Studsvik

Studsvik PIE: Dry storage, Transport and Deep Repository Research of Spent Fuel in Sweden

INMM Spent Fuel Management Seminar XXVIII,
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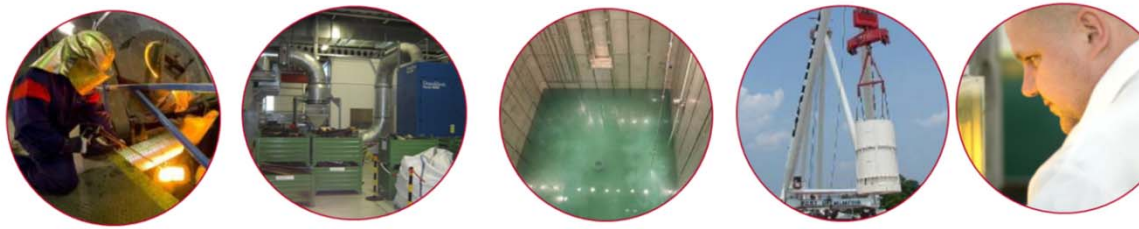
The Presentation

Five operating segments

Sweden	United Kingdom	Germany	USA	Global Services
Waste Treatment performed in the facilities in Sweden Customers in Europe; Sweden, Germany and neighboring countries, UK	Waste Treatment and decommissioning in the United Kingdom	Decommissioning and Engineering & Services in Germany and neighboring countries	Waste Treatment facilities service customers in North America. Engineering & Services for global customers.	Operating Efficiency; materials technology and fuel optimization software Global customer base, business in many countries



1. PIE at Studsvik
2. Transport and dry storage related research
3. Geological repository related research

Studsvik – laboratories/facilities

Hot Cell Laboratory

Active metals laboratory

Transports

Corrosion and water chemistry lab

Pool facility

Studsvik: we work with everybody

Worldwide

- US
- Sweden
- Spain
- Japan
- UK
- Finland
- Germany
- France
- Russia
- Korea

Vendors such as:

- WESTINGHOUSE
- AREVA
- ENUSA
- GNF
- MHI
- NFI

Organizations such as:

- EPRI
- NRC
- JNES
- CRIEPI
- EDF
- Vattenfall
- SSM

Studsvik SCIP Project, an OECD/NEA project

Studsvik Experience and material bank

Started 1960

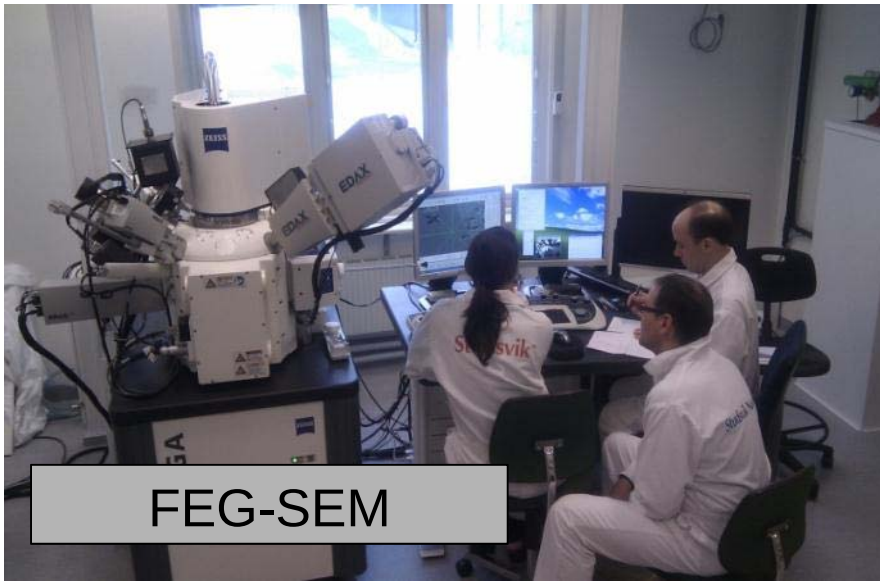
Material available

- Today material from more than 300 different fuel rods in the HCL
- BWR and PWR
- All big fuel suppliers
- Different generations of fuel
- Different operation environments and irradiation histories
- Burnup up to ~75 GWd/tU (small amounts ~90)

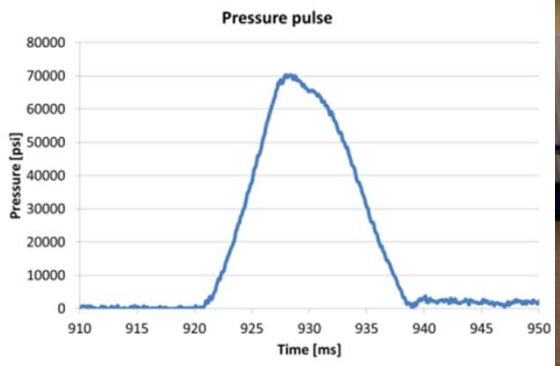
Tools at Studsvik

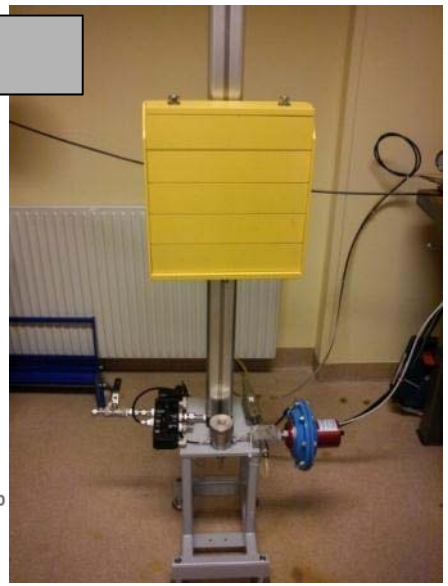
Studsvik has:

- All standard NDE & DE methods
- Advanced microscopy
- Advanced mechanical testing

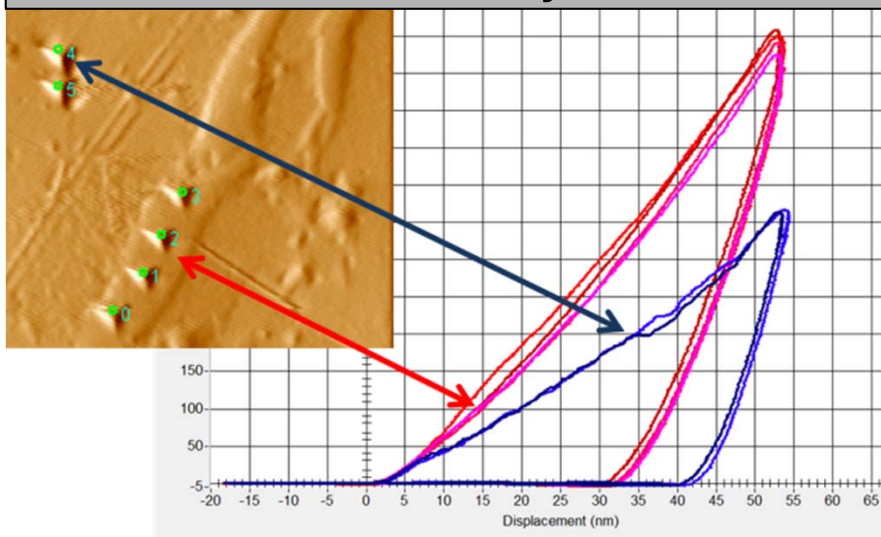


Simulated RIA testing





Nano-indentation in hydride & matrix



Transport and dry-storage of spent nuclear fuel

- Possible fuel failure mechanisms during transport and dry-storage conditions
  - Creep to failure
  - Delayed Hydride Cracking (DHC)
  - Hydride embrittlement and hydride re-orientation

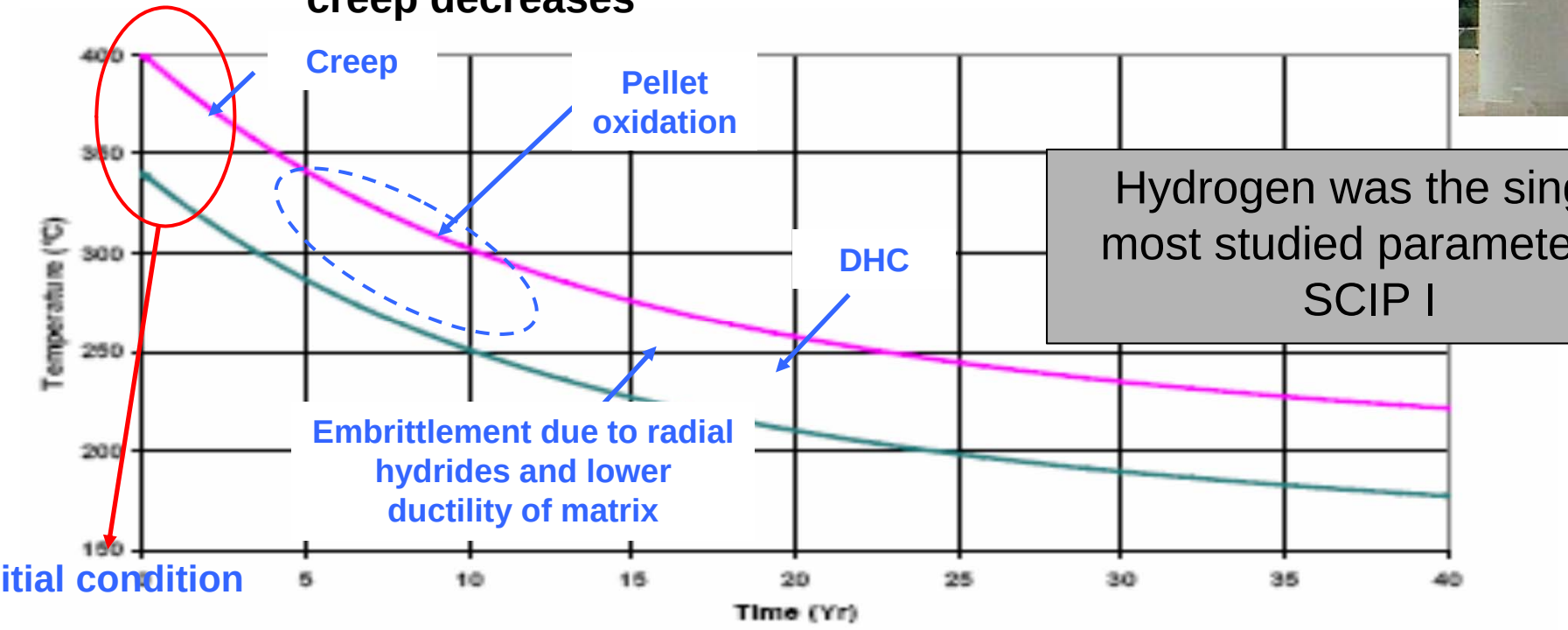
  Standard Studsvik methods
- Additional issues in long term storage
  - Moisture content in cask and in failed fuel => Oxidation of fuel and cladding
  - Fuel fragmentation and rise of rod pressure due to decay generation of He

  Under development at Studsvik
- Source term data for high burnup fuel rods
  - Better isotopic data support long term dry storage (criticality, decay heat and nuclide activity)

  Standard Studsvik methods

Dry storage – conditions change over the years

- **Temperature evolution with time**
  - **Temperature decreases**
  - **Pressure decreases, hoop stress decreases, creep decreases**



Hydrogen was the single most studied parameter in SCIP I

itial condition

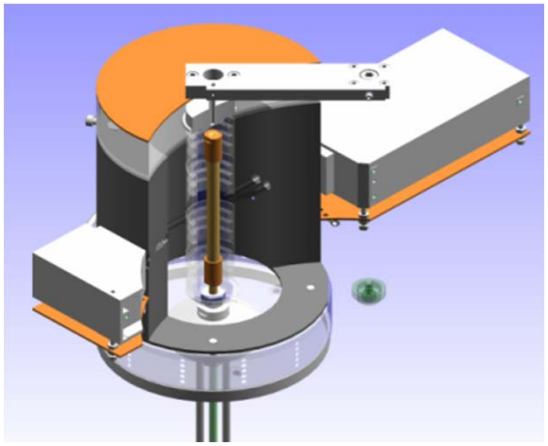
gher hoop stress

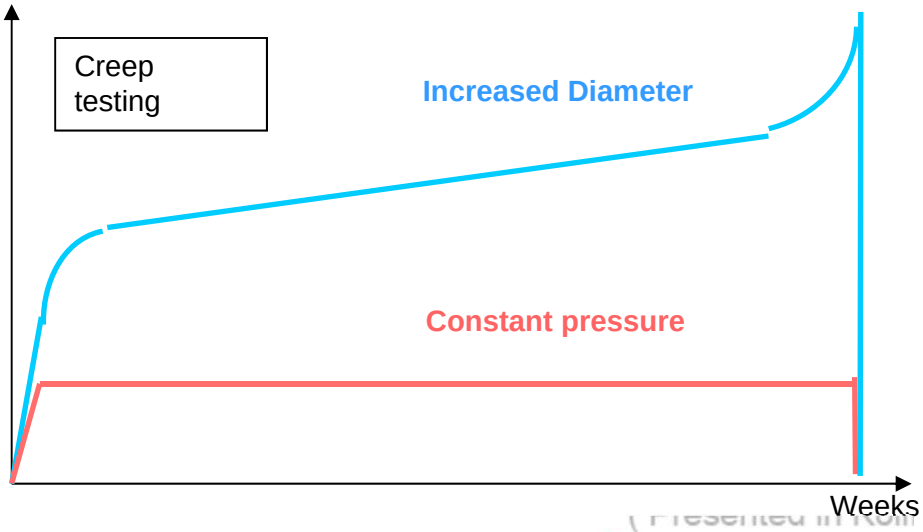
gher creep demanding

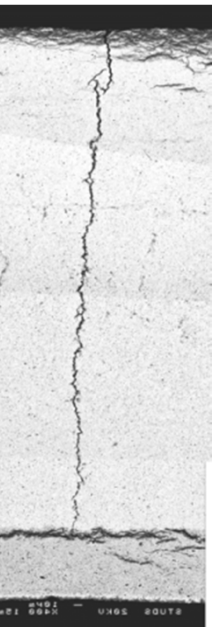
Ref: M. Lloret, M. Quecedo, ENUSA, Nov. 2009, SCIP Workshop on Hydrogen Induced Failures

Test methods at Studsvik for creep & DHC

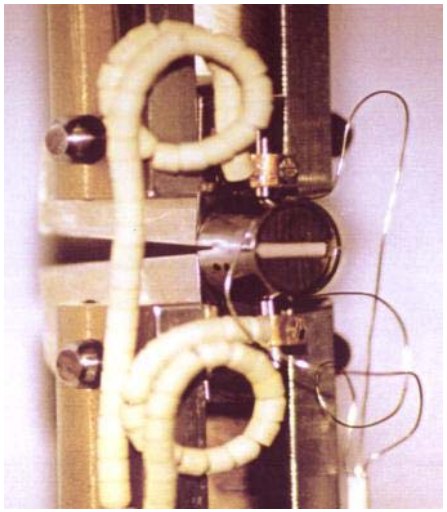
Creep testing



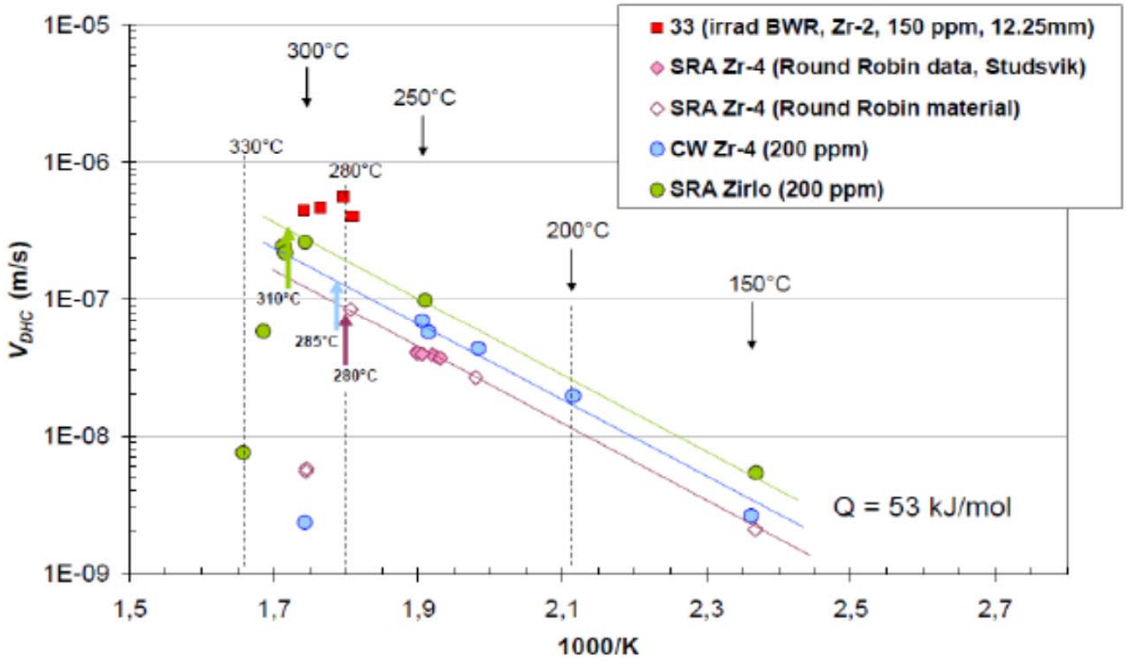




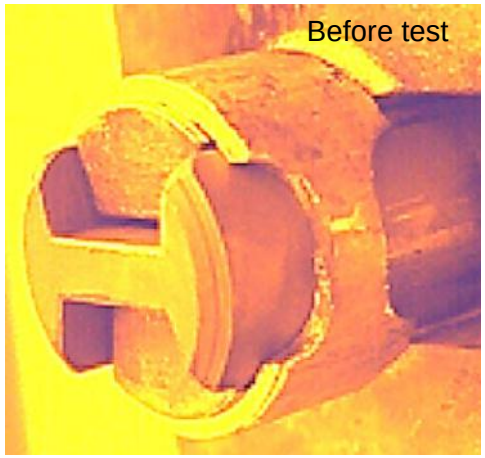
DHC



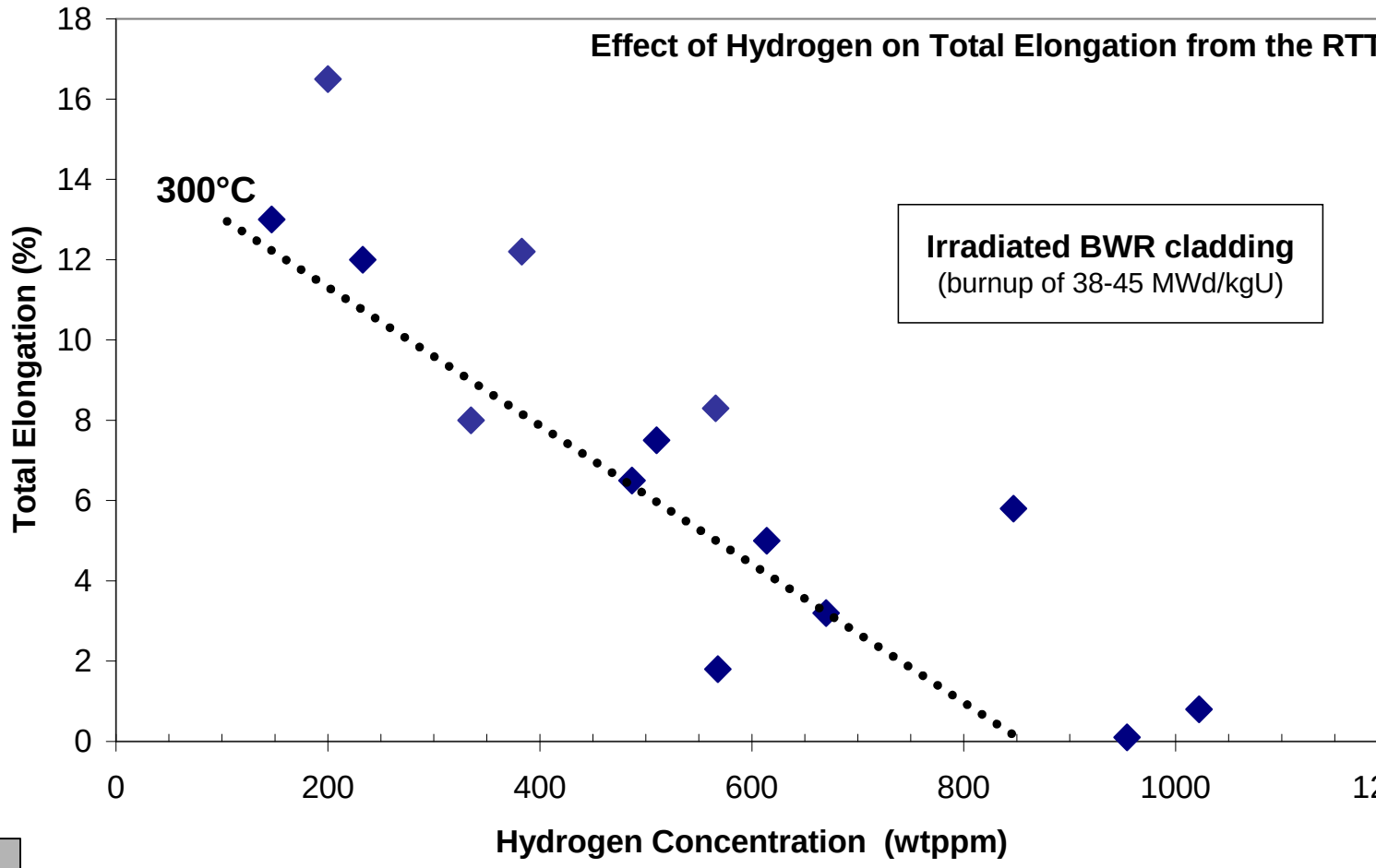
DHC-PLT testing



Hydride embrittlement and characterization of cladding properties by RTT



Ring Tensile Test (RTT)



Research in the pipeline

Long-term fuel degradation

- US NRC priority
- Rods dry-stored for 40+ years available at Studsvik

Moisture content in cask/failed fuel

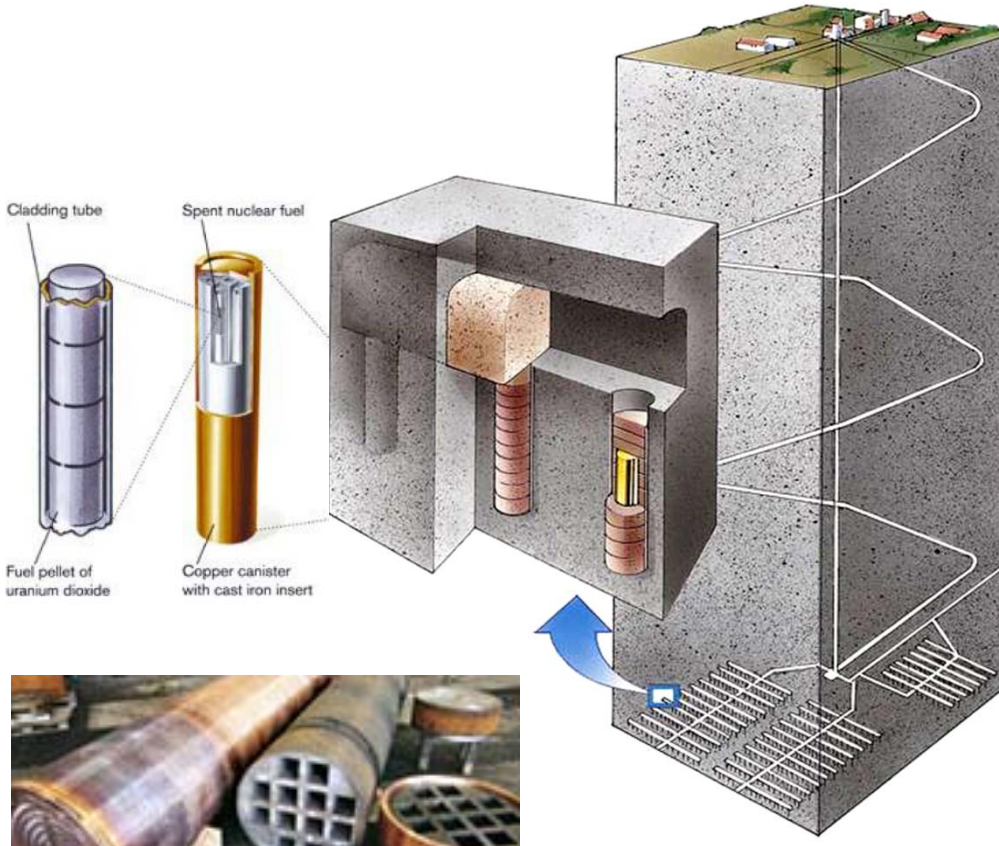
- Moisture hidden in failed fuel
- A program of fuel drying procedures related to failed fuel at Studsvik

Fuel issues under transport accident conditions

- Available test methods at Studsvik HCL:
  - Bending tests with rod break and fuel loss measurements
  - Impact tests

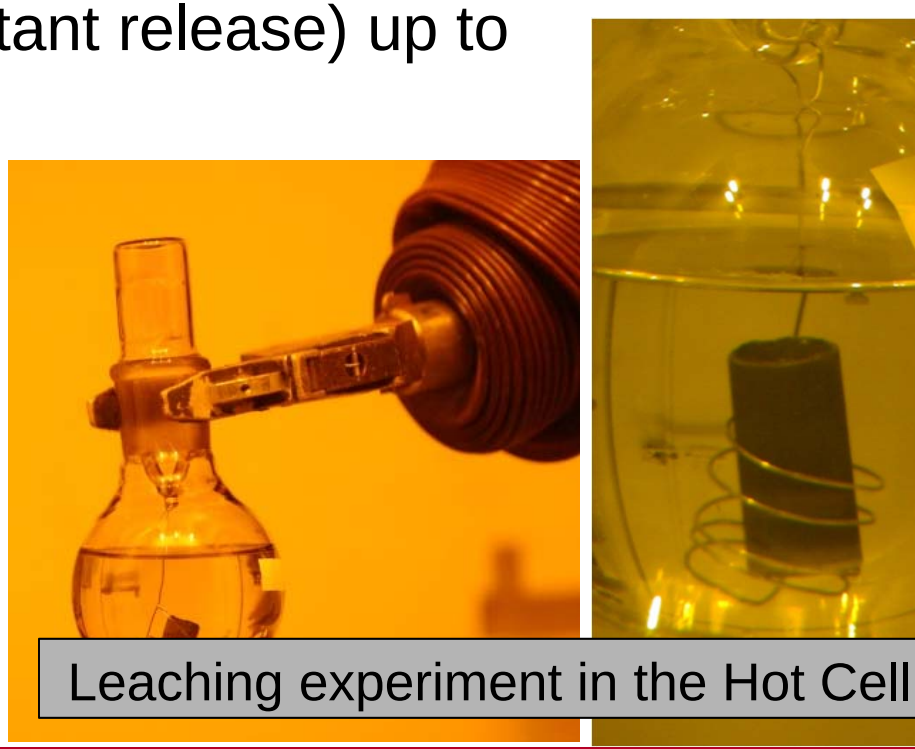
Deep Repository KBS-3 Concept (SKB)

- Issue: Radionuclide release to groundwater (barrier failure)
- Long term safety assessment based on modeling of the fundamental processes and reliable input data
- Fundamental processes affecting radionuclide release e.g.:
  - Oxidative dissolution of the SNF matrix
  - Instant release mechanism
  - H_2 inhibition of fuel dissolution



Studsvik Research Projects

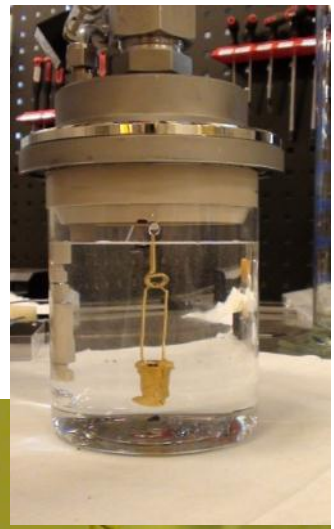
- Leaching of spent nuclear fuel in hot cell (ongoing for more than 30 years)
  - Experiments performed on irradiated nuclear fuel
  - Duration from days and months (instant release) up to several decades (matrix dissolution)
  - Leaching under oxidizing (air) conditions (“worst case”)
  - Release rate of key radionuclides and uranium measured

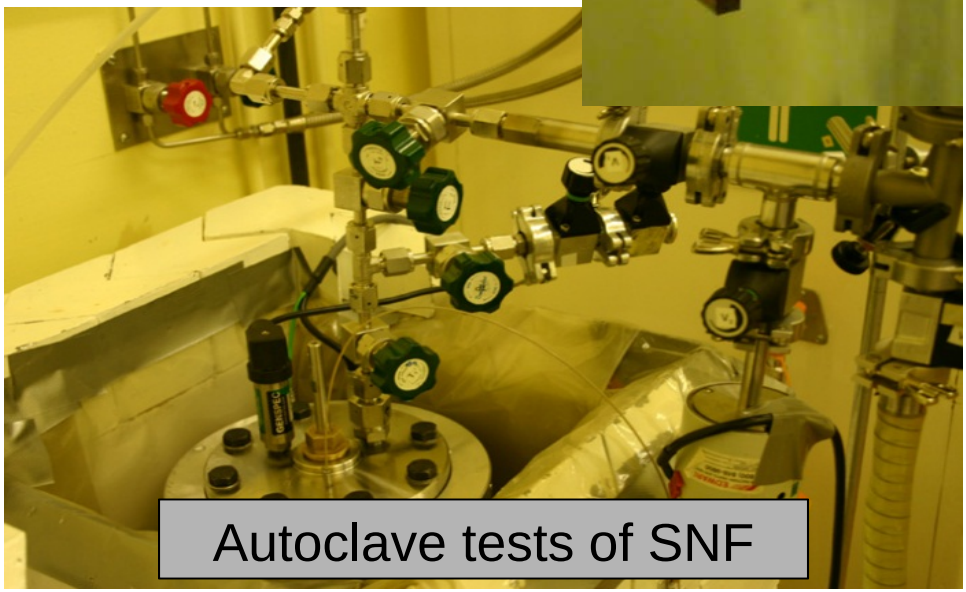


Leaching experiment in the Hot Cell

Research Projects cont.

- High pressure leaching of spent fuel in autoclaves
  - Control: Temperature, pressure and atmosphere
  - Allows leaching under more realistic deep repository conditions (ex. reducing (H_2) or inert (Ar) atmosphere)
  - Allows mechanistic studies of the inhibiting effect of H_2 on spent fuel dissolution and the effect of iron



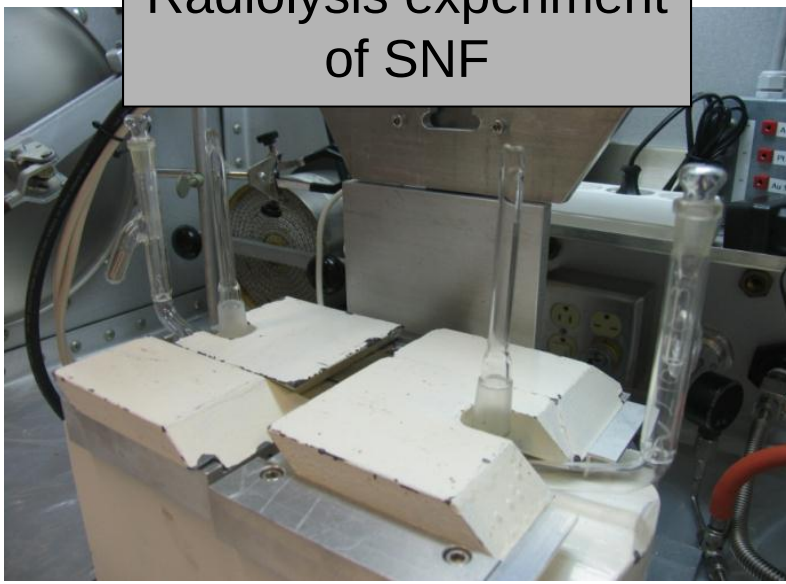


Autoclave tests of SNF

Research Projects cont.

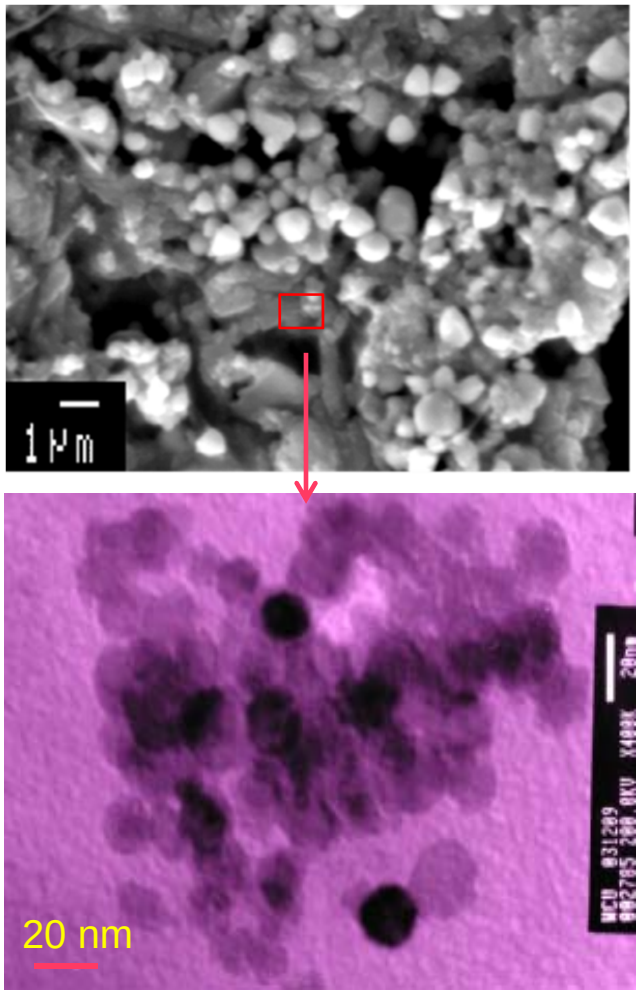
- Radiolysis experiments in sealed ampoules
  - Measure the evolution of radiolysis products (H_2, O_2 and H_2O_2) in relation to released amount of uranium/radionuclides
  - Results used as input and validation of models simulating spent fuel dissolution

Radiolysis experiment of SNF



Research Projects cont.

- Studies of SNF metallic particles
  - Non-destructive extraction of metallic particles
  - SEM and TEM analysis
  - Determine nanostructure, composition and lattice parameters
  - Results used e.g. for understanding the role of metallic particles in H_2 inhibition of spent fuel dissolution



In summary

Studsvik:

- Provides data
- Supports understanding
- Utilizing a large material bank and long experience

Supporting the nuclear community:

- Authorities
- Vendors
- Utilities

Studsvik

Anything about Studsvik:

http://www.studsvik.com/en/

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Data from the repository work is often published by SKB:

http://www.skb.se/