitrogen bag should be sufficient) over the open box to provide a dust shield.
- Change the nitrogen inflow to use a dewar (if using a bottle, switch to using the international).
- Maintain the nitrogen flow and monitor it from refuge through the all stations call

If there is an all stations call with a side-rope box cover partially in place (i.e. subset of screws installed) or between o-ring replacement procedures.

- Change the nitrogen inflow to use a dewar (if using a bottle, switch to using the international).
- Maintain the nitrogen flow and monitor it from refuge through the all stations call

Assess the situation at the end of the all stations, and determine if work can resume, or if the UI must be put into a safe state (i.e. Cover-gas bags reconnected) until next the working day.

6 South Load Cell Box Remediation

1		Remove the cover from the South load cell box by systematically removing the screws from the cover. One or more screws may be stripped, so use the torx bit or vice grip to extract those cap screws.
2		Remove the o-rings. The TEV o-rings should be considered single use parts.
3		Examine the surface of the flange. The suspicion is that masking tape residue has been left on the load cell box flange based on the earlier attempt and that is responsible for the current leak rate.
4		Replace the TEV o-rings with the new load cell box o-rings. There may be some resistance as the o-ring is a tight fit.
5		With one worker holding the box cover, a second worker starts installing the new screws in the cover at the corners. Once the corner screws are started, the cover is eased into place, taking care that the o-ring does not roll or leave their groove. The corner screws tighten should be then be tightened and the remaining screws can be put into place. All the screws should be tightened using a star pattern.
6		Check the seal using the helium leak checker. • Open one of the inter-o-ring seal VCR ports and connect it to the leak checker (ensuring that the opposing VCR plug is in tact). • Start the leak checker. Once the turbo pump activates (allowing "fine" measurements to be taken) systematically spray each of the edges with helium looking for the maximum leak rates on each edge. • If a good vacuum cannot be achieved by the leak checker or the leak rate on any particular edge is less that 10^{-7} mbar L/s, stop the leak checker and tighten the screws again. • Repeat as necessary.

6.1 Procedure time estimates

For guidance, it is expected that the following procedures will take the following time.

- Remove cover screws: 5 minutes
- Time with direct gas path open to UI: 2-5 minutes to examine, remove, and replace the o-ring, 5-10 minutes to examine and clean the flange, for a total of 7-15 minutes
- Replace cover screws: 5 minutes
- Flush the side rope box 30 minutes

- Leak test the side rope box 30 minutes (can be done at the same time as flushing).