Reliability Studies, a Tool in the Development of Techniques for NDT of the Canister for the Swedish Spent Nuclear Fuel

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Abstract

The Swedish KBS-3 design for the disposal of spent fuel is based on encapsulation of the fuel in canisters consisting of cast iron inserts and an outer 5 cm thick shield of copper. The canisters are embedded in bentonite clay and will be disposed in crystalline bedrock at a depth of about 500 m. To verify that the canisters fulfil the requirements, an extensive programme for quality control is developed. In this programme the use of non-destructive testing (NDT) is vital and therefore it is very important to develop reliable NDT methods.

Commonly, the reliability of NDT in the nuclear field is only analyzed on a technical basis, and only in the stage of the technical justification of the methods. Within the development of mechanical ultrasonic inspection techniques for the canister for the spent nuclear fuel, reliability analyses are used as an integrated tool already in the development phase. Sophisticated POD-calculations (Probability of Detection) are used to analyze the detection capabilities and thereby identify the weak spots and the needs for further improvement. Additionally, the reliability analyses also focus on the human factors during the application of mechanical inspection techniques, especially in the field of evaluation of collected data. Aided by the eye tracking methodology, the written instructions and their use during the data evaluation were experimentally investigated. The results will serve as a basis for optimization of the instructions and definition of needs for specific operator training.

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Ulf Ronneteg

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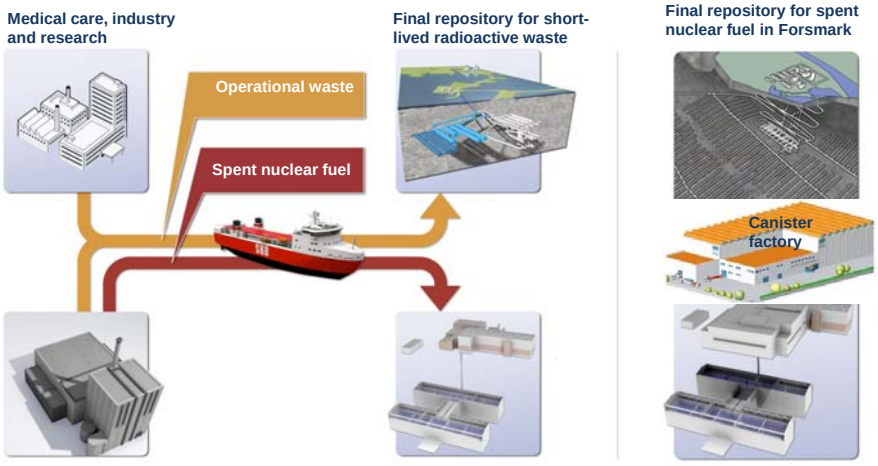
- **Exova Materials Technology, Linköping (Sweden)**
  - NDT personnel

Safe for 100000 years

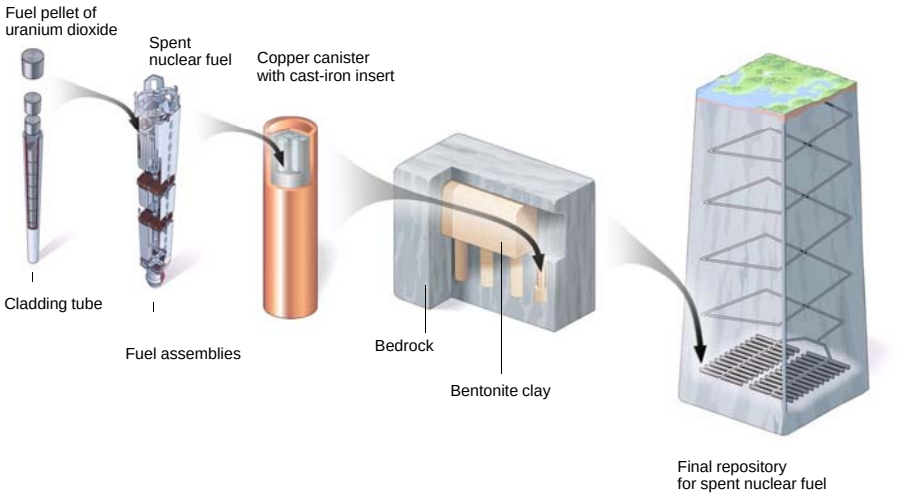
Requires high degree of reliability

Withstand:
- The Ice Age
- Rock shear from earthquakes

SKB's system

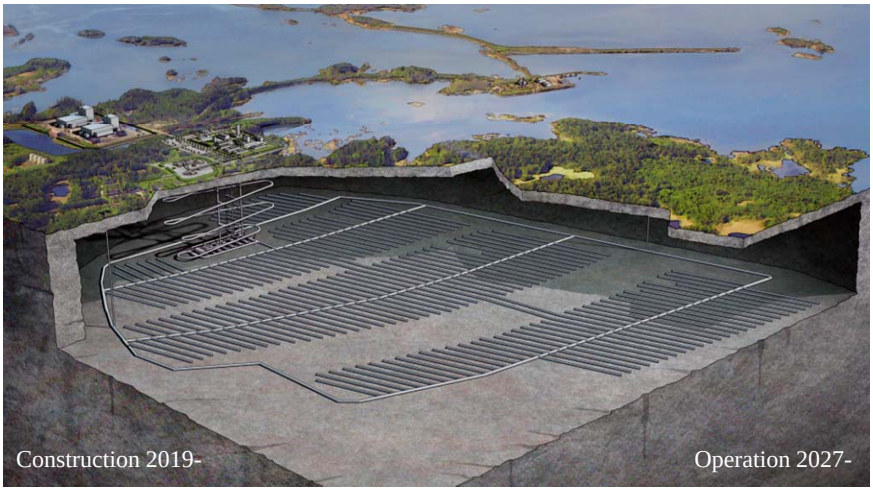


The barriers



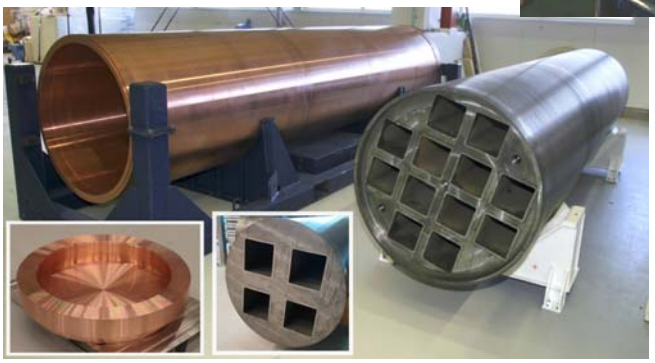
Final repository for spent nuclear fuel

Final repository for spent nuclear fuel



6000 canisters

- Cast iron insert – mechanical strength
- Copper shell – corrosion resistance
  - Tube
  - Base/lid
  - Welds (FSW)



The Canister Laboratory

The Canister Laboratory

Main goals

- Development of welding techniques
- Development of manufacturing processes for the canister components
- Development of NDT techniques for the canister components and welds

The Canister Laboratory

Questions

Why only use reliability studies to verify the developed NDT techniques?

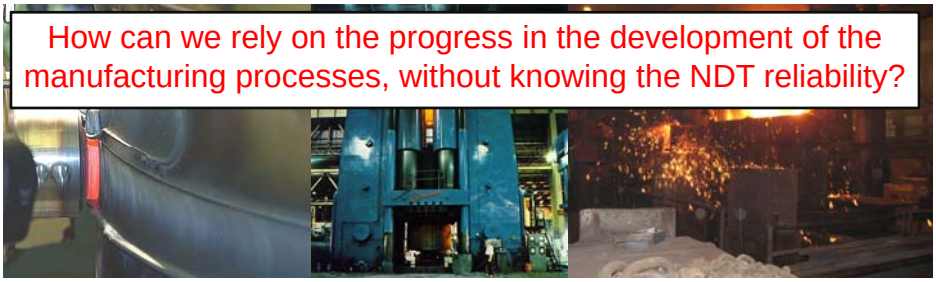
Why not use reliability studies **during** the NDT development?

Why study the reliability early in the development of the NDT?

Development of manufacturing processes

- Casting of inserts
- Extrusion of copper tubes
- Forging of copper lid
- Friction stir welding of copper shell

How can we rely on the progress in the development of the manufacturing processes, without knowing the NDT reliability?



The NDT techniques - a tool in the development of the manufacturing and weld processes

Why study the reliability early in the development of the NDT?

Low production rate

- Long time between the inspections
- Every time the operator is a ”rookie”

Especially important with good instructions!

Example of reliability studies

- POD studies
  - Conventional POD
  - Volume POD
  - Multi-parameter POD
- Human factor studies
  - FMEA
  - Theoretical studies
  - Eye-tracker experiments

POD studies

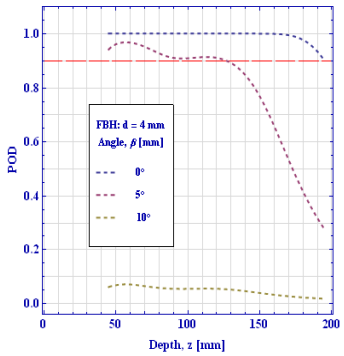
Used to identify/determine

- Coverage
- Detectability
- Sensitivity for different parameters
  - Defect position
  - Defect orientation
  - Sound attenuation
  - Etc

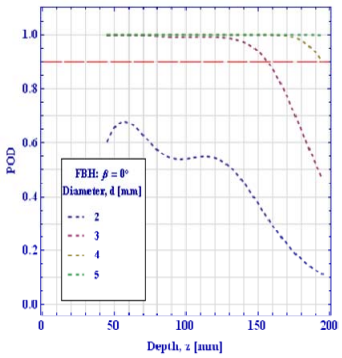
Identified needs for further technical improvements

POD vs influencing parameters (1)

POD vs defect angle

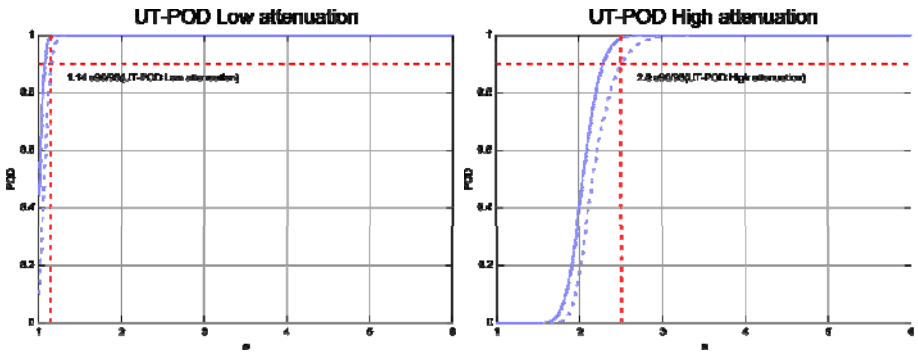


POD vs defect depth



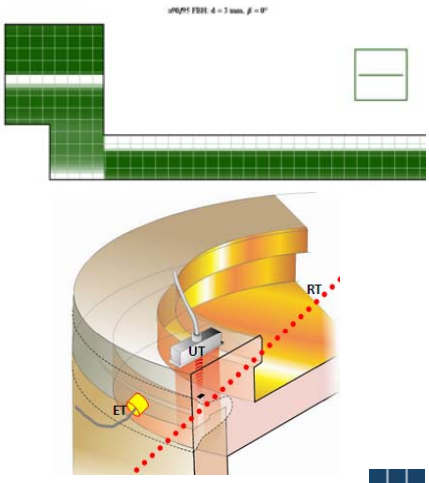
POD vs influencing parameters (2)

POD vs ultrasonic attenuation



Volume POD

- Optimization tool for NDT
  - Identify areas with lower POD
  - Identify defect orientations with lower POD
- Combined POD
  - From several UT-inspections
  - From several NDT techniques



Human factors

Customized Failure Modes and Effects Analysis, FMEA

- Identified a number of weaknesses
  - Preparation
  - Sensitivity setting
  - Inspection
  - Data evaluation

Emphasize the need of good instructions

Human factors – Instruction (1)

Theoretical studies

- What's available in standards?
  - Only recommendations on content
  - Nothing about how to write
- PANI 3 study – recommendations of
  - Structure
  - Format

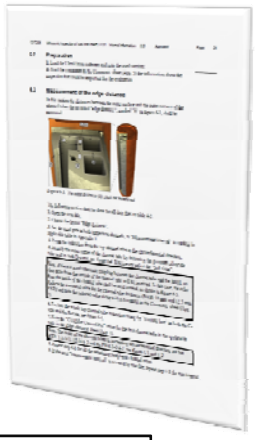
Human factors – Instruction (2)

Eye-tracker experiments – in several steps

- Data evaluation based on written instruction monitored by
  - Eye-tracker
  - Supervisor
- The experiments were evaluated based on
  - Quality of instructions
  - Performance vs experience/training
  - Individual & group discussions
- Results
  - Reasons for errors were identified
  - Actions initiated based on the errors
  - The instruction was optimized in several steps

Lessons learned

- Found differences in how to read and interpret the instruction
  - Emphasize the need for consensus for interpretation of data
- Important to include operators when instruction is written
- Important that the instruction is accepted and used
- The results from the studies have been used as input to set more clear criteria's for data evaluation



The use of instructions is complex, but can be improved by a number of actions

Summary / conclusions

- POD studies have been used to identify
  - Coverage
  - Detectability
  - Sensitivity to different parameters
- Human factor studies have been used to
  - Identify week points in the inspection chain
  - Improve the instructions
    - Format
    - Content
- A concept for reliable NDT instructions has been developed