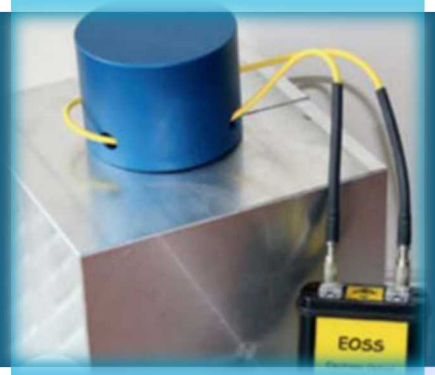
SAND2018-7775C

Sandia National Laboratories

Containment & Surveillance and Canister ID Applied to the Final Disposal of Spent Nuclear Fuel



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2017 IAEA Special Technical Report STR-384

Application of Safeguards to Geological Repositories (ASTOR)

- IAEA expert group
- Summarizes ASTOR work 2011 to 2016

Five focus groups

1. Design Information Verification
2. Non-Destructive Assay Verification
3. Containment and Surveillance
   - Operations
4. Satellite Imagery & Geophysical Techniques
   - Post-closure
5. Long-Term Data Management

Continuity of Knowledge (CoK)

"*Uninterrupted and authentic data or information about nuclear material that provide the IAEA with adequate insight to draw definitive conclusions that nuclear material is not being diverted from peaceful purposes.*" – Blair et al.*

CoK is an outcome, not a process

CoK must be attained … and then maintained

Maintaining CoK requires Containment and Surveillance

* D.S. Blair, N.C. Rowe (2014) *A Global Perspective on Continuity of Knowledge: Concepts and Challenges.* Presented at the 2014 INMM Annual Meeting. Sandia National Laboratories technical report (SAND2014-17676C).

Geological Repository and Related Facilities & Operations

Transportation

Encapsulation plants

Geological repository

- Surface Facilities
- Emplacement/Disposal area (underground)

Disposal canister ID

- Technologies for uniquely identifying spent fuel disposal canisters

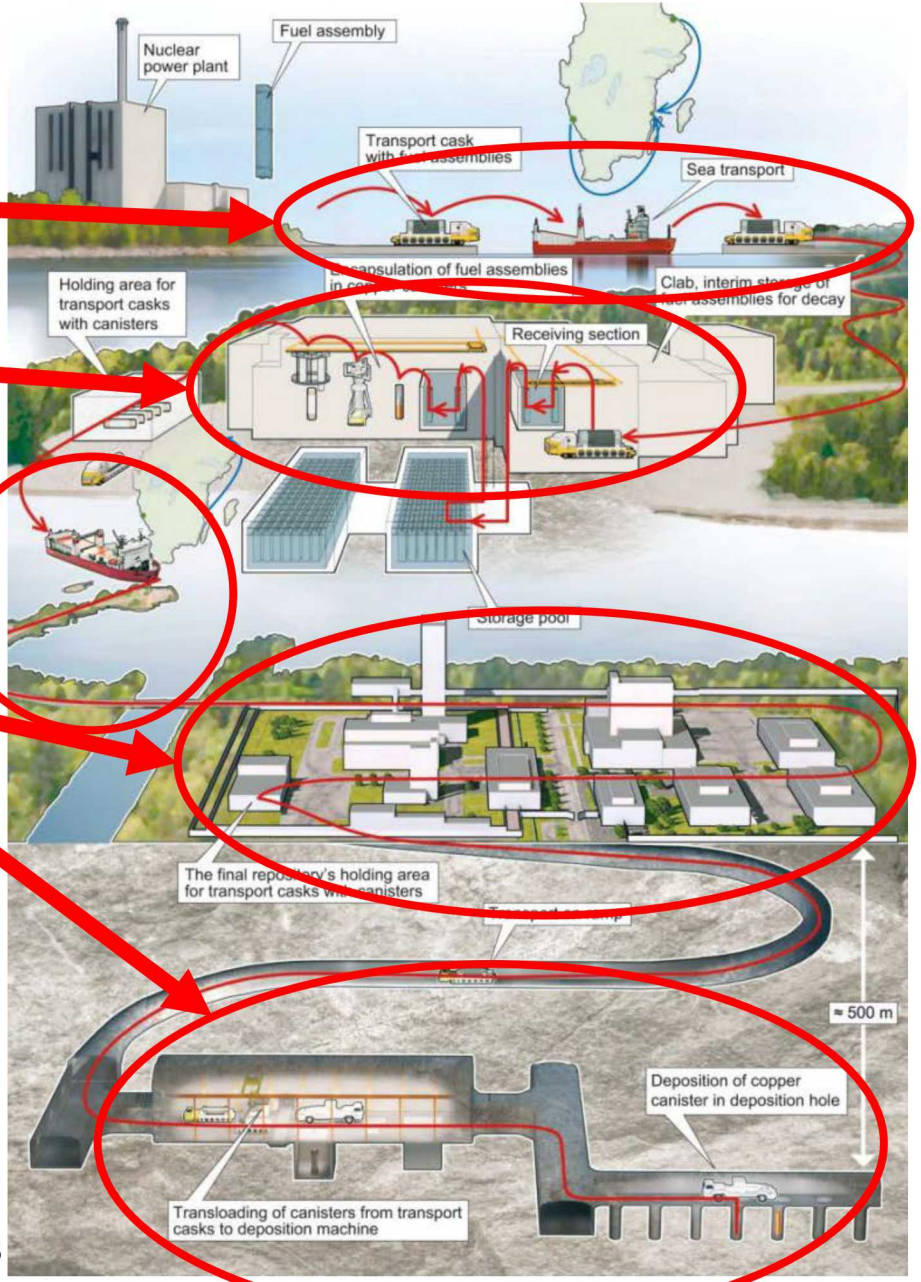


Image from SKB

Repository Containment & Surveillance

CONTAINMENT

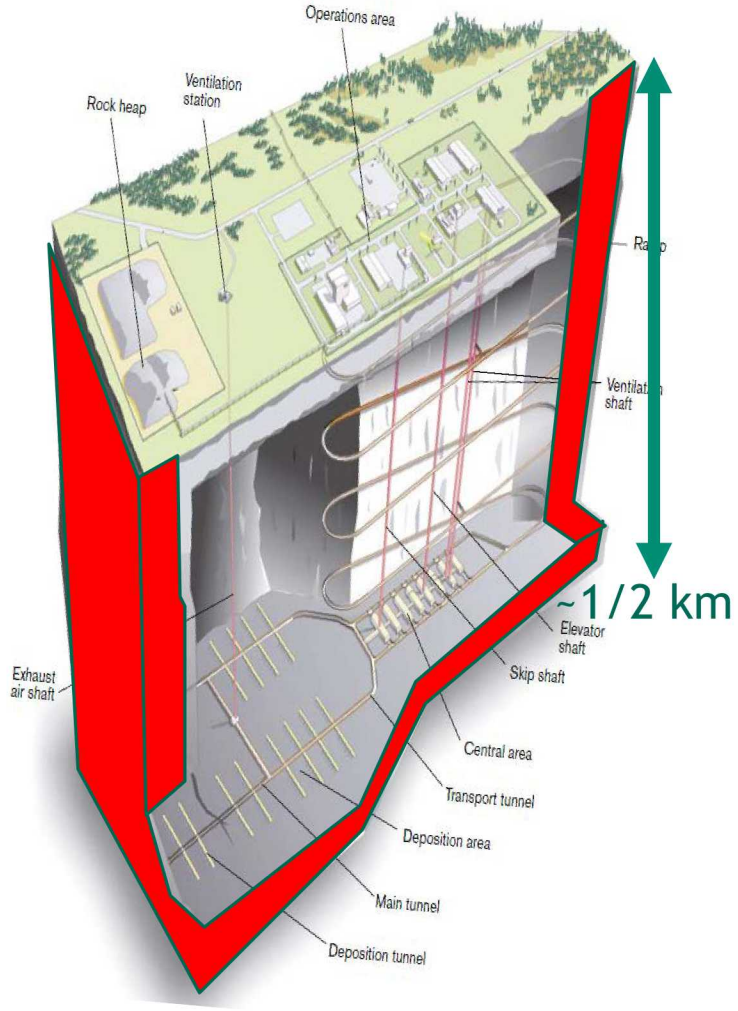
"**structural features** of a facility, containers, or equipment … used to establish the **physical integrity** of an area or items and can be used to **maintain continuity of knowledge** of the area or items by **preventing undetected access** to or movement of material, or interference with the items."

The "**restricted zone**" is the repository's containment

- Defined by the State

SURVEILLANCE measures

- Cameras
- Radiation monitors
- Mass measurements
- Ultrasound
- Laser scanning



Multiple independent C/S measures at every access point

Image from SKB

1. Encapsulation Plant

Last opportunity to observe fuel assemblies
- Before they are put into disposal canisters

Standard C/S equipment
- Radiation monitors
- Surveillance cameras

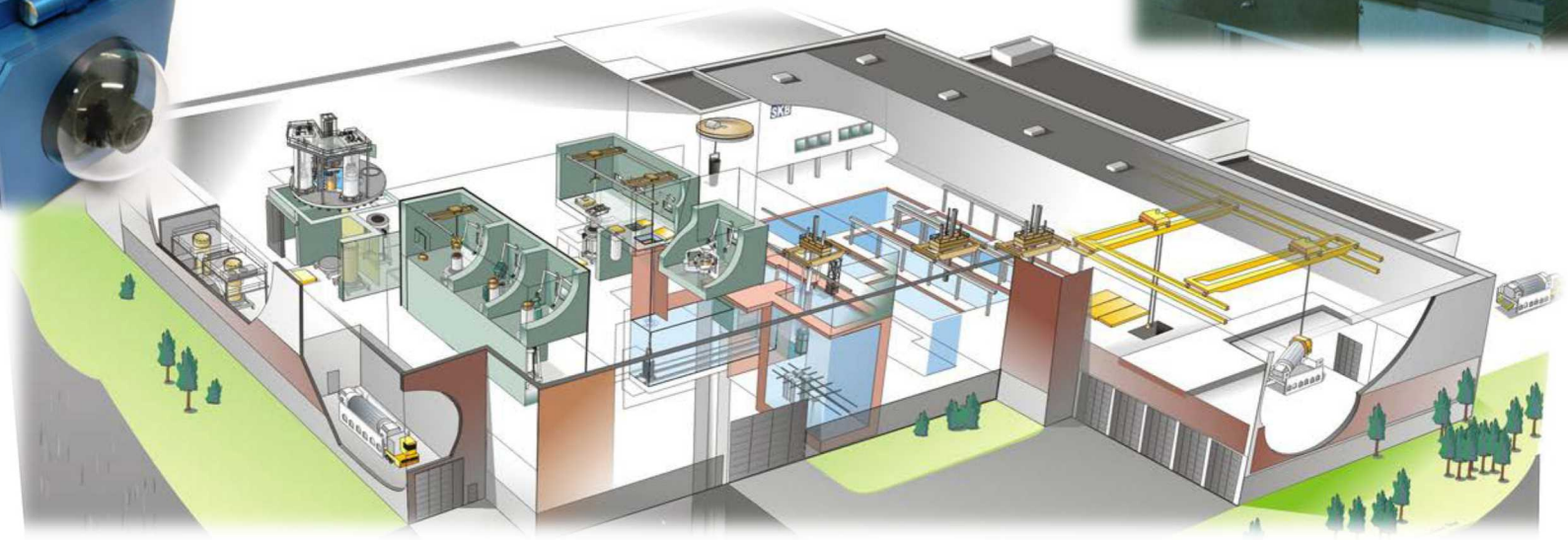


Image from SKB

2. Transportation

Maintain CoK

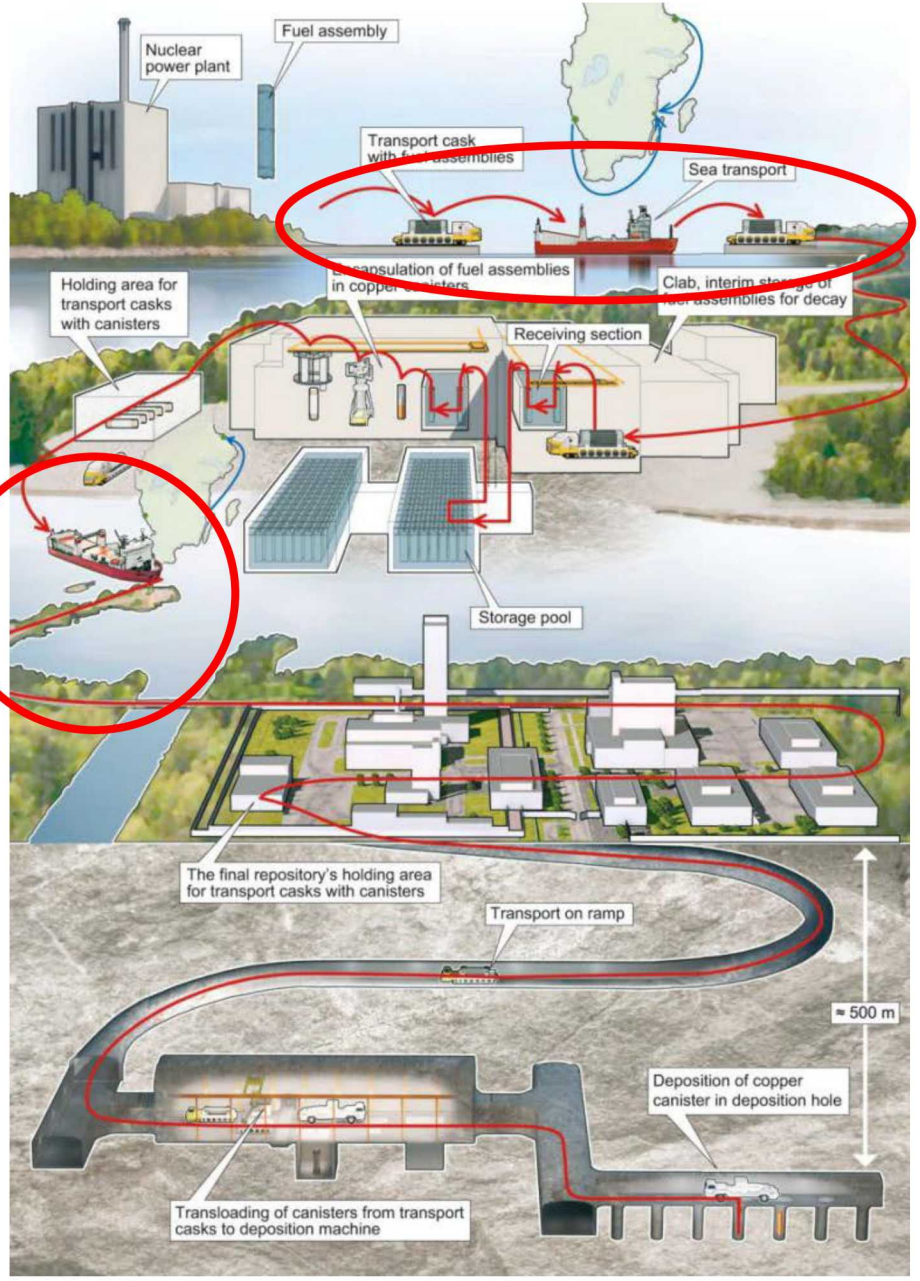
- From final accountancy measurement through final disposal

Transport casks seals

- Seals *applied* & *removed* by the State/operator

Additional C/S measures

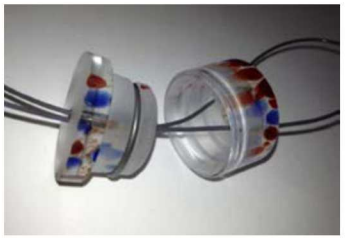
- Surveillance cameras (ships & trucks)
- Radiation detectors
- Geolocation
  - Data transmission and authentication



Passive sealing systems

- No power needed to operate
- Integrity verified manually
  - During inspection (in the field)
  - After removal

Metal seal (CAPS)



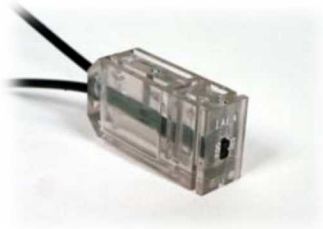
Glass seal

Ceramic seal

Passive Fiber-Optic Sealing system (FBOS)

Ultrasonic Sealing Bolts

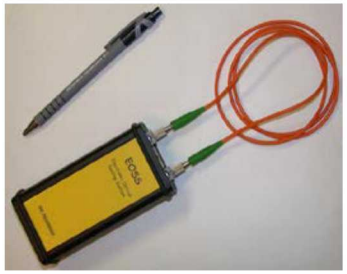
- Ultrasonic Optical Sealing Bolt (UOSB)
- Ultrasonic Sealing System Bolt (USSB)



Active sealing systems

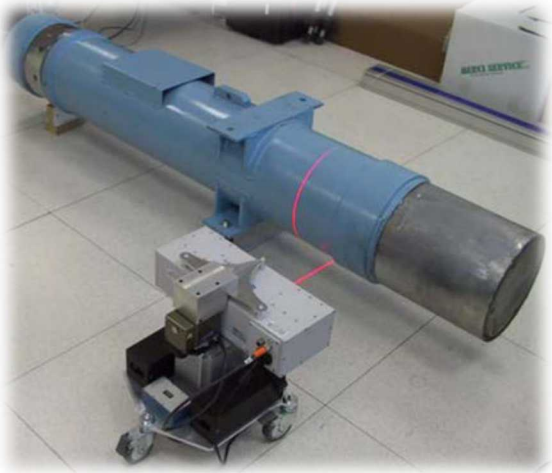
- Power source required
- Integrity continuously monitored
  - Opening, closing & tampering
- Data retrieval
  - On-site inspections
  - Remote monitoring (data transmission)

Active Fiber-Optic Seal (EOSS)



Remotely Monitored Sealing Array (RMSA)

Laser Mapping system for Containment Verification (LMCV)



Surveillance Systems

Optical -- Next Generation Surveillance System (NGSS)

Infrared (IR) camera

Laser Surveillance System (LASSY)

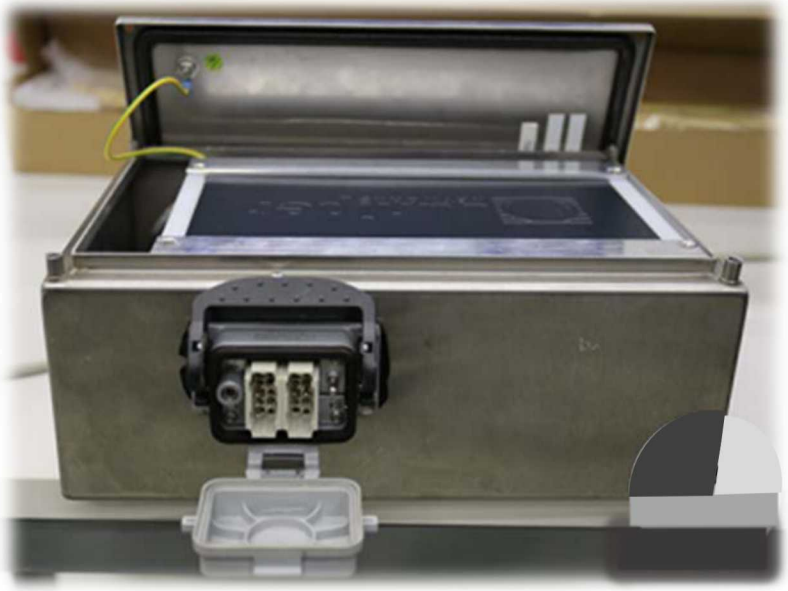
Surveillance – Radiation Detection Systems

Mobile Unit for Neutron Detection (MUND)

Battery powered

- 8 weeks

Remotely monitored

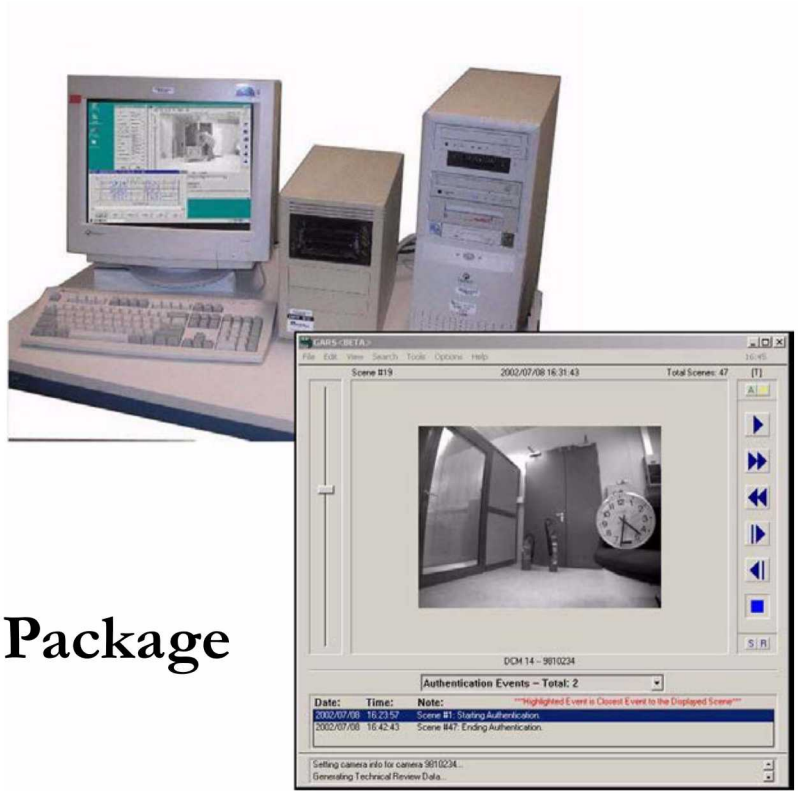


Transportation casks

Surveillance & Radiation Detection Review Tools

1. **General Advanced Review Station Software (GARS)**

- Optical surveillance images
  - Inspector evaluated
- Scene-change detection



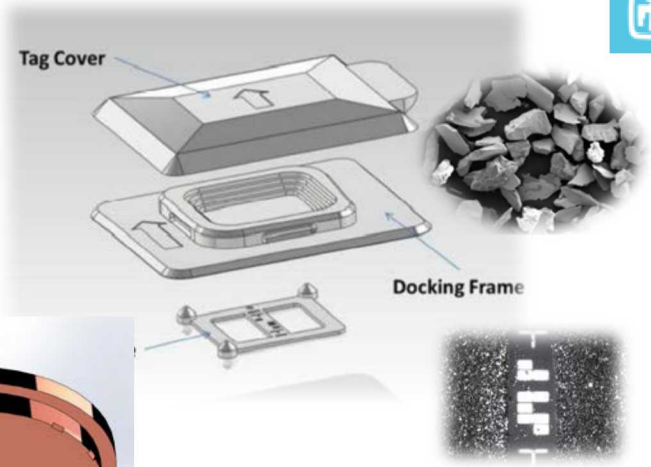
2. **Integrated Review and Analysis Package (iRAP)**

- Modular software package
  - Developed by EURATOM
  - Successor to Central RADAR5 Inspection Support Package (CRISP)
- Recently adopted by the IAEA

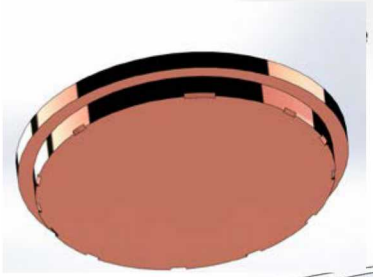
Disposal Canister Identification

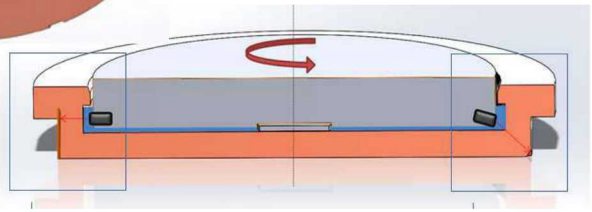
Disposal Canister Identification

Reflective Particle Tag (RPT)

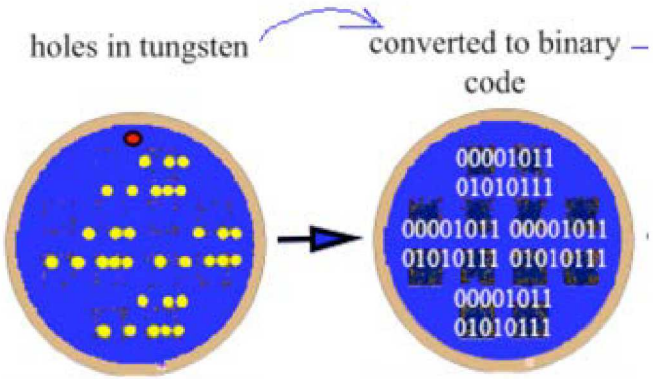


Ultrasonic ID for Copper Canisters





Tungsten-Based Identifiers



SUMMARY

Permanent disposal of spent fuel will require unprecedented need to maintain CoK

- Highly effective C/S measures
- Final accountancy through final disposal

C/S measures applied to

- Encapsulation plant
- Transportation
- Repository

For more detail on C/S technologies reviewed here see the 2017 IAEA/ASTOR Group Report (STR-384)

Acknowledgements

Funding provided by NNSA's Office of International Nuclear Safeguards under the Concepts and Approaches subprogram.

Thank You

Ultrasonic ID for Copper Canisters

Chamfers milled on the canister lid's inner surface before closure are read by an ultrasonic transducer while rotating about the lid's circumference.

4 (lab demo)

Reading takes ~5 minutes per canister (expected); requires acoustic-coupling medium (e.g., water)

€20 000 (estimated for two scanning systems: EP* & GR*)

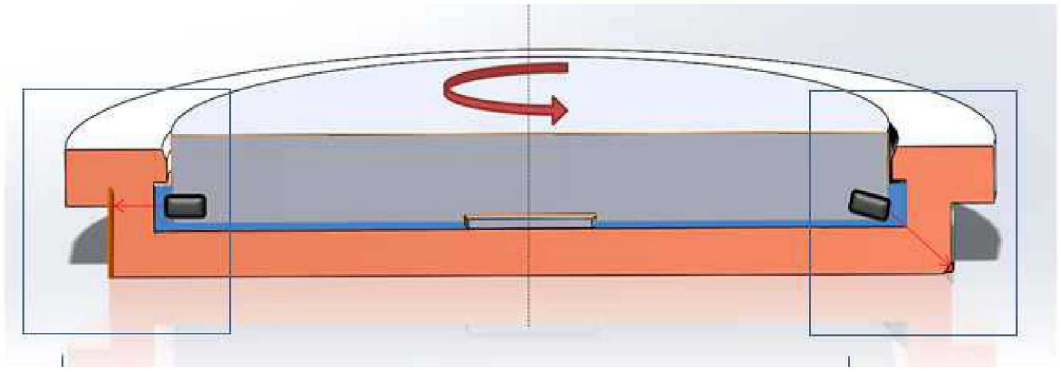
Standard COTS* hardware

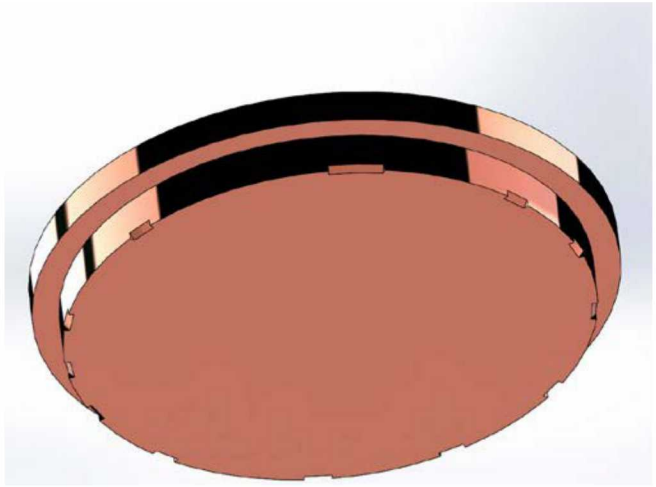
Standard inspector skills

Ultrasonic authentication signature combined with random Cu flow generated during welding

Zero

High





Tungsten-Based Identifiers

A tungsten insert, with a hole pattern based on a binary code, is placed between the cast-iron lid and the copper lid of a Cu canister. Selectively collimated gamma rays reveal a unique tag pattern as recorded by a gamma detector.

4 (lab demo)

Gamma signal weakens over time, increasing measurement time.

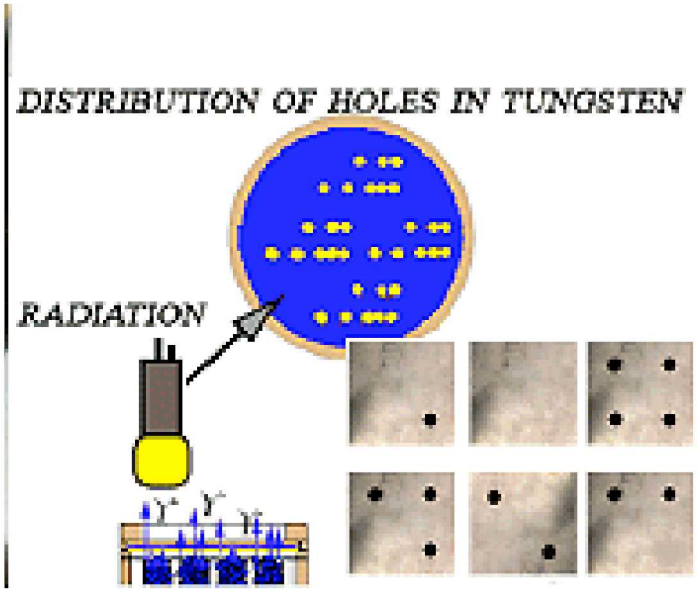
Unknown

Standard COTS* hardware used to read insert

Standard inspector skills plus training in the use of COTS* reader equipment (e.g. gamma camera)

Unknown

Potentially low; Could combine with other 'intrinsic' characteristics



Disposal Canister Identification

	Reflective Particle Tag (RPT)	*Ultrasonic ID for Copper Canisters*	*Tungsten-Based Identifiers*
Technology description	*Field-applied tag composed of specular hematite particles randomly dispersed in a clear, adhesive polymer matrix*	Chamfers milled on the canister lid's inner surface before closure are read by an ultrasonic transducer while rotating about the lid's circumference.	A tungsten insert, with a hole pattern based on a binary code, is placed between the cast-iron lid and the copper lid of a Cu canister. Selectively collimated gamma rays reveal a unique tag pattern as recorded by a gamma detector.
Technology readiness level (TRL)	*4-5 (prototype)*	4 (lab demo)	4 (lab demo)
Technical limitations	*Uncertain reliability over a repository's operational timeframe*	Reading takes ~5 minutes per canister (expected); requires acoustic-coupling medium (e.g., water)	Gamma signal weakens over time, increasing measurement time.
Estimated costs	*Unknown*	€20 000 (estimated for two scanning systems: EP* & GR*)	Unknown
Sustainability, standardization, supply chain	*Unknown*	Standard COTS* hardware	Standard COTS* hardware used to read insert
Ease of use/Level of operator skill/Major infrastructure needs	*Easy to use* *Low skill level required*	Standard inspector skills	Standard inspector skills plus training in the use of COTS* reader equipment (e.g. gamma camera)
Methods of data validation/authentication	*Dedicated reader system*	Ultrasonic authentication signature combined with random Cu flow generated during welding	
Expected 'Alarm' rates	*Unknown (expected to be low)*	Zero	Unknown
Uniqueness against duplication/falsification	*High*	High	Potentially low Could combine with other 'intrinsic' characteristics