NUCLEAR WASTE MANAGEMENT ORGANIZATION
SOCIÉTÉ DE GESTION DES DÉCHETS NUCLÉAIRES

APM Repository – Safety and Technology Development

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APM Repository – Safety and Technology Development

Agenda:

1. What does Safety Assessment do?
2. Repository and EBS Components
   - Multiple Barriers
   - Natural Analogues
3. Design and Proof-Testing Program for Engineered Barriers
   - Pressure Testing
   - Crush Testing
   - Clay (HCB) Technology

Safety

'Safety' means protecting the public, the workers and the environment from hazards associated with facility operation

In general, safety is achieved through a combination of:

- Robust design that complies with all applicable standards
- Engineered barriers
- Trained staff and proper equipment
- A good site
- Favourable host rock
- Durable, non-reactive wasteform
- Repository depth
- Monitoring and oversight

Safety is determined (in part) by comparing estimated effects (doses) against approved acceptance criteria

If margins are deemed insufficient, key assumptions are examined and iteration with design and operations may occur to implement improvements

Safety Case

The **Safety Case** is an integrated collection of arguments and evidence that together demonstrate the safety of the facility

The Safety Case addresses all aspects of safety:

- Conventional Health and Safety
- Transportation Safety
- Preclosure Safety
- Postclosure Safety

The portion addressing radiological safety will include a Safety Assessment, a Geosynthesis, information on R&D support, information on Natural Analogues and more

It will be subjected to peer review (national and international reviewers)

It will be subjected to independent review and checking by the CNSC

Licenses will not be granted until the CNSC is satisfied that the health and safety of the public, the workers and the environment are protected

Postclosure Safety Assessment

Postclosure safety is demonstrated (in part) via a 'safety assessment'

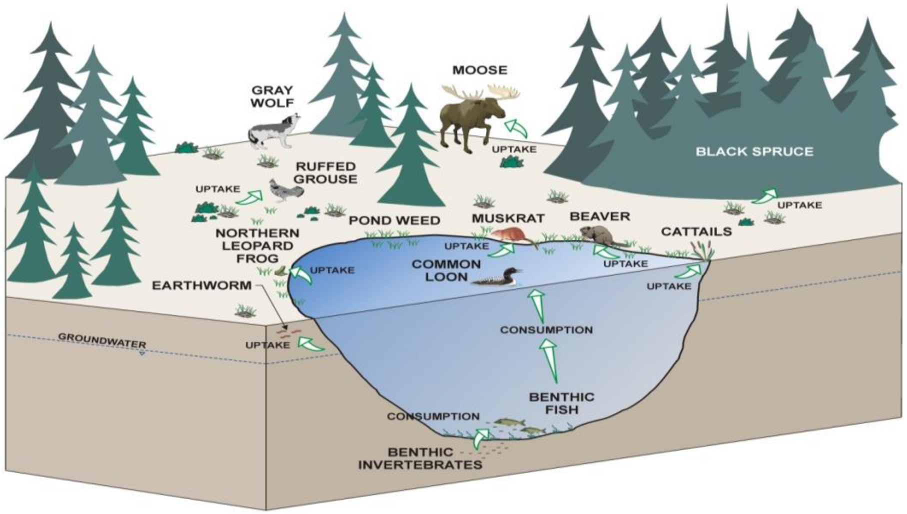
Safety Assessment provides a quantitative estimate of the ability of the repository to isolate and contain radioactivity in the used fuel in the long term

Uses computer models of the repository, the surrounding host rock and the biosphere

Follows guidance in CNSC G-320 'Assessing the Long Term Safety of Radioactive Waste Management'

Considers

- The effects on people due to radiological and non-radiological hazards
- The effects on the environment due to radiological and non-radiological hazards



Postclosure Safety Assessment

Safety Assessment Timescale:

Considers a 1 million year timeframe because this period covers key processes, including:

- The initial large decrease in used fuel radioactivity within the first 1000 years
- The subsequent slow decrease in used fuel radioactivity to the level of that in an equivalent amount of natural uranium
- Future glaciation, assuming first glacial cycle in about 60,000 years
- The potential for container failure, and
- Is sufficient to determine the maximum impact

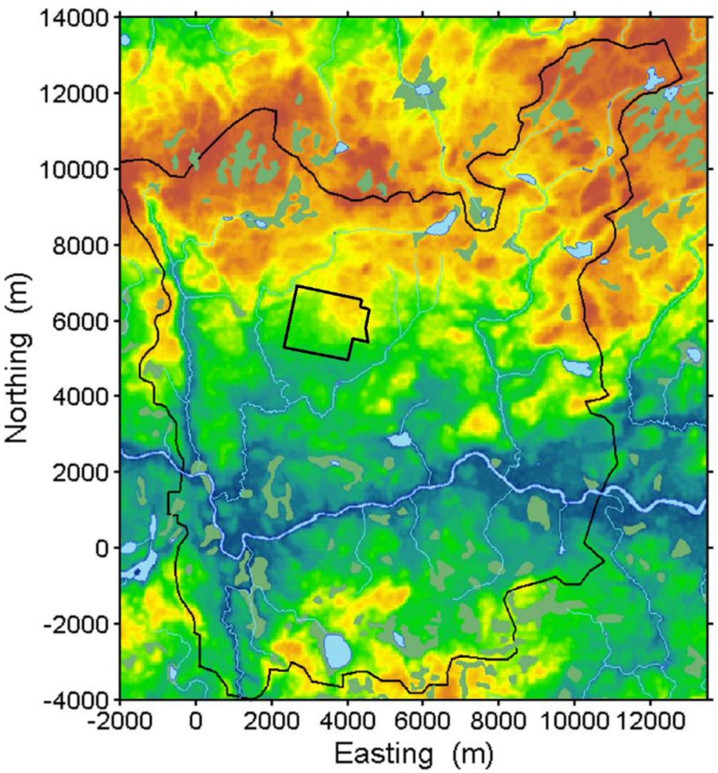
Postclosure Safety Assessment

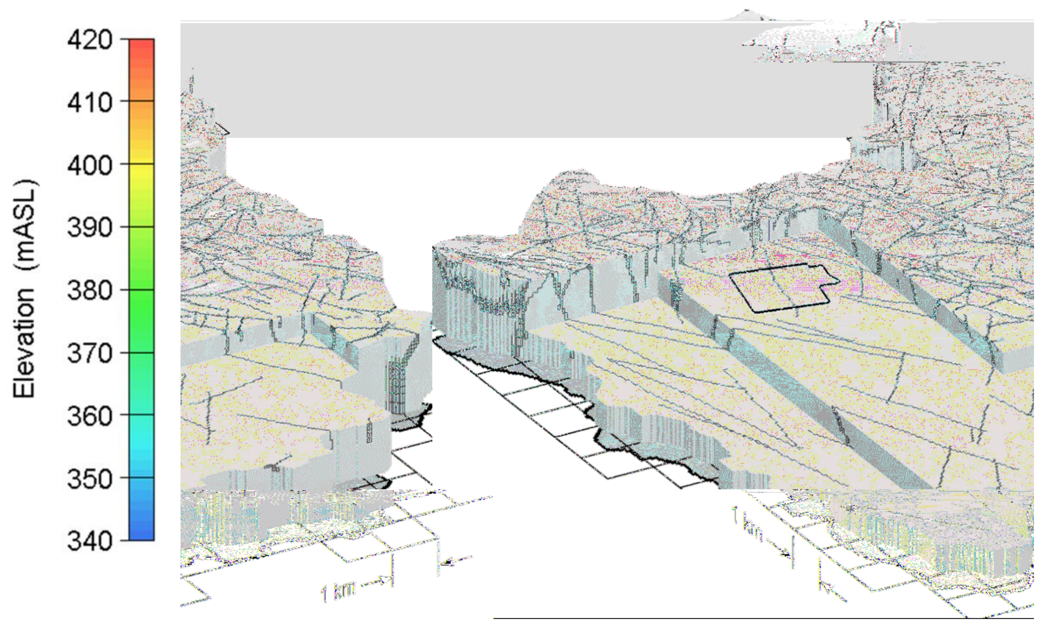
Normal Evolution Scenario - Some Key Assumptions:

- People in the future are similar to people of today
- Should protect future people to the same degree that we protect ourselves
- People in the future behave plausibly, with characteristics that maximize exposure
- A self-sufficient farm family unknowingly lives on top of the repository and:
  - Grows all their food on top of the repository
  - Obtains all their drinking water from a deep well
  - Well is in the location that maximizes the uptake of repository contaminants
- If it can be shown that this hypothetical family is safe, then real families would be safer

Postclosure Safety Assessment

Some Modelling Illustrations:





Surface and Subsurface Model around Hypothetical Repository

Postclosure Safety Assessment

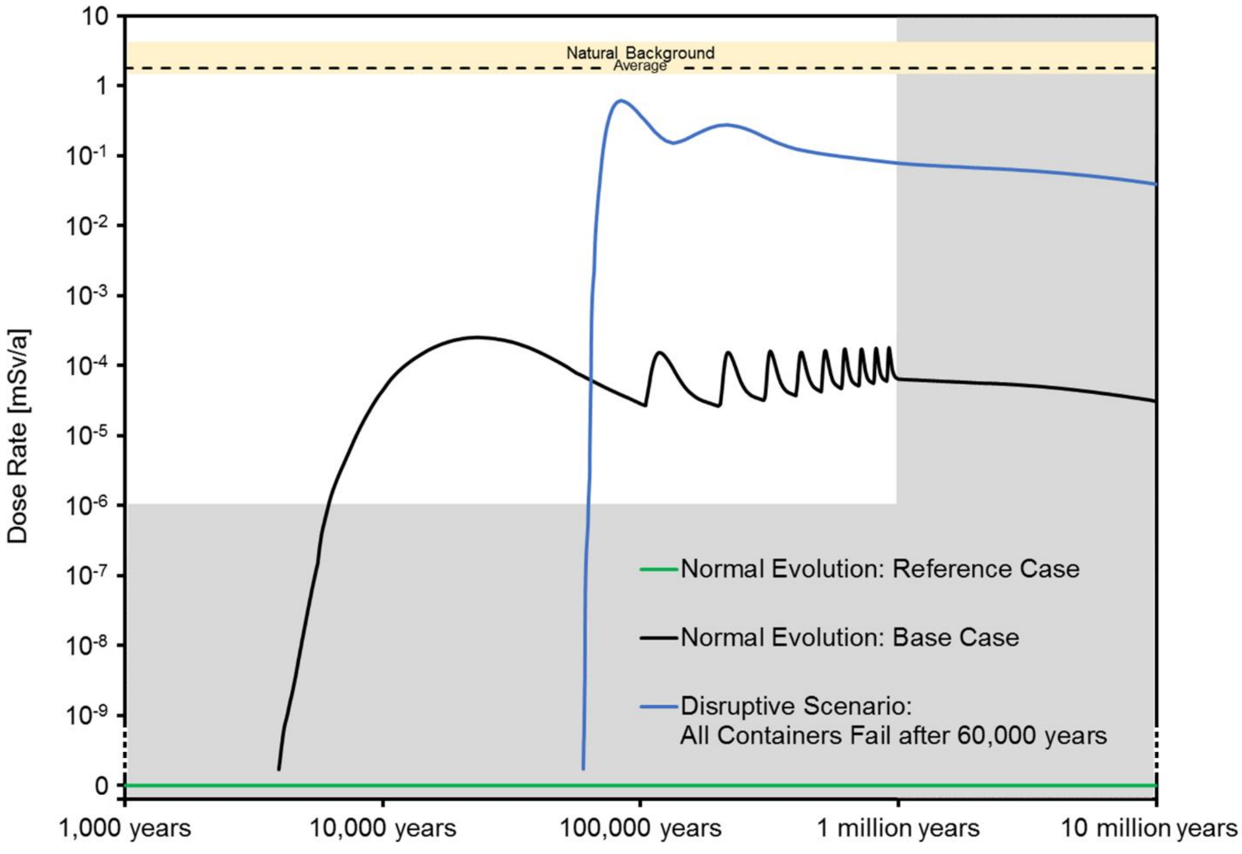
Normal Evolution Scenario, Reference and Sensitivity Cases

- Reference Case
- Base Case
- Barrier Sensitivity Cases
  - Used Fuel (e.g., Fuel Dissolution Rate)
  - Zircaloy Sheath (e.g., Zircaloy Dissolution Rate)
  - Used Fuel Container (e.g., Times of Hypothetical Failures)
  - Engineered Sealing Materials (e.g., Conductivity, Sorption)
  - Geosphere (e.g., Fractures, Sorption)
- Bounding Assessments (e.g., No ESM Sorption)
- Probabilistic Assessments (Uncertainty Across Multiple Parameters)

Postclosure Safety Assessment

Disruptive Scenarios

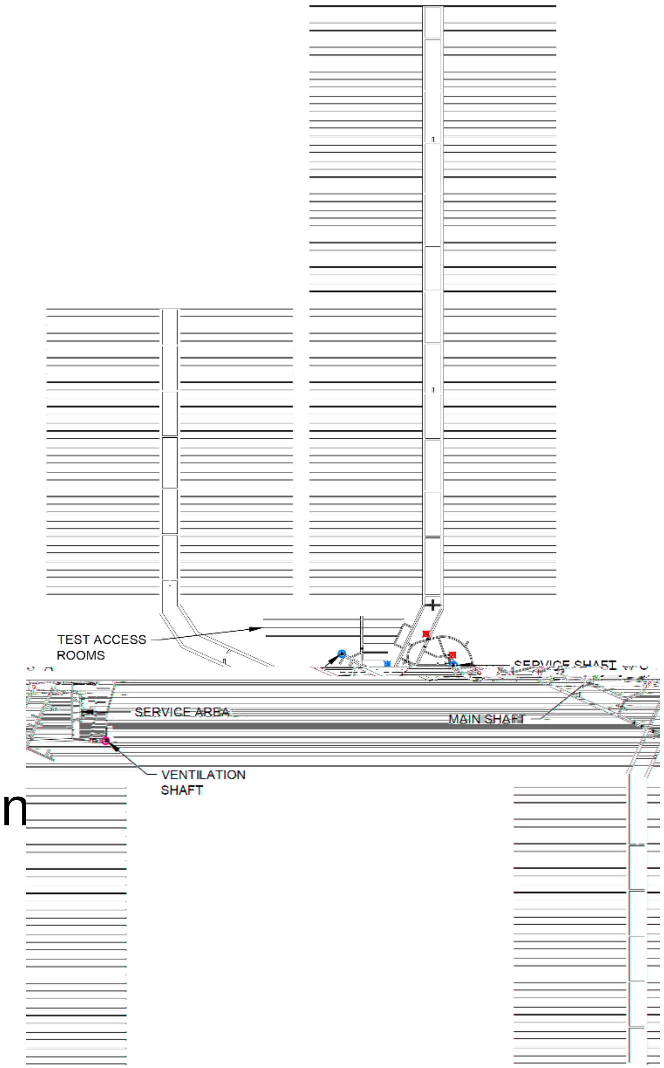
- Undetected Fault
- Failure of Borehole Seals
- Failure of Repository Seals
- Partially Sealed Repository
- Inadvertent Human Intrusion
- All Containers Fail simultaneously at 60,000 years postclosure



Description of Repository and EBS Components

- Depth ~500 m
- Adaptable 3-arm repository with 3 centrally located shafts
- No perimeter tunnels
- Underground Demonstration Facility
- Above ground Centre of Expertise (in place in 2023)

- For either crystalline or sedimentary rock
- Allows for concurrent operation and excavation
- Separate arms so Construction / Operation ventilation air is separate



Description of Repository and EBS Components

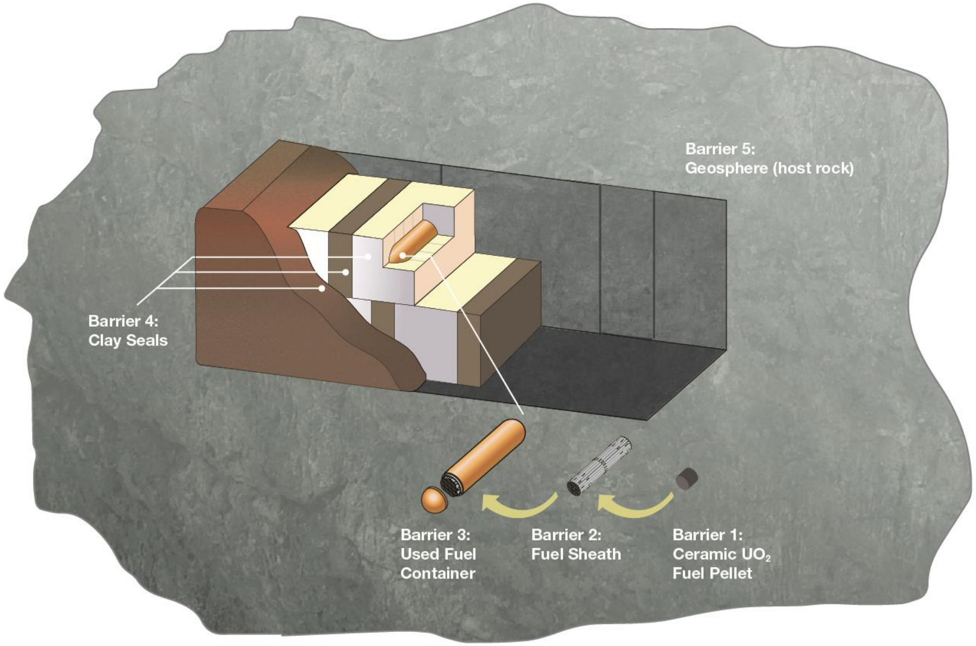
Postclosure safety is achieved via a combination of overlapping engineered and natural barriers

Purpose of the Barriers:

- To prevent water from contacting the used fuel
- If water does contact the fuel, to inhibit and slow down the migration of contaminants to allow more time for radioactive decay

Barriers :

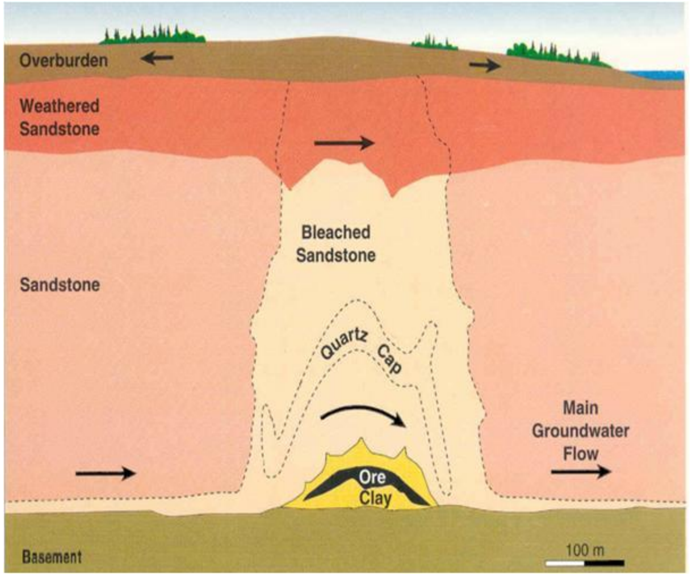
- Fuel pellet
- Fuel sheath
- Used fuel container
- Clay based sealing materials
- Geosphere

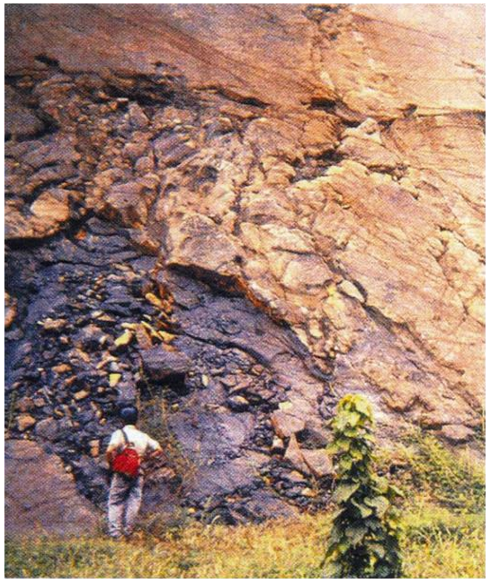


Natural Analogues

Postclosure Safety is Supported by Natural Analogues:

- These are natural features that exist under conditions or processes occurring over long periods of time that are similar to those expected in some part of a deep geological repository
- They build confidence that the system will perform as expected
- Analogues exist for all repository components





Overview of Design and Proof-Testing Program

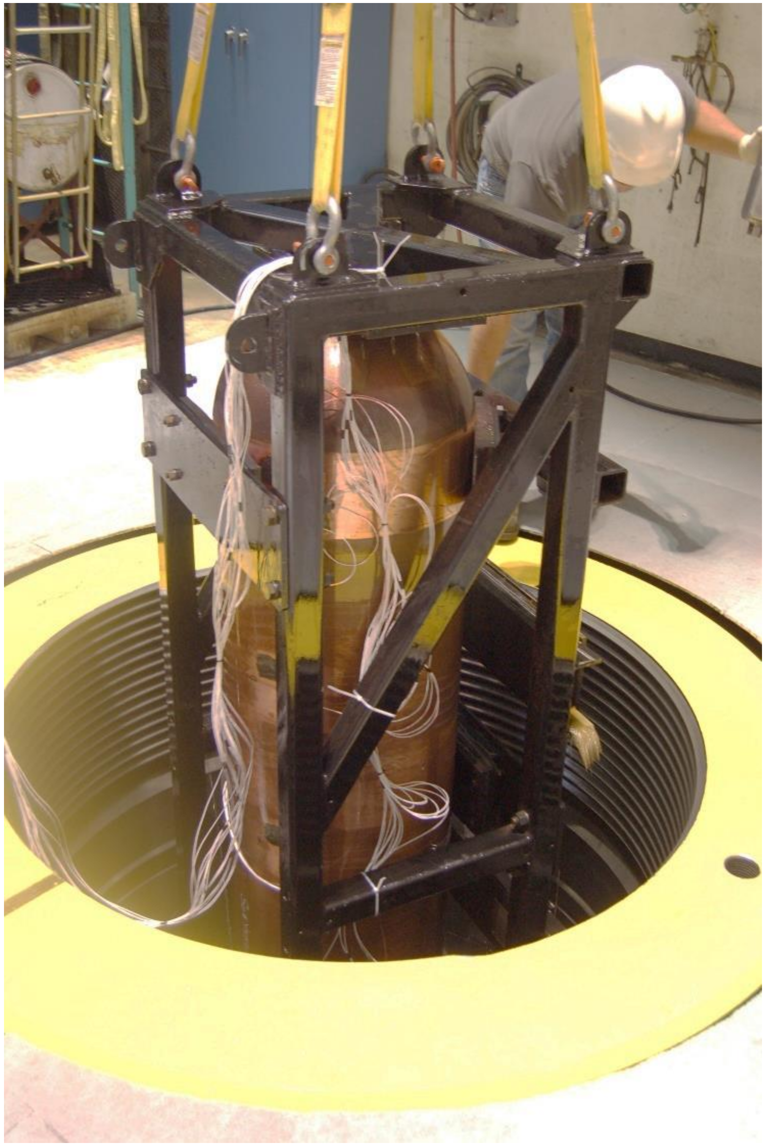
- Ongoing - activities have been planned and costed up to 2022
- Why 2022? To coincide with the estimated date for selection of a host community
- Program cost is $150 million Canadian dollars
- In the absence of a site, our focus is on above ground activities
- All activities and operations will be proof tested above ground

- Once a site is selected, additional to-be-defined work will be implemented in the Underground Demonstration Facility and above ground. This will likely include:
  - Full-scale underground demonstration of the disposal sequence and backfilling using remote handling equipment
  - Assorted tests to provide additional confidence in barrier performance
  - Geoscientific verification tests

Mechanical Integrity - External Pressure Test

Full-Scale prototype test at Penn State (USA)

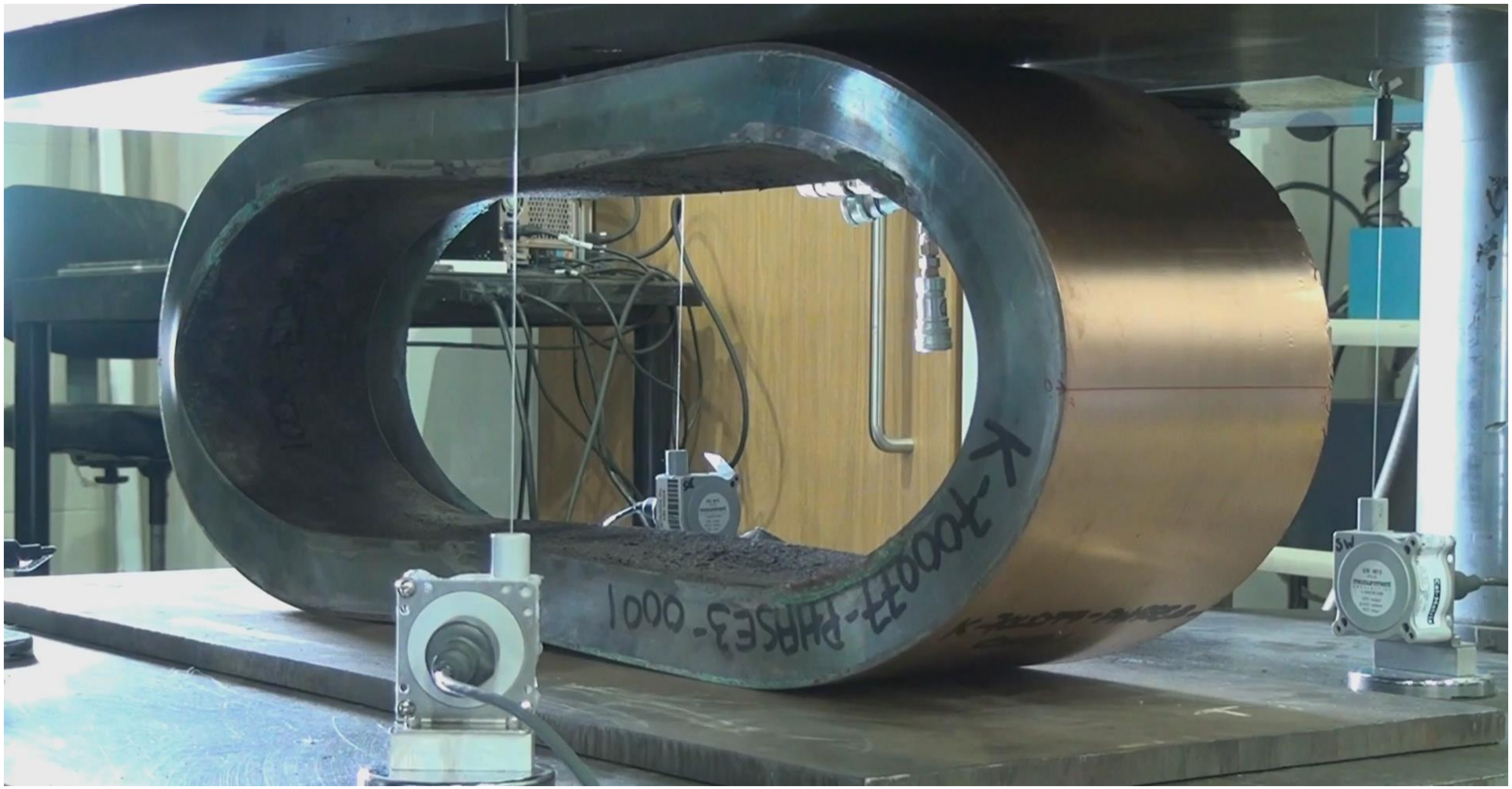
- Design pressure is 45 MPa (accounts for hydrostatic pressure, bentonite swelling pressure and glacial load)
- No evidence of damage at 45 MPa
- Buckling occurred at 57 MPa
- Test results were as predicted
- Further tests planned



Mechanical Integrity - Crush Testing

Structural Vessel Shell

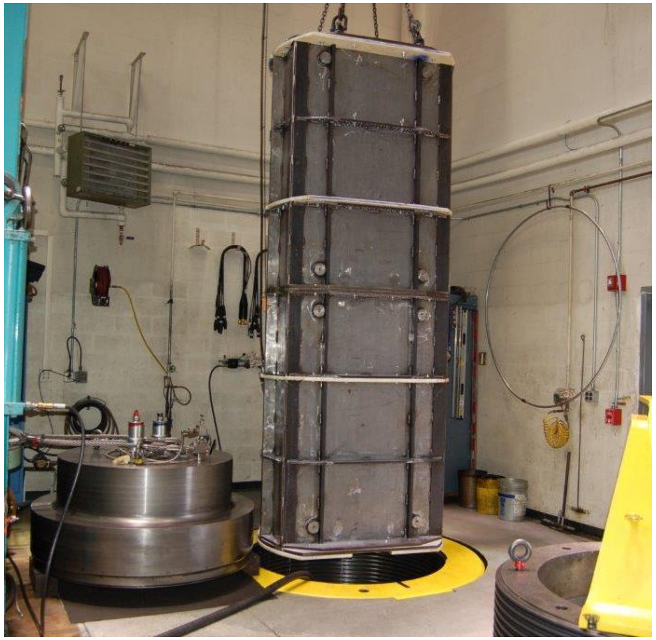
- Crushed until opposite edges touch to examine copper / weld integrity
- Copper coating did not delaminate
- No damage to weld



HCB Consolidation and Shaping Demonstration

- Full size block produced (four produced to date)
- Large scale blocks can be pressed using commercial suppliers and a large, cold isostatic press
- A uniform block was pressed under an isostatic pressure of 100 MPa to within 25 mm of the expected dimensions.
- The dry densities exceed the minimum required value of 1.7 g/cm^3
- Three blocks shaped to date
- Ongoing work continues to build confidence in the process and product

HCB Consolidation and Shaping



Gapfill Placement

Gapfill Placement

Summary

Safety means protecting the public, the workers, and the environment from hazards associated with the repository

- The Safety Case is an integrated collection of arguments and evidence
- Safety Assessment estimates the ability to isolate and contain radioactivity

NWMO has an extensive design, optimization and proof-testing program underway:

- Addresses engineered barriers and placement technology
- Addresses above and below ground design concept
- Activities beyond 2022 will be further defined based on current work

Design includes full-scale room excavation trials underground in the Underground Demonstration Facility:

- Prove excavation methods and rock stability
- Available for full-scale placement trials with backfill
- As a minimum, will include inactive tests and staff training
- Possibility of active tests is under consideration