Sustaining Material Testing Capacity in France: From OSIRIS to JHR

to support industry and public organizations in R&D irradiation programs on nuclear fuel and materials

Stéphanie MARTIN, French Alternative Energies and Atomic Energy Commission (CEA Saclay, France)
Gilles BIGNAN, CEA Cadarache, France
Context: An ageing fleet of MTR in Europe

Necessity to at least one new MTR in Europe (ESFRI, SNE-TP...
The OSIRIS reactor

- **Main characteristics of OSIRIS research reactor:**
  - Open core pool type
  - Compact core: $57 \times 57 \times 60$ cm$^3$
  - Fuel
    - 38 standard elements
    - 6 control elements with Hafnium as absorber
    - $U3Si2Al$ plates (enriched to 19.75%)
  - Moderator, coolant & biological protection: $H_2O$
  - Thermal power: 70 MW
  - Maximum neutron flux
    - *fast* ($E > 1$ MeV): $2.5 \times 10^{14} \text{n/cm}^2/\text{s}$
    - *thermal*: $2.5 \times 10^{14} \text{n/cm}^2/\text{s}$

The main goal of OSIRIS reactor is to carry out irradiation tests of fuel and structural materials of nuclear power plants, and to produce radioisotopes.
The current status of OSIRIS

• Annual operation:
  – 180 operating days (8 cycles)
  – Intercycles of around 10 days
  – Two specific maintenance periods in spring and summer

• Operation extended up to middle of this decade
  – Specific up grades required by the Safety Authority performed in 2009-2010
    • Truck hatch
    • Polar Cranes
    • Control rod room (-15 m)
    • Ventilation system
Material irradiation devices (OSIRIS CHOUCA)

• Goals:
  – Material irradiations (grids, fuel clad, pressure tubes, vessel, guide tubes, …)
  – Parametric studies, qualification, thermal mechanic behavior
  – Various reactors:
    • Gen 2, 3 and 3+ (Steel, Zircaloy, …)
    • Gen 4 (SiC, ODS…)
    • MTR (Aluminum alloys)

• Main characteristics
  – Irradiated in core or in periphery of core
  – Temperature:
    • from 250 to 400 °C (+/-15°C) – NaK
    • Up to 1100°C – gas
  – 6 independent electrical heating elements to automatically adjust the temperature

• Instrumentation
  – Thermocouples
  – Dosimeters of Fe, Cu and AlCo types
  – In situ dimensional measurements
Material irradiation devices (JHR MICA & CALIPSO)

Main characteristics

– MICA: same as CHOUCA
– CALIPSO: 250°C to 450°C integrated electromagnetic pump to circulate the NaK medium (to improve heat removal from sample materials surfaces => better temperature control).

Know-how transfer:

– take into account the OSIRIS feed-back for the design of JHR devices (to reduce thermal gradients on samples, to simplify hot lab operations, …)
– develop more innovative sample holders (highly instrumented) and test some parts in OSIRIS : ex MELODIE
Preparing JHR with OSIRIS: the MELODIE experiment

- **Goal**: to assess the interest of a biaxial stresses, online-controlled concept for the creep study of fuel cladding

- **Key features**:
  - Irradiation start in OSIRIS: 2012
  - Joint CEA-VTT team in the framework of the JHR project
  - 350°C, static NaK coolant
  - Stress limits $\sigma_r - \sigma_z$: 120 – 180 MPa
  - Online-controlled biaxial stress by:
    - Sample pressurization
    - Push-pull axial loading cell
  - Online biaxial measurement:
    - Elongation measurement with a self-compensating LVDT (by IFE Halden)
    - Diameter measurement with an electromagnetic gauge (DG) designed by IFE and CEA
Fuel irradiation device (OSIRIS ISABELLE1 loop)

• **Goals:**
  - test new fuel rods (with new clad material, new pellet size, or new type of fuel) until clad failure to determine technological limit
  - by realizing power ramps representative of class 2 incidental transients

• **Main characteristics**
  - periphery pressurized loop with PWR or BWR conditions
  - UO$_2$, MOX, high burn-up fuels
  - moving device perpendicularly to OSIRIS core, slaved to neutron flux (SPND) to guarantee the speed, and stopped according to thermal power to guarantee the target
  - very good accuracy of the target’s linear heat rate
  - clad failure monitoring: gamma detector, delayed neutron detector, and on-line gamma spectrometry
  - expansion of the rod monitored by LVDT elongation sensor.
Main characteristics

- sample holder (which contains possibly instrumented fuel: fuel centerline thermocouple and back-pressure sensor to analyze fission products and helium release kinetics -> used in OSIRIS GRIFFONOS loop)
- instrumentation holder (which contains the thermocouples for thermal balance)

Know-how transfer:

- take into account the OSIRIS feed-back for design of JHR loop (easy device handling, minimizing thermal leaks and pressure losses, reducing time of cladding failure detection so improving the loop operation, …)
- make more ramps per cycle avoiding connecting/reconnecting phases and hot cells transfer
CEA Strategy for future Irradiation Capacity:
Improve on-line analysis for JHR

→

R&D and Innovation on Instrumentation :
Recent developments
Examples of CEA’s recent developments in reactor instrumentation

Fission Gas Release determination using acoustic measurement

Online measurement of the **molar mass** of the gas inside the fuel rod (⇒ fraction of released fission gas)

The sensor is implemented on pre-irradiated PWR fuel rods

⇒ Operational in OSIRIS reactor since 2010 (REMORA-3 experiment)
Collaboration on photonic and neutronic measurements devices

- **CALMOS in OSIRIS**: new calorimetric probe (in-core measurements, mobile system) 2011
  - continuous axial distribution of total heating
  - measurements inside and above the core
  - calorimetric probe remaining in the irradiation field only for measurements (limiting the ageing)
  - simultaneously thermal flux measurement (Rhodium SPND)

- **CARMEN2 in JHR**: to characterize experimental locations with photonic & neutronic measurements
- **CARMEN1**: 2 mock-ups tested in OSIRIS in 2012
  One with CALMOS mobile probe concept + gamma thermometer (gamma heating measurement)
  One with fission chambers and Rhodium SPND (fast/thermal neutron flux measurement)
=> to select the most appropriate detectors
THANK YOU FOR YOUR ATTENTION....
Stephanie.martin@cea.fr