DE LA RECHERCHE À L'INDUSTRIE

Future MTR capabilities : Jules Horowitz Reactor

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Joint ICTP/IAEA Workshop "Research Reactors for Development of Materials and Fuels for Innovative Nuclear Energy Systems"
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Summary

1. Context and objectives of the JHR

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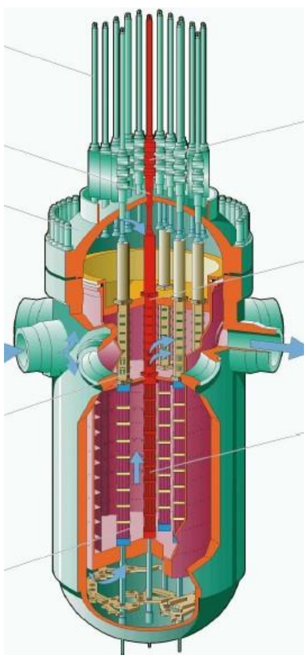
In-pile testing in support of the nuclear Industry

Just for France, 58 NPPs means more than 10 000 fuel assemblies under irradiation at a time…



The fuel has to be carefully designed, with enough **Safety Analysis Design Margins**

\+ **new fuel managements**

\+ **new LWR standards**…

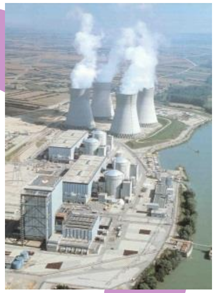
→ need to generate additional margins

1. **Improve Modeling, Calculation tools and Testing**
2. **Improve Safety Analysis design Methods**
3. **Improve Fuel Product**

In-pile data required !

1. Context and objectives of the JHR

The Key-Role of Material Testing Reactors for Fuel and Material qualification under irradiation

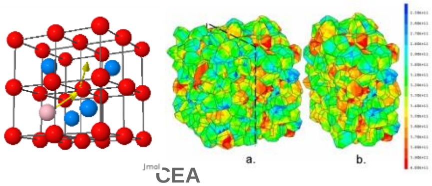


CODES Validation

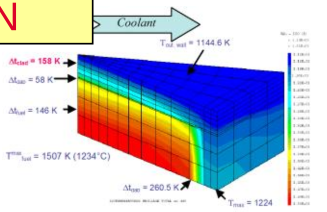
QUALIFICATION Documents

EXPERIMENTAL DATA EXPERTISE

BASIS RESEARCH & NUMERICAL SIMULATION



DESIGN



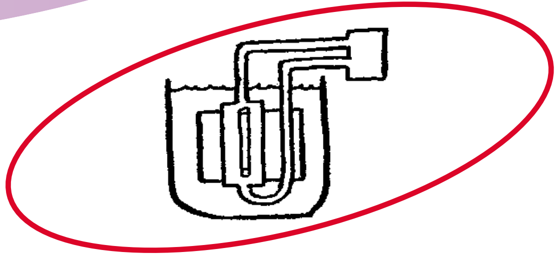
POST IRRADIATION EXAMINATIONS

SINGLE EFFECT EXPERIMENTS

Hot lab. for PIE

BEHAVIOUR UNDER IRRADIATION

Material Test Reactor

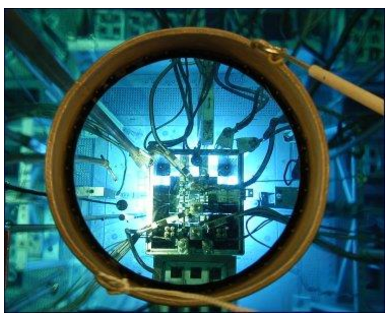


MANUFACTURING REFABRICATION CHARACTERIZATION

Hot Lab.

MTRs in France

SILOE
Shutdown 1997



OSIRIS
Shutdown 2015

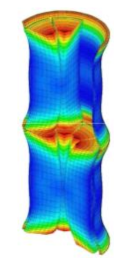
PHENIX
Shutdown 2010

1. Context and objectives of the JHR

Jules Horowitz Reactor
Main objectives

1. R&D in support to nuclear Industry

- Safety and Plant life time management (ageing & new plants)
- **Fuel behavior validation in incidental and accidental situation**
- Assess innovations and related safety for future NPPs



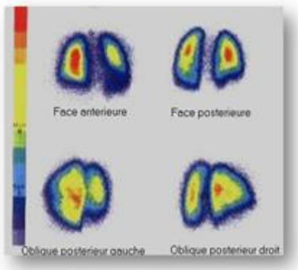
2. Radio-isotopes supply for medical application

- **^{99}Mo production**

  JHR will supply 25% of the European demand

  (today about 8 millions protocols/year)

  + Up to 50% upon specific request



3. A key tool to support expertise

- Training new generations (JHR simulator, secondees program)
- Maintaining a national expertise staff and credibility for public acceptance
- Assessing safety requirements evolution and international regulation harmonization

2. General figures of the JHR

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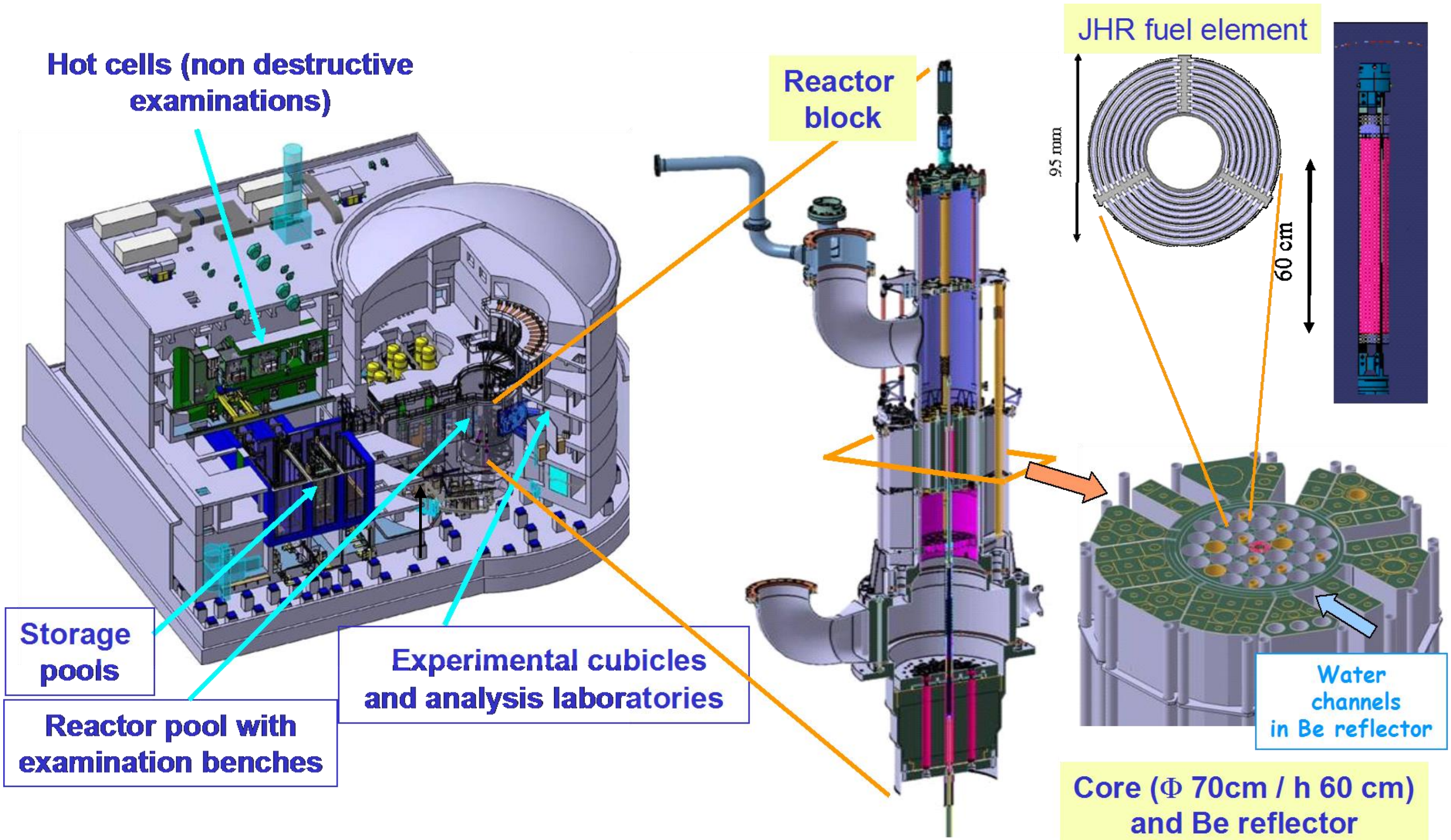
JHR: a modern 100 MWth pool-type light water MTR optimized for fuel and material testing



2. General figures of the JHR

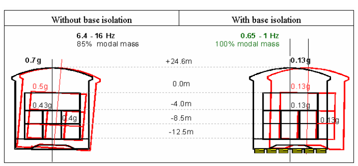
General layout of the JHR site

Reactor Building

Reactor pool
(DD, NDE)

Experimental rooms

About 200 aseismic pads



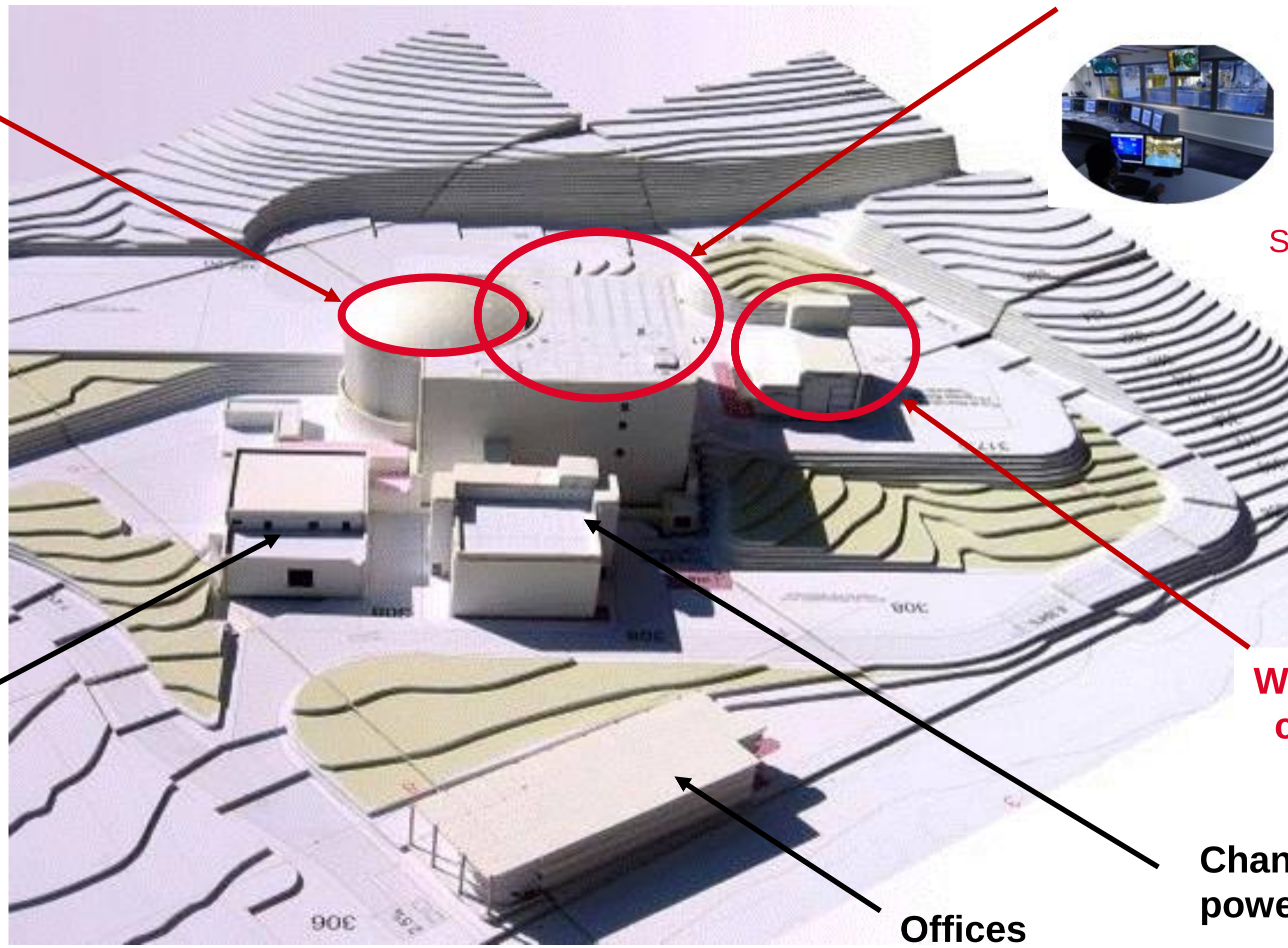
Nuclear Auxiliary Building

Laboratories

Control room

Hot cells
(NDE + handling)

Storage pools (NDE)



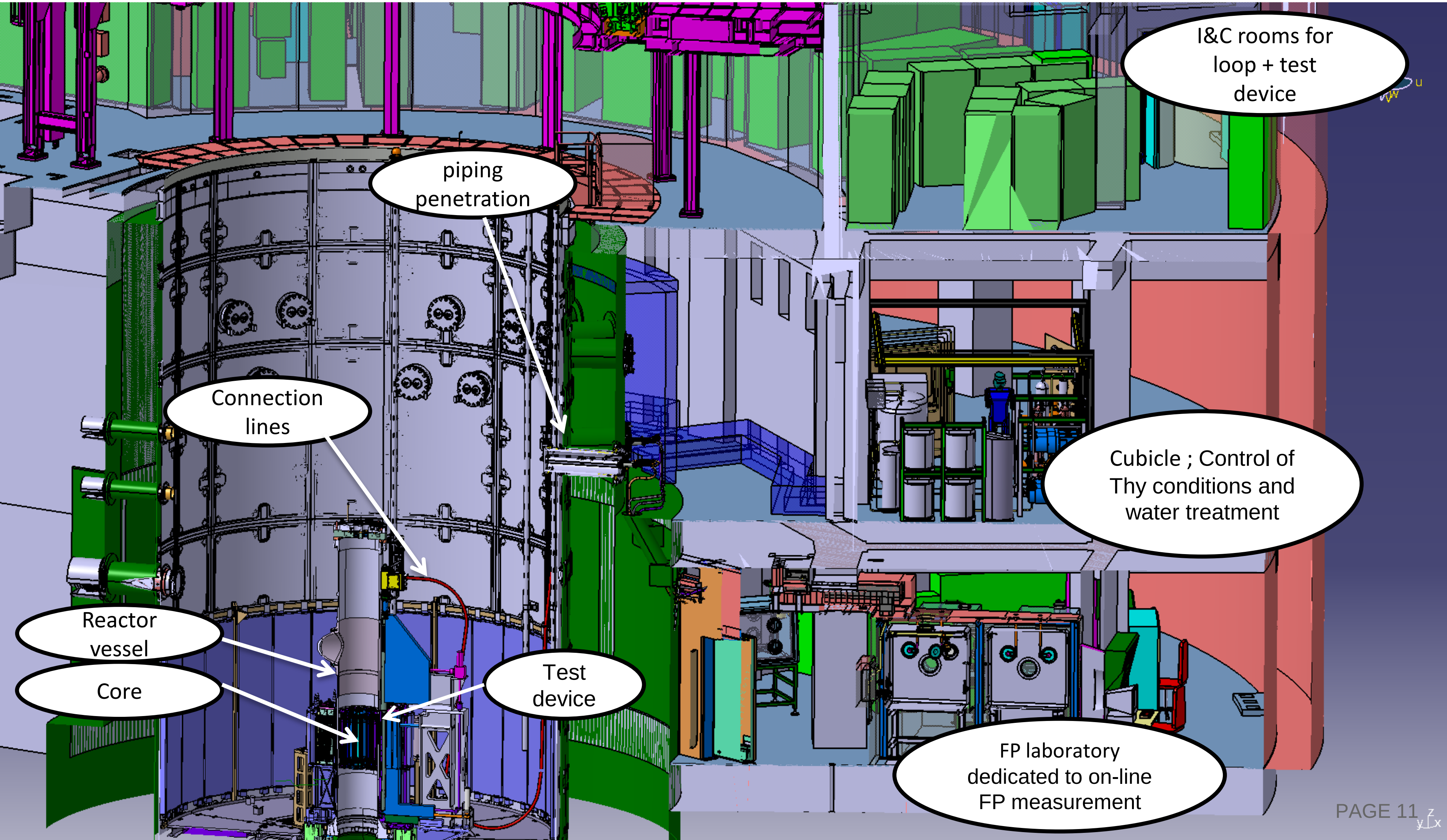
Cooling systems

Warehouse and cold workshop

Changing rooms + power supply

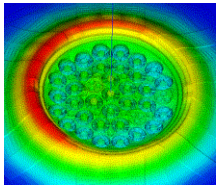
Offices

Reactor building

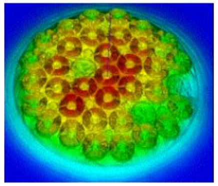


2. General figures of the JHR

Thermal neutron flux



Fast neutron flux

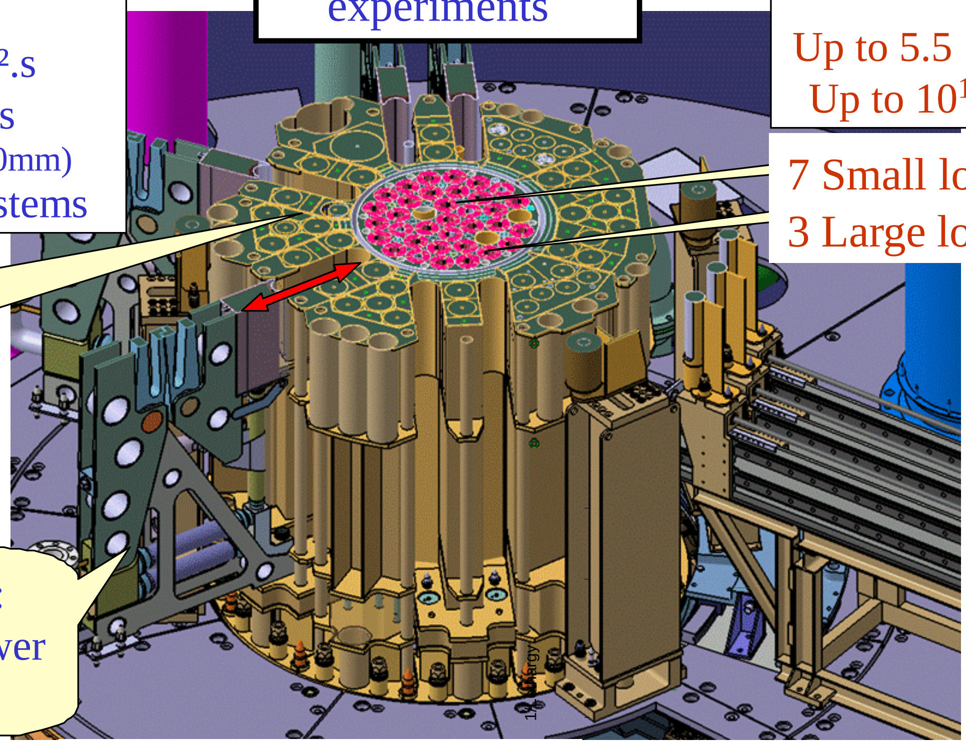


The core is under moderated:
→High fast neutron flux in the core
→High thermal neutron flux in the reflector

~20 simultaneous experiments

In reflector
Up to 5.5 10^{14} n/cm².s
~20 fixed positions
(100mm ; 1 position 200mm)
and 6 displacement systems

In core
Up to 5.5 10^{14} n/cm².s > 1 MeV
Up to 10^{15} n/cm².s > 0.1 MeV



7 Small locations (F ~ 32 mm)
3 Large locations (F ~ 80 mm)

Fuel studies: up to 600 W/cm with a 1% ^{235}U PWR rod

Material ageing
(low ageing rate)

Displacement systems:
- Adjust the fissile power
- Study transients

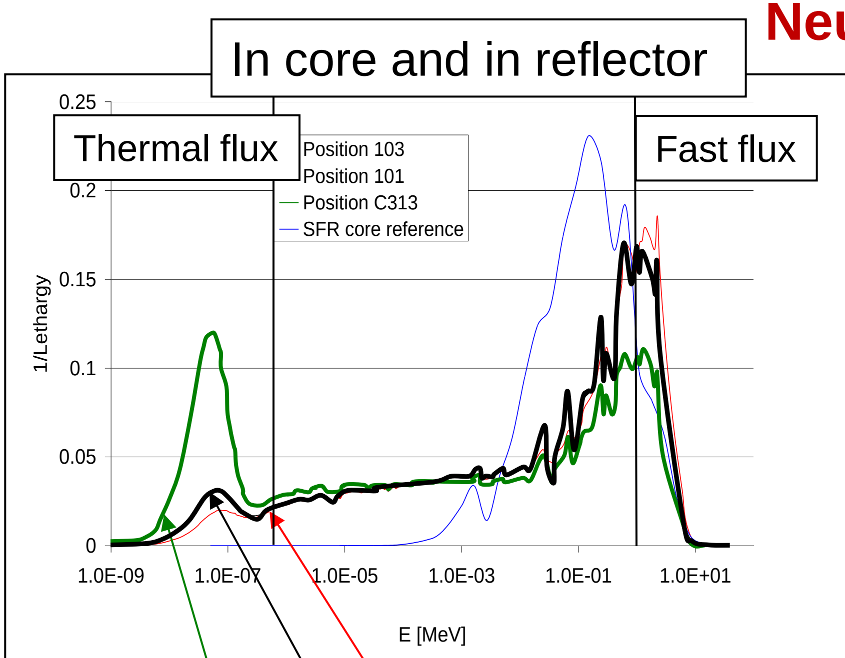
Fuel experiment
(fast neutron flux– GEN IV)

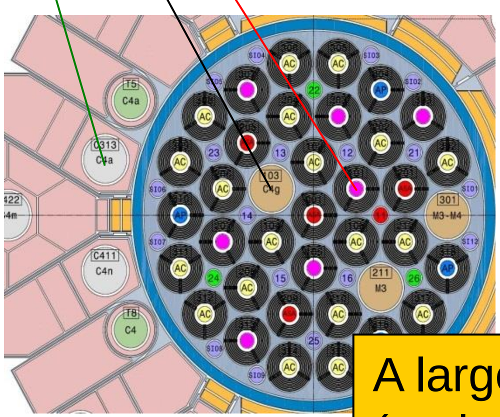
Material ageing
(up to 16 dpa/y)
GEN II & III + GEN IV

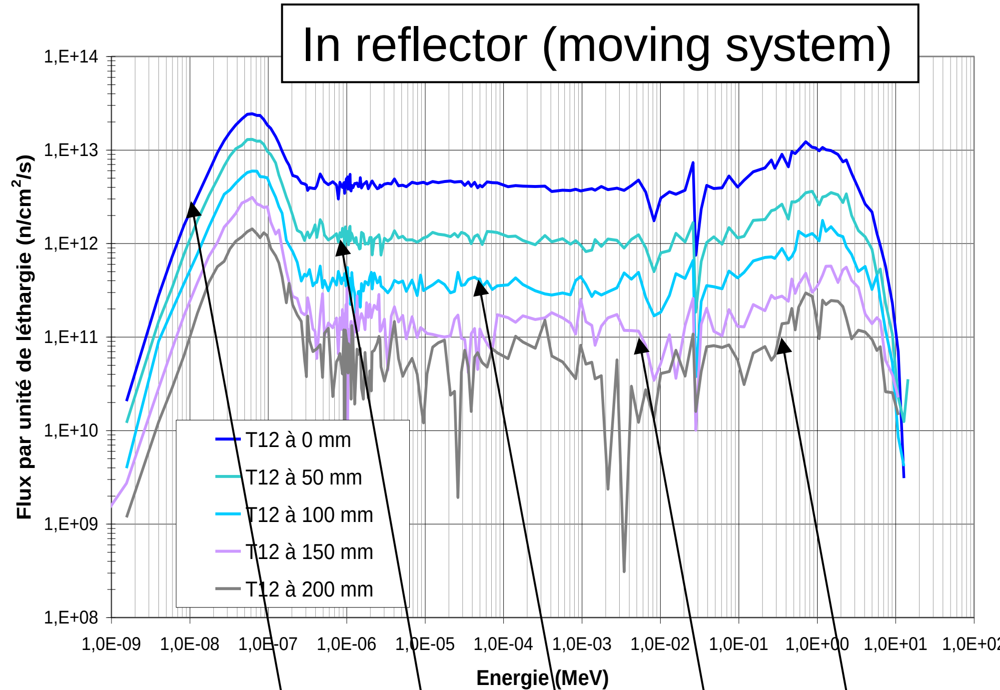
Core Designed for UMoAl fuel
Start-up with U_3Si_2-Al fuel
70 MWth / 100 MWth
25 to 30 days cycle length
6-7 days shutdown

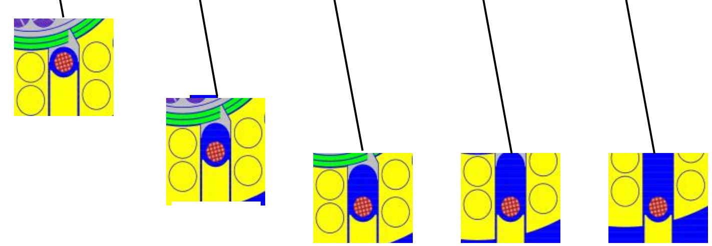
2. General figures of the JHR

Neutron spectra









A large range of neutron fluxes and spectra
(and possible adaptation with « neutron filters »)

3. Experimental capabilities of the JHR

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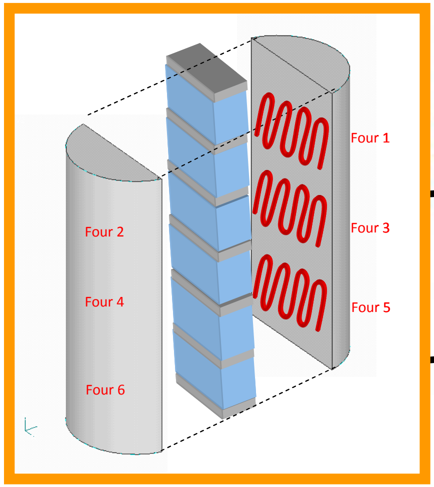
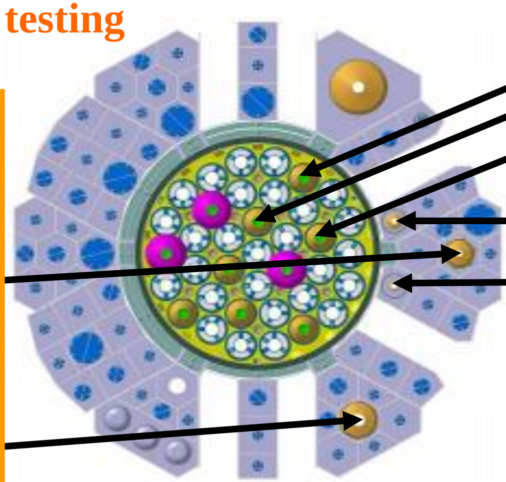
Hosting experimental systems (dedicated to LWR material testing)

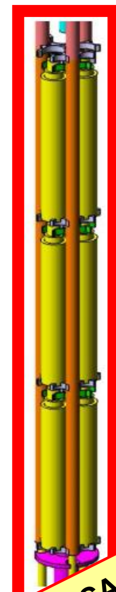
OCCITANE
For pressure vessel steel testing





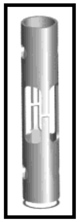
- Irradiated material behaviour
Tensile tests, resilience test (Charpy), crack propagation tests …..

- Behaviour of Thermal affected zones

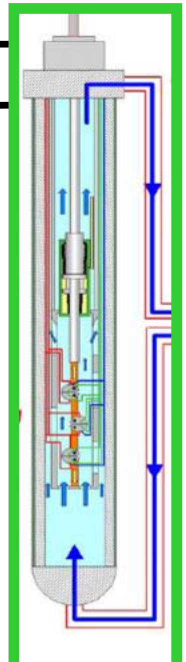


CALIPSO, MICA
For material testing under high dpa and accurate temperature control (+ mechanical loading)

specimen for µ structure evolution, tensile test ; for 1 or 2 D creep tests ; for bending tests (stress releiving experiments) ;…



MICA Available at JHR start-up

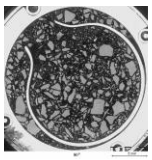


CLOE Corrosion loop for "Zr alloy Corrosion" and "Irradiation Assisted Stress Corrosion Cracking"

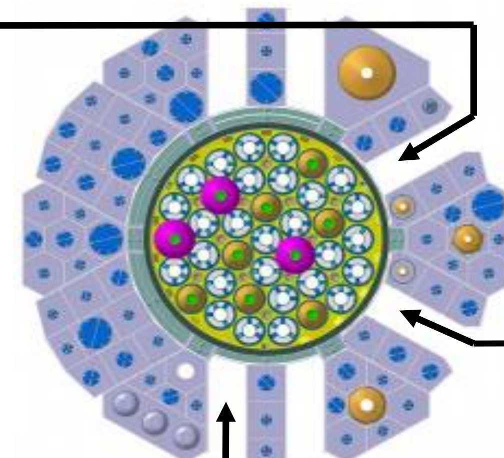
3. Experimental capabilities of the JHR

Hosting experimental systems (dedicated to LWR fuel testing)

LORELEI fuel testing under accidental conditions (LOCA)



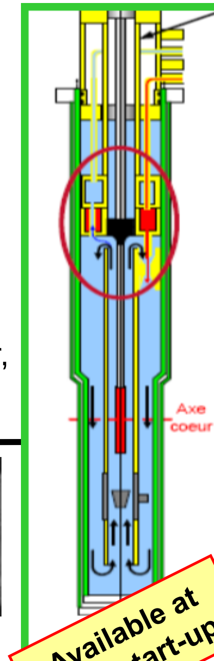

- Source Term (FP releases)
- Rod thermal-mechanical behaviour
  - ➢ Ballooning and clad burst (fuel relocation)
  - ➢ Corrosion at high temperature
  - ➢ Quenching and post-quench behaviour



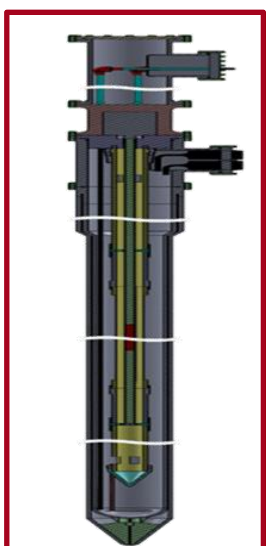
ADELINE
For fuel testing under off-normal conditions

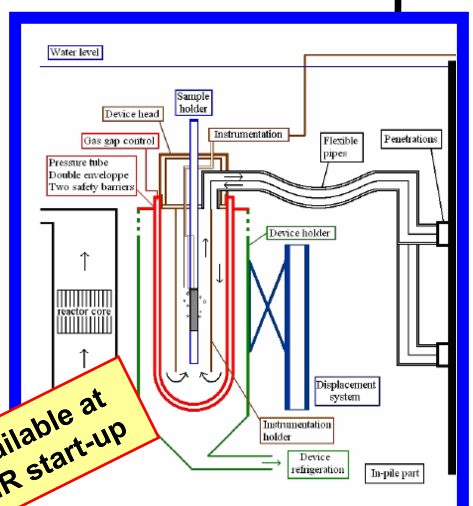
Power transient,
post clad failure fuel behavior,
Lift-off experiment…





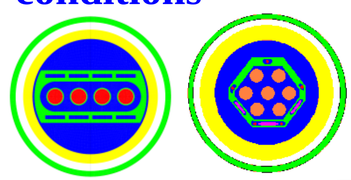
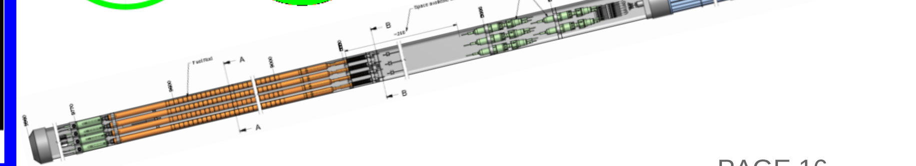
Available at JHR start-up





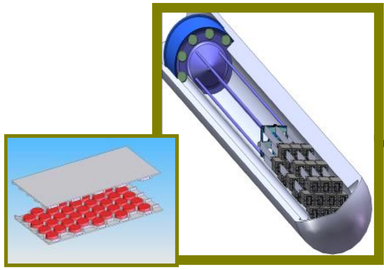
Available at JHR start-up

MADISON
For fuel testing under nominal conditions

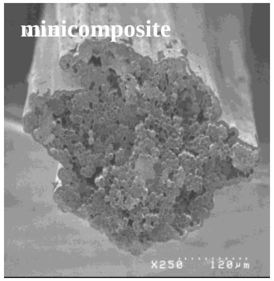



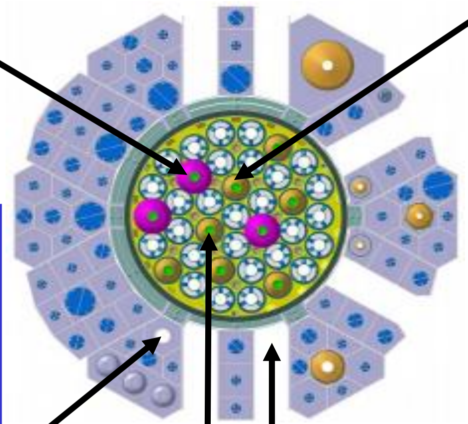
Other possible hosting experimental systems (conceptual studies)

High temp.material irradiation (600-1000°C)
Large capacity

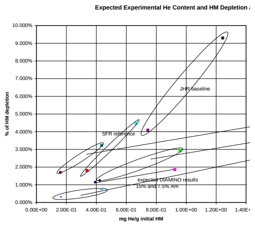


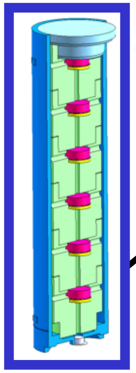
MICA (material irrad) adapted to 1000°C gas conditions (Phaeton type – Osiris technology)





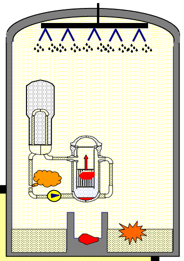
Transmutation studies





Other topics

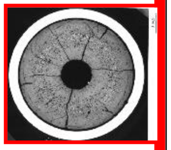
LWR : Adeline « FP » ; Adeline "power to melt"
LWR severe accident studies
GFR : fuel irradiation (normal and off-normal conditions)
Fuel characterization : basic properties under irradiation (thermal diffusivity, thermal creep,..)

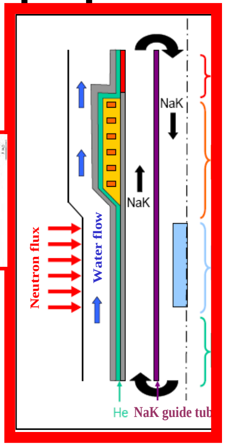


CALIPSO adapted to SFR fuel and material

Normal=> in core

Off normal => in reflector





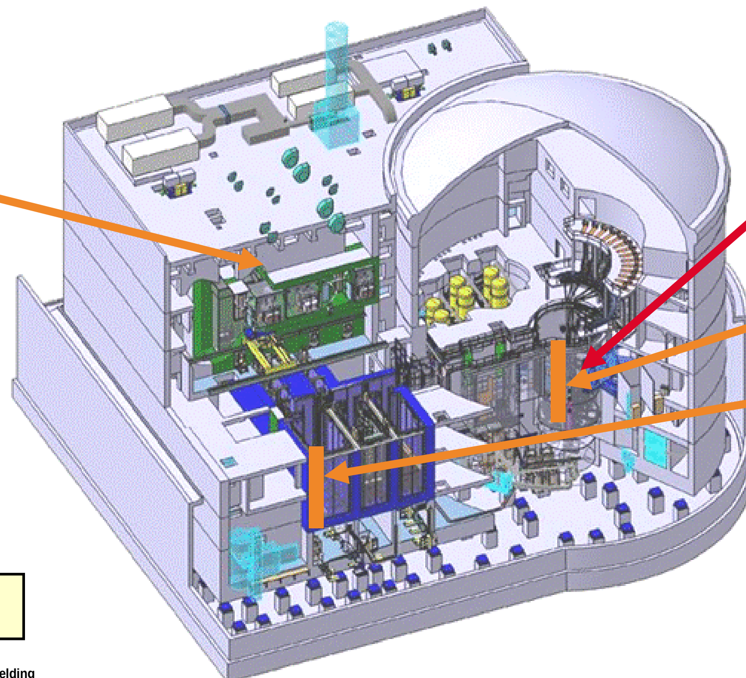
3. Experimental capabilities of the JHR

Non Destructive Examination (NDE) Benches

Sample examination in hot cells

Gamma and X-Ray tomography systems

Multipurpose test benches



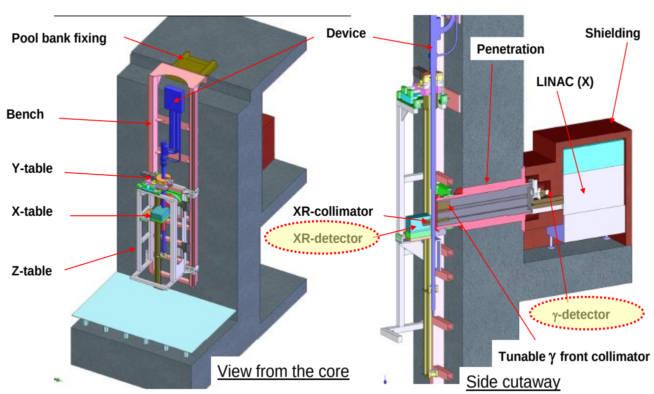
Test device examination in pools

Neutron imaging system in reactor pool

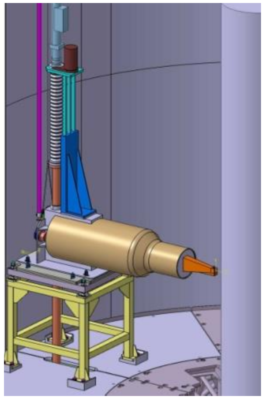
Coupled X-ray & γ bench in reactor pool

Coupled X-ray & γ bench in storage pool

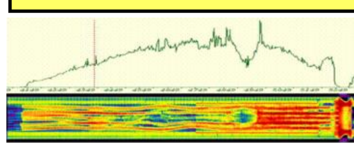
Coupled Gamma &X-ray bench

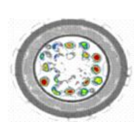


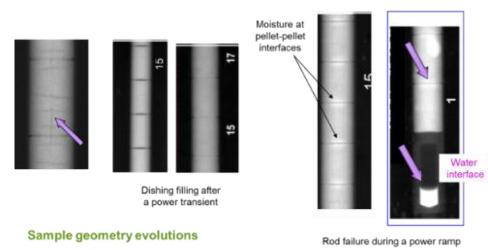
Neutron Imaging System



- Initial checks of the experimental loading
- Adjustment of the experimental protocol
- On-site NDE tests after the irradiation phase







4. JHR consortium and collaborations

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JHR Consortium : economical model for investment & operation

- CEA = Owner & nuclear operator with all liabilities
- JHR Consortium Members own **Guaranteed Access Rights** (in proportion of their financial commitment to the construction)
- A Member can use totally or partly his access rights for implementing **proprietary programs with full property of results** and/or for participating to the **Joint International Programs** open to non-members
- ***Open to new member entrance until JHR completion***

JHR Consortium current partnership: Research centers & Industrial companies

Associated Partnership: JAEA

4. JHR consortium and collaborations

THE JHR AND ANCILLARY FACILITIES AS AN “ICERR”

Objectives of the CEA-ICERR (IAEA Terms of Ref):

- **Create international scientific networks**
- **Make available CEA facilities and experience to affiliates**
- **Lead innovative joint programs with shared results**
- **Enhance utilization of Research Reactors**
- **Host international scientists / engineers (visiting scientists, operators…)**
- **Provide “hands on” nuclear education “in the field”**

Since CEA designation in September 2015, 6 Member States from the IAEA have signed an Agreement with CEA

Strong CEA intention to welcome Junior and/or Senior Scientists, Nuclear Engineers, Operators, Safety Managers… within JHR teams for various topics (R&D programs, Hands-on training on equipment…)

5. Status of the reactor construction

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Civil work of Reactor Building and Auxiliary Unit Building nearly completed

Preparation for pool liner setting-up

Delivery of Hot Cells
end of 2016
(Czech partners)

5. Status of the reactor construction

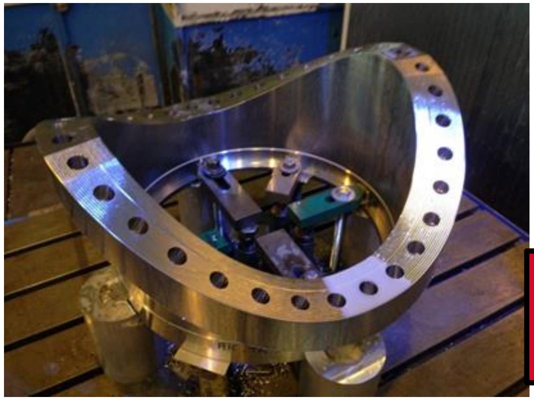
March 2017 : NUCLEAR UNIT CLOSURE

December 2016

March 2017

5. Status of the reactor construction

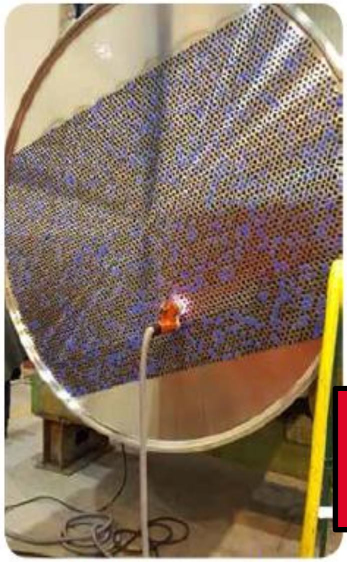
Core components



Horse saddle flange

Main water box with primary system connection

Last welding on the vessel
Electron beam welding

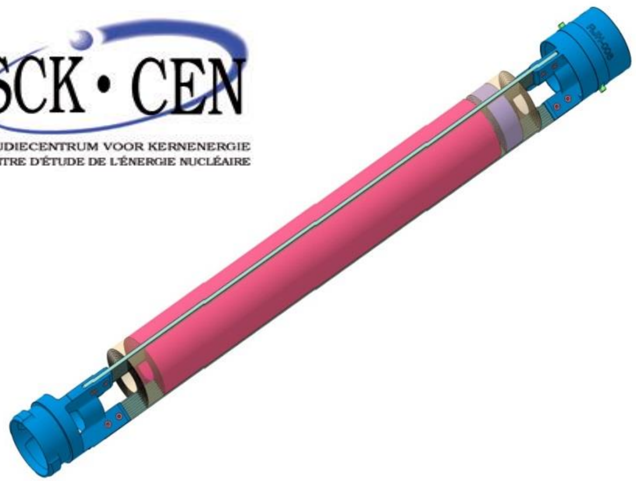


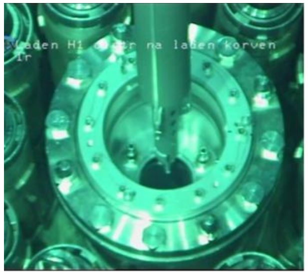
Rack for fuel elements

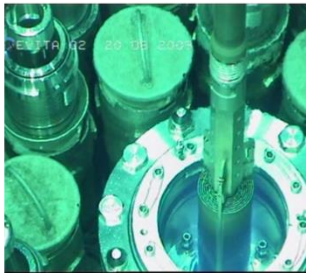
Heat Exchangers (Spanish partner)

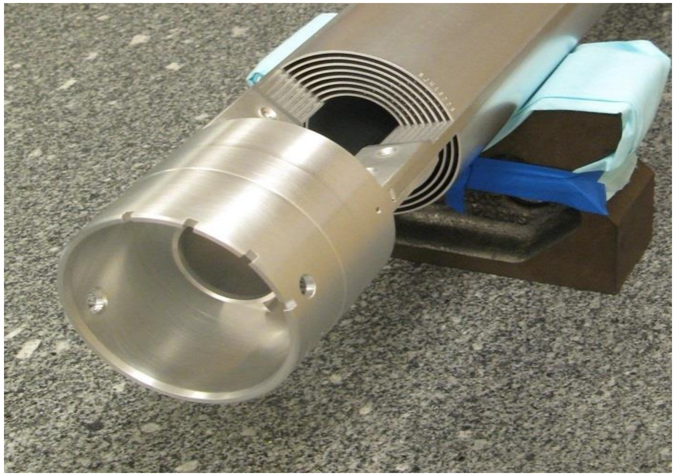
JHR Fuel qualification
(EVITA Program performed in BR2 reactor)

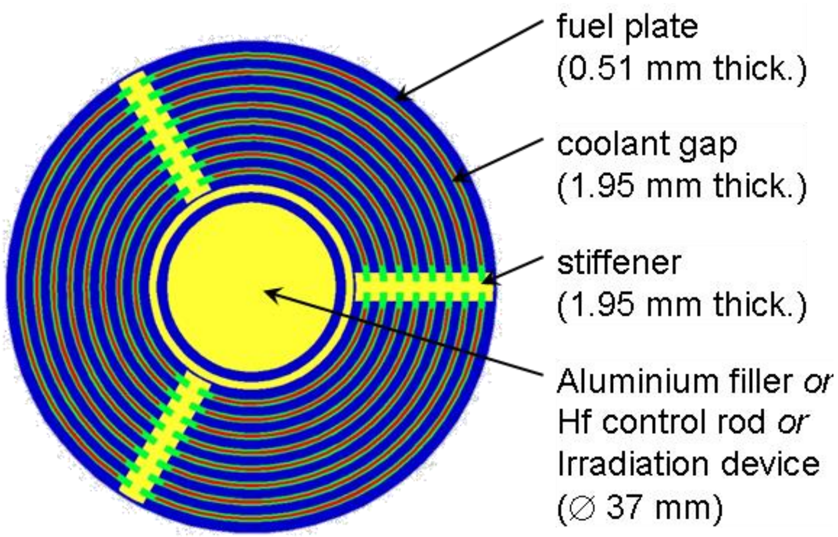
SCK • CEN
STUDIECENTRUM VOOR KERNENERGIE
CENTRE D'ÉTUDE DE L'ÉNERGIE NUCLÉAIRE





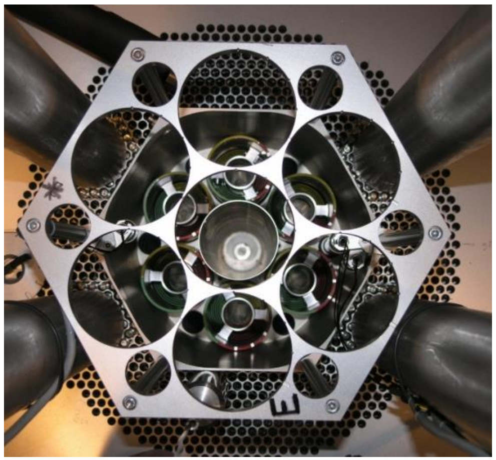




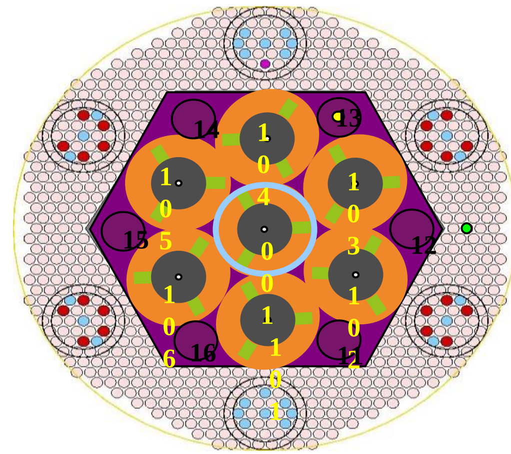


5. Status of the reactor construction

Development and experimental validation of a new calculation scheme for JHR



AMMON program performed in EOLE reactor (2010-2013) : provided relevant experimental data for the qualification of the main JHR safety and design parameters



AMMON « reference » configuration

Neutron/photon parameter	Experimental uncertainty (1σ)
Core excess reactivity	± 12 pcm
Hafnium reactivity worth	< ± 0.5% (critical state technique) ± 5% (MSM technique)
Assembly power	± 1 %
Plate power density	± 1 %
Axial plate power profile	± 1 to 1.5%
Azimuthal plate power profile	± 1 to 1.5%
Fuel plate modified conversion ratio	± 2 %
Spectrum indexes	± 1.8 to 3 %
Effective delayed neutron fraction	± 19 pcm
Effective prompt neutron generation time	± 0.8 $
Photon heating (TLDs/OSLDs)	± 4 to 4.5 %

General conclusion

1. **Material Testing Reactors remains key-tools in R&D support for nuclear power industry**

2. **Research Reactors are now more "costly machines" than in the past…**

3. **Considering the increasing complexity of the experiments (due to enhanced requirements from simulation) the use of international platform (as will be JHR) is recommended**

4. **Innovative in-core instrumentation** is a key for the quality and attractiveness of future MTR experimental programs, together with **Post-Irradiation Analysis capabilities**

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