Liners & Seals

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The SNO$^{(+)}$ Experience

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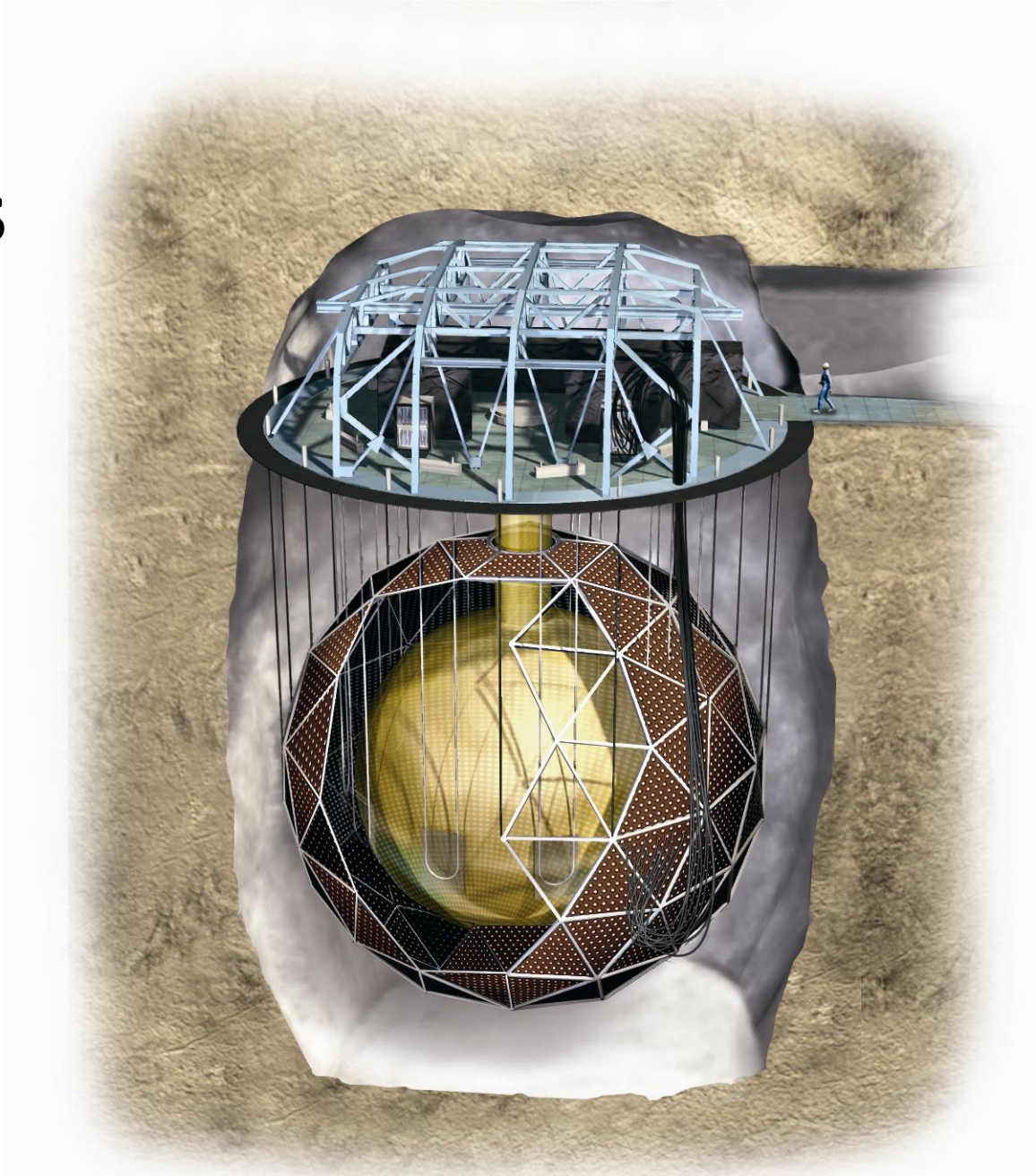

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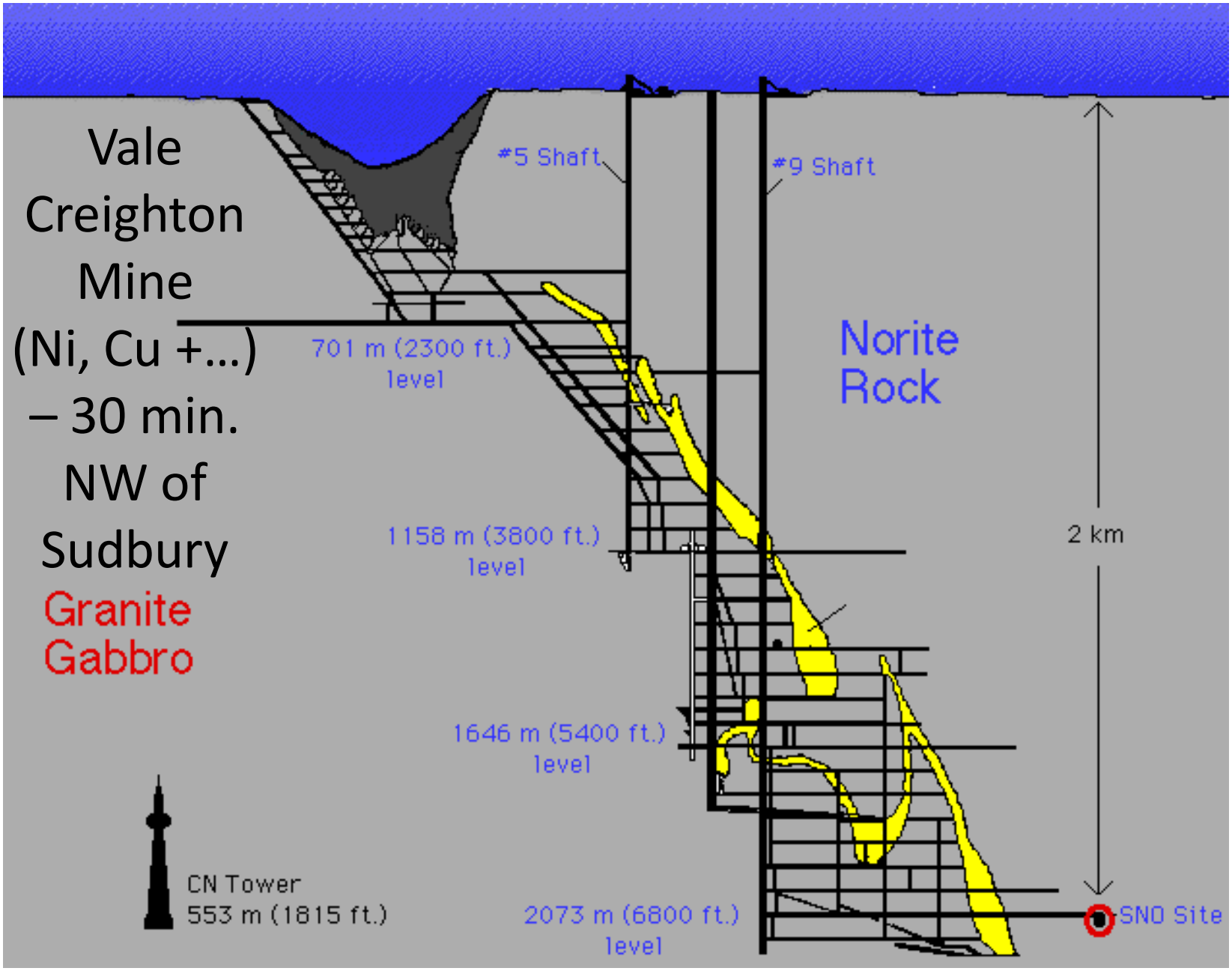

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Creighton Mine

- hardrock mine (Sudbury Basin - Canadian Shield)
- no natural groundwater below ~ 1000 ft. depth
- at 6800 ft level (6000 mwe) – 70 muons/day inside PMT sphere
- granites can have up to 75 ppm Th and 25 ppm U, so chosen SNO location is in norite (hanging wall)
- norite rock – 5.5 µg/g Th, 1.1 µg/g U
- concrete layer – 2.4 µg/g Th, 1.2 µg/g U
- target ^{222}Rn diffusion $\leq$ 12 atoms/m^2.hr into water (requires ~ $2x10^{-7}$ blocking factor for liner)

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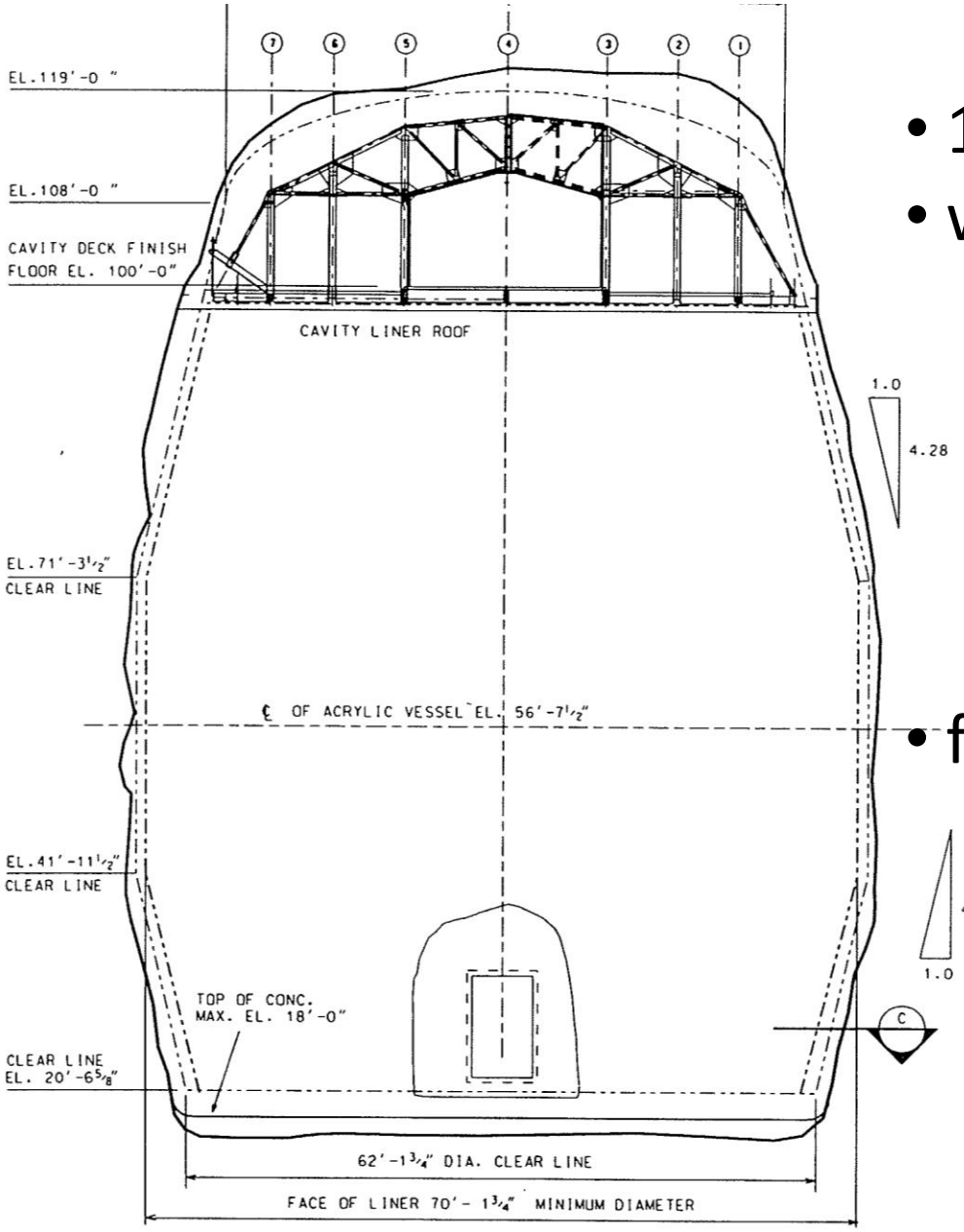
The SNO Cavity



- 100 ft high, 72 ft max. diam.
- walls (22,000 sq.ft.)
  - rock/cable bolts,
  - ground control shotcrete
  - geotextile drainage layer
  - troweled 6" thick smooth concrete surface
- floor (4000 sq.ft.)
  - rock bolts
  - poured concrete (variable thickness up to 3 ft.)
  - geotextile drainage 1 ft. below poured floor, with drain to sump system.

Cavity water capacity
~ 9000 tonnes

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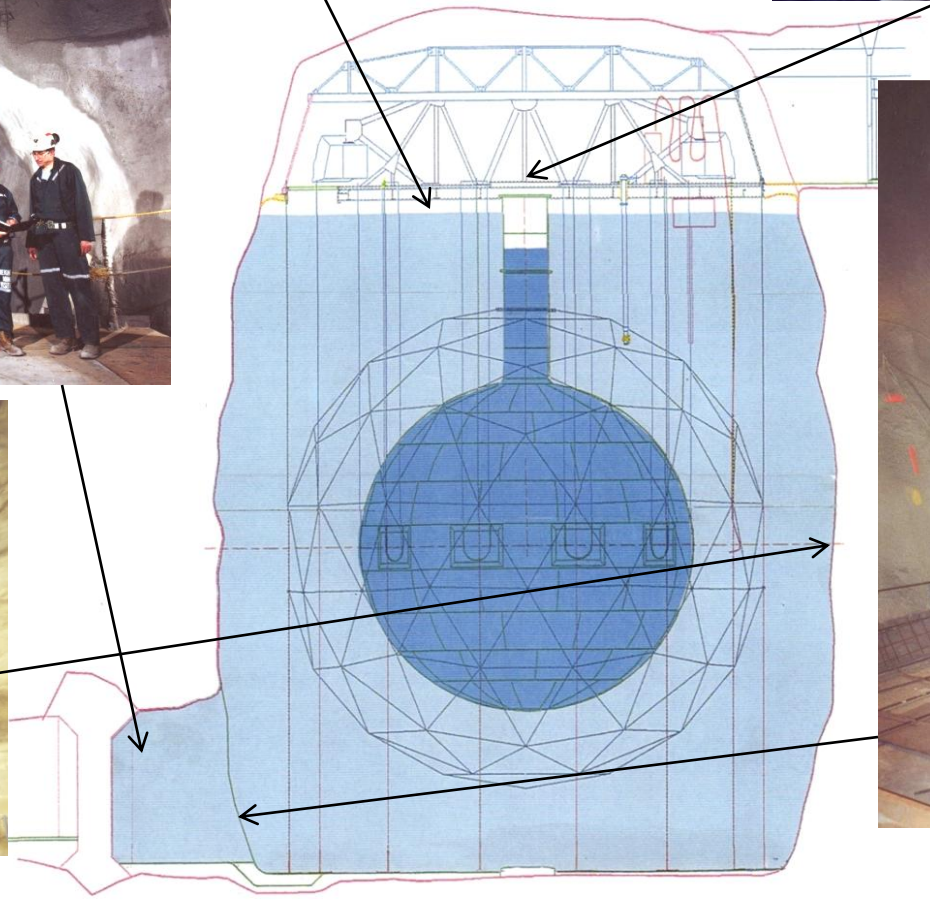
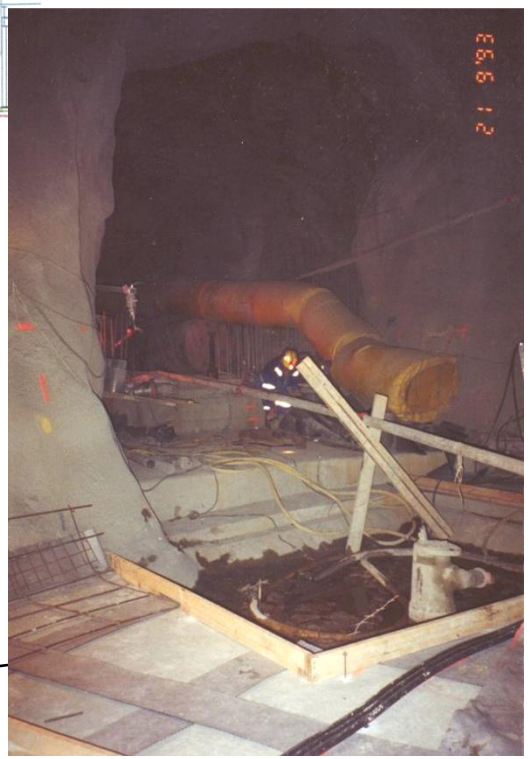
SNO Cavity





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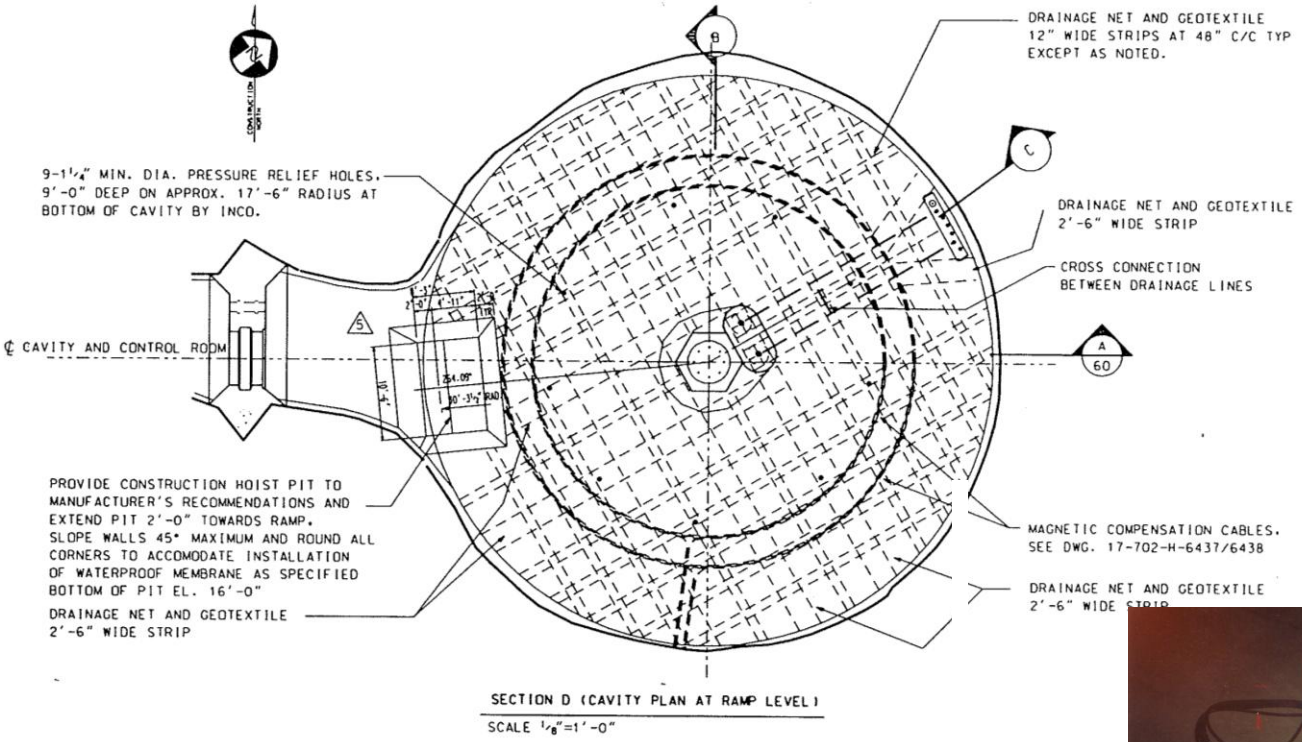
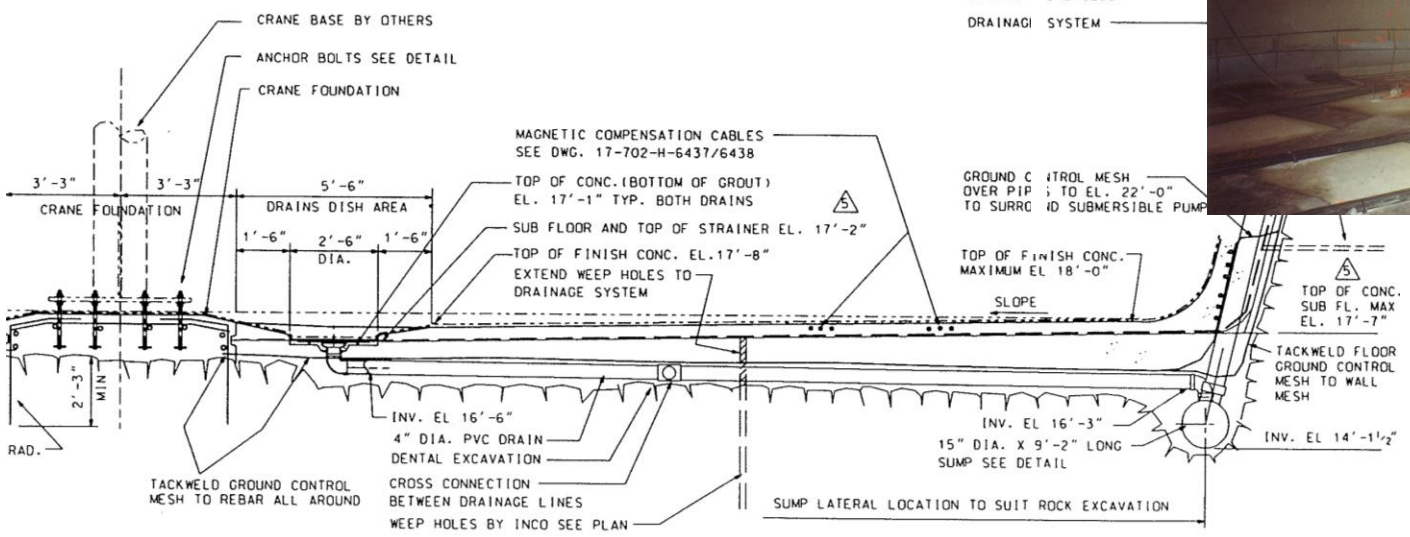
SNO Cavity Floor Layout





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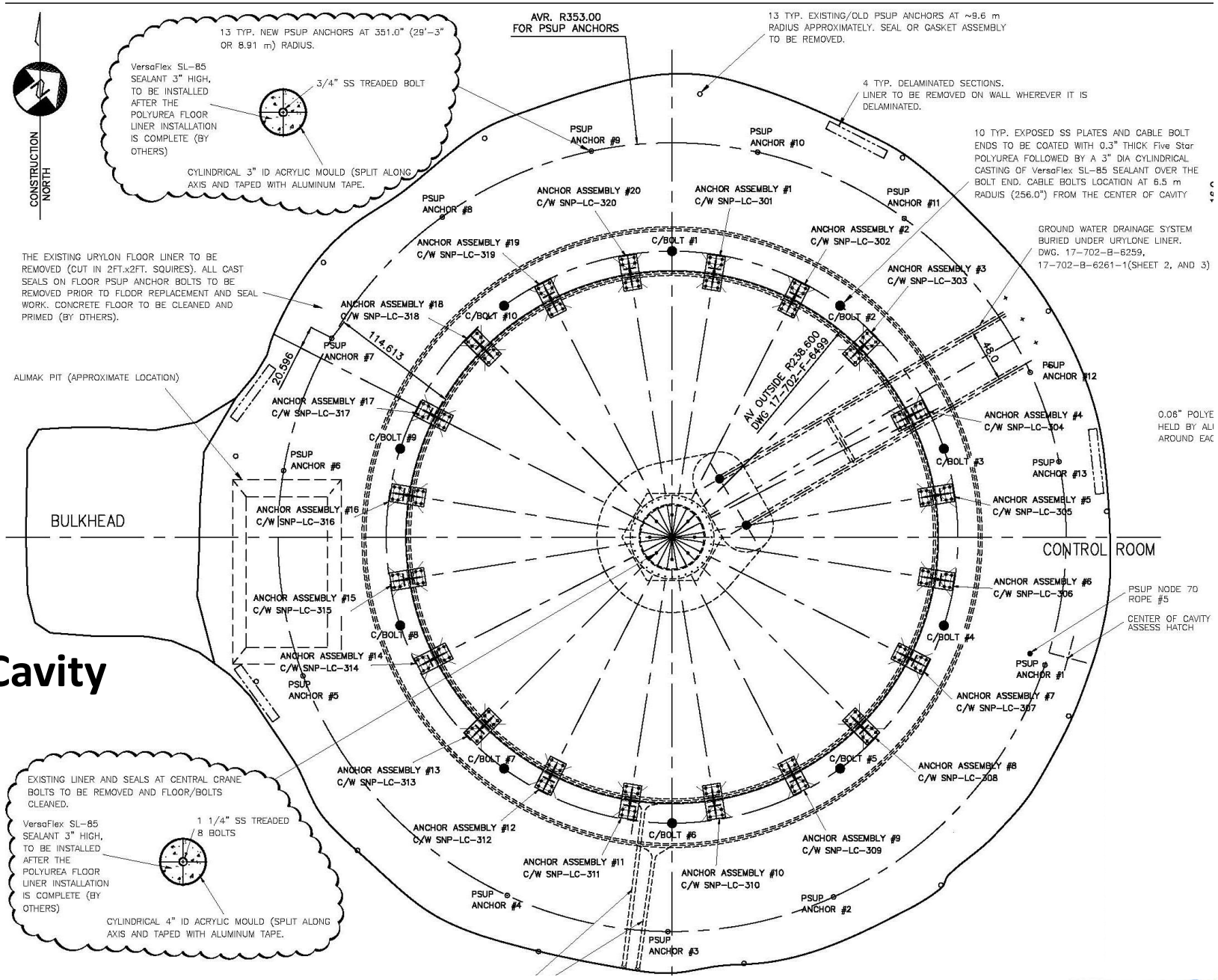
The SNO Liner

- installed in May-June 1994 – water fill in 1998.
- 9 layers of alternating white/gray colour, sprayed by contractor *Spray On Plastics*.
- first 3 layers Urylon HH453 with water scavenger/fire retardent.
- top 6 layers Urylon 201-25 polyurethane.
- total thickness 8 ± 1 mm
- sprayed on troweled concrete – 8 ft high rings, using construction platform
- thickness monitoring every 2 layers – x-ray backscatter probe. Pinhole inspections and filling (by SNO personnel). By 3rd layer, virtually no pinholes.

SNO+ Cavity Layout



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SNO Anchor Seals

- Three sets of bolts – central crane, PMT support structure hold down bolts, wall anchor bolts for final cavity access scaffolding – required seals
- seals were cast with two component polyurethane liquid sealant (*Action 90*), using acrylic molds.
- inspections showed that these seals remained intact through the 8 year SNO operations phase.

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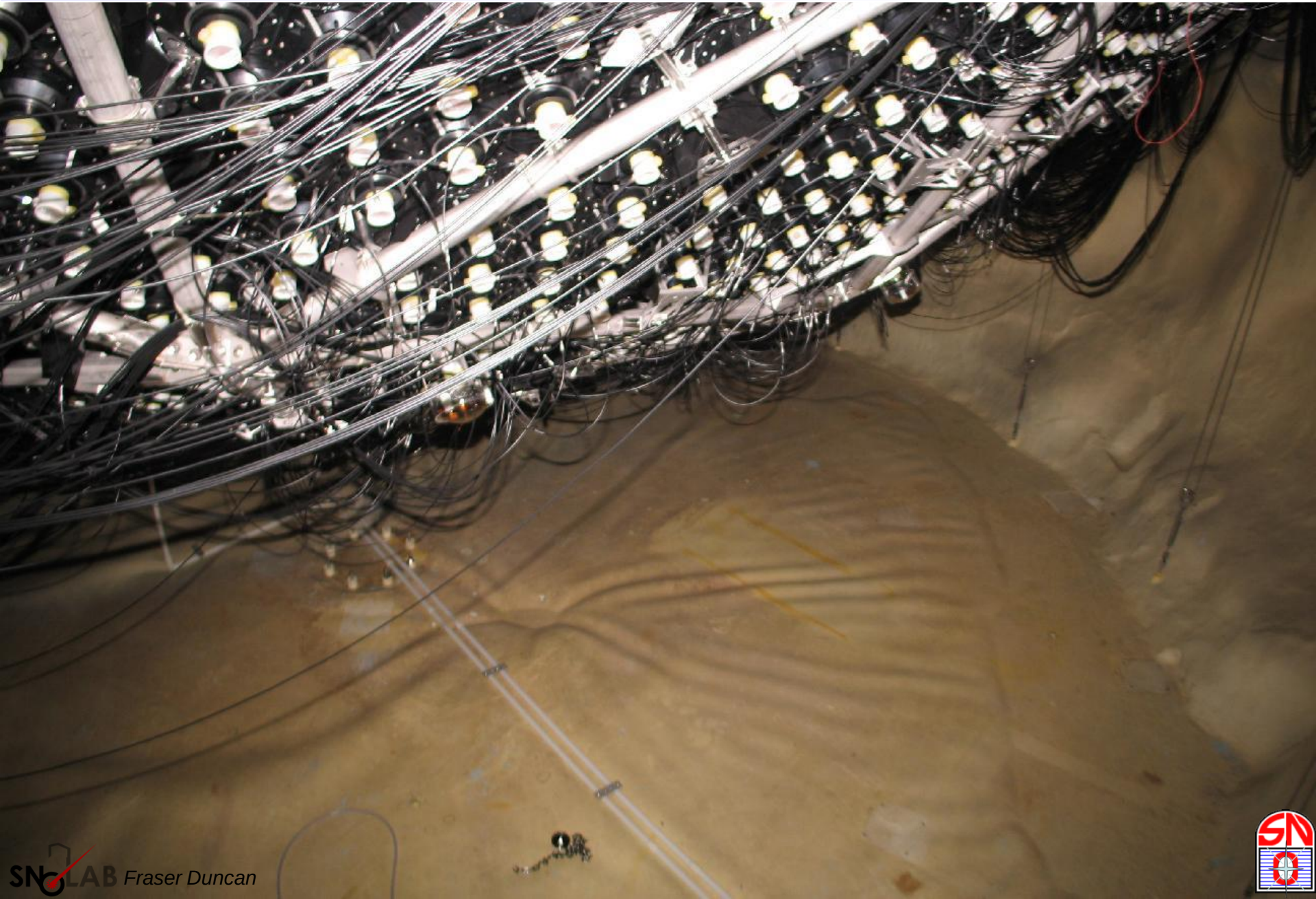
SNO Operations – Liner Effectiveness

- radon ingress targets in the H_2O were more than met:
  Th $\leq 3.7 \times 10^{-14}$ g/g, U $\leq 4.5 \times 10^{-13}$ g/g.
- small water leak (equivalent leak entry area ~ 2 mm^2) required approximately 1 ton/day of light water replacement (and regular pumping from sumps) through most of SNO operations phase.
- leak source is unknown, but an examination of floor showed that some surface blemishes could have deeper associated crack structures.
- The floor was exposed for the 3 years of detector assembly in the cavity (largely but not completely protected by the construction platform).

SNO+ Floor Liner Replacement (August 2011)

- When the cavity was drained at the end of the SNO experiment in 2006, insufficient time was allowed for the sump pumps to relieve backpressure from water in surrounding rock and the liner lifted from the floor. A set of wrinkles also developed in the floor liner.
- The remaining water was pumped out through several 1.5” diameter holes made in the floor liner.
- These holes were sealed prior to a refill of the cavity (for data taking with light water in the acrylic vessel).
- Camera images revealed that the wrinkles did not flatten out but formed tighter folds, ultimately resulting in several cracks through the liner, and a larger leak rate.

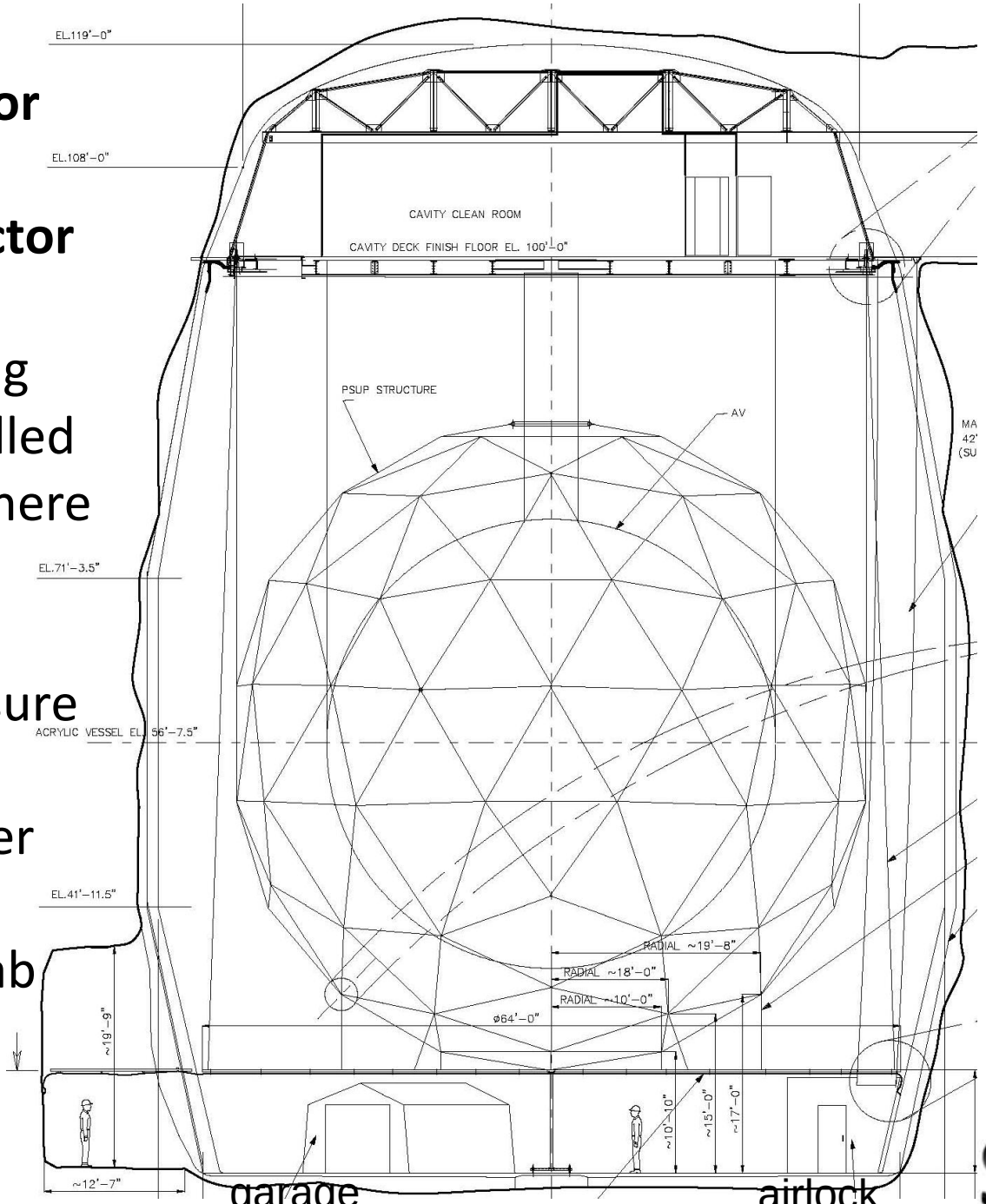
Cavity Floor - wrinkles



- A decision to replace the SNO floor liner was made, given uncertainties of repairing the damaged existing floor liner and the need to install and seal additional floor anchors for the acrylic vessel (required since the liquid scintillator placed in the AV has a 0.85 specific gravity).
- anchor installation – drilling of anchor bolt holes required isolation tent in bottom of cavity – frame plus tarp plus exhaust system to create negative air pressure differential with rest of cavity.
- Floor prep. and wall joint feathering was completed
- A two component polyurea primer (roller-applied liquid) was used to enhance adhesion with concrete.
- Liner - 6 alternating gray/white layers each1.5 mm thick.

SNO+ Cavity floor isolation to maintain detector cleanliness

- "umbrella" (ceiling frame + tarp) installed just below PMT sphere
- "garage" used for floor drilling
- negative air pressure to prevent dirty air from entering upper cavity
- exhaust duct to lab entrance.



Exhaust duct & cavity entry tube with hoist & bos'n's chair

garage

airlock

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Drilling on the SNO Cavity Floor

Drilling to install anchors for the AV hold-down net

in the SNO+ cavity, under the umbrella

Floor liner replacement

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SNO+ Floor Liner Statistics:

Material: *Five Star Polyurea (white)* from *Spray On Plastics*

Installation Time: about 8 days (including set up and take down). Approximately 1 layer per day was sprayed at an effectively 4.5 hour spray time per day rate.

Cost: - materials – about $10/sq.ft.
- labour/equipment/mobilization – about $12/sq.ft.
(excludes safety/hoist support personnel, prep time)

Challenges: access to floor only by bos'n's chair – requires two hoist persons on deck and a bottom guard.

Safety Issues: - air supply respirators required and cavity floor area exhaust was ducted to mine return air system at lab entrance. Work was done on evening shifts when SNOLab was otherwise unoccupied.

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• A 0.5 gal per day ingress of water into the pit in cavity floor, was addressed by installation of geotextile cloth in the pit floor and coating this with a similar thickness of polyurea. A central drain was left open. This will be sealed just prior to water fill. This water is likely lab process water from the top of the cavity which migrates through the cavity wall drainage system.

• Some minor wall seals/ceiling repairs will be made during the water fill.

• a better monitoring system and new protocol for draining should prevent future backpressure issues.

SNO+ Seals

Additional seals were required, following the floor spraying, to complete the waterproofing for:

- 20 anchor plates with 4 rock bolts each
- 10 cable bolt anchor tips and plates
- 13 PMT sphere hold down anchors
- 8 central crane bolts
- Polyethylene molds were prepared so that the sealant VersaFlex SL-85 could be cast around all bolts and around the vertical plates of the acrylic vessel anchors.
- The sealant's tensile strength prevents any tendency for the floor polyurea to separate from the steel.

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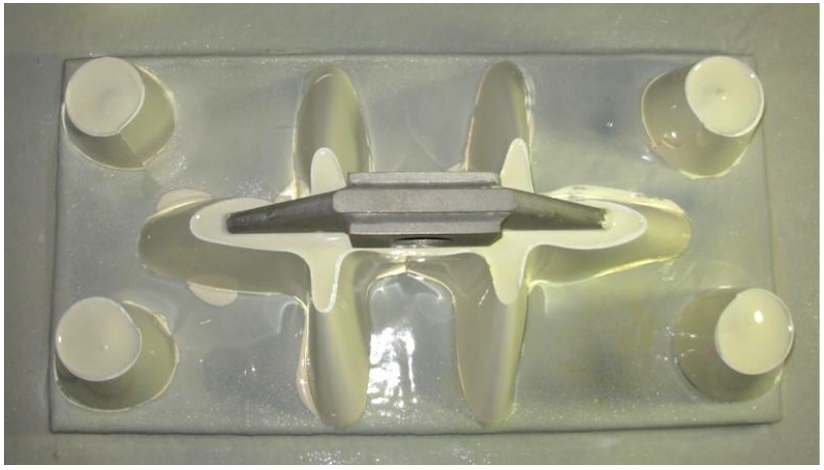

Floor anchor seals

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SNO+ Floor Seal Statistics

Material: *VersaFlex SL-85* polyurea joint sealant (two component polyurea liquid sealant

Application: a small pump unit was lowered to the cavity floor – seal molds filled at a rate of 1 L/min.

Time required: two working days.

Amount. required: 55 US gallons (A+B component total).

Safety: half mask respirators for applicator personnel, no other special exhaust or exclusion requirements.

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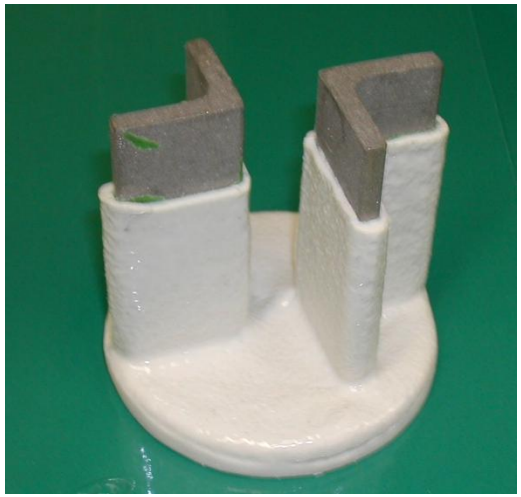
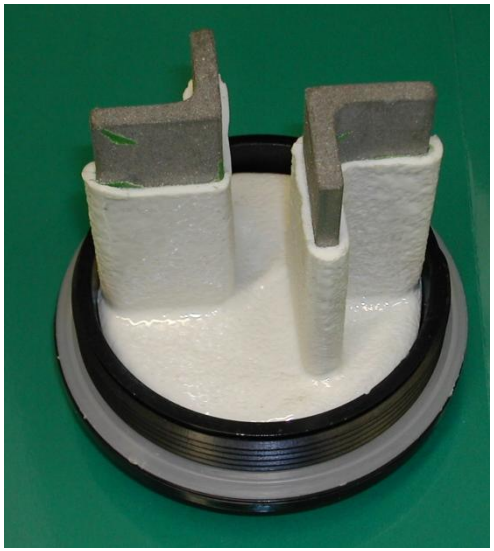
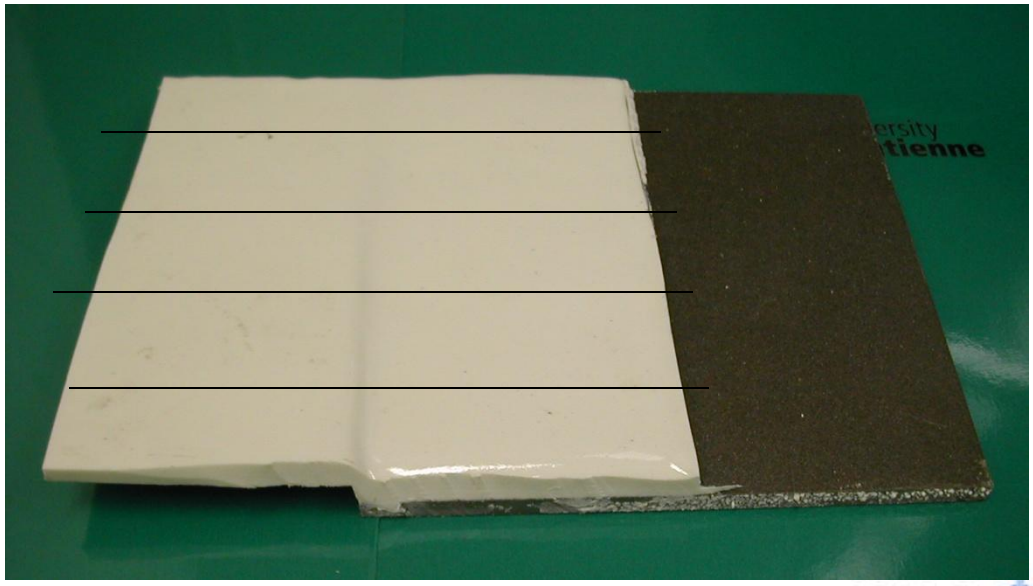
Anchor Seals R & D Tests

- sandblasted & degreased stainless steel samples showed strongest polyurea bond in peal tests.
- water pressure tests (@ 70 psi) show no leakage after 3 months.
- pull and peel tests are continuing after UP water soak periods.
- VersaFlex sealant castings are used to prevent separation of polyurea coat from stainless steel over the large contact distances.







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Summary

- SNO's polyurethane liner has performed quite well for the 8 year operations phase and, with the new floor, is expected to work well for SNO+.
- problems with the liner on the cavity floor have been remedied and can be avoided by future operations protocols.
- the liner and seals system is very flexible with respect to changes in anchors and other penetrations, and repairs & modifications can be made with established techniques.

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References

SNO Construction

The Sudbury Neutrino Observatory, J. Bolger et al, Nucl. Inst. Meth. A 449 (2000), 172-207.

SNO Operations

Clean Fabrication and Cleanliness Monitoring in SNO, E.D. Hallman, LRT 2004 Topical Workshop, Sudbury, AIP Conference Proceedings 785, 2005.

SNO+ Renovations/Refurbishing

Replacement of the SNO Cavity Floor Liner - Procedures, E.D. Hallman, SNO+ technical report, January 29, 2010.

Adhesion and water seal testing for the SNO+ floor liner replacement, E.D. Hallman, SNO+ technical report (in progress).

Liner/Seals

Websites: www.sprayonplastics.com
www.versaflex.com
www.snoplus.phy.queensu.ca

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