The NWMO Copper Coated Container

Peter Keech, Manager Engineered Barrier Science, NWMO

October 25, 2016
Reference Designs – Pre Mark Program

» Conceptual Reference design is based on SKB/NAGRA concepts

» SKB (Sweden) crystalline rock
  • In-floor bore hole
  • Dual vessel (steel/copper)

» NAGRA (Switzerland) sedimentary rock
  • Horizontal tunnel in-room
  • Steel and steel/copper vessels

» Costing & Communication

» $16-24 Billion (CAD)
Design Optimization: Keys

» Can we use copper coatings?

» Is technology ready?
  - What are implications for cost? For size of container? For safety?
  - Identified two container design and emplacement concepts for further development:

Mark I
  - Leverages SKB/Posiva KBS-3 designs and emplacement concepts; all steel option being assessed for sedimentary

Mark II
  - Customized for CANDU fuel, standard manufacturing and copper coated
  - Standard ASME materials (pipe/plate), no custom forging
  - Significant potential for life-cycle cost reduction ($2Billion CAD)
Two 2012 Design Concepts

Mark 1 – Dual-shell design

» Copy the KBS-3 concept as much as possible to be able to take advantage of SKB’s learning curve

Mark 2 - Optimized design for CANDU fuel

» Design alternatives related to size and geometry

» Apply advances in copper coating technology to apply required thickness of corrosion barrier

Mark-2      Mark-1

565 mm

2440 mm
Analysis: Flat vs. Spherical Head

- Flat Head
  - Maximum Principal Stress
  - Type: Maximum Principal Stress
  - Unit: MPa
  - Time: 1
  - 15/04/2012 11:46 AM

- Spherical Head

Tensile Only

Spherical Head
Advanced techniques available for achieving fully bonded, metallurgical and corrosion compliant coatings

- Cold spray
- Electrodeposition

Allows corrosion needs (not manufacturing) to define copper thickness

2011 Corrosion allowances
- 100,000 year = 0.4 mm
- 1,000,000 year = 1.3 mm

2 Coating needs
- Container & lid
- Weld zone (hot cell)
Copper Coating Development: Cold Spray

» High pressure gas propels powder toward surface to produce coating
  - Solid state process
  - Adhesion via mechanical bond
  - No melting of powder

» Optimized for Adhesion
  - Requires He carrier gas for 1st layer, adhesion > 60 MPa

» Brittle coating
  - Requires annealing to increase ductility
5 Years of Cold Spray Development

» Many variables:
  - Pressure
  - Temperature
  - Gas type (He vs. N₂)
  - Surface Preparation
  - Powder

» Reference parameters defined
  - 1 layer He carrier, N₂ after
  - Spherical powder, 30 µm average particle size
  - 5 MPa
  - 600 – 800 °C

» Annealing required (> 350°C)
  - EBSD shows grain growth
General Coating Development

**Tensile Testing**
ASTM E8

- As-sprayed
- 1 h at 300 °C
- 1 h at 600 °C

**Bend Testing**
ASTM E290 for Annealing

- As-sprayed
- 300 °C, 1 h
- 600 °C, 1 h

**Bond Strength Testing**
ASTM C633 & modified E8
Results: Experiment vs. Modeling

• Copper Coating – As Sprayed
  – Failure within 1 mm of deflection, <1% strain
Results: Experiment vs. Modeling

- Copper Coating – Coldspray (Partly Annealed)
Results: Experiment vs. Modeling

• Copper Coating – Fully Ductile
Other Cold Spray Samples

- Rod Samples
- Rod Ends, Discs
- Plates
- 18" long 20" Diameter pipe Samples
The “Stubby Assembly”
Cold Spray & Machining a Lower Assembly
Coating Development: Electrodeposition

» 3 mm coating

» Standard ASME substrate steel
  ✦ A516 Gr. 70 or equivalent
Electrodeposited Hemihead
Electrodeposited Hemihead
The First Hemihead Machined
The Stubby Assembly
The Stubby Assembly
The Leading Vessel: 2013-15 Manufacturing
The Finished Product
Serial Manufacturing: 2017-2019

1. Procurement of materials

2. Machining of shell / head components for assembly

3. Welding of Hemi-Head Assemblies (structural attachments)

4. Welding of Lower Assembly (HLAW or GMAW)

5. Machining of Lower Assembly Weld Cap

6. NDE (and repair) of Lower Assembly Weld Zone

7. Copper Coating of Lower Assembly and Upper Head via Electrodeposition

8. Machining of Copper Coated Surfaces

9. NDE (and repair) of Copper Coated Surfaces
Conceptual Hot Cell Operations

10. **Closure Welding** after Fuel Loaded

11. **Machining** of Closure Weld Cap

12. **NDE** (and repair) of Closure Weld Zone

13. **Copper Coating** of Closure Weld Zone via Cold Spray

14. **Annealing** of Copper Coating at Weld Zone

15. **Machining** of Copper Coating at Weld Zone

16. **NDE** (and repair) of Copper Coating at Weld Zone
NWMO’s vision for a Waste Facility

1. Surface Facilities
2. Main Shaft Complex
3. Placement Rooms
4. Ventilation Exhaust Shaft

Legend
Challenges & Future R&D

» Application to other materials
  ◦ Cast iron
  ◦ Different steels
  ◦ Welded materials

» Electrodeposition optimization
  ◦ Pre-treatment of steel
  ◦ Smooth coatings

» Interface between coatings
  ◦ Characterize with advanced methods
  ◦ Validate that adhesion is high & free of contaminants

» Handling Challenges
Vacuum Lift for Handling Bentonite & UFCs
Conclusions & Ongoing Work

» Copper coatings are viable for NWMO containers
  ♦ Ongoing work to continue to develop concept

» Significant cost savings and flexibility in container size can be realized

» Participation with international community has proven beneficial
  ♦ Nagra partnership on program since 2012
  ♦ RWM co-funded work on electroplating
  ♦ BEP of UK has initiated work on larger containers
  ♦ Surao, NUMO in corrosion work at Grimsel

» NWMO is looking to collaborate on future work and would benefit from an international effort
  ♦ Regulator
  ♦ Public
Acknowledgements

» National Research Council of Boucherville (Montreal): Cold Spray
» Integran Technologies Inc. Toronto: Electrodeposition
» Surface Science Western / Western University & the David Shoesmith Research group: Characterization and Corrosion Testing
» Novika of Quebec: Laser Welding
» Nagra
» RWM
Questions?