Institutt for Energiteknikk

OECD Halden Reactor Project

ORGANISATION

FACILITIES & RESEARCH

Why is there a reactor in Halden?

1938 Otto Hahn and Lise Meitner discover nuclear fission

1942 Enrico Fermi generates the first controlled chain reaction (Chicago pile)

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

1954 Decision to build the Halden reactor as joint Dutch – Norwegian project. Develop a reactor prototype for delivering energy (steam to paper factory)

1958 Official opening of the Halden reactor,
OECD Halden Reactor Project 3 years co-operation period

1978 Norway decides not to utilise nuclear power

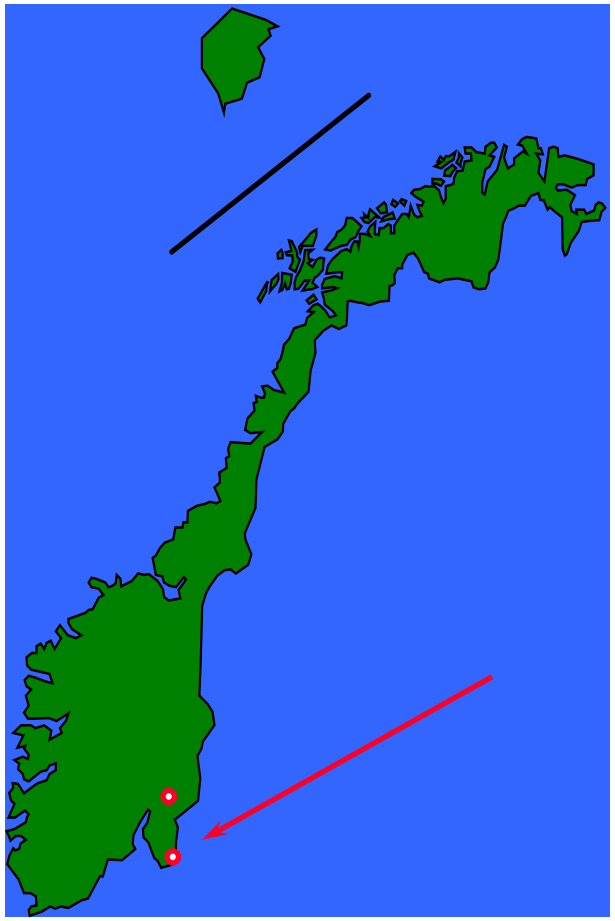
2012 Co-operation period #18 started (19 member countries)

Halden Reactor

- Conceived as a joint Norwegian – Dutch development
  - The Netherlands: several tons of (natural) uranium
  - Norway: heavy water
- Nuclear fission as a source of power for industry
  - Paper factory Saugbrugs utilises steam from HBWR
- First years used to check out HBWR
  - Nuclear characteristics
  - Stability (natural circulation)
- Then gradual transition to today's applications

OECD Halden Reactor Project

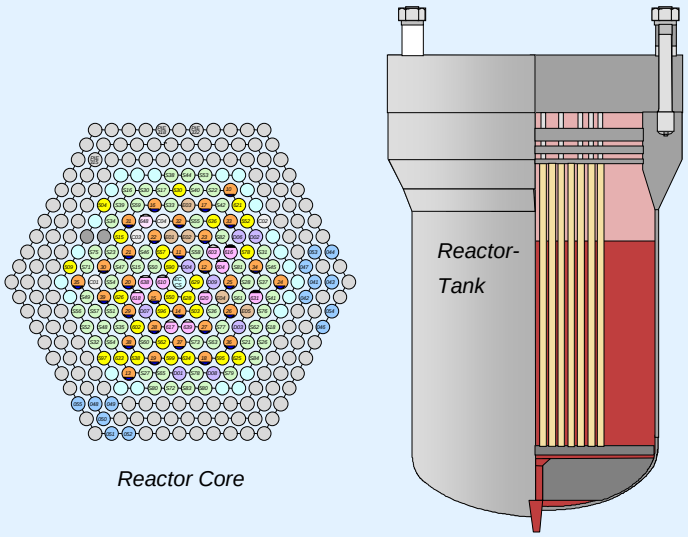
- International co-operative effort
  - Committed to research on the safe and reliable utilisation of nuclear energy
  - Under the auspices of OECD NEA / Paris
  - Hosted by Institutt for energiteknikk (IFE)
- Jointly funded by its Members:
  - 19 countries
  - More than 100 organisations
- Participant types
  - Utilities, vendors, licensing authorities, R&D centres
- 3 year program periods, current one from 1.1.2012 to 31.12.2014 (agreement period 18)



Halden Project Facilities

- Halden Heavy Boiling Water Reactor HBWR
  - 20 MW thermal
  - Conditions provided for different types of reactors
  - Hot laboratory (Kjeller)
- Halden Man-Machine Laboratory HAMMLAB
  - Simulation of normal and accident conditions
  - Human factors studies
- Halden Virtual Reality Center HVRC
  - Design, training, maintenance, planning
  - Augmented reality

Main Program Areas



- ***Fuel High Burnup Capabilities***
- ***Fuel Response to Transients***
- ***Cladding Corrosion & Water Chemistry***
- ***Plant Lifetime Assessments***
- ***Development of Instrumentation***

- ***Human Performance***
- ***Design & Evalaluation of Human System Interfaces and Control Centres***
- ***Visualisation Tech. for Design, Planning, Training***
- ***Surveillance & Control in Operation and Maintenance***
- ***Software Systems Dependability***

International research co-operation between 19 nations

Fuels and Materials Program 2012-2014 Overview

Fuel Safety & Operational Margins

- *Studies related to gas release under irradiation*
- *Thermo-mechanical studies*
- *Fuel behaviour under accident conditions*
- *Fuel behaviour under demanding operation conditions*
- *Innovative fuels and claddings*

Plant Ageing & Degradation

- *Irradiation assisted stress corrosion cracking*
- *Irradiation enhanced creep and stress relaxation*
- *Pressure vessel integrity study*
- *Other plant ageing issues*

Contribution to Gen-IV International Research

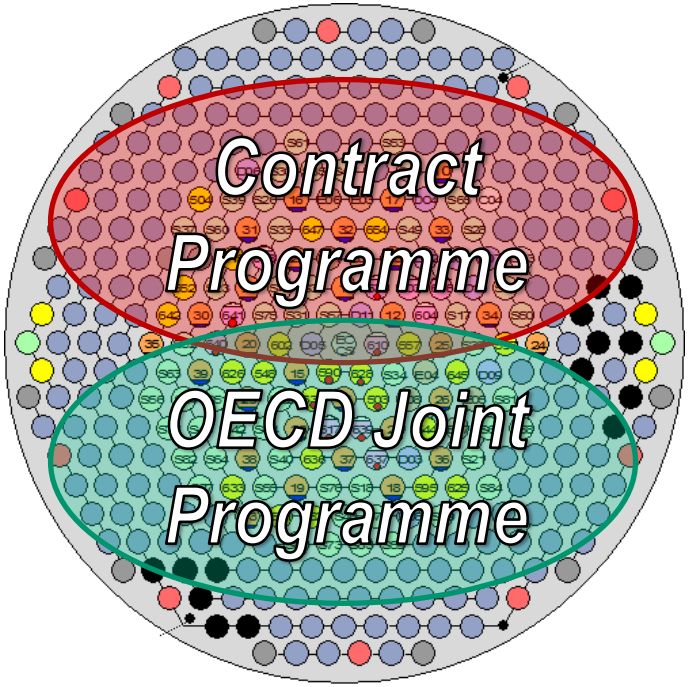
- *Instrument development*
- *Materials testing*

Program Basis: Halden Reactor & Workshops – Kjeller Hot Labs

Fuels & Materials Research

Workshop

- rig fabrication
- instrument development



Hot lab

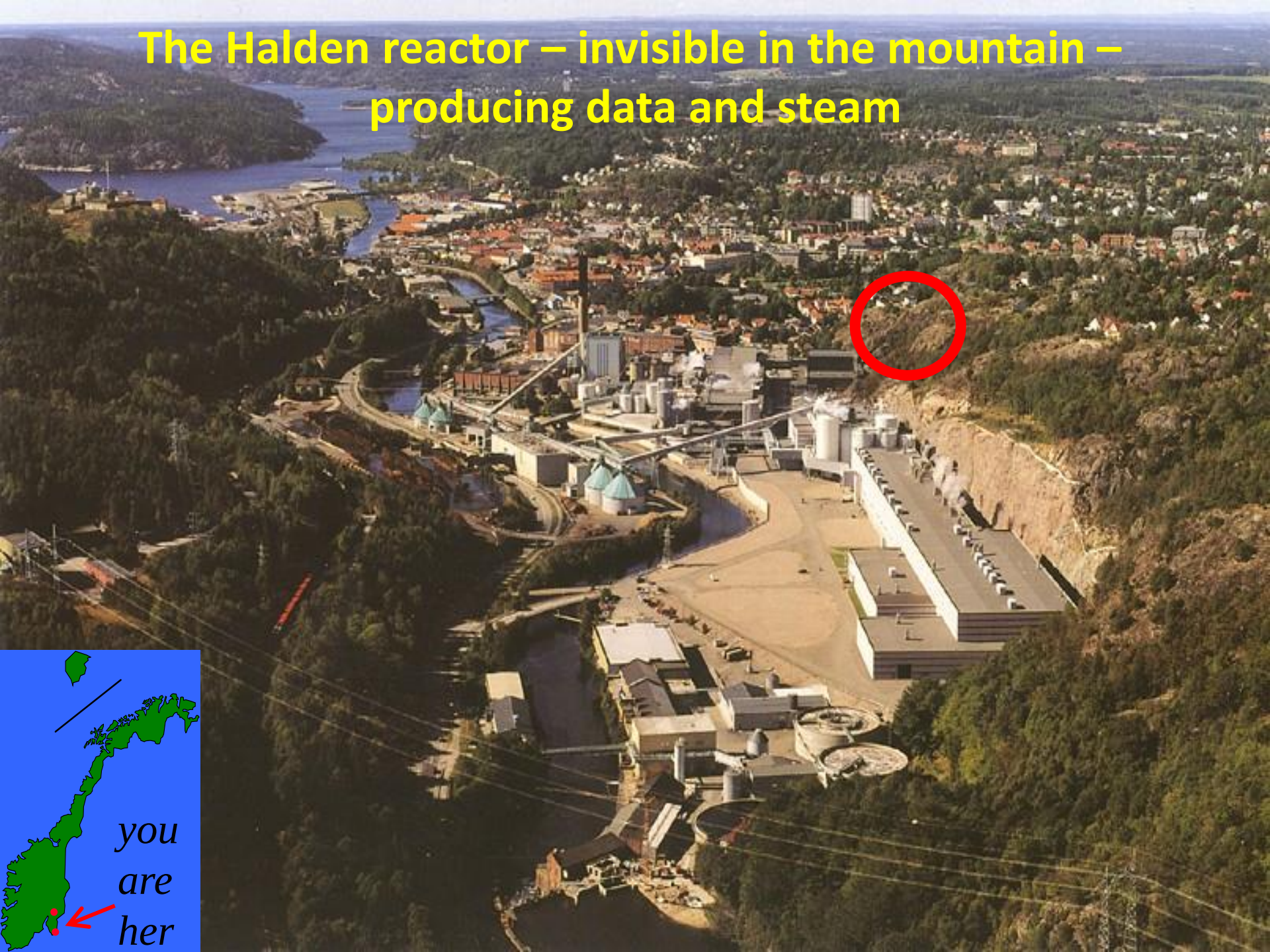
- fuel fabrication
- post irradiation examinations

Reactor operation

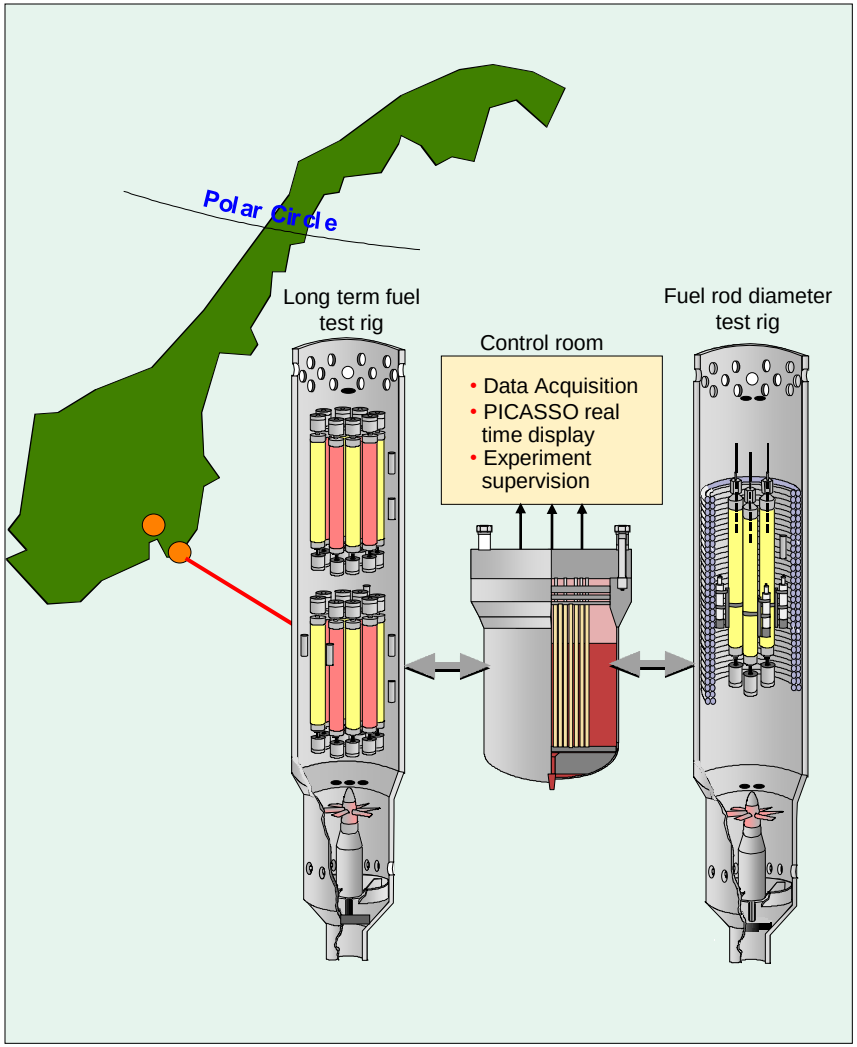
Project types

- Joint international research
  - OECD Halden Reactor Project
    (10-15 experiments active in the HBWR)
- Multi-national projects
  - Fuel failure degradation
  - (Thorium fuel irradiation)
- Bilateral projects
  - Fuel development
  - Cladding development
  - Materials research
  - Regulatory research
    (10-15 experiments active in the HBWR)

The Halden reactor – invisible in the mountain – producing data and steam

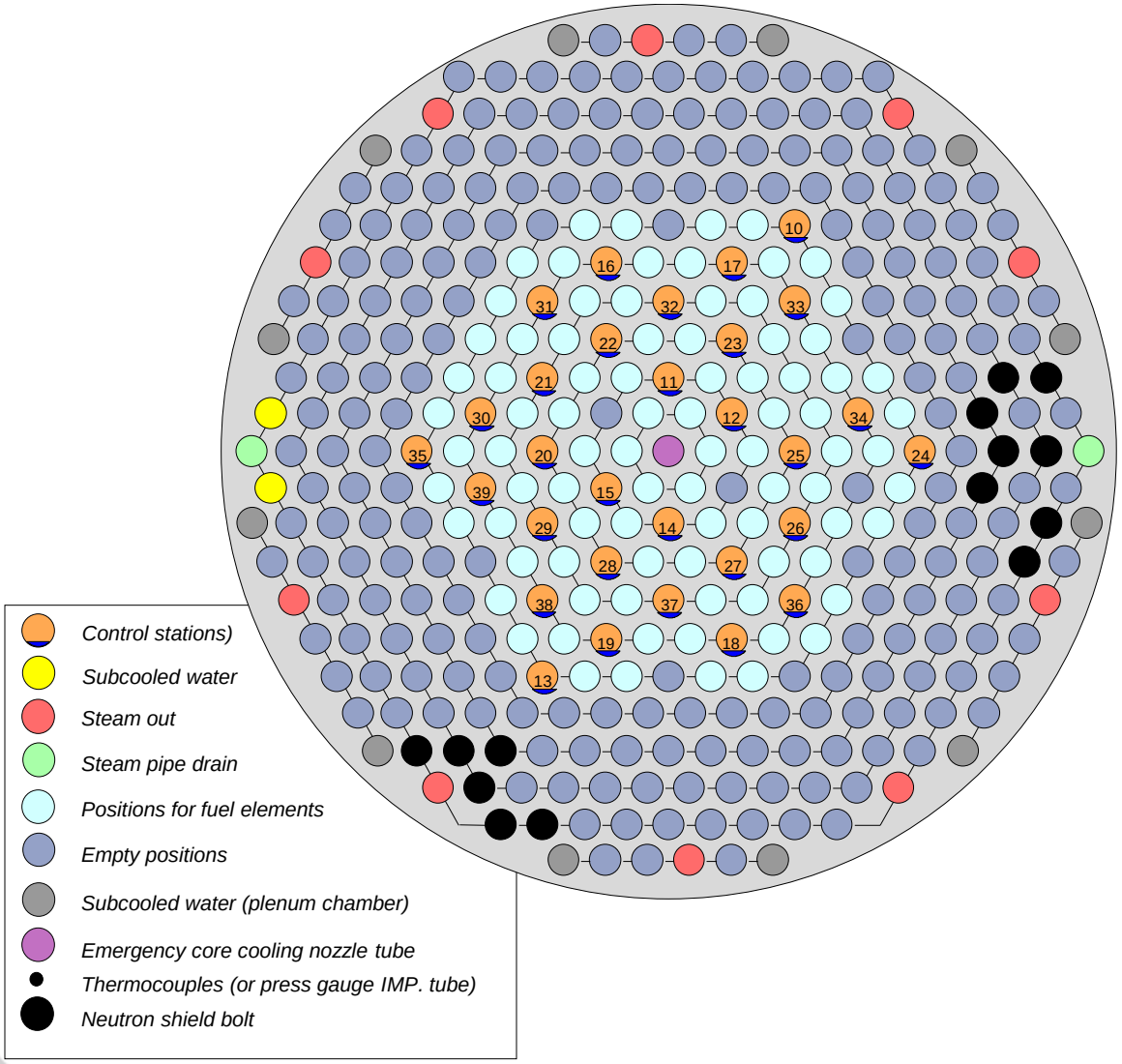


The Halden Reactor



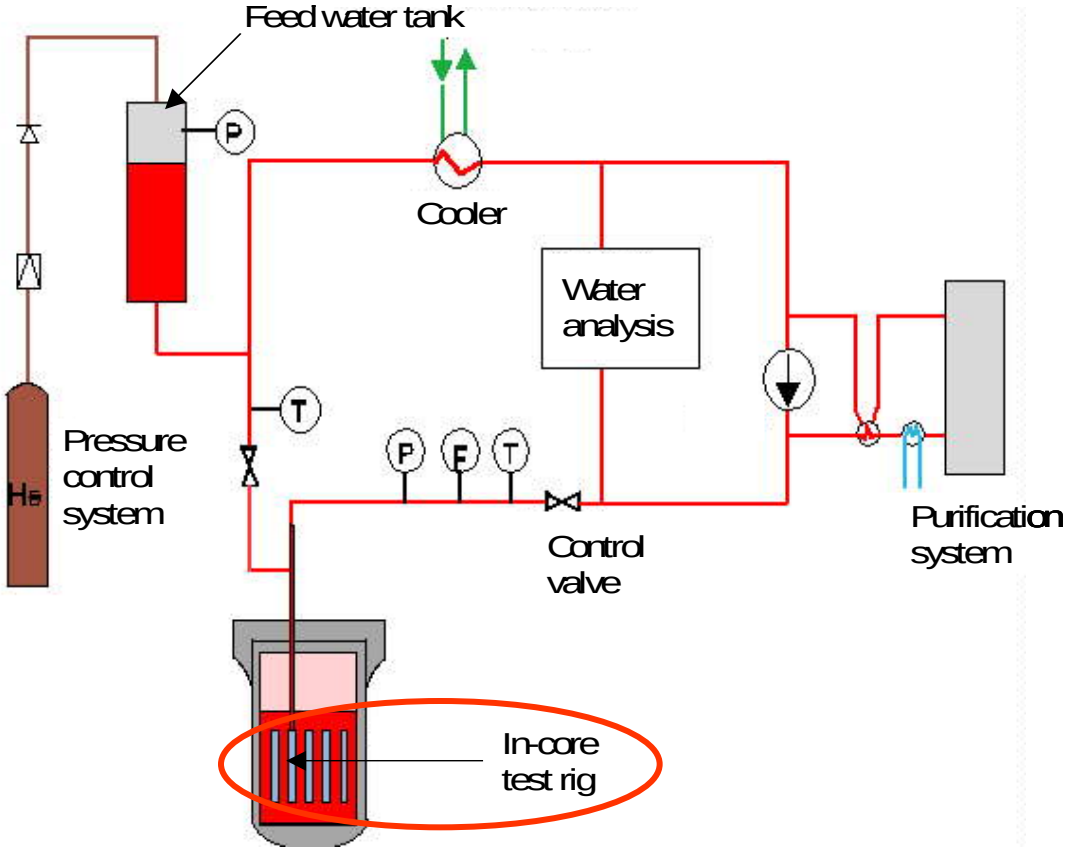
- Managed and owned by Institutt for energiteknikk, Norway
- Research facility for the OECD Halden Reactor Project
- Available for contract work for utilities, vendors, licensing authorities and R&D centers in the member countries
- More than 400 test rig loadings with several thousand instrumented fuel rods and other materials
- All data since 1972 available in electronic form

Characteristics of the Halden Reactor



- 20 MW heavy water reactor, 33 bar and 240°C
- Height of active core 80 cm
- Hexagonal array of 300 positions within pressure vessel
- Rings 1-6 used for experiments (about 30/110 positions used)
- Test rigs directly in HBWR coolant have inner diameter of 71 mm
- Test rigs in pressure flasks have inner diameter of 32 mm or 45 mm
- 10-11 water loops in operation at any given time

Loop systems in the Halden Reactor



- *Test rigs placed in pressure flasks connected to external loop systems*
- *Allows testing of fuel under simulated BWR, PWR or PHWR conditions:*
  - *Coolant pressure*
  - *Coolant temperature*
  - *Water chemistry*
- *Used for IASCC and corrosion testing and e.g. PCMI fuel testing*

A key factor in Halden reactor experimental work

Reliable and versatile in-core instrumentation

In-core instrumentation

is essential for fuels & materials performance studies, providing

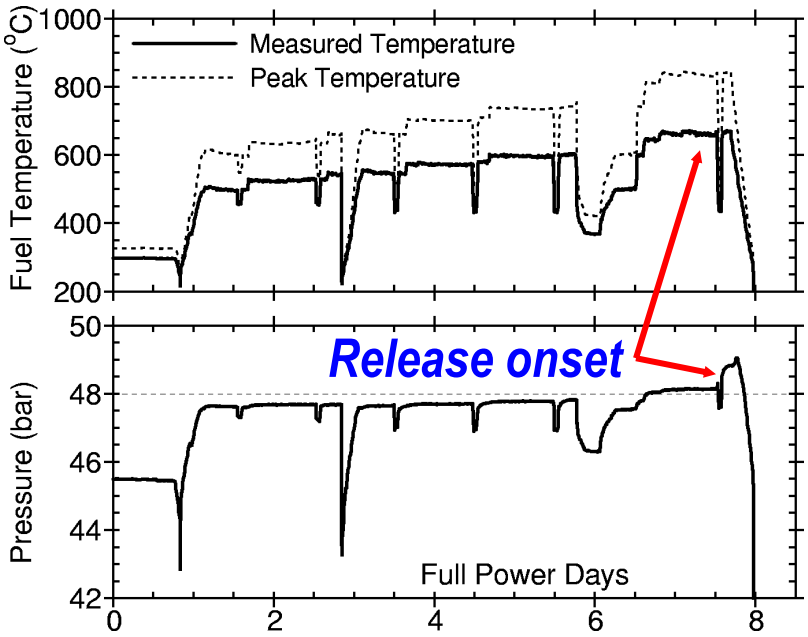
- direct insight into phenomena while they are going on
- cross-correlations between interrelated phenomena

The Halden Project has more than 40 years of experience with in-core measurements and has perfected the instrumentation to function reliably in a demanding environment.

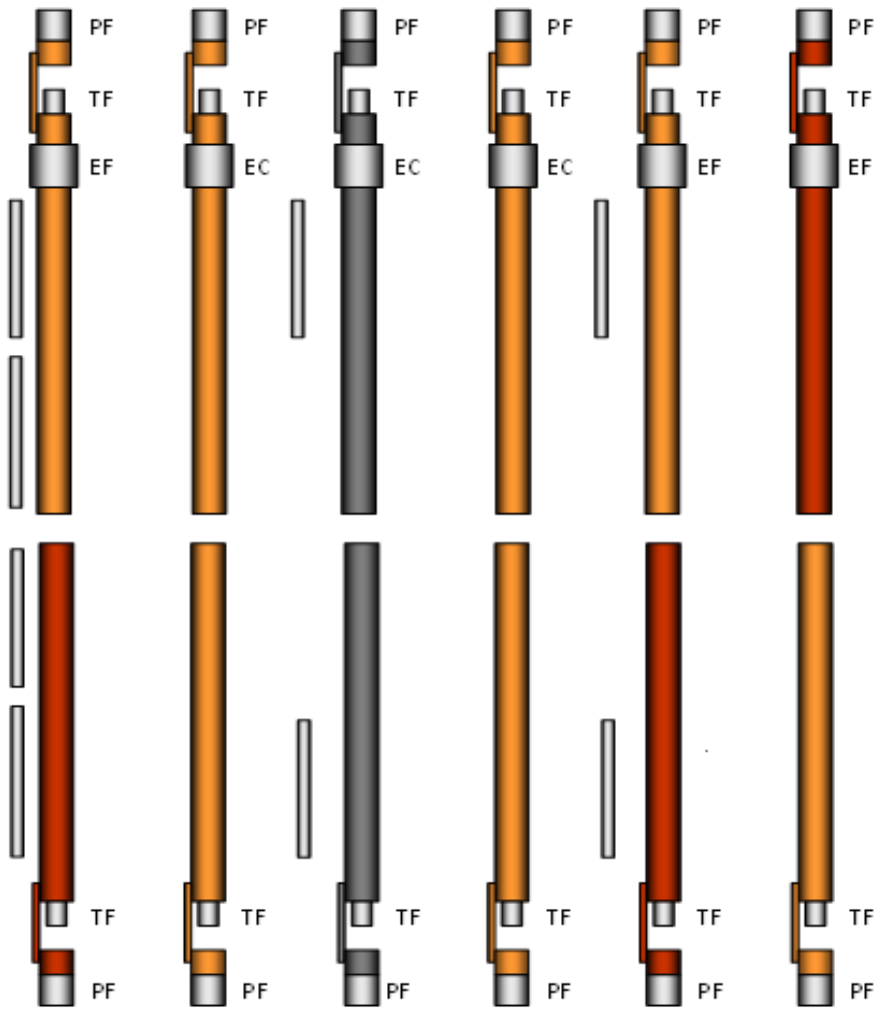
More on instrumentation: see presentation by R. van Nieuwenhove in this meeting

Fuel performance

Simultaneous measurement of temperature and pressure



Typical fuel test rig configuration / instrumentation



The rods are equipped with

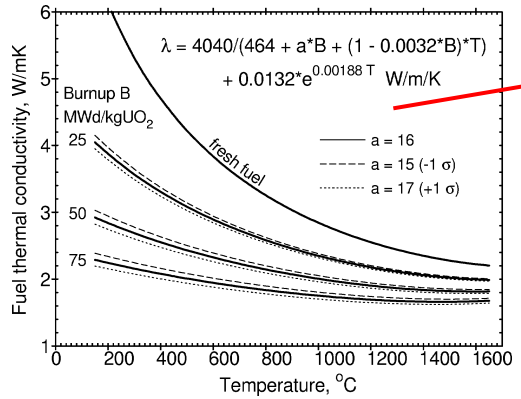
- Fuel thermocouples (TF)
- Rod pressure sensor (PF)
- Fuel stack elongation detector (EF)
- Cladding elongation detector (EC)

Neutron detectors are installed at

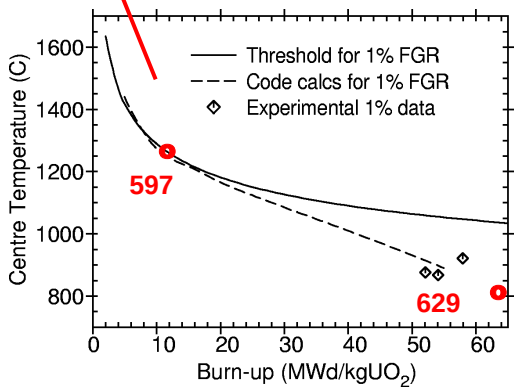
- thermocouple elevation for exact local power determination
- different axial elevations for determination of flux profile

Typical Results Fuels Testing

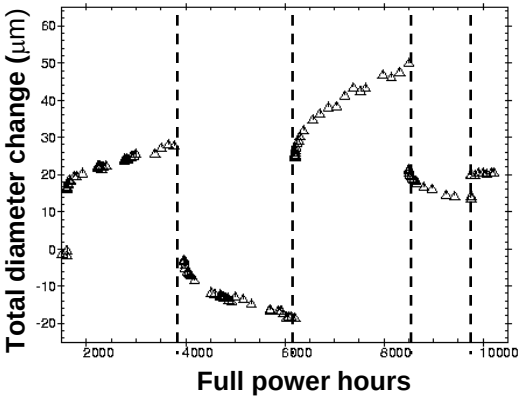
- Conductivity degradation



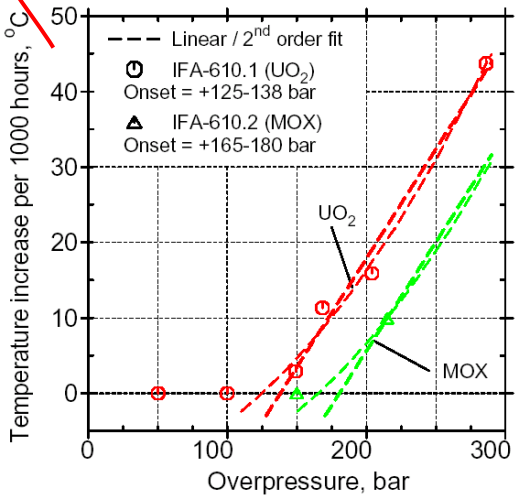
UO_2, MOX
Gd-UO_2



- Fission gas release



- Cladding creep

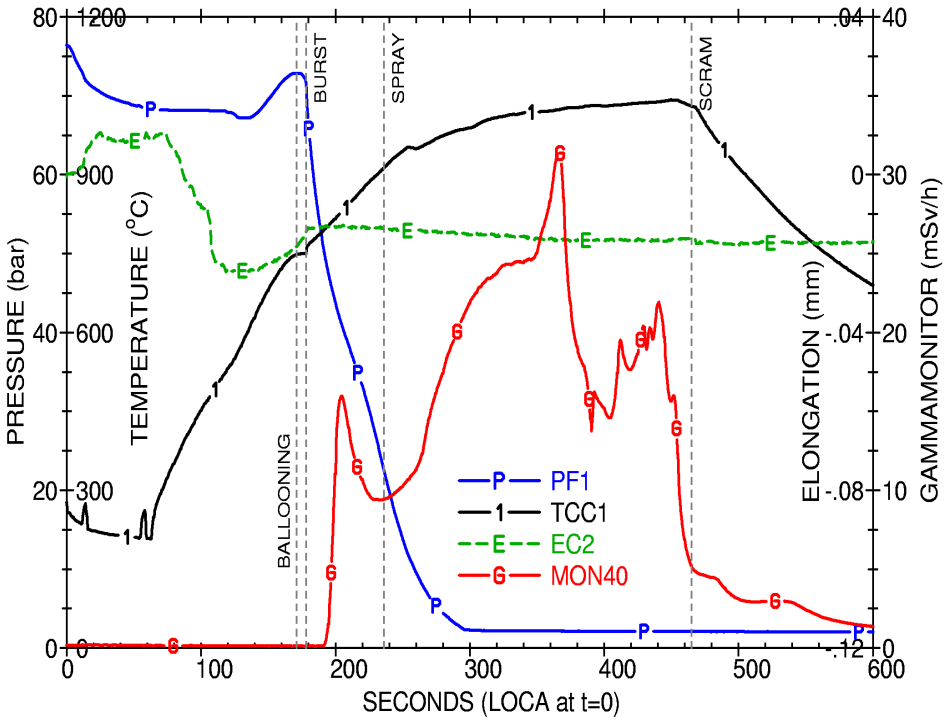


- Overpressure – clad lift-off

Loss-of-coolant accident (LOCA) studies

The OECD HRP has an on-going series of LOCA-related fuel testing

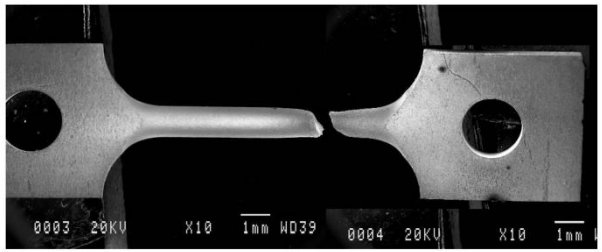
- Address validity of LOCA safety criteria for medium and high burnup fuels
- Study
  - cladding oxidation and hydriding
  - fuel fragmentation and relocation



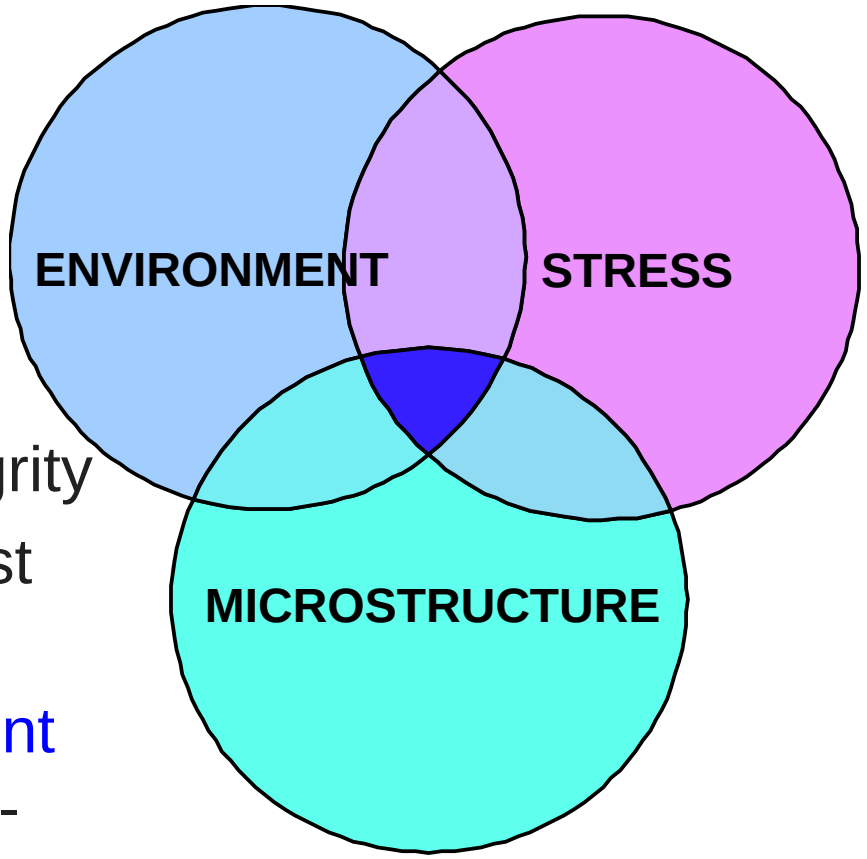
Example of a HBWR LOCA test

- 1 - cladding temperature
- p - rod pressure
- E - cladding elongation
- G - radioactivity

Plant Lifetime Assessment



- Crack Growth Rate Investigations
- PWR Crack Growth Studies
- BWR Crack Growth Studies
- Crack Initiation Study (Integrated time to failure)
- Stress Relaxation Study
- Reactor Pressure Vessel Integrity
- Characterisation of IASCC Test Materials



More on plant lifetime assessment and instrumentation: see presentation by T. Karlsen in this meeting

Halden Reactor Project Membership

The Halden Reactor Project provides facilities for joint international and bilateral research on the safe and economic utilisation of nuclear power. Membership includes:

- Access to all results and products of the Joint Programme
- Possibility to utilise the facilities (Halden Reactor, hot lab, Hammlab, Virtual Reality Centre) for bilateral activities
- Influence on the definition of the Joint Programme
- Possibility to delegate staff for working at the Halden Project for a certain period
- Participation in workshops and meetings arranged by the Halden Project
- Being part of an international network and discussion forum

ENLARGED HALDEN PROGRAMME GROUP MEETING

Storefjell Resort Hotel
Gol, Norway
March 10 - 15, 2013
http://ehpg.hrp.no/

High Burn-up Fuel Performance, Safety and Reliability

Degradation of In-core Materials and Water Chemistry Effects

Safety, Man-Technology-Organisation