AESJ

Foreign Professional Societies Coodination Committee

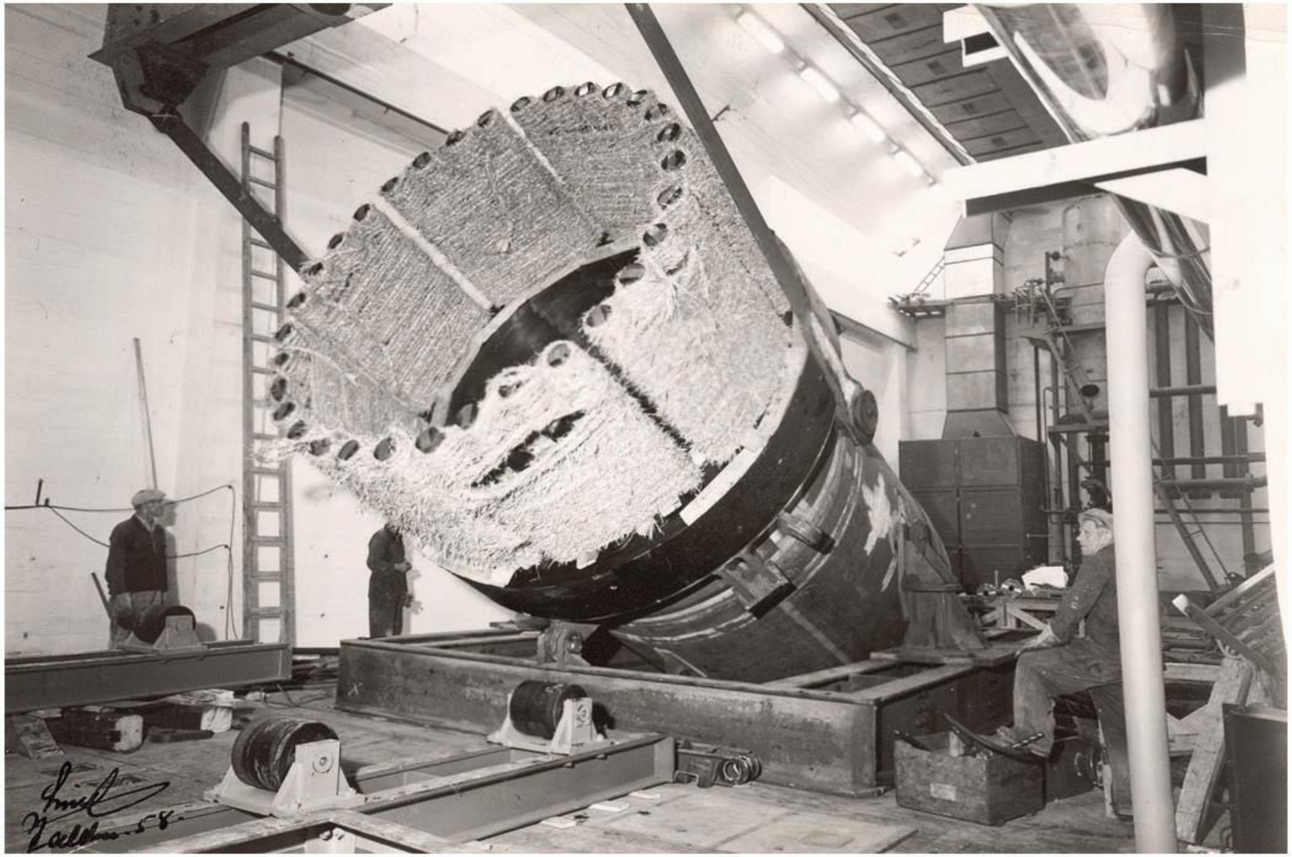
October *23, 2008*

ハルデン50周年記念講演

皆川　洋治
OECD Halden Reactor Project

The Halden Project - History and Values

- The construction of the Halden reactor was originally meant as part of the Norwegian-Dutch co-operation that had developed after ww2
- It was intended to be a first demonstration of use of nuclear power for process industry, i.e., for delivery of steam to a paper production line
- It was first conceived in 1953, designed in ’54, modified and decided upon in ’55. The construction was started in summer 1955 and completed in 1958. The reactor was officially opened on 10th October 1959
- The international OECD Halden Reactor Project (HRP) was initiated in 1958 with the participation of 10 countries including France, USA and Canada

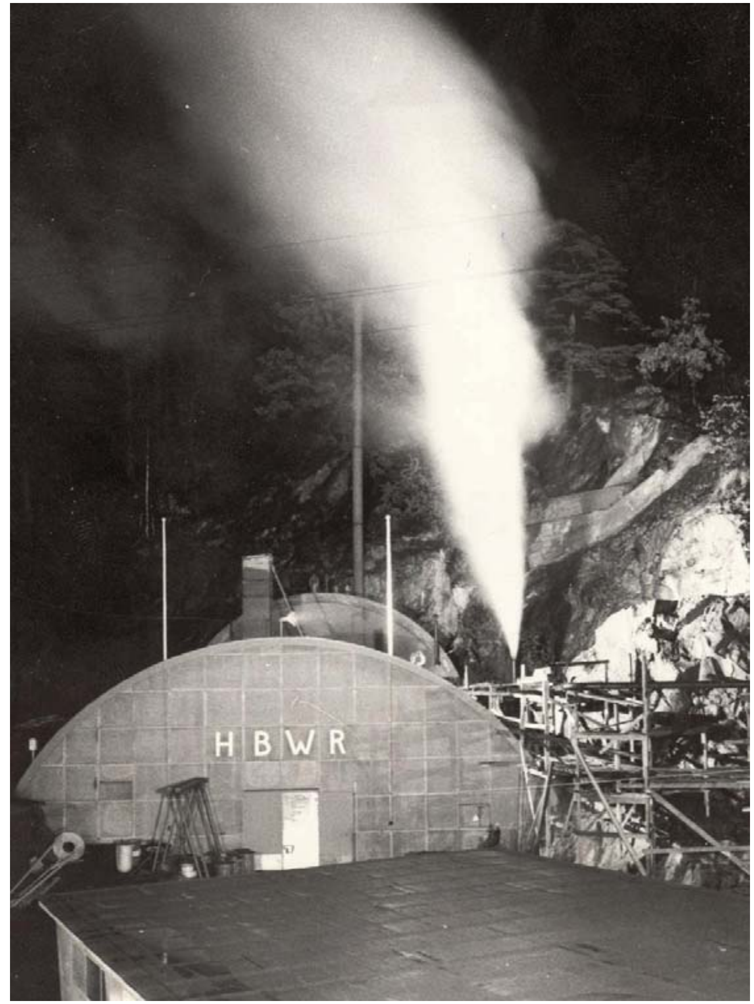


Montering av tanken

Positioning of the reactor vessel

Kongen

Official opening by the King of Norway



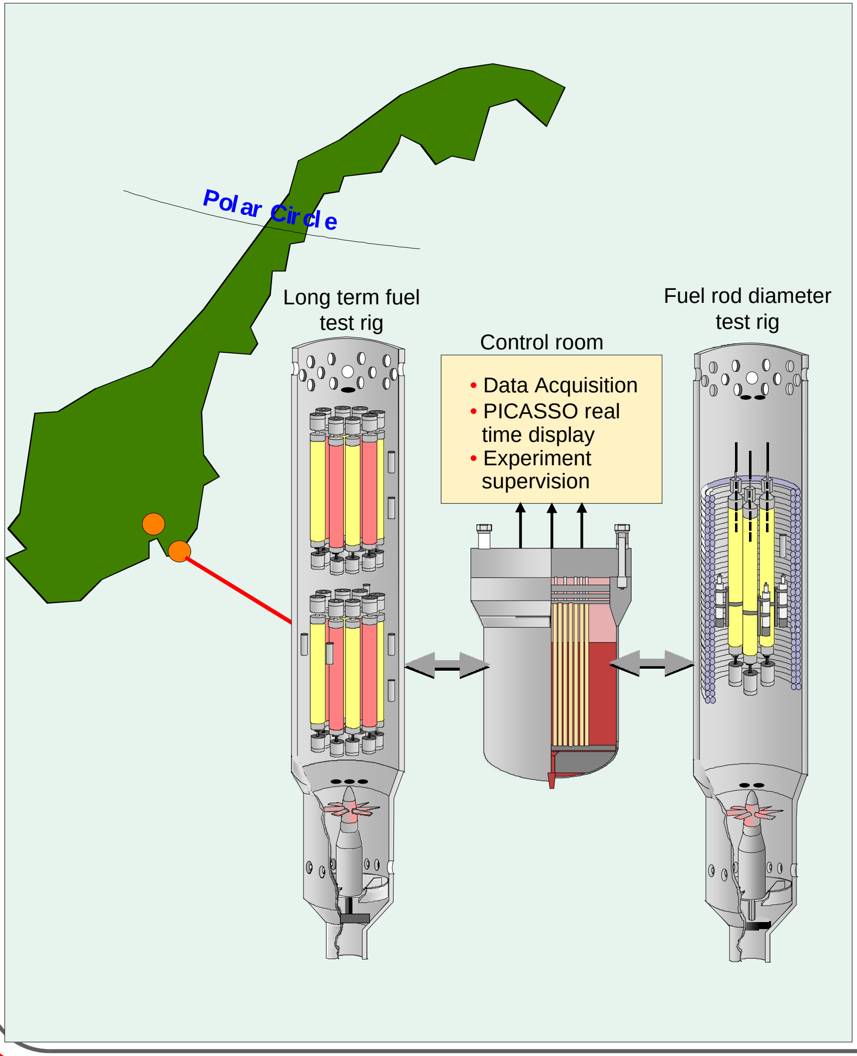
First steam production

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

The Halden Project - History and Values

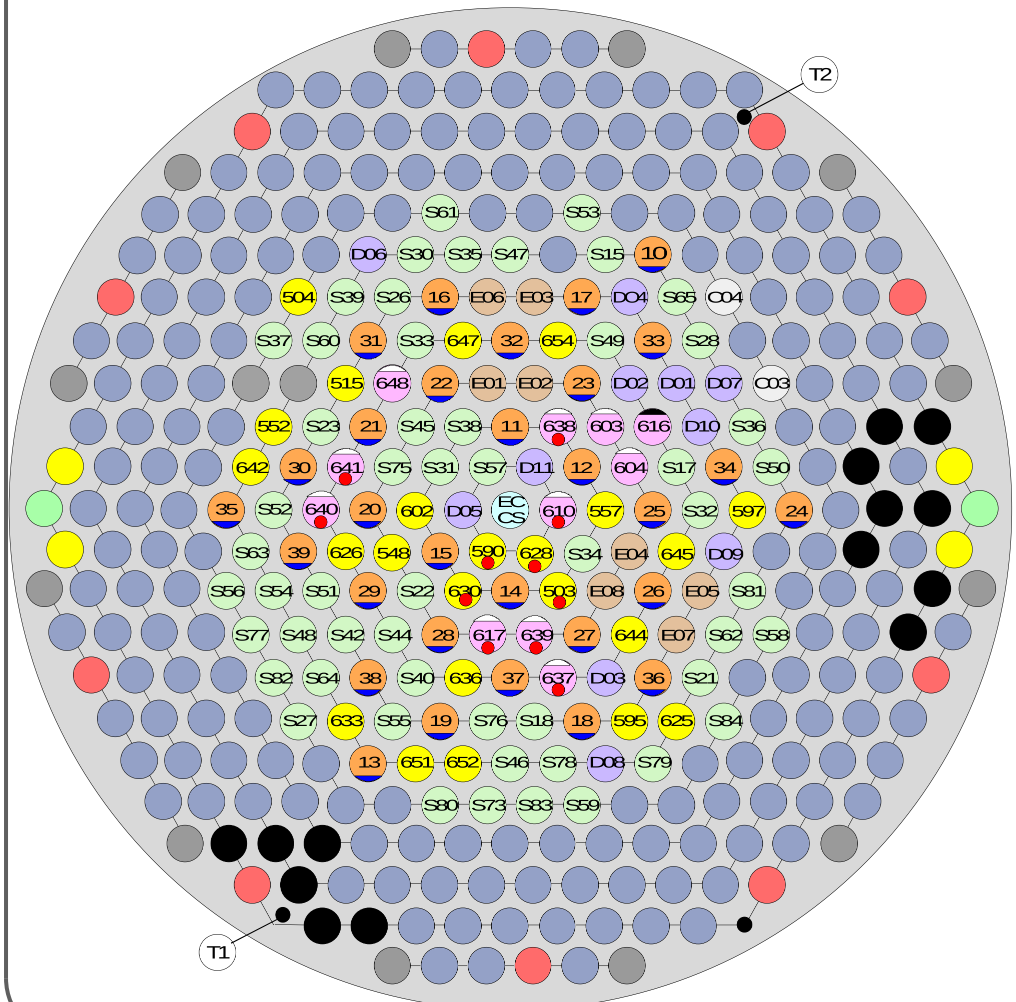
- It has always been international – from the very beginning
- Participants discuss / decide, ”soft” leadership from Norwegian side
- Management acts pro-actively by means of numerous work proposals
- It takes full responsibility for the reactor and test operation
- It uses own technology to the maximum possible degree
- It puts technical excellence as key goal for all staff members
- It always completes contracted work
- It never asks for extra funds beyond what originally agreed

The Halden Reactor



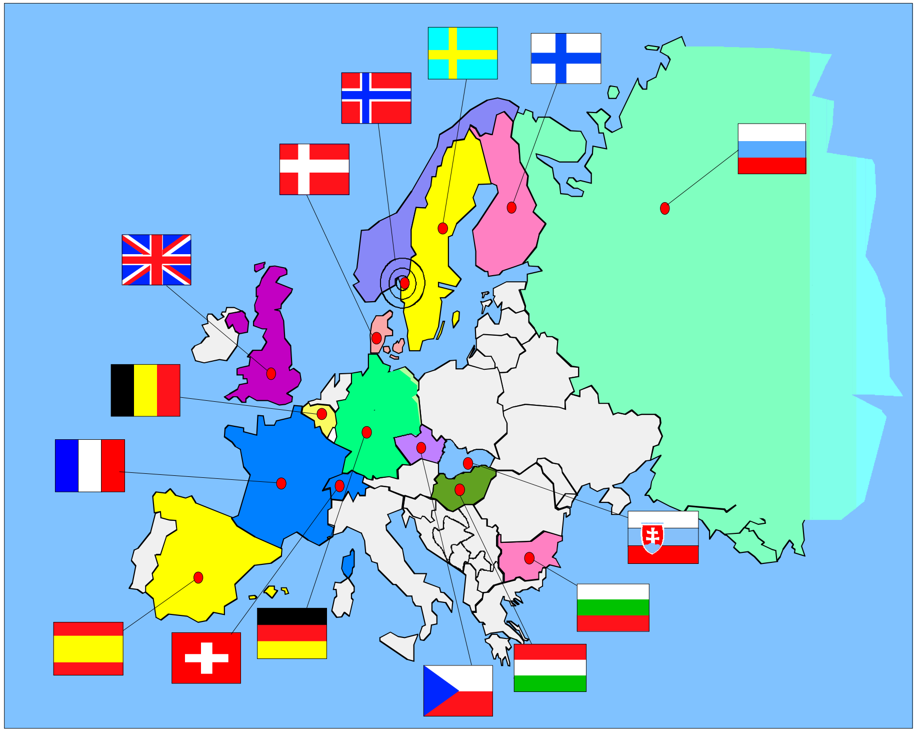
- Managed and owned by Institutt for energiteknikk, Norway
- Research facility for the OECD Halden Reactor Project
- Available for contract work for utilities, vendors, licensing authorities and R&D centers in the member countries
- More than 400 test rig loadings with several thousand instrumented fuel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

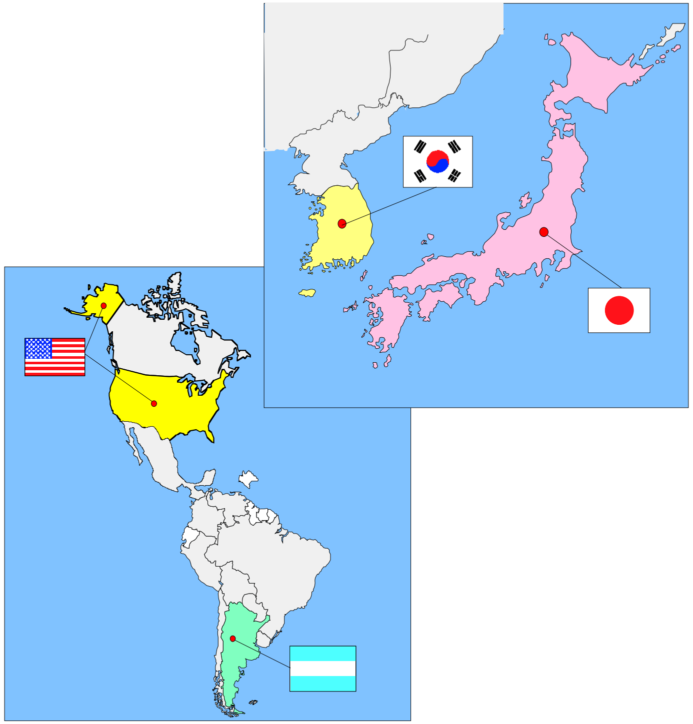
HBWR Core



- More than 300 positions individually accessible
- About 110 positions in central core
- About 30 positions for experimental purposes (any of 110/300)
- Height of active core 80cm
  - driver element consists of 8 fuel rods with standard cladding tube / fuel pellet geometry, 6% enrichment
- Usable length within moderator about 160cm
- Experimental channel Ø:
  - 70mm in HBWR moderator
  - 35-45mm in pressure flask
- Loop systems for simulation of BWR/PWR conditions

PARTICIPATING COUNTRIES

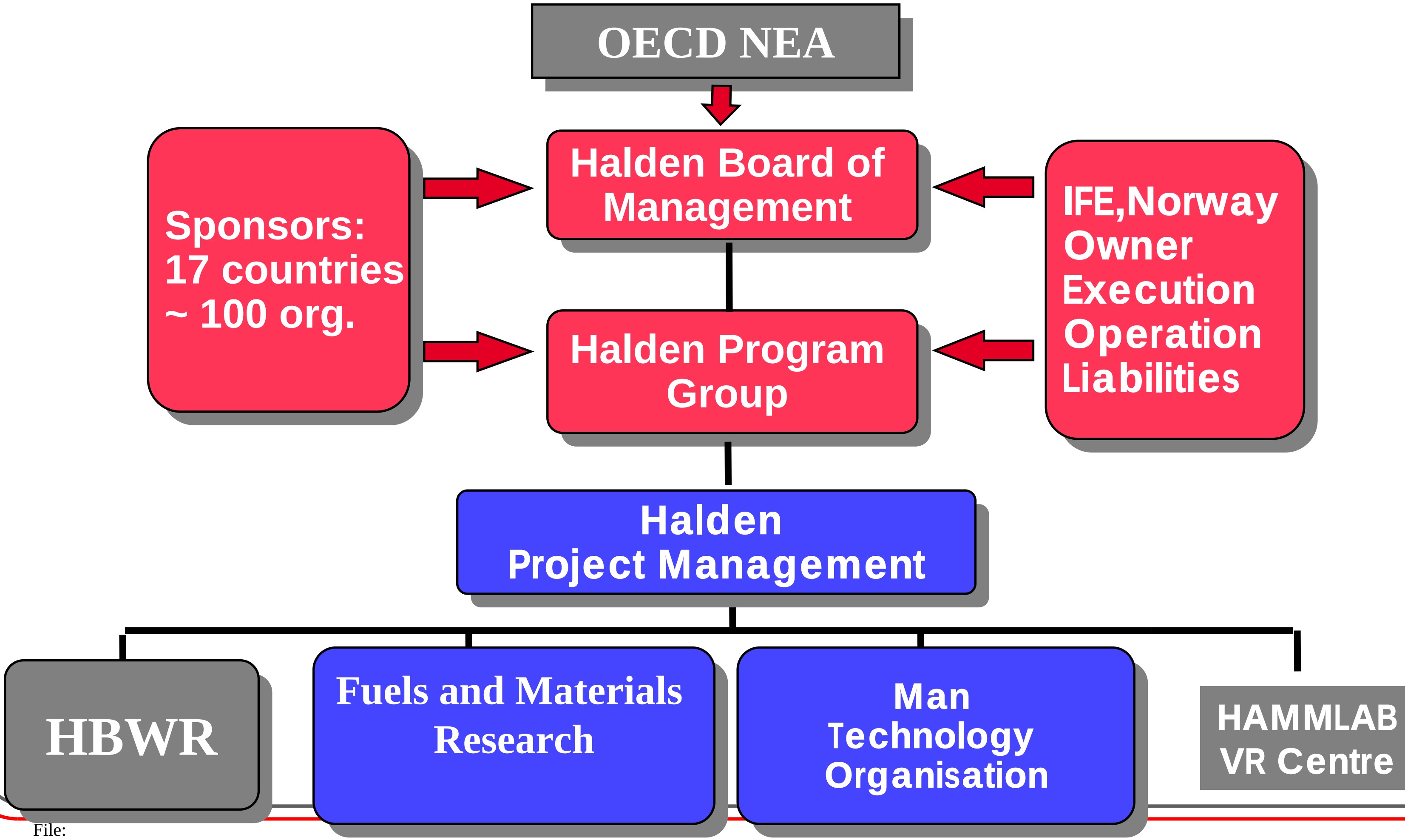




Organisation and Structure

- The Halden operation constitutes a major part of the Norwegian Institute for Energy technology (IFE)
- It is a government-linked entity, but with a large degree of autonomy
- It carries out the OECD joint program and bilateral contract work
- It is a non-profit organisation, but can generate financial assets
- Financial assets can be carried over from year to year and are normally re-invested in upgrades and development
- It has a ”flat” organisational structure with very few management levels with straight responsibility lines
- It is very efficient, bureaucracy is reduced to a minimum

Halden Reactor Project Organisation



Institutt for energiteknikk

CTO

Staff Organisation

Advisory Group

Quality Assurance - N. Foshaug
Financial Adviser - H. Valseth
Adviser MTO - Å.S Sølie
Marketing & Contract - H. Thoresen
Co-ordinator: F&M
Technical Co-ord. F&M - I. Thoresen

Project Manager
W. Wiesenack

Deputy Project Manager
F. Øwre

Administrative Functions
H. Valseth

Logistics - R. Skarning
Buildings & Maint. - M. Engebretsen
Human res. - J.P. Kvalvik
IKT - T.T. Olsen

Test Rig Design and Production
K.W. Eriksen

Experimental Engineering
Y. Minagawa

Operation Centres
J. Kvalem

Visual Interface Technology
T. Johnsen

Data Production and Evaluation
E. Kolstad

Reactor Operations and Engineering
T. Elisenberg

Computerised Operation Support Systems
Ø. Berg

Industrial Psychology
A. Bye

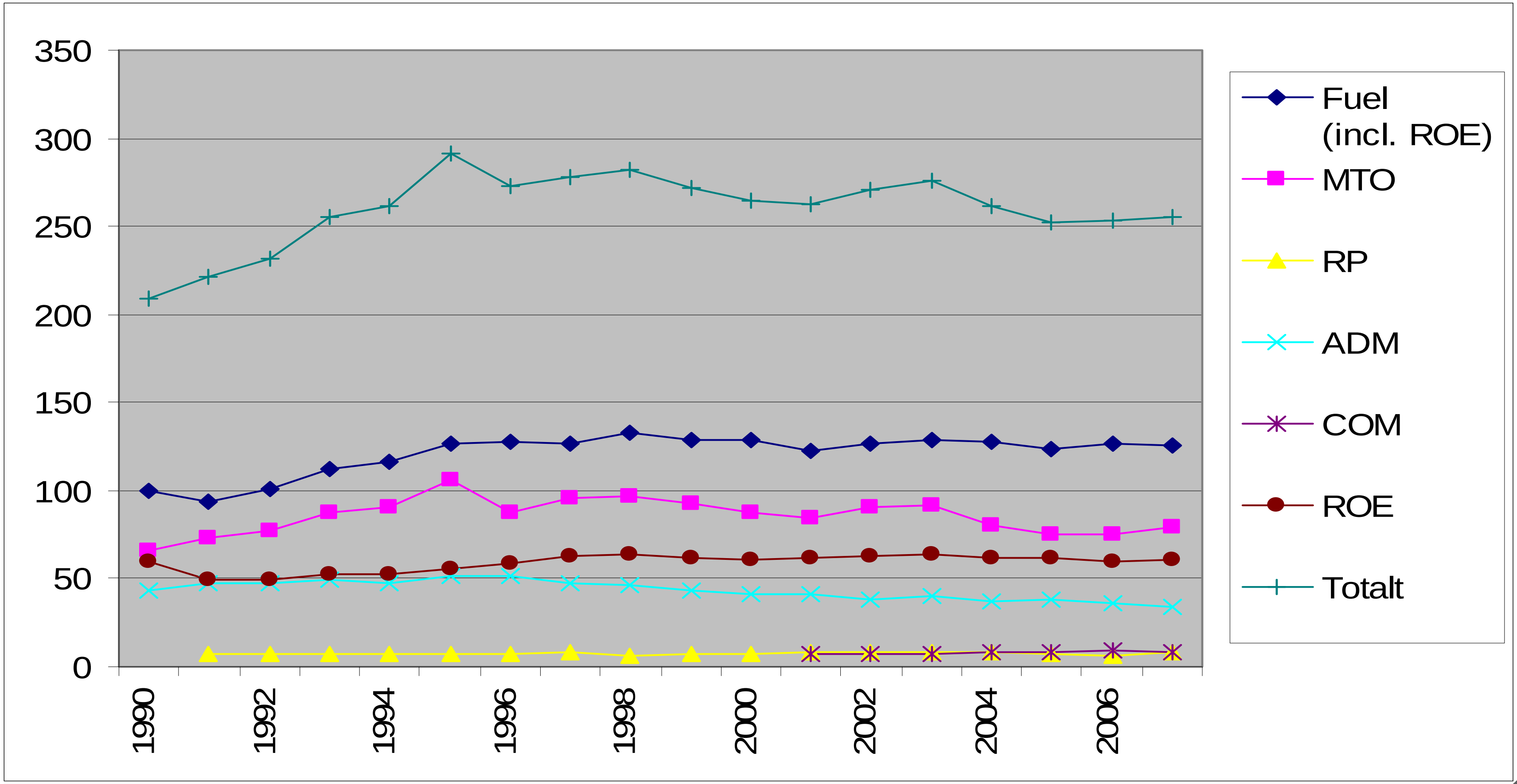
Radiation Protection
E. Foshaug

Nuclear Materials
B. Oberländer

ICT Risk and Dependability
B. A. Gran

The staff at Halden represents about 260 man-years. In addition, about 20 man-years are financed at Kjeller.

Overview of number of employees (positions) at HRP 1990 – 2007 (including foreign staff)



Continuity and innovation

- The reactor main parameters – basic design, coolant and moderator type, operating pressure and temperature – have been kept the same for 50 years
- The reactor core has been profoundly changed to enable more experiments. Most components have been replaced. Several loops have been installed
- The focus has always been on use of reactor for making good experiments. But the nature of these experiment has profoundly changed with time. A major evolution has occurred in materials and water chemistry investigations
- The Halden speciality is in-core instrumentation. Sensor development started in the 60-ies and has been constantly improved
- The Halden staff organisation has been basically the same for 40 years, but all personnel has been replaced – with apparently no problem to retain key knowledge. There has never been a strike.
- Knowledge management is simple but works: Overlapping and training for most jobs and maintaining ALL documentation are key factors

Main classes of experimental Systems

- Water Loops :
  - Loop systems for fuel testing
  - Loop systems for material testing
- Gas cooled loop systems :
  - CO_2 loop for simulation of AGR conditions
- Material Rig Gas flow Systems
- Ultra High Gas Pressurization System (600bar)
- Fuel rod Gas flow control system.

Hydraulic drive system

- Movement of diameter gauge
- Movement of fuel rod
- Movement of other device
- All above when the reactor is in full operation

He3 system

- Load follow experiment
- Fast ramp
- Slow ramp
- Can be connected to test device installed in reactor tank or loop system.

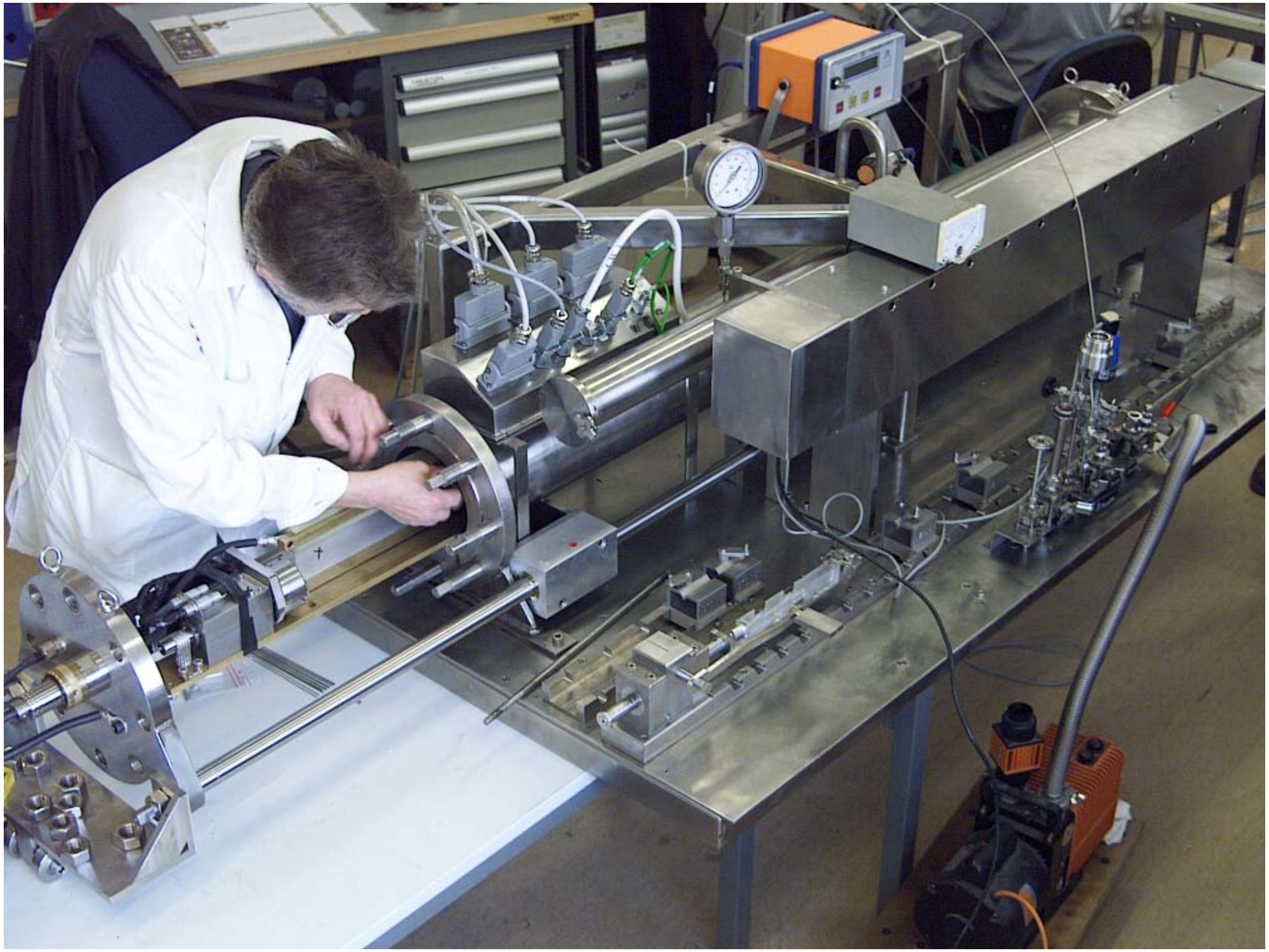
Ultra High Gas Pressurization System (600bar)

- Load control of precracked specimen
- Load follow posibilites
- Pressure control ± 0.05 bar

Principal In-core Measurements

- Fuel centreline temperature, TF
- Fuel stack length change, EF
- Fuel rod internal pressure, PF
- Cladding elongation, EC
- Cladding diameter (PCMI, creep), DG
- Crack growth
- Water chemistry parameters
- Thermal-hydraulic parameters
- Neutron flux / power rating, ND

Instrument workshop in 2005



LONG TERM IRRADIATION TEST RIG

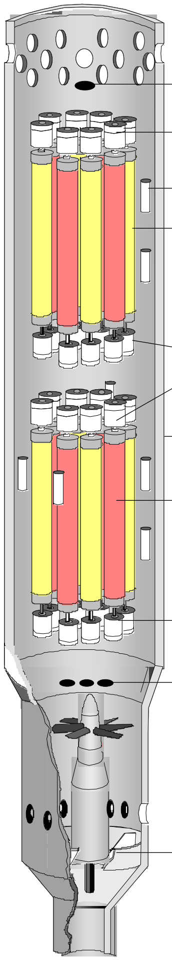
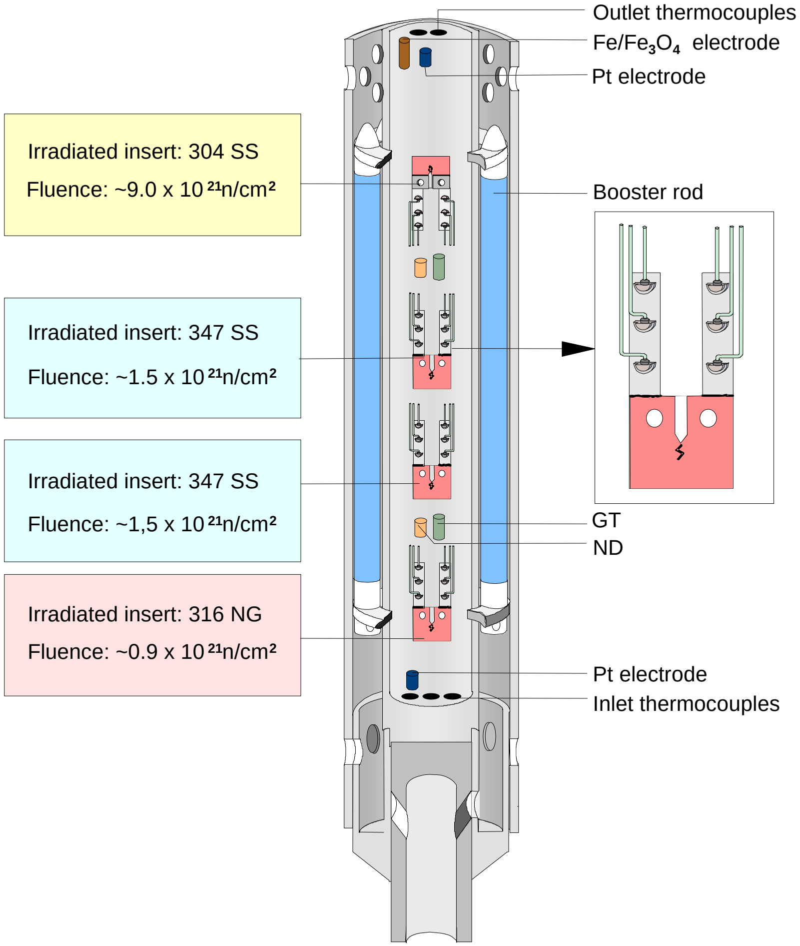
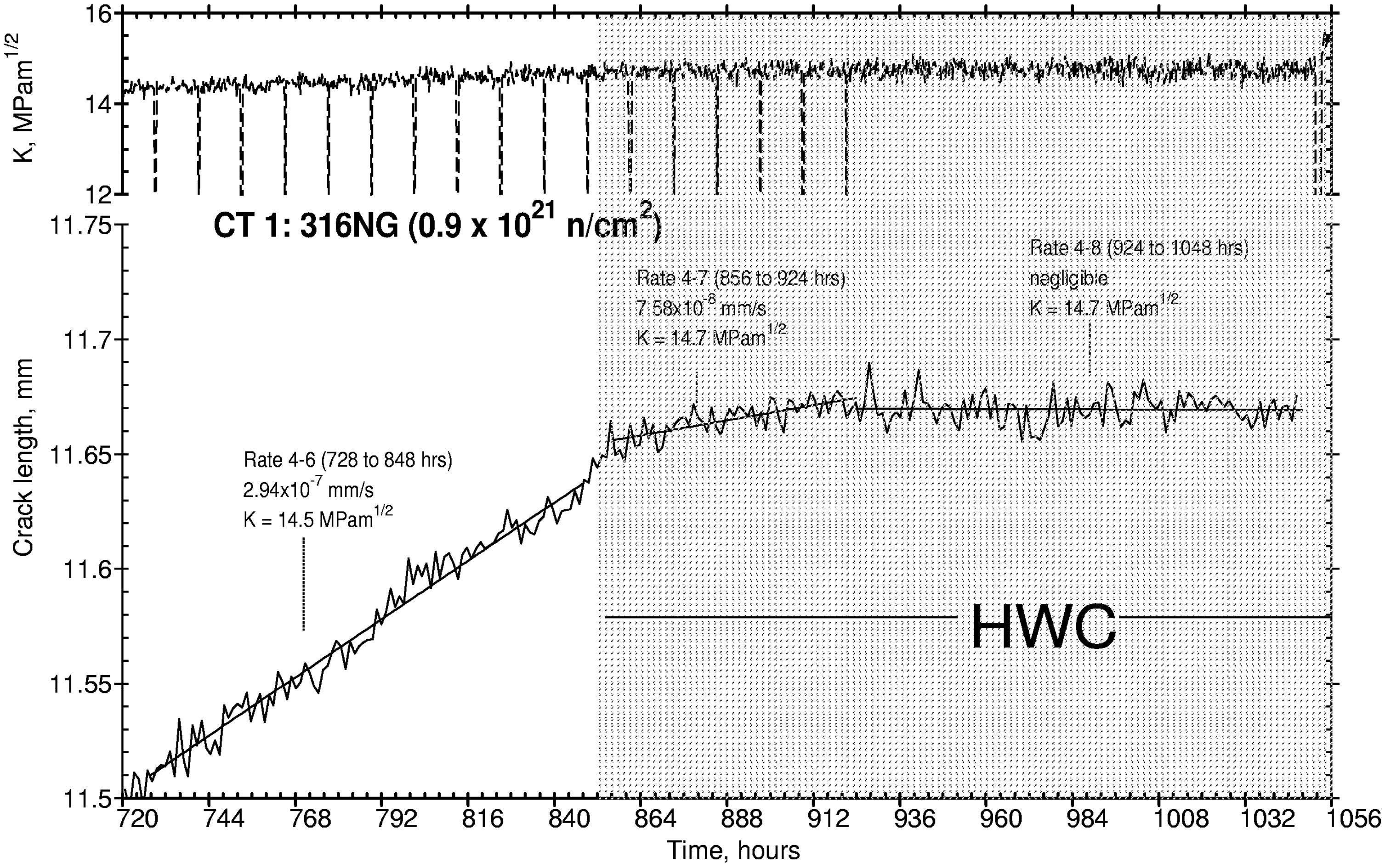


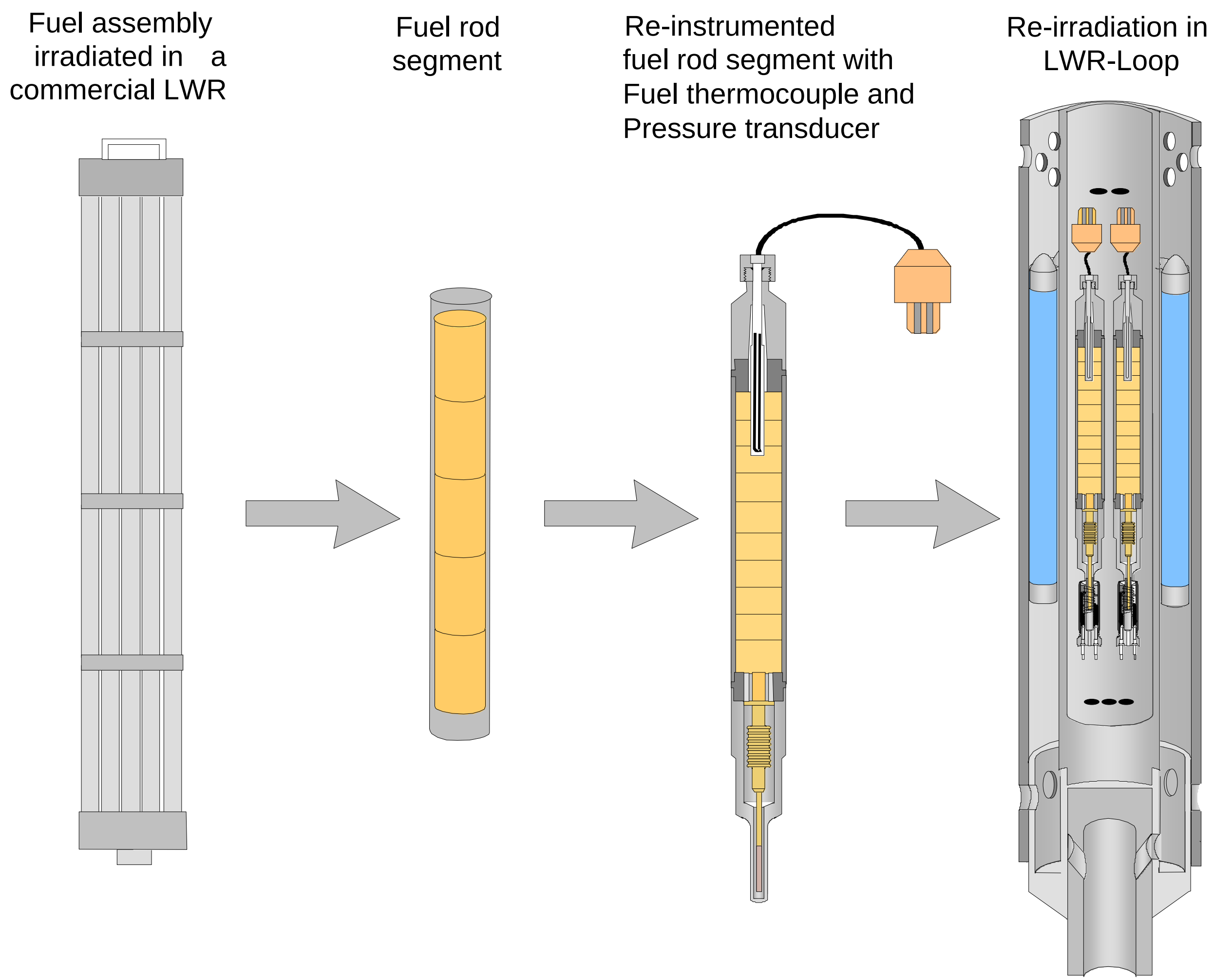
ILLUSTRATION OF THE TEST RIG, IFA-639



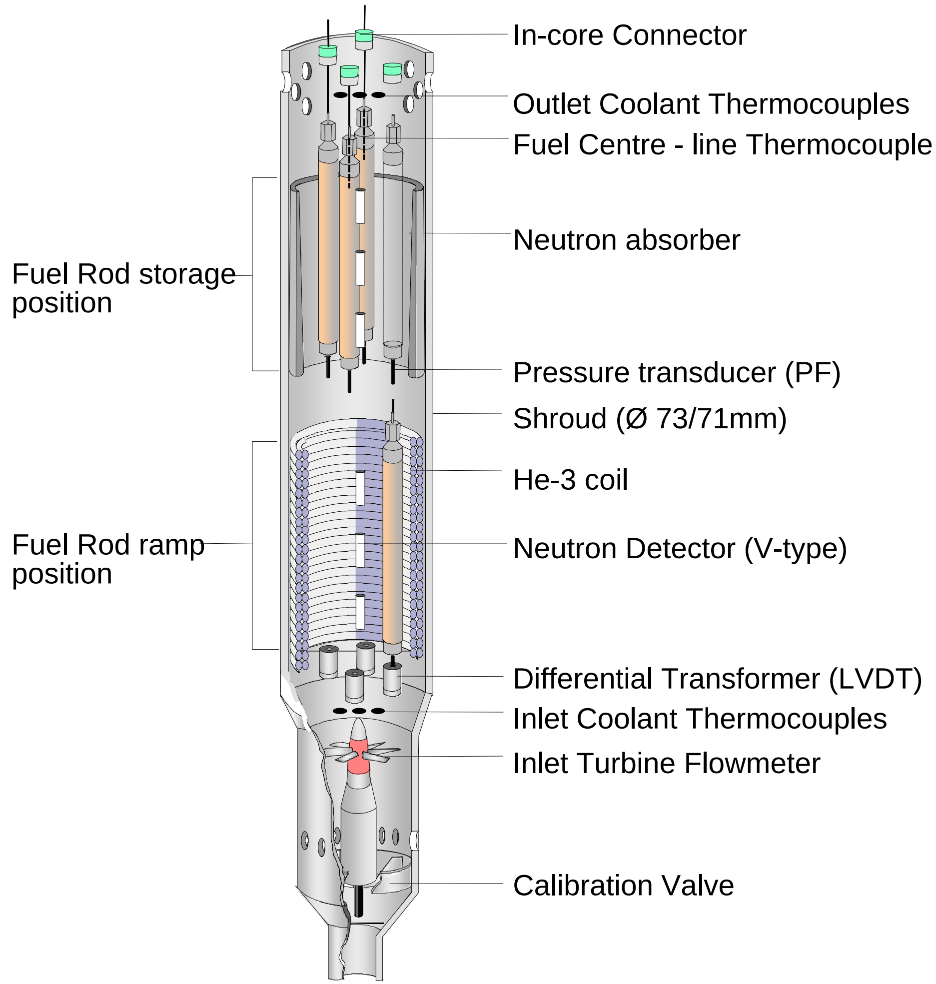
Crack-growth data from BWR irradiation test



Test rig for re-instrumented fuel rods



4 RODS RAMP RIG FOR RE-INSTRUMENTATION



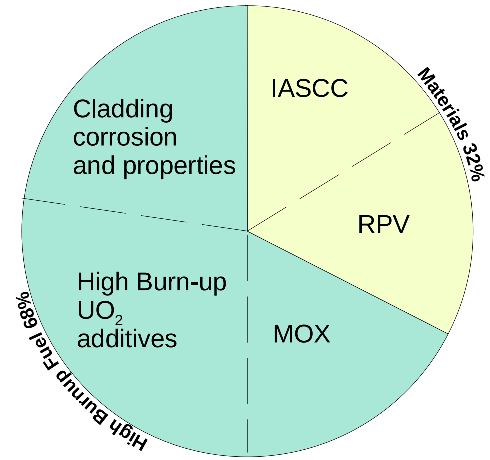
Examples of Halden contributions

- Fuel temperature, fission gas release, swelling
- Comparative tests with various types of fuel pellets
- MOX fuel as compared with UO_2 fuel
- Fuel failure threshold for various fuels (power ramps)
- Fuel failure degradation, pellet-water reaction
- High burn-up properties (FGR, thermal conductivity)
- Cladding creep reversal at high burn-up
- Rod overpressure at high burn-up
- Cladding oxidation, effect of water chemistry
- Crud deposition, effect of water chemistry
- Components endurance, effect of water chemistry
- IASCC, effect of water chemistry
- Short-term dry-out (re-usability of fuel)
- Integral LOCA experiments

MIX OF EXPERIMENTS, ANALYSES AND MODELLING WORK

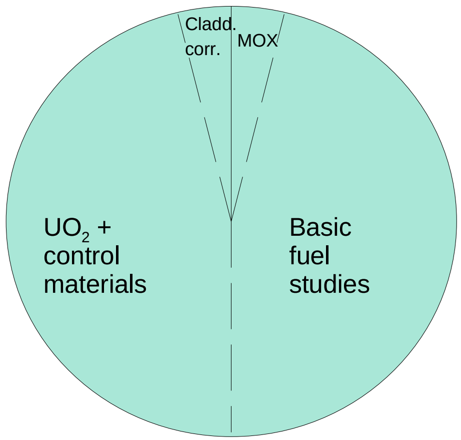
Trend of Halden Studies

1999



Materials 0%

1989



Fuel 100%

History of Halden cooperation with Japan

- Japan became a member of the HRP in 1967 (May, 5) Dr. J. Miida (JAERI) is the person who took the initiative to establish the Japan - Halden cooperation
- JAERI (STA) was the representing organization of Japan. From 2006: JAEA (MEXT), CRIEPI & MHI
- Secondees from Japan: 70 (+9 “Board of Management” + 14 “Program Group”- 7 = 86)
- Cooperation partners (almost 40 organizations altogether)
  . Governmental organizations (MEXT): JAEA (Earlier JAERI & JNC) etc.

  . Governmental organizations (METI): JNES (Earlier NUPEC & JAPEIC)

  . Vendors : MHI, Hi, To, NFI, NDC, GNF, NFD etc.

  . Utilities : TEPCO, KEPCO, EPDC, JAPCO etc.
  (Prof. Mishima supported the HRP strongly)

  . Universities :Tokyo, Sophia, Kyoto, Osaka, Kyushu, Iwate etc.
- Japanese Irradiation Tests : Ca. 70 test programs
  Ca. 100 new test rigs fabrication & Ca. 200 test rig loadings
- Software and Human factors work in co-operation with Japanese companies 7 co-operative projects

Cooperating Organizations in Japan

1 MEXT (Ministry of Education, Culture, Sports, Science and Technology)
Earlier STA (Science and Technology Agency)

2 JAEA (Japan Atomic Energy Agency) Tokyo, Tokai, Oarai,Tsuruga
Earlier JAERI & JNC (merged in Oct. 2005)
. JAERI (Japan Atomic Energy research Institute)
. JNC (Japan Nuclear Cycle Development Agency)
Earlier PNC (Power Reactor and Nuclear Fuel Development Corporation)

3 METI (Ministry of Economy, Trade and Industry)
Earlier MITI (Ministry of International Trade and Industry)

4 JNES (Japan Nuclear Energy Safety Organization)
. Earlier NUPEC (Nuclear Power Engineering Corporation)
. Earlier JAPEIC (Japan Power Engineering and Inspection Corporation)

5 EPDC (Electric Power Development Co. Ltd.)
6 TEPCO (Tokyo Electric Power Co.)
7 KEPCO (Kansai Electric Power Co. Inc.)
8 JAPCO (Japan Atomic Power Co.)
9 CRIEPI (Central Research Institute of Electric Power Industry) Tokyo, Komae

10 Hitach Ltd., Hitachi

11 Toshiba Corporation

12 GNF (Global Nuclear Fuel, Joint venture of GE, To & Hi)

13 NFD (Nippon Nuclear Fuel Development Co. Ltd.)

14 MHI (Mitsubishi Heavy Industries Ltd.), Tokyo, Yokohama, Kobe

15 NDC (Nuclear Development Corporation)

16 NFI (Nuclear Fuel Industries Ltd.), Osaka, Tokyo, Kumatori, Tokai

Universities : Tokyo, Sophia, Kyoto, Osaka, Kyushu, Iwate etc.

Cooperation with Japan in Human Factors, Virtual Reality and other Software Systems

- **JAERI, Tokai – Application of Picasso graphic tool in simulator laboratory**
- **JAERI, STA – Joint effort to deliver reactor core surveillance system to NPP Dukovany in the Czech republic**
- **JAERI, STA – Joint effort to deliver EOP support system to NPP Paks in Hungary**
- **CSD, Tokyo Co-operation in developing guidelines for computerised procedures**
- **JNC - Virtual Reality as a planning tool for decommissioning activities at NPP FUGEN**
- **TEPSYS (TEPCO) Co-operation in software QA, reactor core surveillance, and physics methods for core design**
- **Yonden, Shikoku Co-operation in reactor core surveillance and physics methods for core design**

Future

- The Halden project is a well reputed centre and has strong international support
- All current members confirmed their participation in the 2009-2011 programme. New members may join. Currently, the interaction is with 100 organisations in 18 countries
- The bilateral sales goal is tough but achievable
- The reactor license is to be renewed in 2008, for 10 years

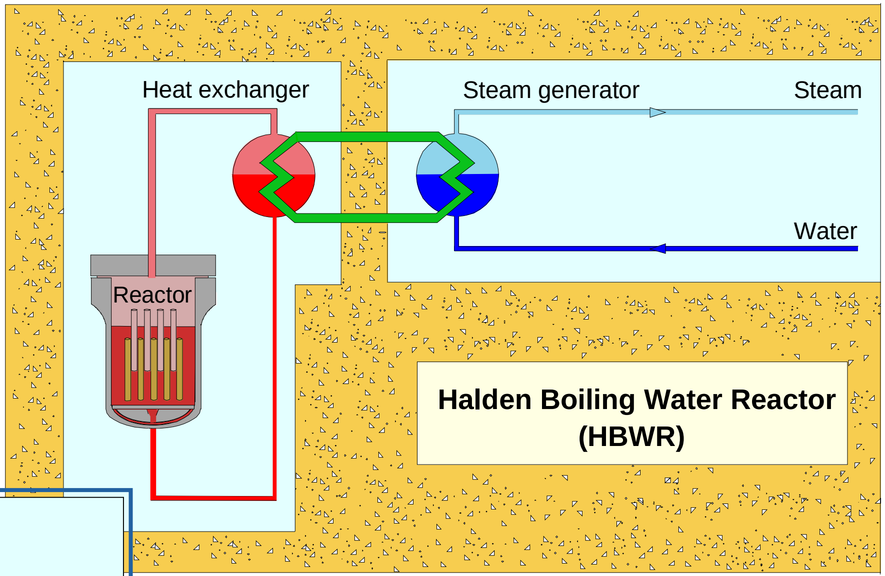
日本の長期に渡るハルデンプロジェクトへの加盟、及び暖かい支援、

精力的な試験研究開発により、ハルデン炉は今日まで支えられてきました。

ハルデンは、まだまだこれからも元気に頑張って行く所存ですので、今後も大いに可愛がって利用してください。

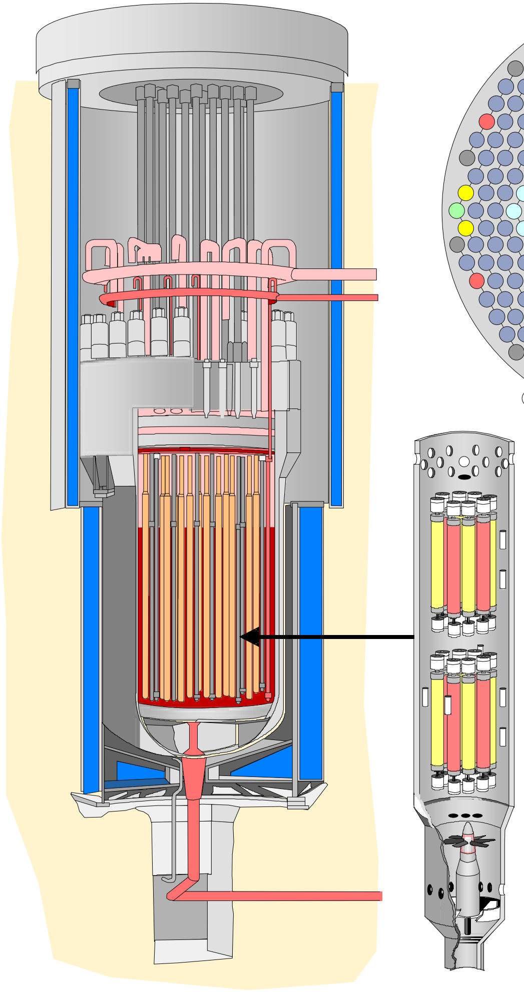
ご清聴ありがとうございました！

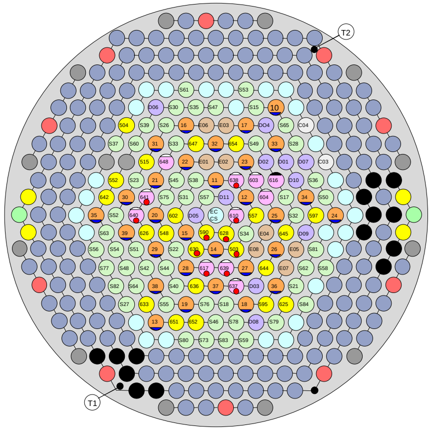
HALDEN BOILING WATER REACTOR (HBWR)



Thermal Power	**: 20 MW**
Operating Temperature	**: 240 °C**
Operating Pressure	**: 33.6 bar**
Moderator	**: Heavy Water (D_2O)**
Heavy Water Volume	**: 14 m^3**
Type of Fuel	**: UO_2**
Power Adjustment	**: 30 Control stations (Ag/Cd)**

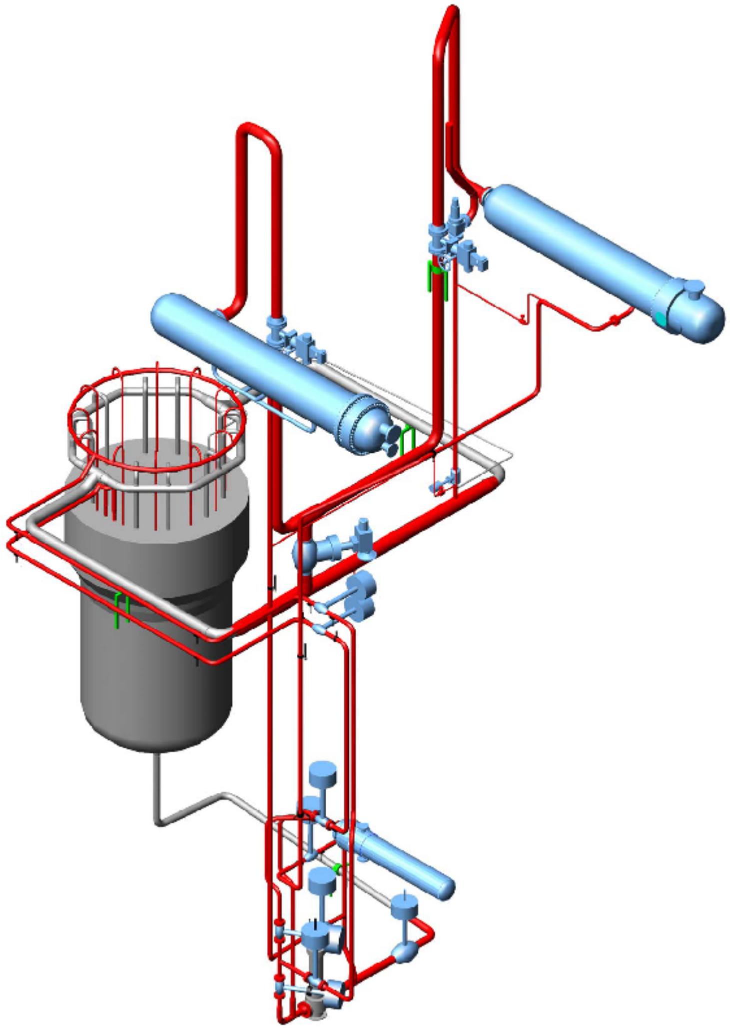
- *The reactor plant is located in rock*
- *Steam production for paper mill (30t/h)*
- *Cooling of the reactor by natural circulation*
- *2 operation periods of about 100 days each per year*



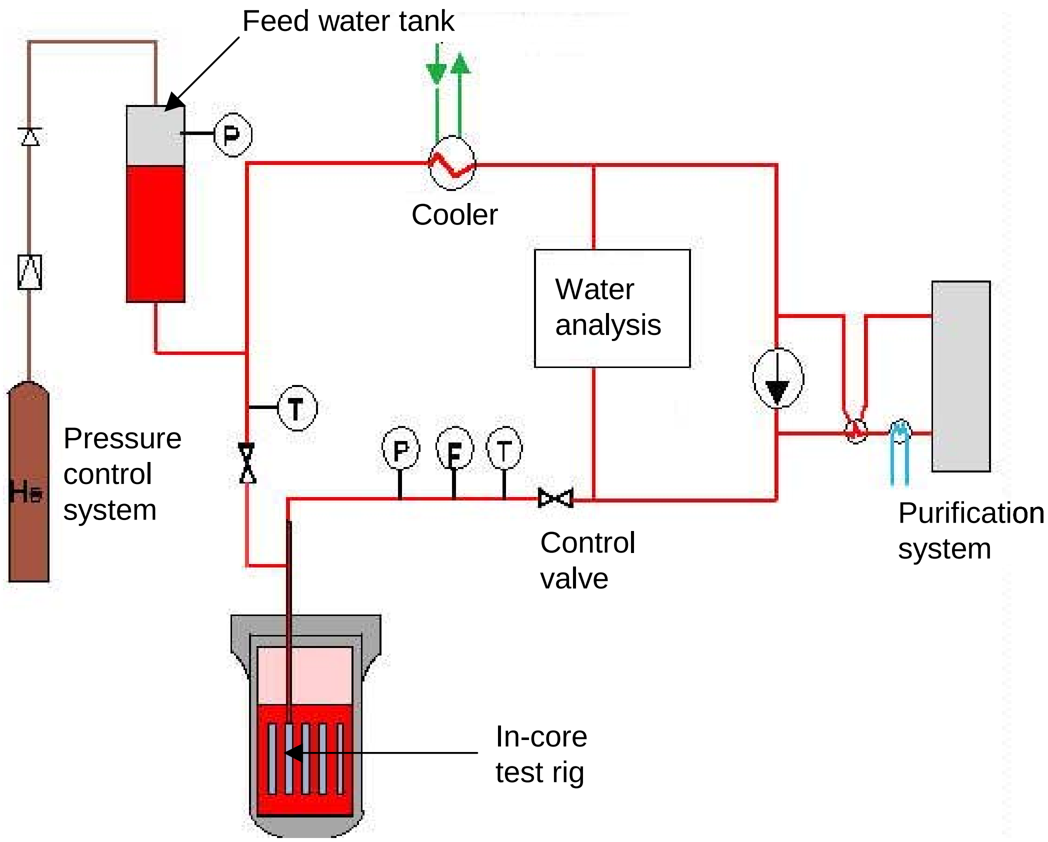


The Halden Boiling Water Reactor (HBWR) is a versatile tool for nuclear fuels and materials investigations:

- More than 300 positions individually accessible
- About 110 positions in central core
- About 30 positions for experimental purposes (any of 110/300)
- Height of active core 80 cm
- Usable length within moderator about 160 cm
- Experimental channel Ø:
  - 70 mm in HBWR moderator
  - 35-45 mm in pressure flask
- Loop systems for simulation of BWR/PWR conditions



Loop Schematic



Loop systems for fuel testing

- Loop types :
  - BWR standard loops
  - Candu loops (heavy water)
  - Specialised loop systems :
  - PWR standard loops
    - Fuel degradation loop
    - LOCA loop
    - PWR CRUD loop
    - Chemical additive loops (zinc, titanium, noble metals etc.)
    - ETC.

Loop systems for material testing

- Loop types :
  - BWR standard loops
  - PWR standard loops

Injection systems

- O2-H2 injection systems
- Noble metal systems
- Sulfat systems
- ETC

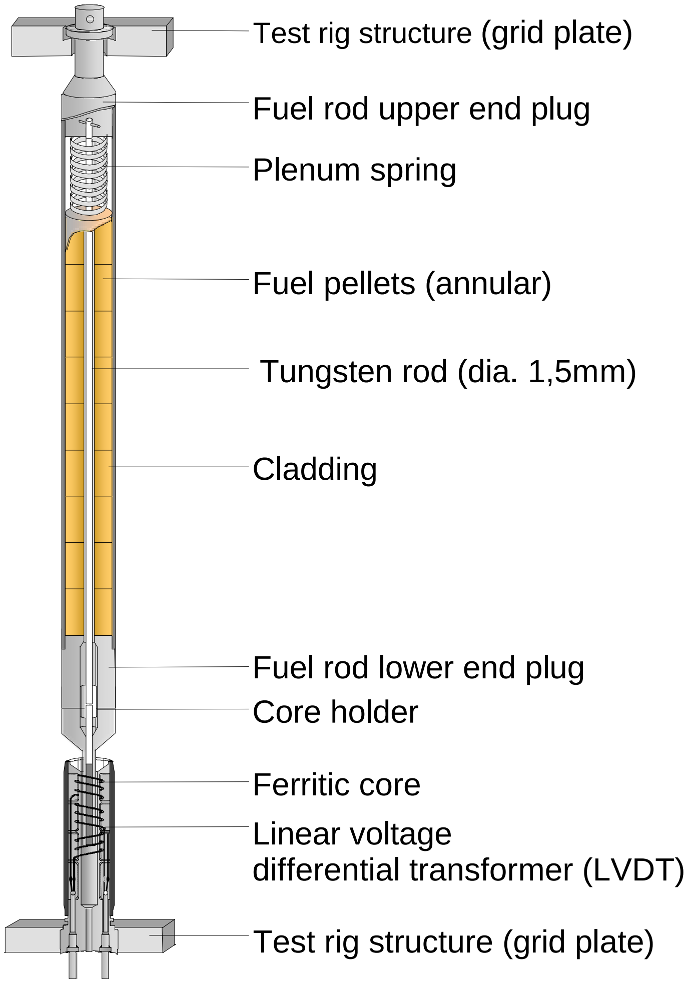
Expansion Thermometer (ET)

Alternative to Fuel Thermocouple (TF). Provides data on fuel rod average centre-line temperature.

Magnetic core fixed to a tiny refractory metal rod penetrating the centre-line of the whole fuel stack.

Core movement sensed by LVDT. Recommended for high-temp. measurements.

No de-calibration with time.

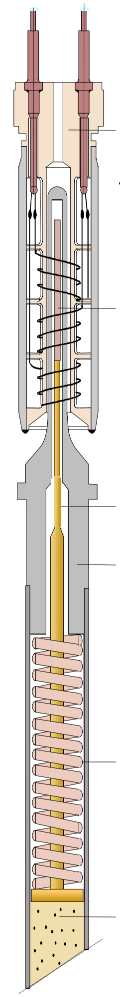


Fuel Stack Elongation Detector (EF)

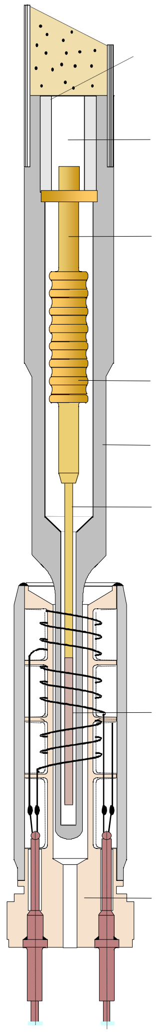
Provides swelling data in terms of axial expansion of the fuel stack.

Magnetic core spring loaded against the fuel column end pellet in the rod plenum.

Core movement sensed by LVDT.



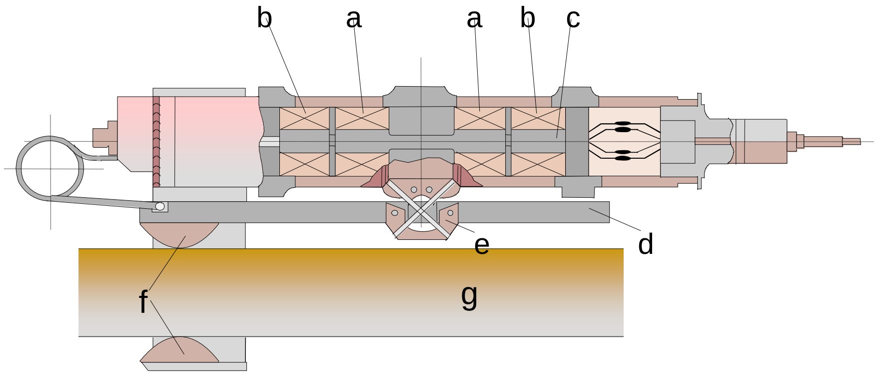
Pressure Gauge



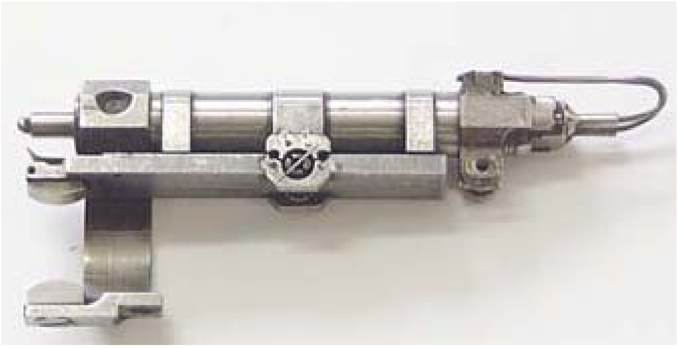
- Provides data on fission gas release by means of measurements of the fuel rod inner pressure.
- Miniaturised bellows with access to the fuel rod plenum mechanically fixed in the fuel rod end plug.
- Magnetic core fixed to the free moving end of the bellows. Core movement sensed by LVDT.
- Pre-conditioned and pre-pressurised bellows in order to reduce creep due to high temperatures and radiation.

Diameter Gauge

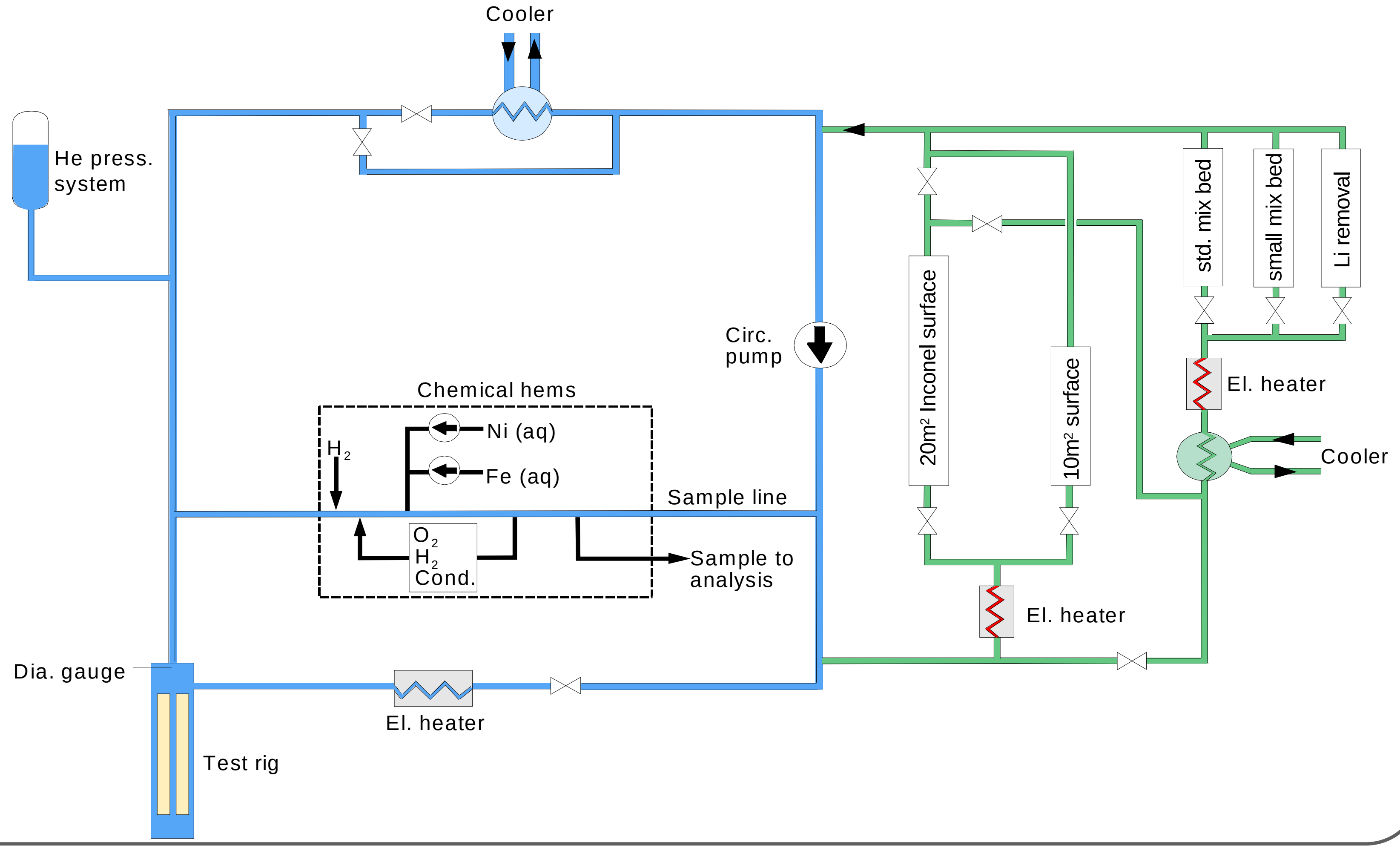
- Provides data on fuel rod diameter profile.
- Instrument based on the LVDT principle.
- Differential transformer with two feelers on opposite sides of the fuel rod.
- DG moved by hydraulic system while a position sensor senses the axial position along the rod.
- Operating conditions: 165 bar, 325°C



a:Primary coil
b:Secondary coil
c:Ferritic bobbin
d:Ferritic armature
e:Cross spring suspension
f:Feelers
g:Fuel rod



PWR Loop **(for Crud/AOA Studies)**



On-line evidence for crud loading by use of DG measurement