The contribution of the bench VENDAUM in LECA-STAR (Cadarache) for Non-Destructive Examinations

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Summary

1 : Non-Destructive Examinations on irradiated fuel rods

- Interest of the Non Destructive Examinations on fuel
- NDE at LEGEND Laboratory in LECA STAR

2: NDE on VENDAUM bench in LECA

- Characteristics of the bench
  - position in the hot cell
  - design
  - modularity
- Overview of the potential of VENDAUM from some results

Conclusion and prospects
LECA-STAR Facility in Cadarache

Post irradiation examinations in hot cells:

- **Non Destructives**
- Drilling, cuttings
- Destructives

**Improvement and characterization of nuclear fuel**

REQUEST
Government, EDF, AREVA, IRSN

- Actual and future PWR’s,
- Metal test reactors and nuclear powered navy ships,
- Future concepts,
- Interim storage

**COMPREHENSION OF THE MECHANISMS**

**COMPUTERIZED SIMULATION**

**FUEL CONCEPTION**
- Mechanical, Thermal, Materials
- Micro-structures, Physics and Chemistry

**QUALIFICATION FOLDERS**
- LECA-STAR VERDON
- LARC
- LEFCA – LBF

**IN-PILE TESTS**
- PWR’s, OSIRIS, CABRI, PHENIX, RJH, HFR, BR2, ATR …

**EXPERIMENTAL DEVICES**
- POST IRRADIATION EXAMINATIONS
- CHEMICAL ANALYSES
- FABRICATION CHARACTERIZATION
- CHEMICAL ANALYSES
NDE in LECA STAR

Arrival of the irradiated elements

Irradiated objects ➔ Hot cells

C2 Star Drilling, cuttings

C3 Star NDE

MEGAFOX Bench

C3 LECA NDE VENDAUM Bench...

Simulation

Measurement

DE
Non Destructive Examinations in hot cells

- Cladding aspects
- Camera
- Eddy currents sensor
- Gamma detector
- Oxide thickness sensor
- LVDT sensor
- Cladding defects, health
- Fuel column
- Diameter measurement
- External corrosion
- Oxide
- Cladding
- Pellet

irradiated

fabricated
2: NDE on VENDAUM bench in LECA

- Characteristics of the bench position in the hot cell design modularity
- Overview of the potential of VENDAUM from some results
Cellule 3 at LECA

VENDAUM in C3

12 hot cells in LECA
NDE, preparation of samples, DE, waste, storage...

Front area of C3 in LECA

Front area in LECA
VENDAUM BENCH: moving the rod in a vertical direction

Thanks to dedicated area under the hot cell a 2.7 m* rod can be scanned from its bottom (a) to its top (b).

Floor of the hot cell

* 106 inches
VENDAUM BENCH: modular

- 1 for visual
- 1 for diameter
- 1 for oxide thickness
- 1 for health...

Motionless sensor

Mechanical set up

Design for tele operation

Acceptance up to Φ 4cm*

* 1.57 inch
VENDAUM BENCH: automatic

Motionless sensors
Moving objects
(L<2.7 m; Φ<4 cm)
Measurement on VENDAUM

1. Measurement cartridge
2. rod
3. chuck
4. motors

Measure at this position
Displacement of the rod
asking for a position \((z, \Theta)\)
on the rod

command control computer

saving the data

For each method, a standard is used in cell to certify our results

Focus on cable

Focus on SBM
Example of diameters Measurements

Changes in diameters

 ↔

to changes of the sensor

1 point / 0.5 mm

0°, 45°, 90°, 135°

<table>
<thead>
<tr>
<th>Position</th>
<th>Measure</th>
</tr>
</thead>
<tbody>
<tr>
<td>Z1</td>
<td>D1 (mm)</td>
</tr>
<tr>
<td>Z2</td>
<td>D2 (mm)</td>
</tr>
</tbody>
</table>

Following diameters all along the rod:

Position Z1

Position Z2

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Characteristics of VENDAUM

- Vertical Examinations on irradiated rods (L<2.7 m ; Φ< 4 cm)
- Diameters, video, oxide thickness, cladding, F column
- Precise positioning comparisons

Measurement cartridge
Command Control
Acquisition block

rod

2: NDE on VENDAUM bench in LECA

- Characteristics of the bench position in the hot cell
design
modularity

- Overview of the potential of VENDAUM from some results
Overview of the VENDAUM’s potential: positioning

Visual examinations

- Precise and reproducible positioning in z and theta
- Detection and localization of defects
- Reception of objects in hot cell
- Identification, nuclear inventory

Data from cc

Photo of the rod

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Overview of the VENDAUM’s potential: reproductibility

With its characteristics, VENDAUM was first dedicated to NDE on fast reactors pins (Phenix).

It has conserved all its capacities in the subject, recently reactivate for transmutations new studies for example.

Diameter measurements on Phenix’s pin

- Same results: (+) positioning, saving
- 1988
- 2012
- $\phi = 6.55\text{mm}$
Overview of the VENDAUM’s potential: large acceptance

With its characteristics, VENDAUM accepts a large scale of irradiated rods,

NDE on part of PWR rod

(φ=9.55mm)

MGX

VDM

Rods from 6.55 mm (or less) …to 40 mm

NDE on rod from foreign reactor

(φ=7.2mm)

diameters

spectrometry
Thanks to its reproducible positioning, VENDAUM allows the comparison of NDE on the same object but also the following of evolution of an object during tests.

Changes of diameter after tests

Changes of diameter after several heatings

Studies on incidental situations

Studies on storage conditions
Step 0: initial diameter measurement
Step 1: diameter measurement after one heating
Step 2: diameter measurement after two heatings
Step 3: diameter measurement after three heatings
Step 4: diameter measurement after four heatings
VENDAUM has many assets and answers already to a broad pallet of needs (L<2.7m φ<4cm).

The diversity of the examined objects and of measurement conditions is a motivating aspect of the use of this bench.

Innovating evolutions, such as metrology without contact by onbroscopy, confocal microscopy, will soon be set on our bench to meet new specificities.
Thank you for your attention

Contribution: LEGEND’s team

with special thanks
to Thierry and Franck
Additional information on VENDAUM

- Cartridges
- Protection box
- Cables

In hot cell

Bio protection

Wall

Outside
Sometimes

Upper cell
(repairs…)

Level 0:
measurement in hot cells