# UNO Cavity Liner System: Update & R&D Proposal Status

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# Overview

- Proposal overview
- Cavity liner preliminary design
- Literature search/SNOLab
- Surface prep/TSM/membranes/testing etc.
- Proposal status
- Summary

Real work done by Warner & Kuchta

# R&D Proposal Overview

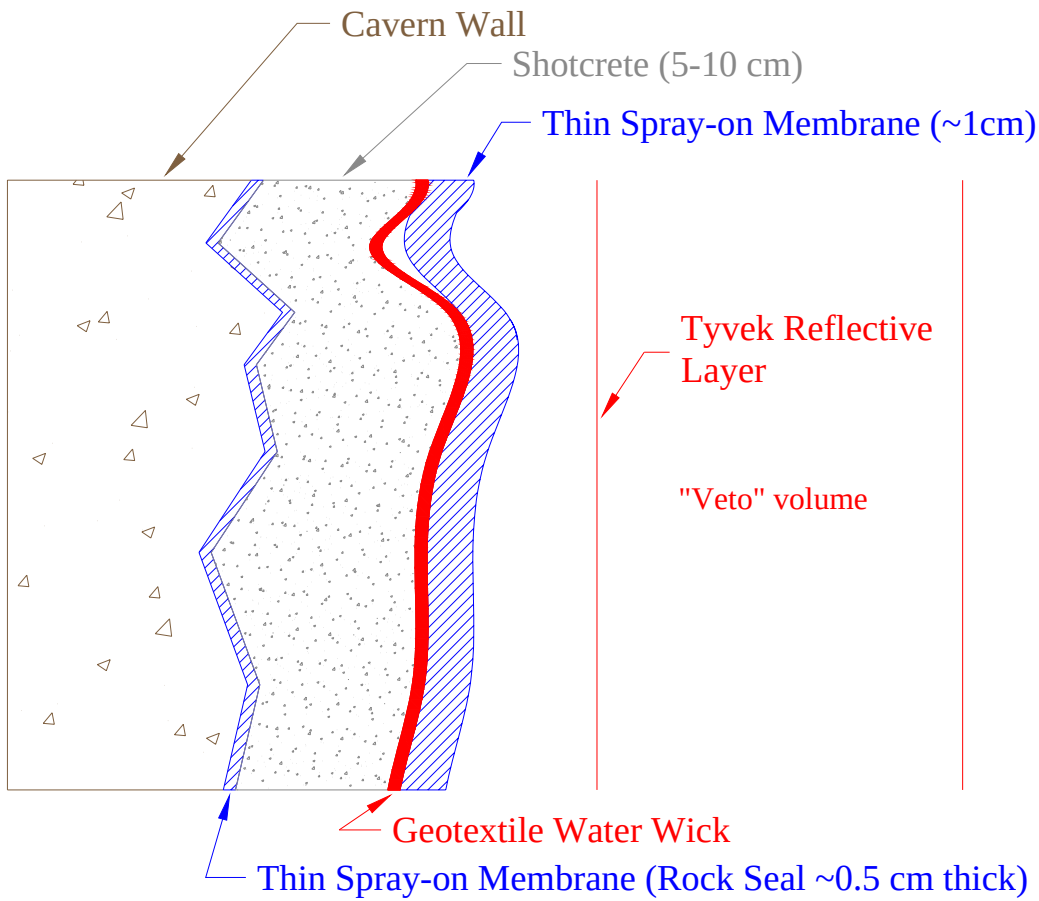
- The main goals of proposal:
  - To provide feedback for cavity design
  - To determine if “Thin Spray-on Membrane” (TSM) lined cavity for water containment is feasible (and cost effective)
- Outline of R&D plan:
  - Determine mechanically acceptable candidate liner system
    - Mechanical tests of candidate TSM materials
    - Application of candidate liner materials at CSM Experimental Mine and studies of system mechanical properties.
  - Test of mechanical and chemical properties of candidate materials before and after immersion in DI water and accelerated aging
  - Field test candidate liner in DI water cistern at CSM experimental mine

# Cavity Liner Requirements

- Provide support for cavity walls
  - Limit and contain fracturing of cavity wall rock
  - Limit damage to equipment/personnel from surface failures
  - Exact bond strength and tensile properties need to be determined in conjunction with cavity design
- Contain a DI water volume of >500kT
  - Seal out external contamination (including radon)
  - Allow contamination only up to the capabilities of “reasonable” water filtration equipment
  - Allow repeated fill/empty cycles
  - Ensure liner systems not damaged by long-term exposure to DI water
  - Provide a reliable seal for 30+ years
  - Avoid breaking the bank!

# Cavern Wall Water Containment: strawman design

- Cavern wall excavated, rock wall stabilized, surface scaled
- Preliminary layer of geomembrane (Thin Spray-on Membrane, or TSM) applied
- Rock bolts/cables, steel mesh installed
- Shotcrete applied, large overhangs filled, surface smoothed
- “Geotextile” layer applied (water wick to sump at detector base)
- Surface prepared, TSM applied (several layers, alternating colors?)
- Water volume makes contact with secondary TSM
- Detector veto volume isolated from membrane by film layer
- Main detector volume further separated cavern wall by additional film layer



# Questions to be addressed by R&D program:

- Mine engineering issues
  - Mechanical requirements - Petersen (CAN), Kuchta
    - What bond strength is required?
    - What tensile strength is required?
  - Application issues - Kuchta
    - What surface treatment of rock is required before application?
    - What are the general and material-specific environmental concerns?
  - Retention of bond to cavern surface
    - What will be the impact of water seepage behind barrier?
    - What is the impact of multiple fill-empty cycles ?
- Detector engineering issues
  - How will we interface with PMT mounting scheme? - Wilkes

# … questions (contd.):

- Detector Engineering Issues (Cont.):
  - Water containment - Warner
    - How many TSM layers needed to ensure water seal
    - What is an acceptable water leak rate (can be supported by reasonable water handling system without compromising liner system)?
  - Extractables/Leachables from liner - Warner
    - What will migrate into the water?
    - How much?
    - Ease of filtration?
  - Migration of contaminants through barrier - Warner
    - What will penetrate, and how fast?
    - Particular concern – radon
  - Stability/chemical resistance - Warner
    - How will the TSM polymer respond to aggressive DI water?
    - What will the impact of DI water on shotcrete mechanical properties be
    - How will water vapor permeating the TSM affect the bond to the rock/shotcrete surface?

# Literature search

- Much of the available information is empirical, even anecdotal.
- Several options exist for both liner mechanical design (number and ordering of layers) and for materials to be used. Custom materials are also an option, particularly for TSM layers
- Specific information about water-filled cavities is limited – most material found is from HEP experience! Not much published literature, some internal notes.

# Experience at SNOLab

- *David Sinclair (SNOLab director) has been very helpful*

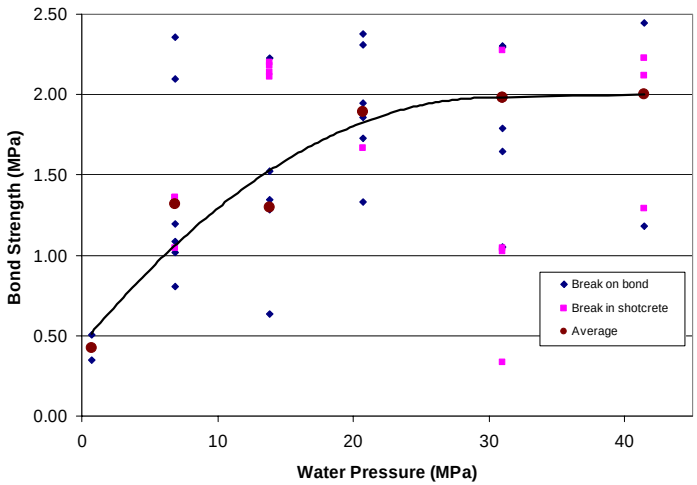
- Not much published data regarding cavity design – Sinclair is looking into securing internal reports/documents for us.
- UNO straw-man design very similar to SNO design, though arrived at independently
- SNO used Urylon for TSM – now “out of favor” due to difficulties with application
- Multi-layer TSM application (alternating colors) necessary to discover pin-prick leaks (initial cistern test leaked badly)
- Smoothing and preparation of shotcrete surface critical
- SNO cavity leaks slowly – believed to be due to penetrations in cavity liner. PMTs should be suspended from top deck

# Inner TSM Layer

- Departure from traditional wall support structure (shotcrete directly onto rock)
- May improve
  - Resistance to external water contamination
  - Bond strength to wall
  - Provide improved wall support (reactive support)
- Need to investigate:
  - Material choice
  - Impact on shotcrete bond strength, overall liner strength and adhesion

# Surface Preparation

- Surface preparation is key to liner adhesion
- Optimal scaling procedure will be determined as part

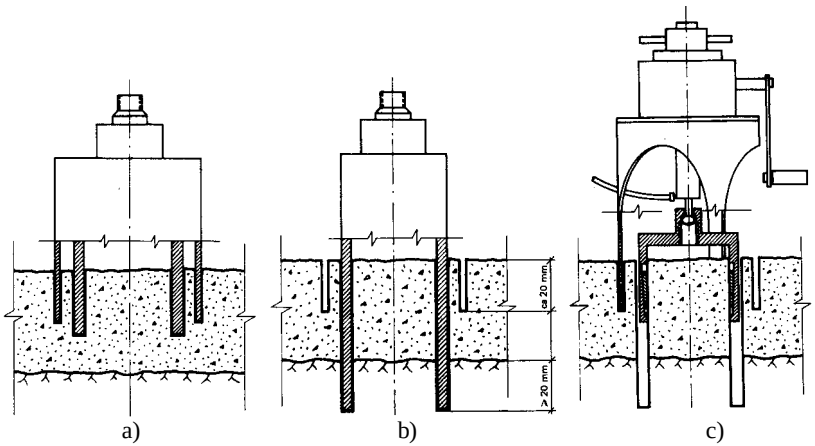



Shotcrete bond vs. water jet pressure

Freshly Blasted Rock

After High-Pressure Scaling

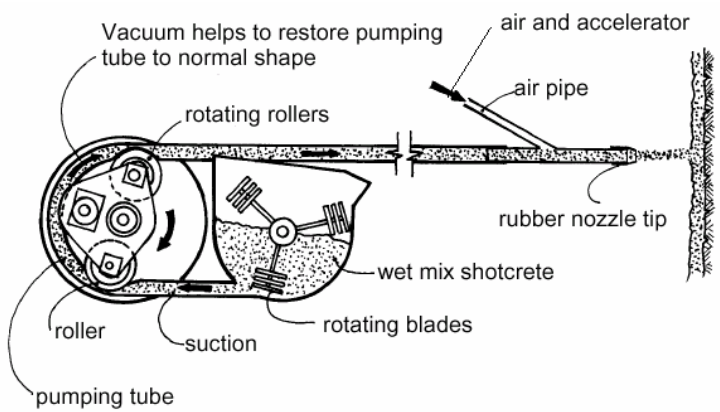
# *In situ* Mechanical Testing

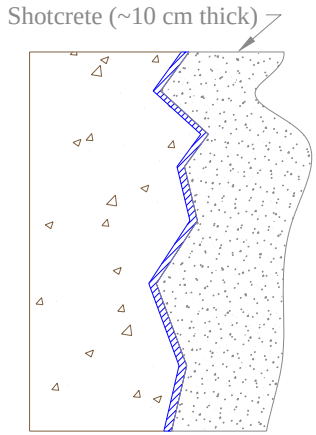



- CSM has a teaching mine available to test proposed liner designs.
- Equipment exists for applying sample TSM/shotcrete liners and testing them.
- Bond strength and ground support can be measured up to 2.5 MPa.

# Shotcrete

- Shotcrete layer (5-10 cm)
- Main questions
  - Formulation (e.g. latex stabilizer)
  - Interaction with DI Water - DOE nuclear-storage people worry about calcium leaching from portlandite, leading to reduction in material properties - material strength, Young's modulus - and stress cracking
  - Will shotcrete benefit from (require?) wire mesh support
  - Bond strength to TSM layer

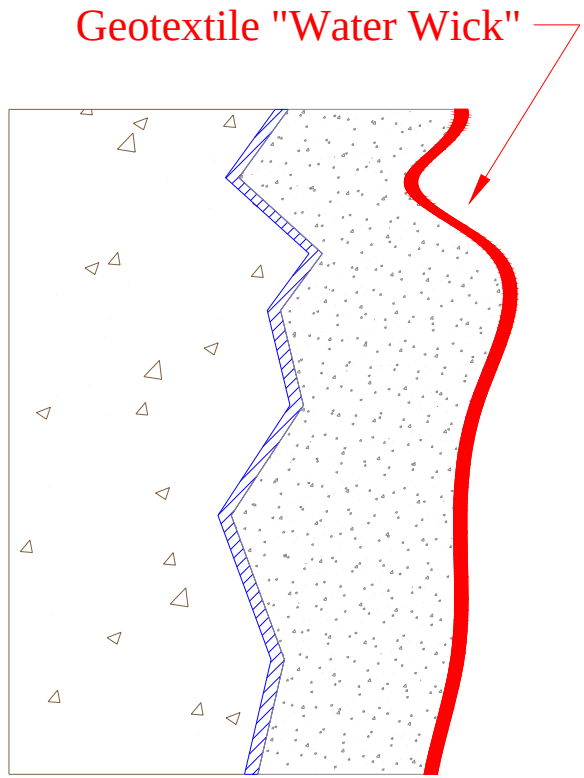



# Shotcrete being applied

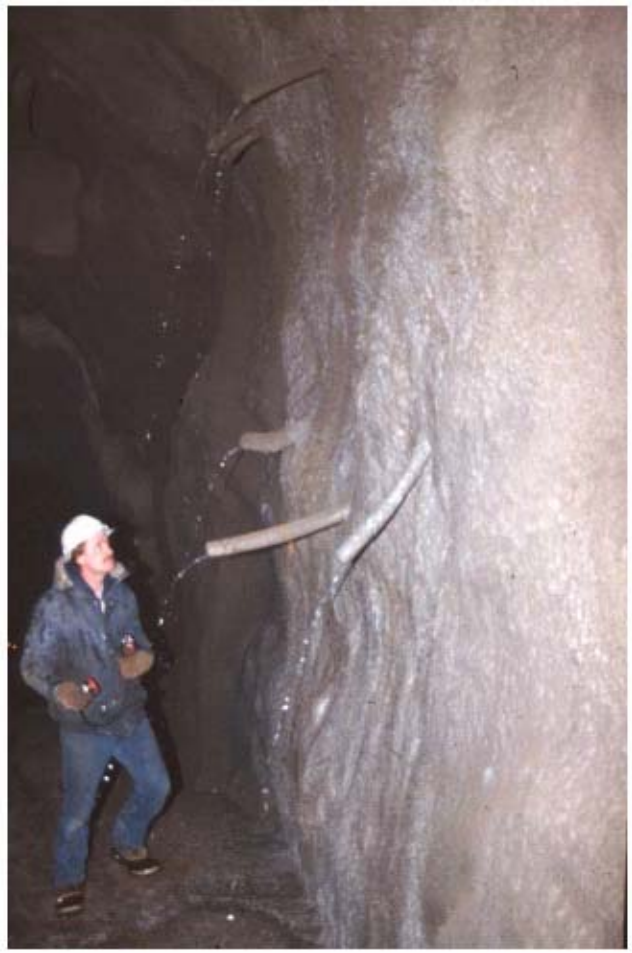
# Geotextile layer

- Acts as “wick” to prevent accumulation of water behind TSM
- Water collects in sump at base of wall and is pumped away
- Typical material – non-woven polyolefin sheet (e.g. Tyvek)
- Need to investigate:
  - Durability
  - Bond to shotcrete
  - Prevent from being center of bacteriological contamination



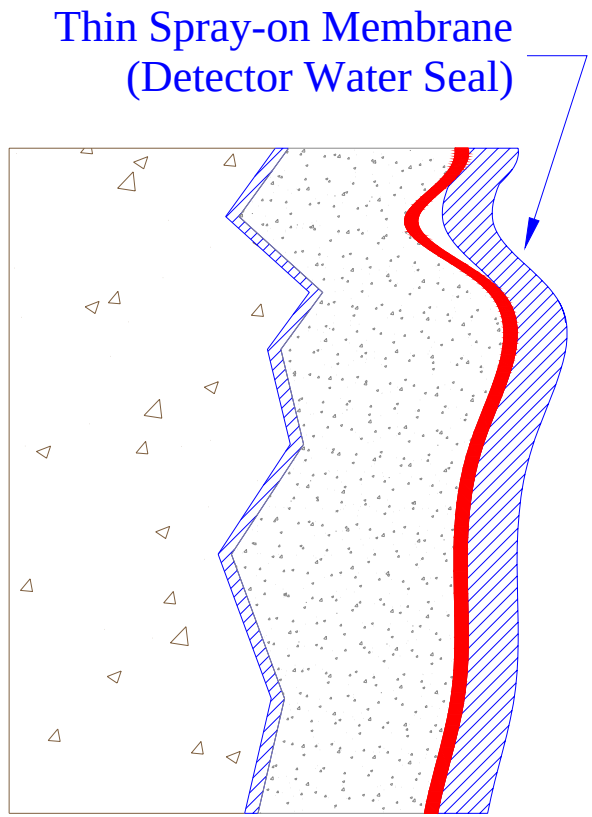
# Liner System Design: Drainage and Geotextiles

- Water draining through tubes in shotcrete wall backed by geotextile membrane
- Similar drainage layer may be needed behind UNO shotcrete wall depending on water seepage rate



# Outer TSM Layer

- Outer TSM layer provides primary water containment
- Prevents infiltration of environmental contaminants (dissolved ions, radon, etc.)
- Prevents detector volume leakage
- May be custom-formulated for our application
- Must not leach excessive contaminants (plasticizers)
- Must be long-term stable for DI water exposure



# Mechanical Testing

- We have access to the materials lab at CSU, which allows us to characterize candidate TSM materials.
  - Bond strength
  - Modulus of elasticity
  - Ultimate strength
  - Elongation at yield
- Provides critical input into cavity design.

# Accelerated Membrane Aging

- Construct a temperature-controlled DI water immersion tank at CSU to allow for accelerated (high temperature) aging of TSM samples
- DI water will be tested before and after sample immersion to look for extractables (commercial testing lab)
- Mechanical properties of TSM materials will be re-tested following immersion aging

# Accelerated Aging in CSM test Mine

- A test cistern (~10,000 L, 10 $m^2$ x 1 m deep) can be produced in CSM experimental mine and candidate liner system applied.
- DI water system from CSU will be used to maintain high-purity, high temperature DI water in cistern
- Tests will be done on cistern leak rate and DI water immersion impact on membrane bond strength to shotcrete and mine wall
- Repeated water fill/empty cycles can also be tested

# Conclusions

- R&D Planning for cavity liner systems is well developed - CSU (Warner), CSM (Kuchta) collaboration
- Examples exist – SNO, KamLAND, but questions remain
- R&D proposal funds to study new TSM/Shotcrete ground support designs and long-term aging effects of DI water on TSMs and adhesion - ~$210k
- Important feedback into cavity design and detector costing.