“Role of the Halden Reactor Project for “TVEL” nuclear fuels & materials development

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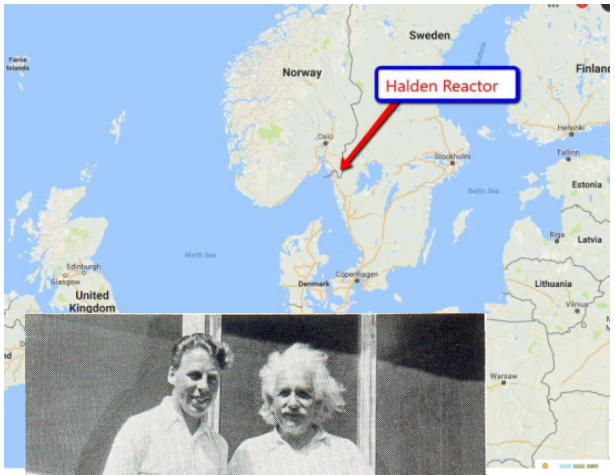
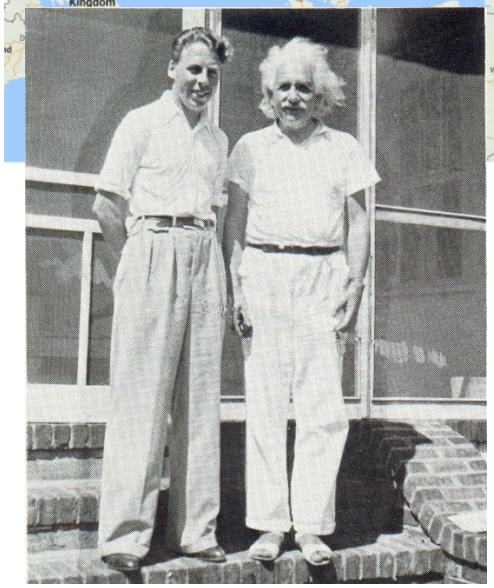
2018 ATOMEXPO

International OECD Halden Reactor Project - foundation and history organisation

One of the successful cooperative research project on peaceful, safe and reliable utilisation of nuclear energy



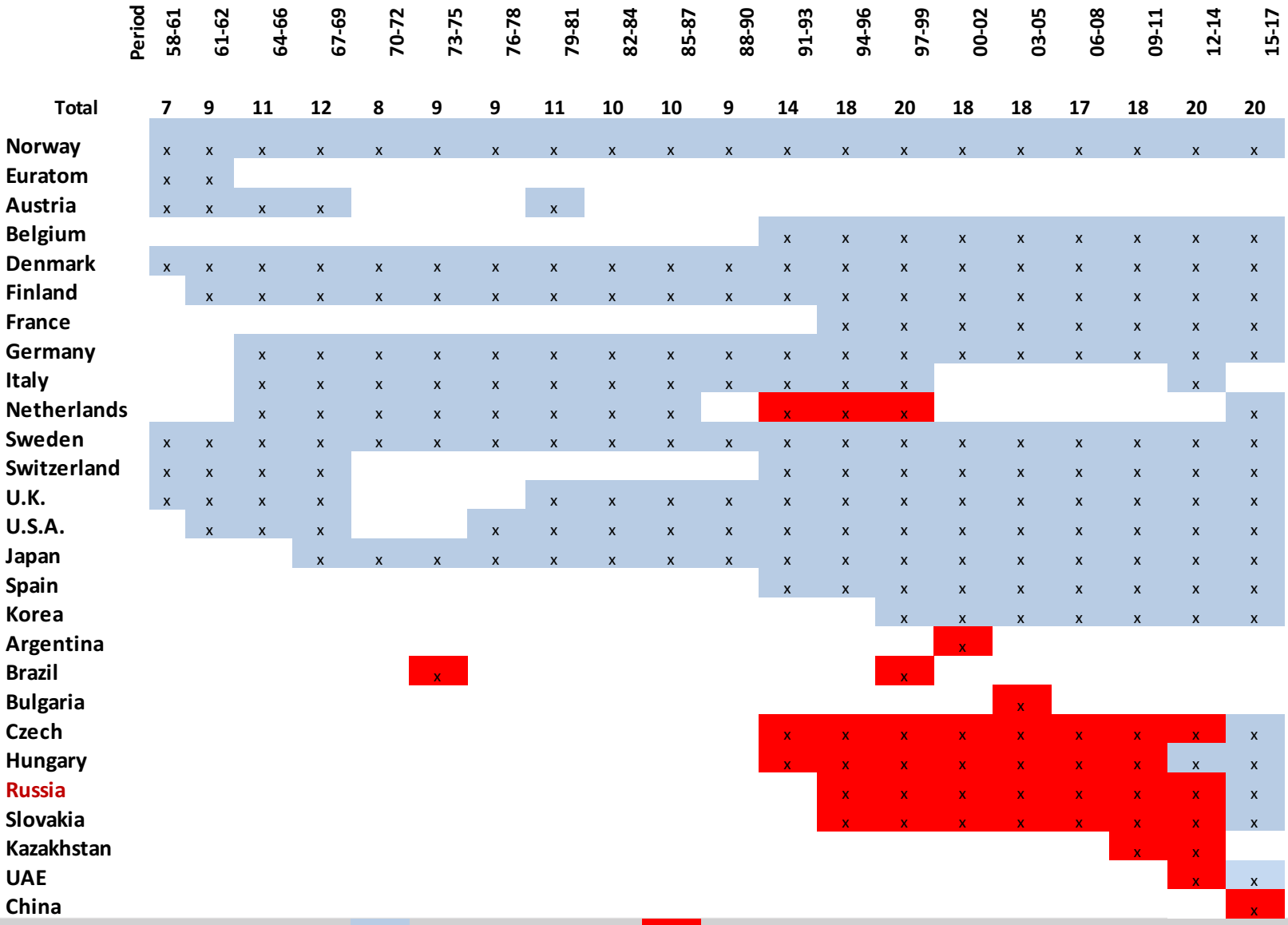


1948 "Institutt for atomenergi" founded for developing the application of nuclear power in Norway.

1958 Official foundation of the Halden Reactor Project operating under auspices of OECD

- Jointly funded by Members for 3-years agreements
  - From ~20 countries
    - More than 100 organisations
- Participating organisations:
  - Utilities (EDF...) and RRs (BR2, HFR, ATR, MIR...),
  - Licensing and Radiation Protection authorities (NRC, STUK...)
  - Vendors (Westinghouse, AREVA, "TVEL",...)
  - R&D centres (ORNL, INL, JAEA, KAERI, VNIINM.....)

Member - countries at OECD HRP



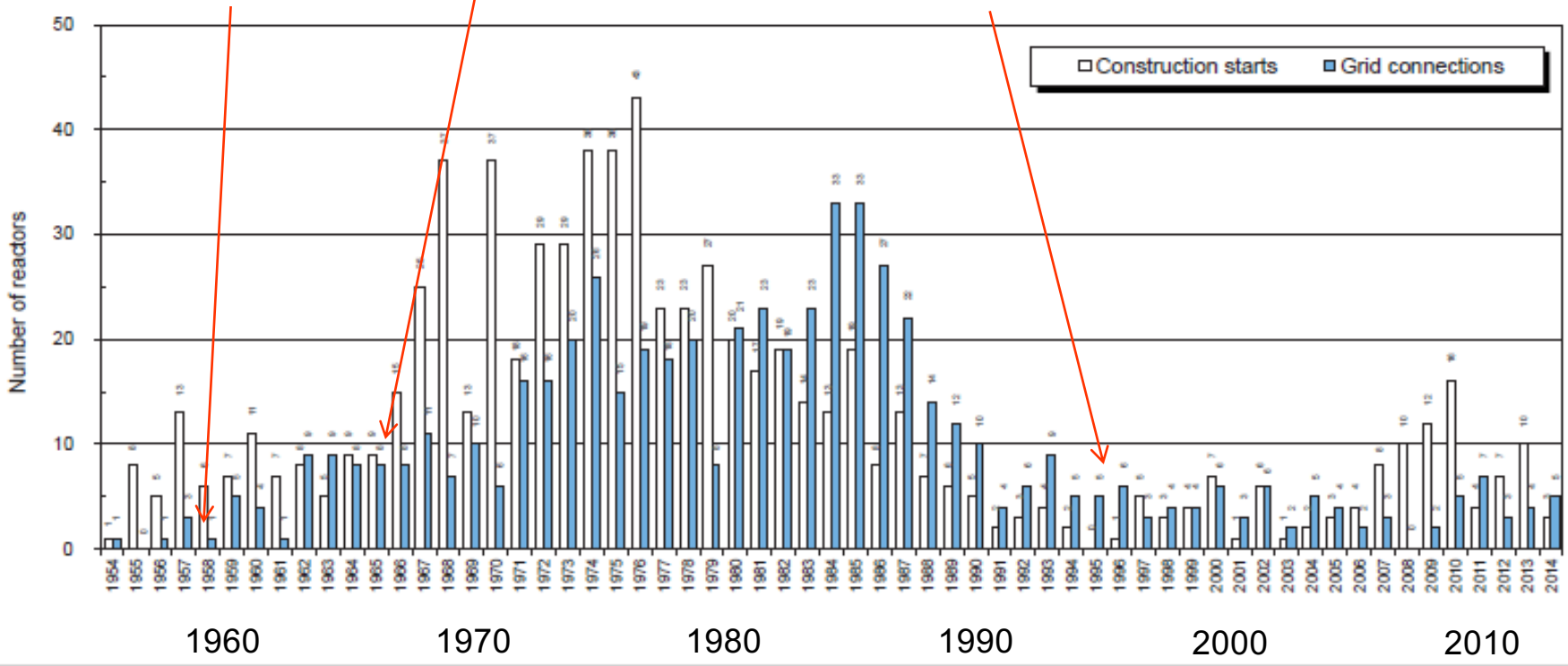
Nuclear energy development and HRP

Original NPP design life 40 years, extensions to 60 or 80 being granted, so Gen-II/-III will still dominate to 2020-2040

Start of HBWR & OECD HRP

First IFAs loaded in HBWR

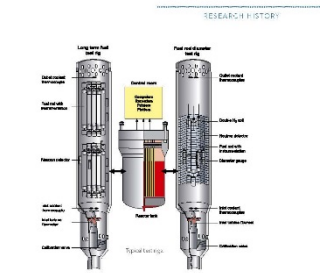
Russian's start at OECD Halden Reactor Project in 1995

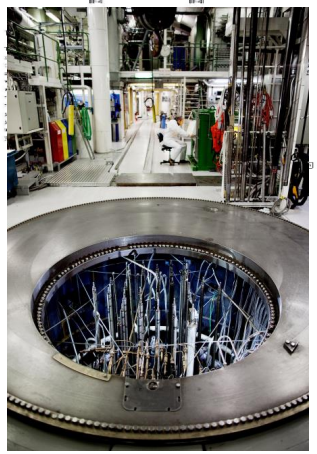


Current HRP Facilities and Activities

Halden Boiling Water Reactor

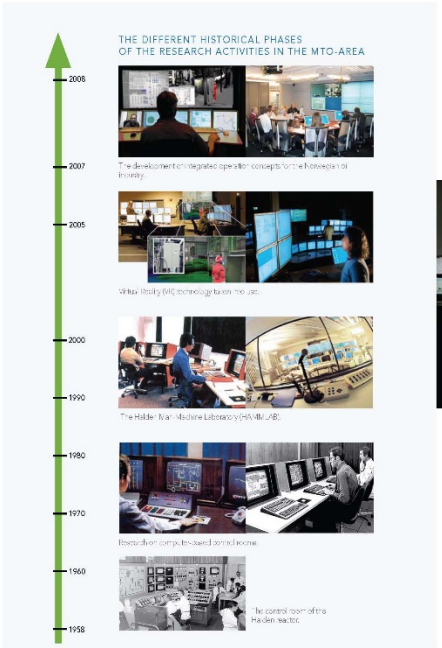
- ✓ Fuels & Materials in-pile testing
- ✓ In-pile instruments and in-reactor test devices development

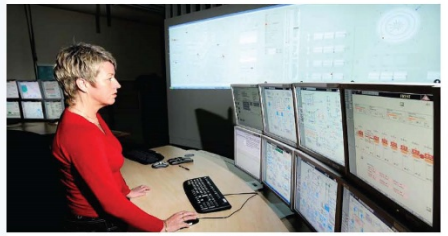




Man-Technology Organisation

- ✓ Halden Man-Machine Laboratory HAMMLAB
- ✓ Halden Virtual Reality Center HVRC



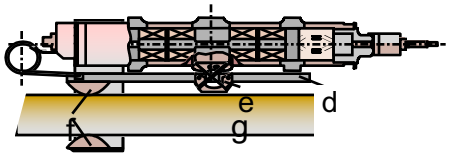


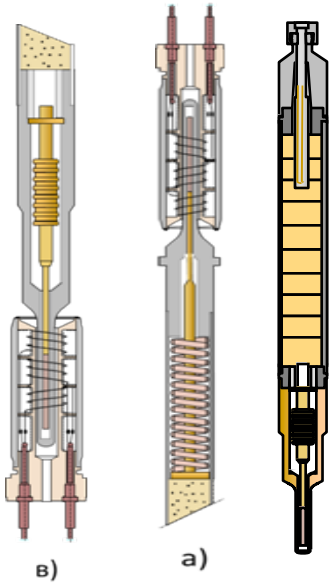
Role of the Halden Reactor Project for Light Water Reactor F&M developments

Common problems in the area of nuclear fuel development motivated the establishment of joint research efforts for investigation of behaviour of LWR fuels and materials under irradiation aiming to improve their reliable and safe utilisation;

The key features of the HRP F&M Programme are:

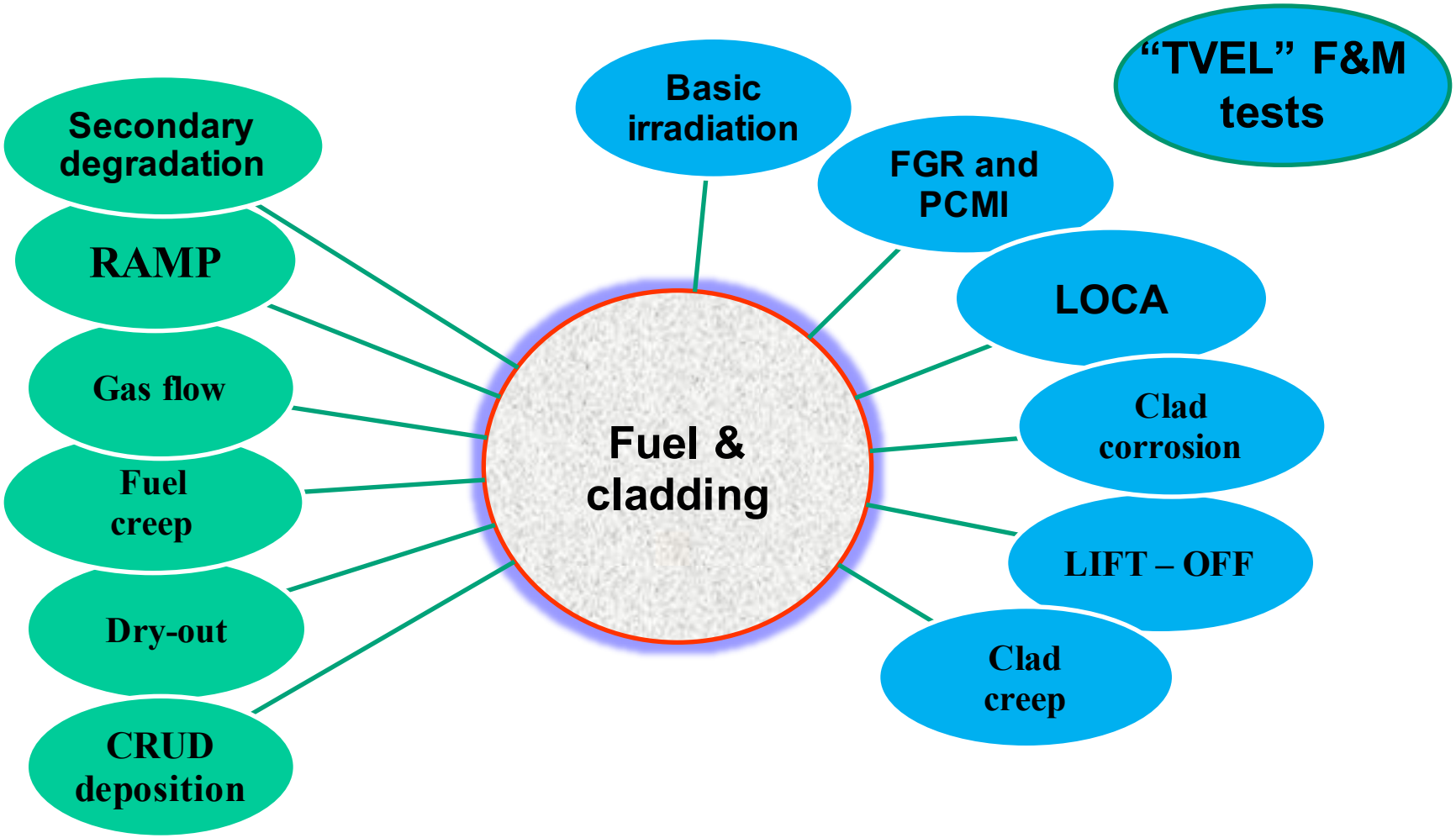
- Fast response to nuclear industry demands;
- Production of results with practical applicability for licensing and independent expertise;
- Reliable instrumentation and unique test devices allows the in-pile measurements for long term irradiation tests (5-10 years) to be performed as well as for short tests for high burnup fuel;
- High quality experimental data were included in NEA OECD and IAEA data base required for fuel performance code validation and model verification;





- More than 1000 tests have been carried out with PWR and BWR fuel since 1970's
- Since 1995 several tests with fresh and commercially pre-irradiated VVER and "TVEL" production fuels and materials have been performed in HBWR

Tests performed in the Halden reactor



Progress research of the «TVEL» production fuels and materials in the Halden reactor

VVER vs PWR

- IFA-503.1 Original VVER fuel testing vs PWR fuel
- IFA-503.2 Modified WWER fuel testing vs PWR fuel

Large grain fuel

- Large grain VVER fuel developed by «TVEL»
- 5% Gd-doped VVER fuel

preirradiated rods

- 5 tests with rods preirradiated in Loviisa NPP
- FGR/PCMI (2 tests), Lift-off (1), LOCA (2)

TVEL for PWR

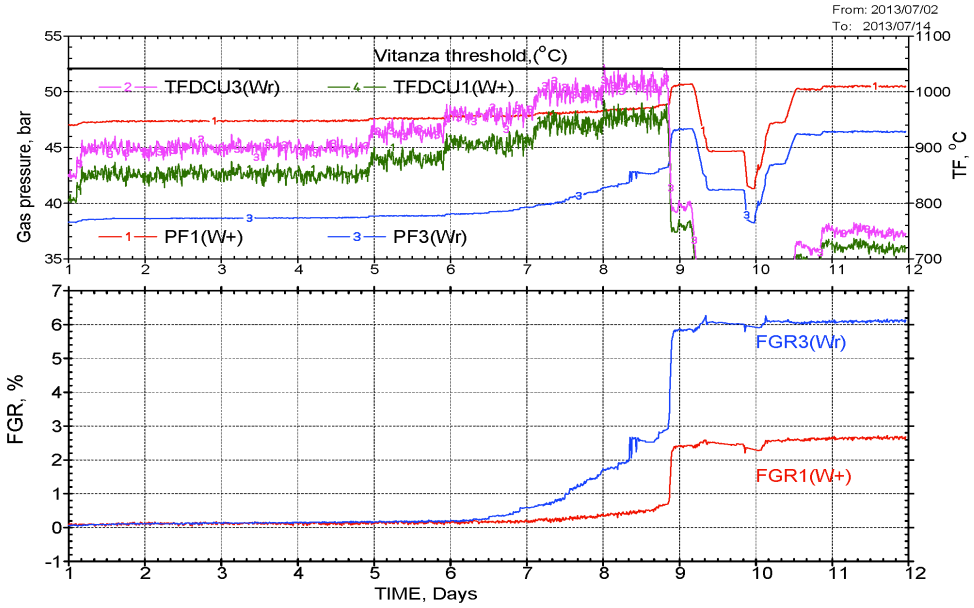
- Bilateral tests under PWR conditions:
- Cladding corrosion test under advanced PWR conditions
- Advanced «Lift-off» tests under PWR conditions

High Burnup VVER fuel

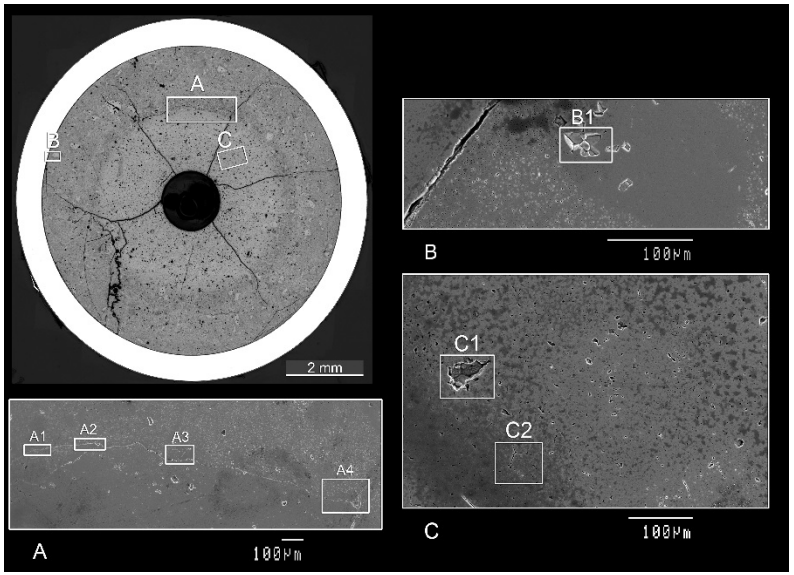
- Multilateral test for VVER fuel burnup accumulation (2 rods from VVER-440 Loviisa NPP, Finland) to a target burnup 75 MWd/kg U
- **Plans for HRP JP to perform FGR & LOCA tests with high burnup VVER fuel**

FGR experiment with large grain VVER fuel at high burnup

Test was performed at a burnup of 60 MWd/kg UO_2



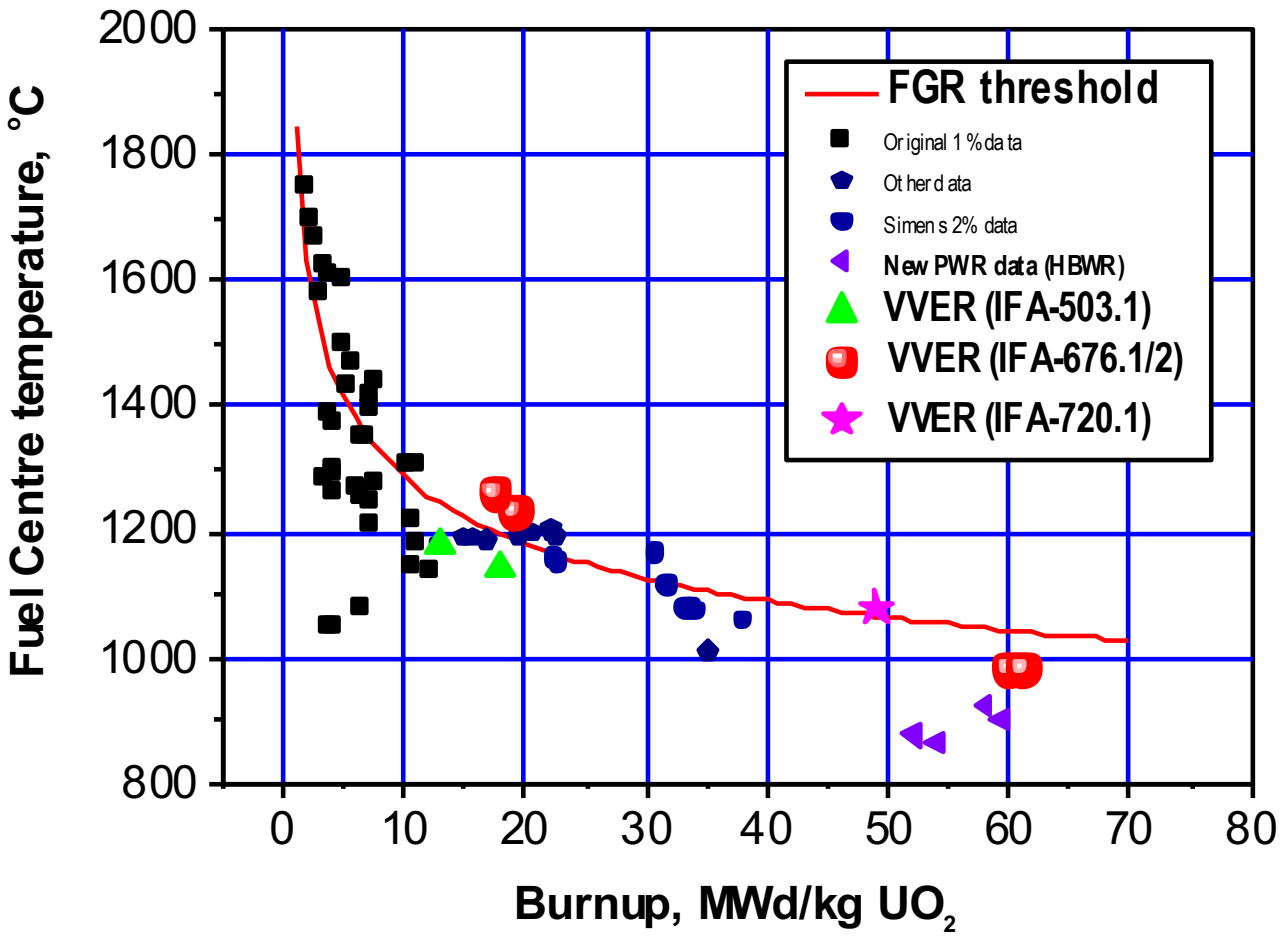
PIE of VVER fuel with detail ceramography analysis



The main goal of the test is to confirm low FGR from the large grain fuel at high burnup

Fuel centreline temperature in both fuels at similar power rating was measured. This fuel temperature was a little lower in the large grain fuel that is indicating better conductivity of the large grain fuel due to delay of high burnup structure formation compared with small grain fuel. As a result lower FGR at high burnup was observed

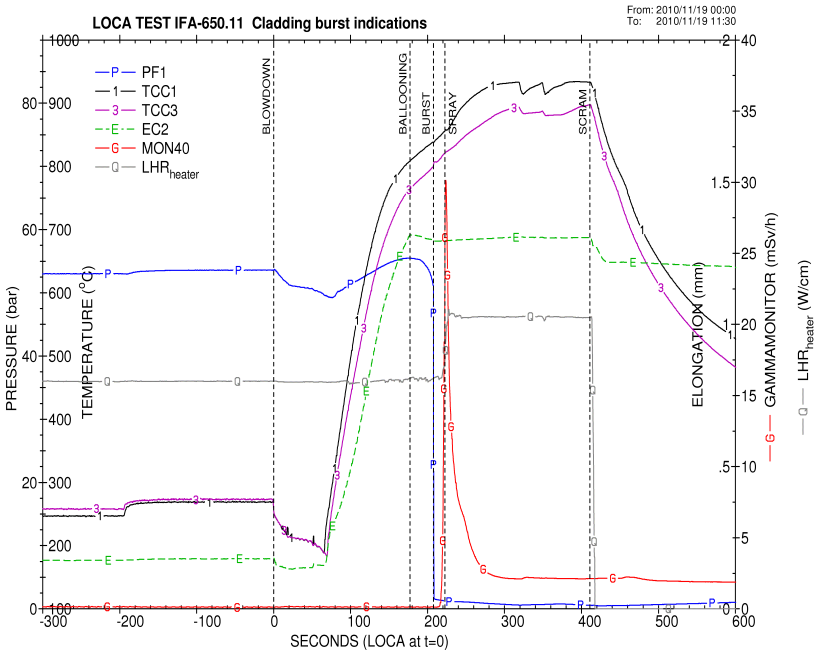
HRP Data Base on Fission Gas Release fuel temperature threshold including VVER fuels



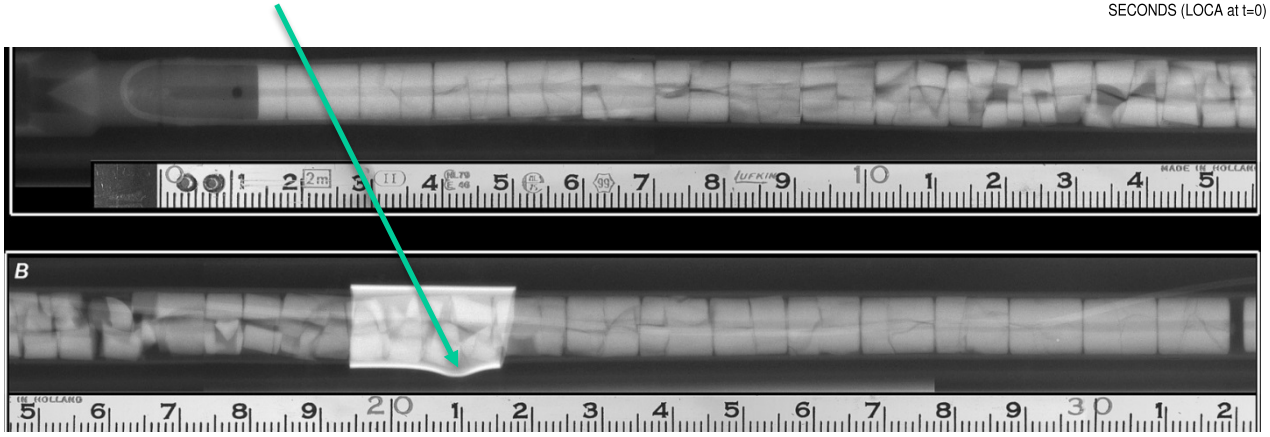
LOCA tests with pre-irradiated VVER rods

Rod burnup ~54 MWd/kg U
(from VVER-440 Loviisa NNP, Finland)

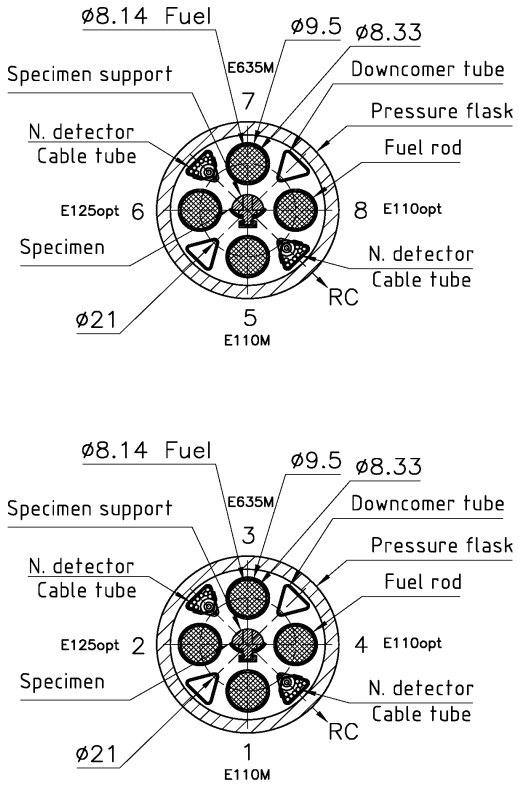
- Fill pressure = 30 bar
- Max Clad T = 940-950 C (target 1000 C)
- Max overpressure **~55.7 bar** reached at **183 s**
- Cladding burst: **207 s** under overpressure of 53 bar at ~**839 °C**



Clad burst

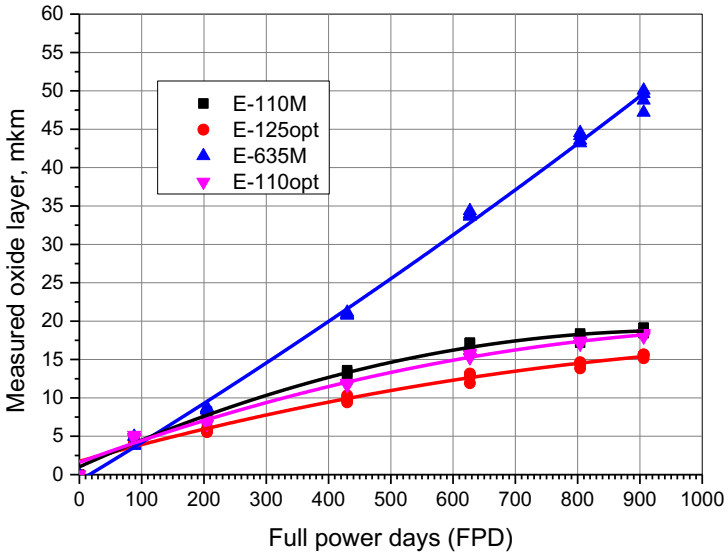


Corrosion experiment with “TVEL” production claddings under advanced PWR conditions

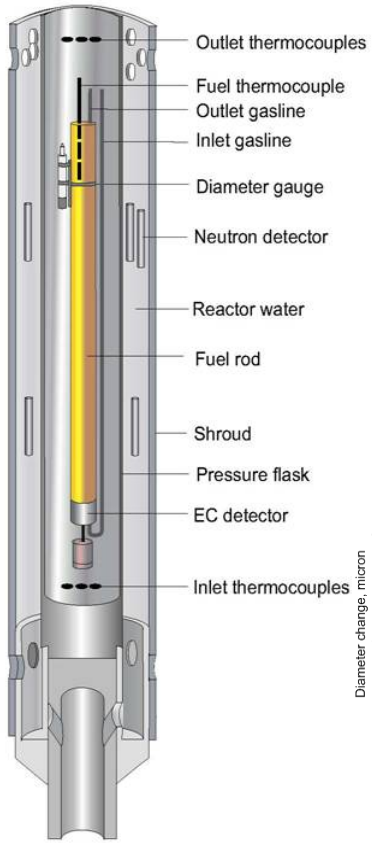


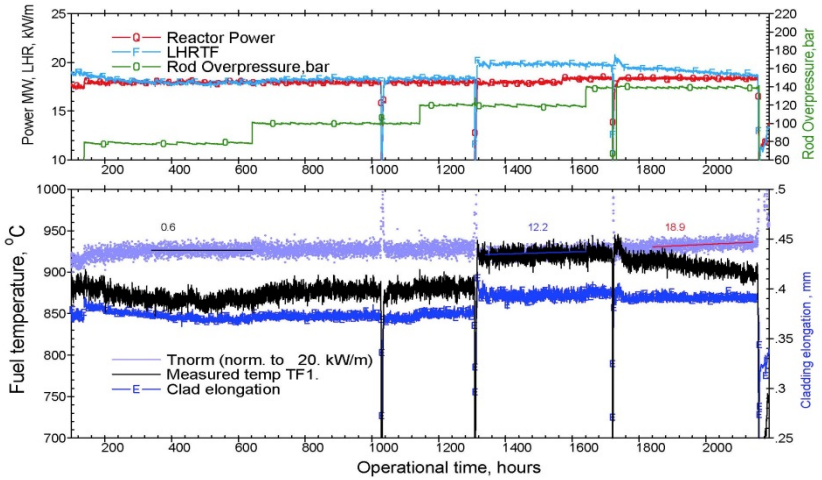
Evaluate the performance of TVEL production cladding materials under aggressive Water Chemistry conditions exceeding those currently allowable in operating PWRs:

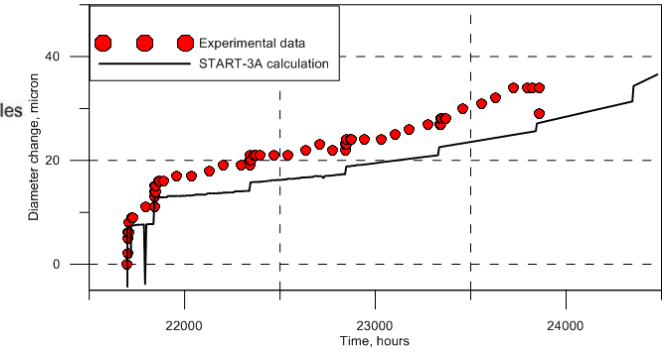
- **high pH ~7.5_{300} (~10 ppm Li)**
- **high heat flux**
- **high mass evaporation rates and outlet void**



Advanced “TVEL” “lift-off” experiment with in-reactor DG measurements of E110opt cladding under PWR conditions







Lift-off effect for higher cladding temperature under PWR conditions was found at internal fuel rod pressure > 260 bar vs. ~ 150 bar coolant pressure

FUEL ROD WITH E110 CLADDING OVERPRESSURE/LIFT-OFF EXPERIMENT AT HALDEN. IN-PILE DATA AND MODELING WITH START-3A CODE were presented in TopFuel2017 Conference in Korea 10-14 September 2017

Summary

2018 Celebration of 60 years of International OECD HRP and 70 years Nowegian Institute for Energy Technology !

- **The OECD-Halden Reactor Project (HRP) is a good example of international cooperative research which has been performed for 60 years with the aim of peaceful nuclear energy utilisation**
- The successful Joint Programme allowed F&M development and modification for the fuel vendors (like AREVA, Wesinghouse, "TVEL") with the aim to enhance safe and reliable nuclear fuel utilisation for LWR NPPs.
- The elaborate test devices and in-reactor instrumentation enabled unique results under long term irradiation to be included into NEA OECD and IAEA Data Base employed for fuel behaviour modeling and fuel performance code validation;
- HRP independent expertise both for F&M and also MTO areas used for the licensing in the member countries;
- HRP role in F&M development for VVERs and PWRs based on both Joint Programme and bilateral in-pile test results were appreciated by «TVEL».
- **OECD HRP is a long functioning International Project and there is a hope that there will be continued demand for innovative F&M developments (like Accident Tolerant Fuel and Cladding) as well for Digital technologies in MTO area.**

We are warmer and safer together
Нам вместе теплее и безопаснее