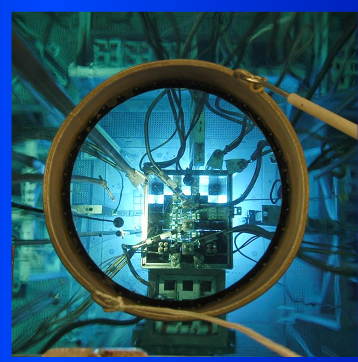
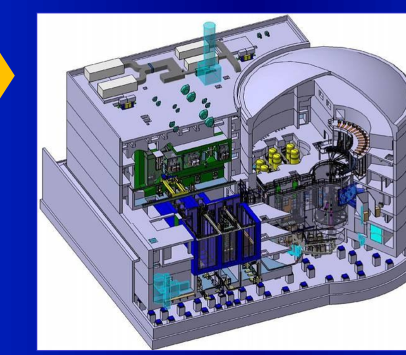
Sustaining Material Testing capacity in France :

from OSIRIS to Jules Horowitz Reactor





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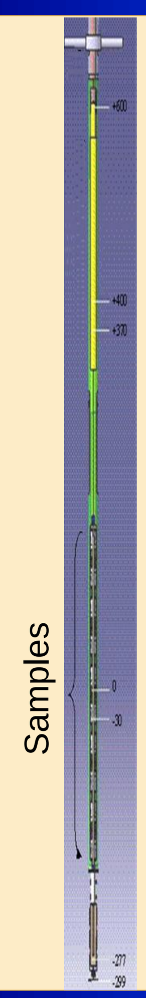
CEA is operating OSIRIS reactor and building JHR with experimental devices to support industry and public organizations in R&D irradiation programs on nuclear fuel and materials.

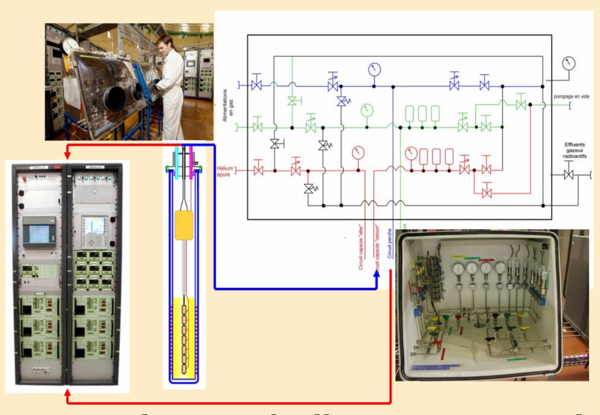
In-core material testing : from CHOUCA to MICA and… CALIPSO



CHOUCA : device for material irradiations (clad, internal structures,…)

The CHOUCA device enables to irradiate materials samples inside the OSIRIS Core. It is made of 2 concentric tubes delimiting a gap filled with gas (used as a thermal barrier and to detect potential leaks). Six temperature-regulated heating elements are located along the sample volume height. Samples are held in position thanks to a sample holder (specific for a given sample load)

- **Medium:** gas or NaK (to improve thermal conductivity and therefore to homogenize sample temperature)
- **Usual operating temperature :** 250°C to 400°C , adjusted ± 5°C
- **Height under flux: 600** mm
- **Effective diameter:** 24mm
- **Fast neutron flux**: up to 2 10^{14} n/cm²/s
- **Gamma heating** : up to 13W.g^{-1}



The CHOUCA device with all its pneumatic and electric components

The CHOUCA sample holder contains many neutron activation dosimeters which enable to determine the neutron fluence received by the samples.

Sample holder

A longstanding experience on capsule and sample holders design that benefits to the JHR

The MICA device is drawn from the OSIRIS'CHOUCA.

The CALIPSO loop will be a further development of MICA. It will use an integrated electromagnetic pump to circulate the NaK medium. This will therefore improve heat removal from sample materials surfaces leading to a better temperature control. A variable exchange length allows to extend the operating temperature range (250°C to 450°C).

These capsules will be used **with more innovative sample holders** like the one designed, in the frame of a collaboration with the VTT Finnish research centre, for the **Melodie Experiment**. This experiment will allow to pilot biaxial stresses on zircaloy tubes and to monitor corresponding axial and radial deformations. First validation experiments are scheduled inside the OSIRIS reactor in 2012.

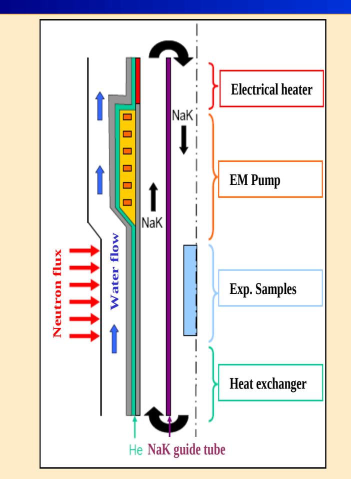


Diagram of the CALIPSO loop

- Recirculating He loop
- 4 independent circuits up to 180 bar
- Computer-controlled (servo-valves)
- Stress or strain mode

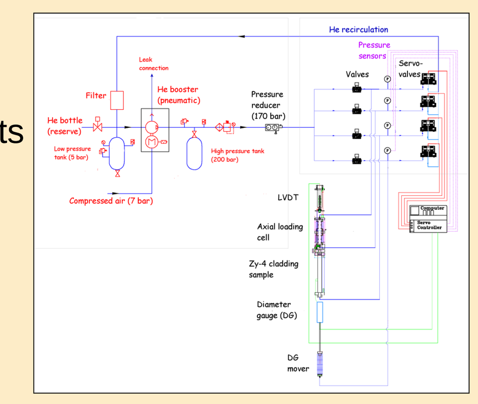
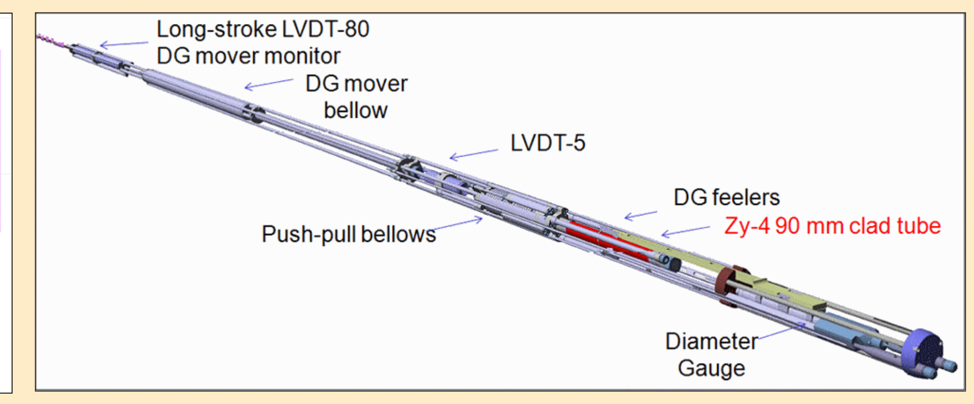


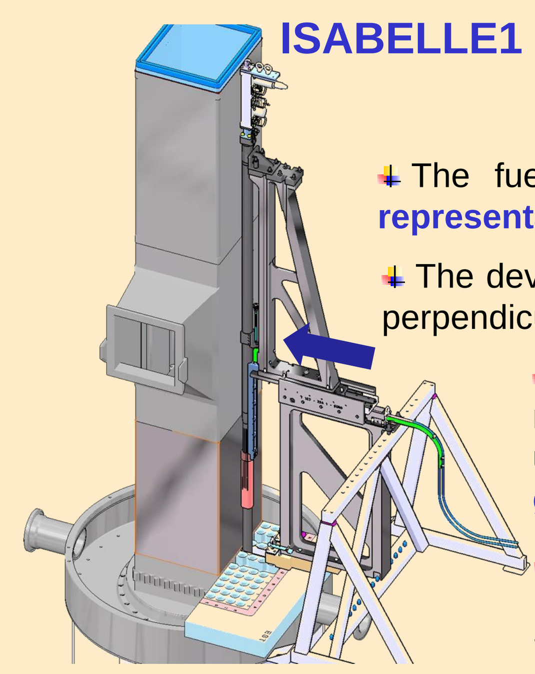
Diagram of the whole installation



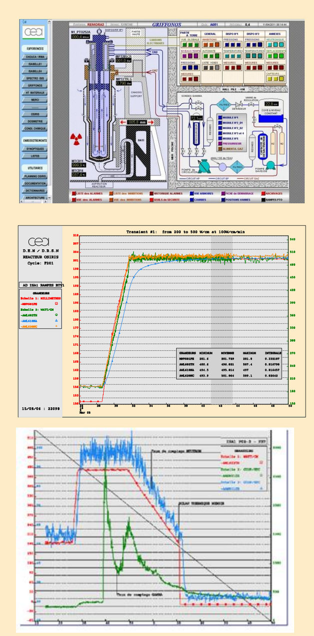
Design of the Melodie sample holder

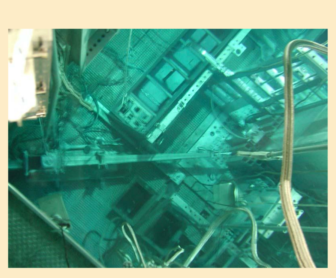
Power ramps : from Isabelle to Adeline

ISABELLE1 : Device for high accuracy power ramps (to determine fuel technological limits in incidental transients)



- The fuel rod is placed into PWR (or BWR) thermohydraulic representative conditions inside the ISABELLE 1 experimental loop.
- The device enables to perform power ramps by moving the fuel rod perpendicular to the core housing.
- The speed of the fuel rod is controlled by neutronic measurements. The thermal power produced by the rod under neutronic flux is frequently measured and enables to guarantee high accuracy power targets (5.8% at 2σ).
- On-line gamma monitoring, delayed neutrons detection, and elongation measurements allow early detection of clad failure.
- Non Destructive Examinations (gamma spectrometry and neutronography) of the fuel rod (before and after power ramps) enable to check for the initial burnup , to check for pellets restructuring, to precise neutron flux profile during the ramp…

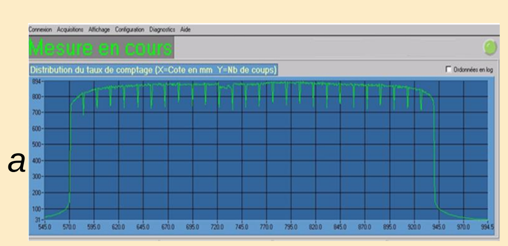


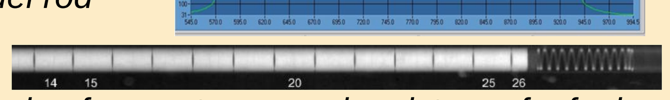


In-pool neutronographic bench

In-pool gamma spectrometry bench

Example of gamma spectrometry of a fuel rod





Example of a neutronography picture of a fuel rod

A longstanding experience on power ramps that will benefit to the JHR

ADELINE

The main features of the Isabelle 1 power-ramp device are maintained for the Adeline design. The fuel rod, placed in PWR or BWR thermohydraulic representative conditions, is moved towards the core to increase its nuclear power production.

With more instrumentation : the sample can be instrumented with a fuel centerline thermocouple and back-pressure sensor (to analyze fission products and helium release kinetics). This type of instrumented fuel rods has been used for several experiments in OSIRIS using GRIFFONOS loop.

Unlike ISABELLE1, ADELINE device will use a sample holder (which contains a fuel rod) **and a separated instrumentation holder** (which contains the thermocouples for thermal balance measurement).

The objectives are also to make more ramps per cycle avoiding connecting/ reconnecting phases and hot cells transfer. This should also reduce delays before nondestructive examination. The loading and unloading of the sample holder underwater is in designing stage.

Axis of the Adeline loop Inserted inside the displacement system

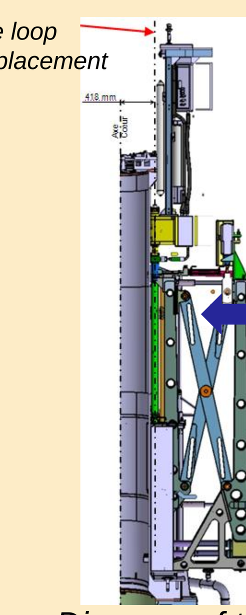


Diagram of the displacement system

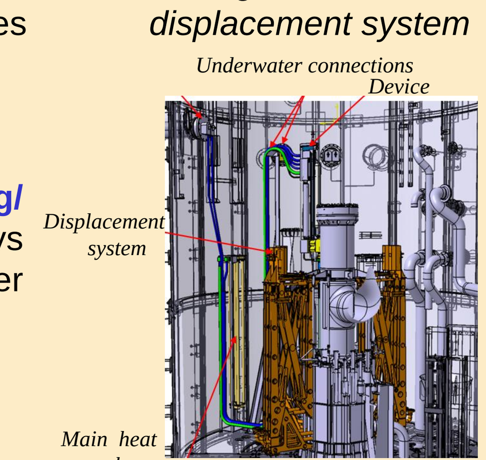


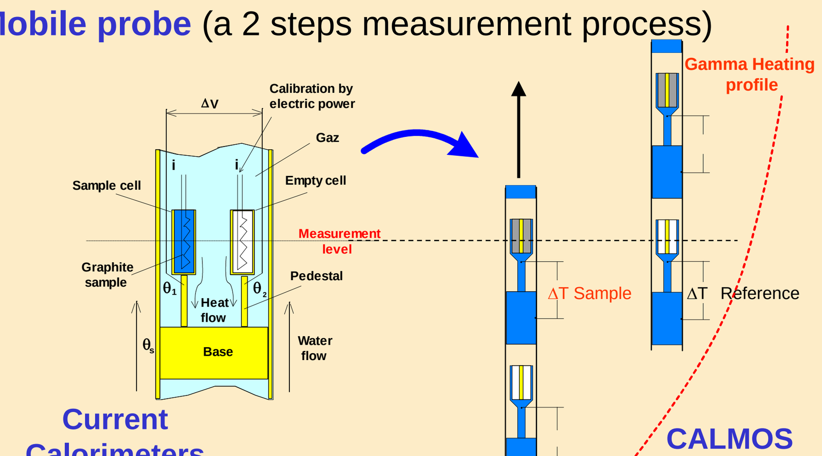
Diagram of the in-pile Adeline loop

Photonic and neutronic measurement devices : from CALMOS to CARMEN

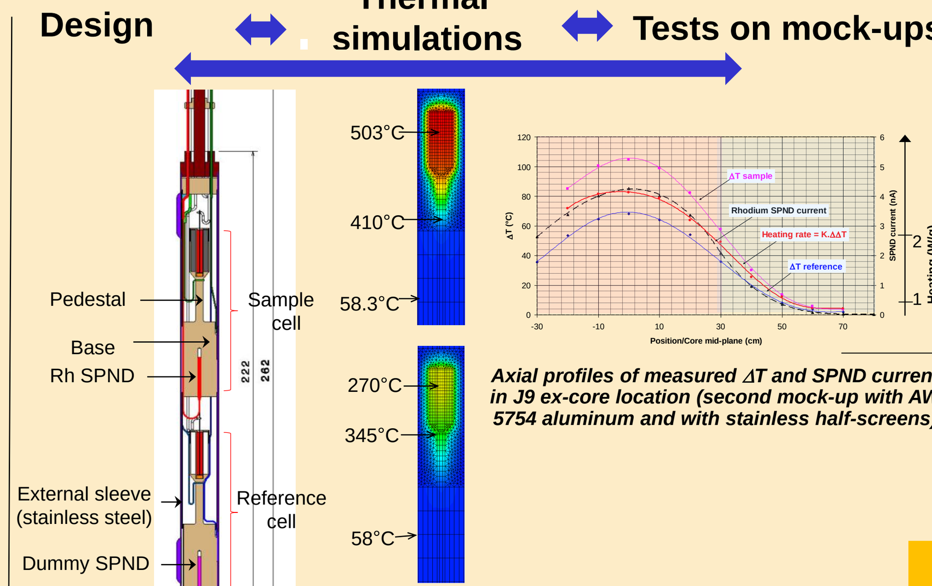
A new OSIRIS calorimetric probe : CALMOS

- To associate **gamma heating** and **thermal flux measurements**
- To be able to perform **measurements at any axial position along the core height or above.**
- To obtain **pointwise** measurements and therefore limit radial gradient effects.
- To access to measurements **inside and above the core (respectively < 2W/g and <13W/g) with a good sensibility.**
- To design a calorimetric probe remaining in the irradiation field only during measurement periods **(limiting the ageing).**

→ **Mobile probe** (a 2 steps measurement process)



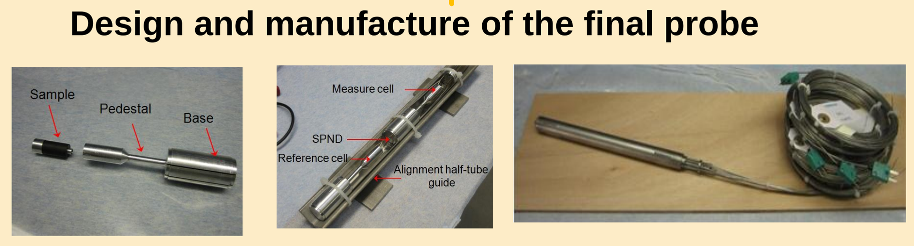
Heating measurement = K (ΔT sample – ΔT reference) = K ΔΔT. K coefficient is determined from a calibration step where heat is generated using electric current



Example of temperature fields calculated with 13 W/g

Axial profiles of measured ΔT and SPND current in J9 ex-core location (second mock-up with AW 5754 aluminum and with stainless half-screens)

Design and manufacture of the final probe



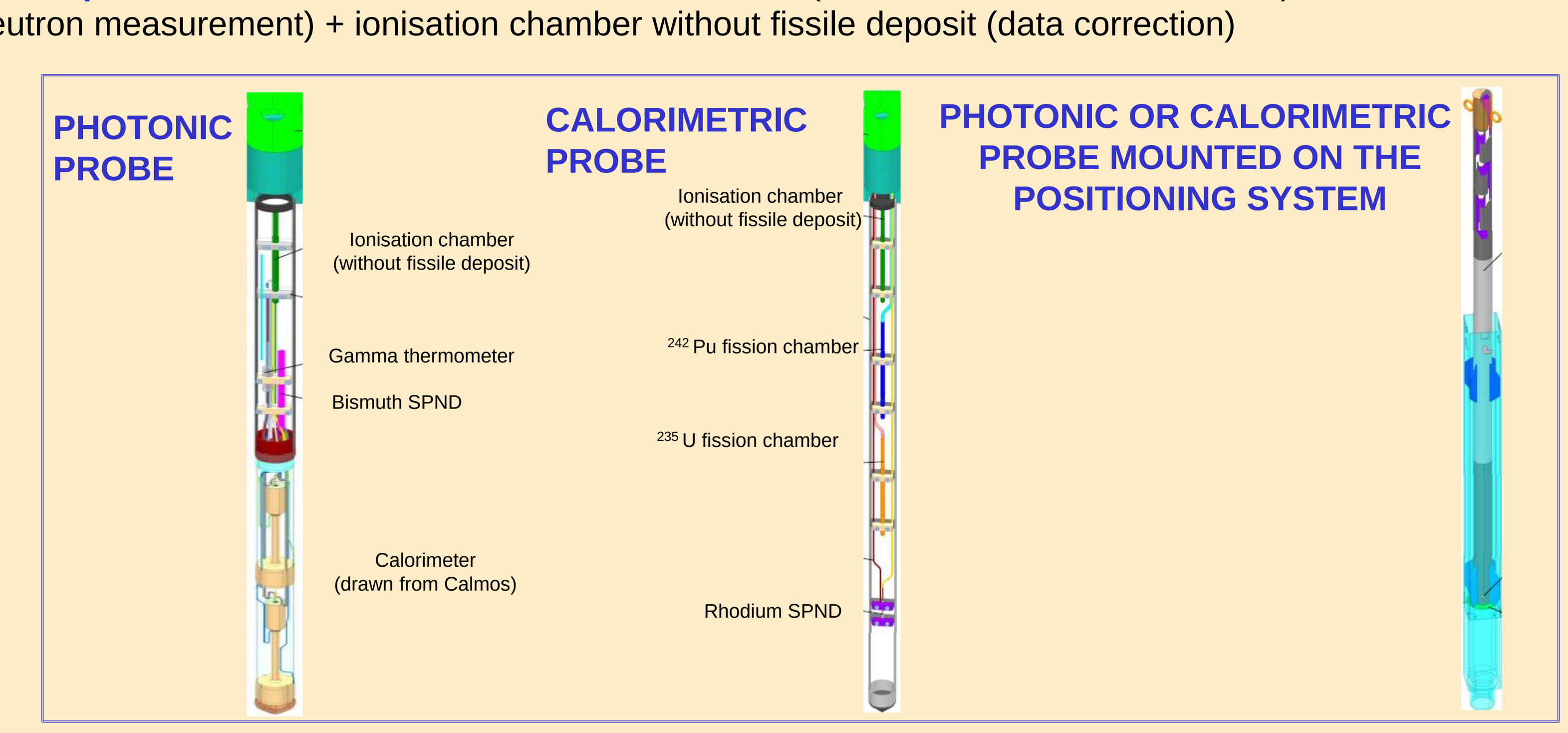
In-core tests of the probe and tests of the whole device (probe + displacement system) in non nuclear conditions were successfull. First in-core measurements are scheduled for november 2011

CARMEN keeps advantages of the mobile probe concept but adds new measurements

2 steps: **CARMEN 1:** 2 mock-ups to compare different measurement technologies in OSIRIS
CARMEN 2: design and manufacture of the final JHR device.

CARMEN 1 design:

- **Photonic probe** : Bismuth SPND + ionisation chamber without fissile deposit (data correction), gamma thermometer + calorimeter
- **Neutronic probe** : Rhodium SPND + ^{235}U fission chamber (thermal neutron measurement) + ^{242} Pu fission chamber (fast neutron measurement) + ionisation chamber without fissile deposit (data correction)



Both probes are going to be manufactured and tested inside the Osiris'pool at the beginning of 2012.

CONCLUSION

The longstanding experience on OSIRIS is being tranferred to the JHR teams. From the OSIRIS' feed-back, more instrumented irradiation devices have been designed in order to offer to JHR customers even better experimental facilitie and to guarantee continuity of programs.