Keys figures and services at the CEA LECA STAR facility

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SUMMARY

- LECA STAR: Structure, organization, objectives, services
- Fuel rodlets manufacturing for irradiation tests in Research Reactors
- Fuel examinations and analytical tests
- Conclusion
STRUCTURE, ORGANIZATION AND OBJECTIVES

CEA
NUCLEAR ENERGY DIVISION
FUEL RESEARCH DEPARTMENT
CADARACHE CENTER
Role of the LECA STAR in the fuel Qualification/development cycle

POST IRRADIATION EXAMINATIONS
ANNEALING TESTS

TEST REACTOR

CHARACTERIZATION
NON DESTRUCTIVE EXAMINATIONS
FUEL RODLET REFABRICATION

HOTLAB 2015 Leuven, Belgium
September 27 - October 1, 2015
A HOT LABORATORY

- 2 Sections (6 laboratories) for operation, maintenance and R and D
- About 130 CEA employees and 50 subcontractors
- Opening time: 6h-21h and round the clock operation
- 20 hot cells (up to 9 m long)
- Shipping casks operation: ~200 per year
- Ability to host a wide range of irradiated fuels
LECA STAR

Has appropriate means to address multiple issues on irradiated nuclear fuel according to customer needs:

- Improve safety and availability of existing fuels
- Develop new fuels
- Perform post irradiation examinations
- Treat non-industrial spent fuel
- Develop processes for hot cells
- Provide its expertise as nuclear operator in hot cell environment
LECA STAR hot lab: overview

Examination from the whole fuel rod to the microscopic scale
Pattern of experimental programmes on irradiated fuels

Experimental & Commercial Irradiated fuels

Non Destructive Examinations (Metrology, corrosion, Fission products, …)

FGR measurement

Cutting

Micrographies, Density, …

Microstructural, elementary and isotopic analyzes (SEM, EPMA, SIMS, XRD…)

Re-Fabrication for in-pile experiments (instrumentation)

Out-of-pile tests (thermal annealing)

Mechanisms understanding

In-pile behavior

Data for codes validation

Fuel qualification

Experimental & Commercial Irradiated fuels

In-pile tests

Development of new fuels

Simulation

Expertise

R&D on fuel fabrication

Innovation

In-pile behavior

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FUEL RODLETS MANUFACTURING

CORALIE BENCH

FABRICE PROCESS
“FABRICE” FUEL RODLET

1. Irradiated fuel rod reception
2. Fuel rod cutting
3. Fuel rodlet equipment
4. Laser welding
5. Rodlet pressurization (> 100 bars)

Fuel drilling

Fuel rodlet internal instrumentation

In pile information:

PIE
FEEDBACK INSTRUMENTED FUEL RODLET
(REMORA DEVICE 2007-2010)

Fuel pellets

Drilling hole

Thermocouple

Lower Part
2015 - 2020
Development of new experimental fuel rods

- Development of our skills and techniques to offer in 2020 a proposal tailored to customer needs

- Increase in the number of experimental rods (ADELINE et MADISON devices for the JHR)

Our goals
Quality (product traceability and customer accessibility)
Quantity and Repeatability (innovative process, task organization)

First irradiation rig: 4 instrumented PWR rods / 2 instrumentations per rod
OUT-OF-PILE TESTS
Study fuel behaviour under incidental or accidental transients

Devices dedicated to heat treatment under several conditions

MERARG (2004)

MEXIICO (2015)

VERDON (2010)
Fuel sample: short irradiated PWR fuel rod, previously re-irradiated in a MTR yielding a complete source term evaluation

Heating up to fuel melting temperature under various mixtures of steam/hydrogen/air

Severe accident studies: FPs release and transport

VERDON: annealing tests with Fission Product release monitoring

Main objectives (RIA, LOCA):

- Pressure influence on Fission Gas release and fuel fragmentation
- Effect of fast depressurization on fuel fragmentation

Main characteristics:

- Max. Pressure: 1600 bars
- Max. temperature: 1600 °C
- Fission gas release kinetic measurements (on-line γ spectrometry – $^{85}$Kr)
- Post test analysis of released gas (stored in capacities): gaseous chromatography or mass spectrometry
- First test: 2015 (NFIR VI)
POST IRRADIATION EXAMINATIONS

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(thermal annealing)

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Simulation

Fuel qualification

Development of new fuels

R&D on fuel fabrication

Material Testing Reactors

Innovations
Non Destructive Examinations

NDEs: essential examinations to assess on the integrity of the whole fuel rod

- Rod geometries:
  - Diameter: From 4 to 40 mm
  - Length: Up to 4.5 m

- Visual inspection
- Diameter and length measurements (metrology)
- Gamma spectrometry
- Oxide layer thickness
- Clad integrity control (Eddy currents)

Fuel: PWR UO₂ / MOX

After irradiation

Fuel: FBR oxide

As fabricated

The large range allows NDE on irradiated elements coming from a wide range of reactors
Rod puncturing and gas analysis

Determination of the:
- Internal rod pressure ⇒ safety criterion
- Released Fission Gas amount & its composition

Fuel: PWR UO\(_2\) / MOX

- Relatively higher fission gas release in MIMAS MOX fuels
- High dependence to the power history
Destructive Examinations: sample preparation

**Objective:** massive and mirror polished sample

- Shielded sample preparation devices

1. Cutting
2. Embedding
3. Polishing
4. Polished radial cross section

Microstructure characterizations at different scales

Sample = ½ pellet, Ø~8 mm
Micro-analyses laboratory

Outside the hot cells

EPMA

Elemental analyses
(quantitative & distribution)

SEM

Morphology
Image analyses

SIMS

Isotopic analyses
FG total inventory

μXRD

Structure analyses

Microanalytical complementarity
NEW SEM

• SEM- FIB (Focused Ion Beam) EDS EBSD

⇒ 3D imaging of the microstructure:
  - gas behavior (tunneling, bubbles interconnection)
  - cracking, porosity

⇒ Micromechanics properties: \( \mu \)-indentation

⇒ Micromechanics properties: \( \mu \)-compressive and bending tests

⇒ Size, shape and orientation of grains
New offers in 2016: to the nanoscale

**MARS: Multi Analyses on Radioactive Samples**

- 2 experimental stations: 3.5 - 36 keV
- Standard Absorption station
- High-resolution XRD
- Commissioning on irradiated fuel in 2016
- TEM (Transmission Electron Microscope)
- Commissioning on irradiated fuel in 2017

*Images of laboratory equipment and microscopic images.*
CONCLUSIONS

THE LECA STAR OFFERS A RANGE OF SERVICES TO MEET THE DIVERSE NEEDS OF CUSTOMER FOR THEIR EXPERIMENTAL PROGRAMS, FROM NON-DESTRUCTIVE EXAMINATIONS ON ENTIRE LONG RODS TO MICROSCALE ANALYSIS OF THE FUEL.

THIS OFFER IS NOW EVOLVING TO MAINTAIN THE FACILITY AT THE LEVEL OF EXCELLENCE REQUIRED TO MEET THE DEMANDS OF FUTURE CUSTOMERS FOR THE STARTUP OF THE CEA NEW EXPERIMENTAL REACTOR JHR.
Under a recently launched scheme, French research centres in Saclay and Cadarache will become international research hubs for institutions from IAEA Member States for education, and joint research and development purposes. (Credit: Dean Calma/IAEA)

Research centres of the French Alternative Energies and Atomic Energy Commission (CEA) will make their research reactors and other facilities available to institutions from IAEA Member States for education, and joint research and development (R&D) projects, Daniel Verwaerde, CEA’s General Administrator announced today.
Thank you for your attention!