JHR PROJECT.
IRRADIATION DEVICES
IN-SERVICE INSPECTION OF
NUCLEAR PRESSURE EQUIPMENT’S.

Investigation of Non DESTRUCTIVE EXAMINATIONS
For INSPECTION Purposes.

S. Gaillot
CEA-France

IGORR 18 & IAEA Workshop
03-07th dec. 2017
SYDNEY – AUSTRALIA
OUTLINES:

- JHR FACILITY OVERVIEW (REACTOR & EXPERIMENTS).
- NUCLEAR PRESSURE EQUIPMENT REGULATION (NPE).
- FRENCH OSIRIS MTR FEEDBACK.
- NPE INSPECTION: APPLICATION TO JHR DEVICES.
- CONCLUSION.
JHR FACILITY: OVERVIEW

MTR designed at 100MWth,
- Compact core geometry (60cm diameter),
- Reflector in Beryllium,
- Light water coolant
  closed primary circuit (12 bar pressurisation),
  - High materials damages capabilities:
    15 dpa/year (core),
  - High thermal neutrons flux (reflector):
    8 x PWR th. neutrons flux,
- High experimental platform: possibility to manage 25
  irradiation devices (x13 in the core and x12 in the reflector),
- Experimental and exploitation equipments integrated in
  the facility (NDE systems, FP laboratory, hot cells with
  specific one for failures rods conditioning).
CODIFICATION RCC (SAFETY BARRIERS, EIPS):
Thermo-mechanical studies respecting RCC-MRX rules
(N2 level for pressure, high pressure & high T components,...).

DESP, ESPN REGULATION:
• data elaboration for ESPN regulator inspection (EPDM, risk analyses,...)
• regulation 3rd part support (ex: APAVE) during detailed design phase.

2012 BNI ORDER, ISO 9001 QUALITY EXIGENCES,...:
130 EIP (Equipments important for the protection) identified for ADELINE irradiation loop. Surveillance actions declinaison (CEA, manufacturer, suppliers,...)
ADELINE LOOP : FUEL IRRADIATION LOOP DEVOTED TO POWER RAMPS TESTS TRANSIENTS

TH conditions : LWR
PWR : 155 bar, 320° C,
BWR : 75-80 bar, 295° C.

- 1 fuel rod (UO$_2$,PuO$_2$)
- Be Reflector zone
- Power plateau : 620W/cm
- Power ramp test up to 700W/cm/min
European Pressure Equipment Directive (PED)  
-> transposed into French law Nuclear Pressure Equipment  
-> requirements governing the level of activity inside in the containers

<table>
<thead>
<tr>
<th>Nuclear pressure equipment classification by level</th>
<th>Impact in the case of equipment failure</th>
</tr>
</thead>
<tbody>
<tr>
<td>Outside nuclear pressure equipment</td>
<td>Activity released in the case of failure &lt;= 370 MBq</td>
</tr>
<tr>
<td>N3</td>
<td>Not classified N1 or N2. Activity released in the case of failure ranging between 370 MBq and 370 GBq</td>
</tr>
<tr>
<td>N2</td>
<td>Not classified N1. Activity released in the case of failure exceeding 370 GBq</td>
</tr>
<tr>
<td>N1</td>
<td>Impact of a failure rendering it impossible to return the equipment to a safe state (according safety report requirements)</td>
</tr>
</tbody>
</table>

The nuclear pressure equipment category (I to IV) is defined with respect to the
- type of equipment (container, pipe),
- type of fluid and its group,
- Pressure and volume of each compartment comprising the equipment.

These regulations cover the potential risks involved in using such pressure equipment and the consequences in the event of their failure
NPE REGULATION (CONTINUED)

- NPE is DESIGNED and BUILT by a Manufacturer under its responsibility,
  - complied with the ESSENTIAL SAFETY and RADIATION PROTECTION REQUIREMENTS stipulated in the regulations reports,
  - conformity assessments of NPE must be performed
    BY A QUALIFIED THIRD PARTY approved
    by the FRENCH NUCLEAR SAFETY AUTHORITY (ASN)
    i.e. an agreed notified body (ANB).

- Once IN SERVICE,
  NPE must be monitored and maintained by the operator,
  undergo PERIODIC TECHNICAL CHECKS BY AN ASN-APPROVED BODY.
Since the application of the ESPN order in 2005, some pressure equipments have been reclassified as nuclear pressure equipments and now liable for in-service monitoring.

For such nuclear pressure equipments, the presence of INTERNAL INSPECTION means or alternative solutions were not a regulatory requirement.
inspection of the equipment (principle)
N2, category IV
newly subjected to ESPN order
Multi-compartment container
(CI-CE-CT)
Pressure tube: Zircaloy
RCCM-N2

Type of inspection: visual in a hot cell
JHR device from a Nuclear Pressure Equipment approach

Cl = internal compartment
CE = external compartment
CT = top compartment

Length ≈ 3.3m

Thickness between int & ext. PRESSURE TUBES 0,5mm !!!

Zircaloy

Thickness ≈ 9 mm

Int. Diam= 4,4cm
To meet the regulations requiring the periodic inspection of NPE, a number of constructive measures have been implemented. Concerning the Adeline irradiation device currently in its design phase,

- the construction of a **REMOVABLE PRESSURE TUBE** would theoretically make it possible

- to **EXTRACT THE INTERNAL TUBE** and to carry out visual examinations during such periodic inspections.

The problems that have so far been identified are listed below:

- operations to be performed on irradiating equipment in hot cell,
- removal and re-introduction after irradiation of the internal tube
Numerical simulation (MODHERATO SOFTWARE) of an X-ray examination is given below for a structure of device with typical defects

(radial cracks of variable thicknesses ranging between 10 and 300 microns).
Examples of NDT using ultrasounds and X-rays on heat exchanger plates.

Non-destructive test using an ultrasonic bar comprising 64 elements at 20 MHz by means of XY scanning of a plate with millimetric-sized channels

resolution of about 100 microns in the steel

2-3D inspection
Main principle:
- Polychromatic source + chromatic lens
- Spatial filter + spectrometer

Applications:
- Surfaces defects
- Fuel rod screening
Mechanical holder for Ultrasonic detector
designed to scan the inner surfaces of the inner tube and the outer surfaces of the outer tube forming the pressure tube, so as to characterise any defects in compliance with the RCCMRX code requirements.

<table>
<thead>
<tr>
<th>INSTRUMENTATION</th>
<th>GAMMA DOSE RATE</th>
</tr>
</thead>
<tbody>
<tr>
<td>INNER TUBE</td>
<td>OUTER TUBE</td>
</tr>
<tr>
<td>6.5 mm</td>
<td>5.5 mm</td>
</tr>
<tr>
<td>TYPE OF DEFECT</td>
<td>RADIAL NOTCH</td>
</tr>
<tr>
<td>GEOMETRY</td>
<td>L = 10 MM,</td>
</tr>
<tr>
<td></td>
<td>W = 1 MM,</td>
</tr>
<tr>
<td></td>
<td>THICKNESS = 320 MICRONS</td>
</tr>
</tbody>
</table>

data regarding the dose rates recorded outside pressure tube No. 4 underwater (Zy4) :
• **PERIODIC INSPECTIONS ARE NECESSARY** in order to meet the requirements of regulations governing pressure equipment and nuclear pressure equipment's.

• The type of **EXPERIMENTAL EQUIPMENT IN THE JHR** (multi-compartment devices, small gaps and irradiation) do not always make it possible to easily visually inspect the different surfaces of the internal and external vessels.

  **IN SOME CASES, VISUAL INSPECTION IS IMPOSSIBLE !**

• To counter such difficulties, we have proposed a number of non-destructive inspection techniques

  **X-RAYS, ULTRASONIC & OPTICAL.**

The implementation of these techniques will first require developing a qualification programme so as to provide the information needed to confirm or refute the relevance of such inspections.