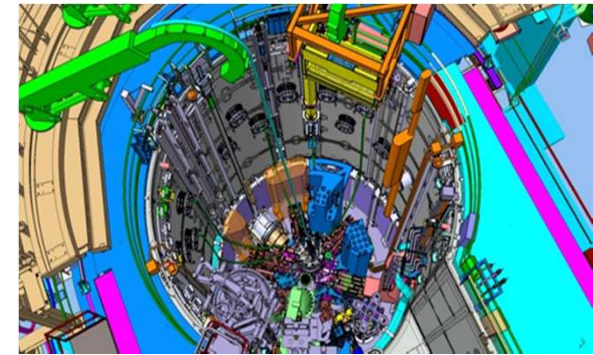


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JHR PROJECT. IRRADIATION DEVICES IN-SERVICE INSPECTION OF NUCLEAR PRESSURE EQUIPMENT'S.



**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.**

cea JHR FACILITY: OVERVIEW

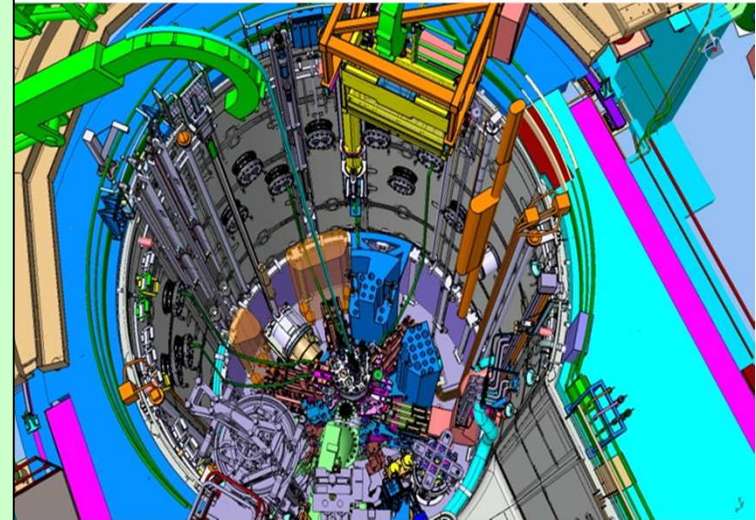
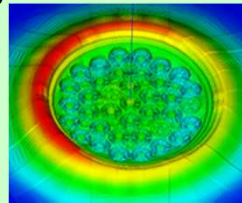
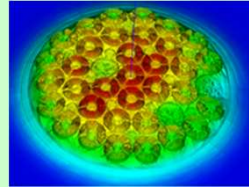
MTR designed at 100MW_{th},

- **Compact core geometry** (60cm diameter),
- **Reflector in Beryllium,**
- **Light water coolant**

closed primary circuit (12 bar pressurisation),

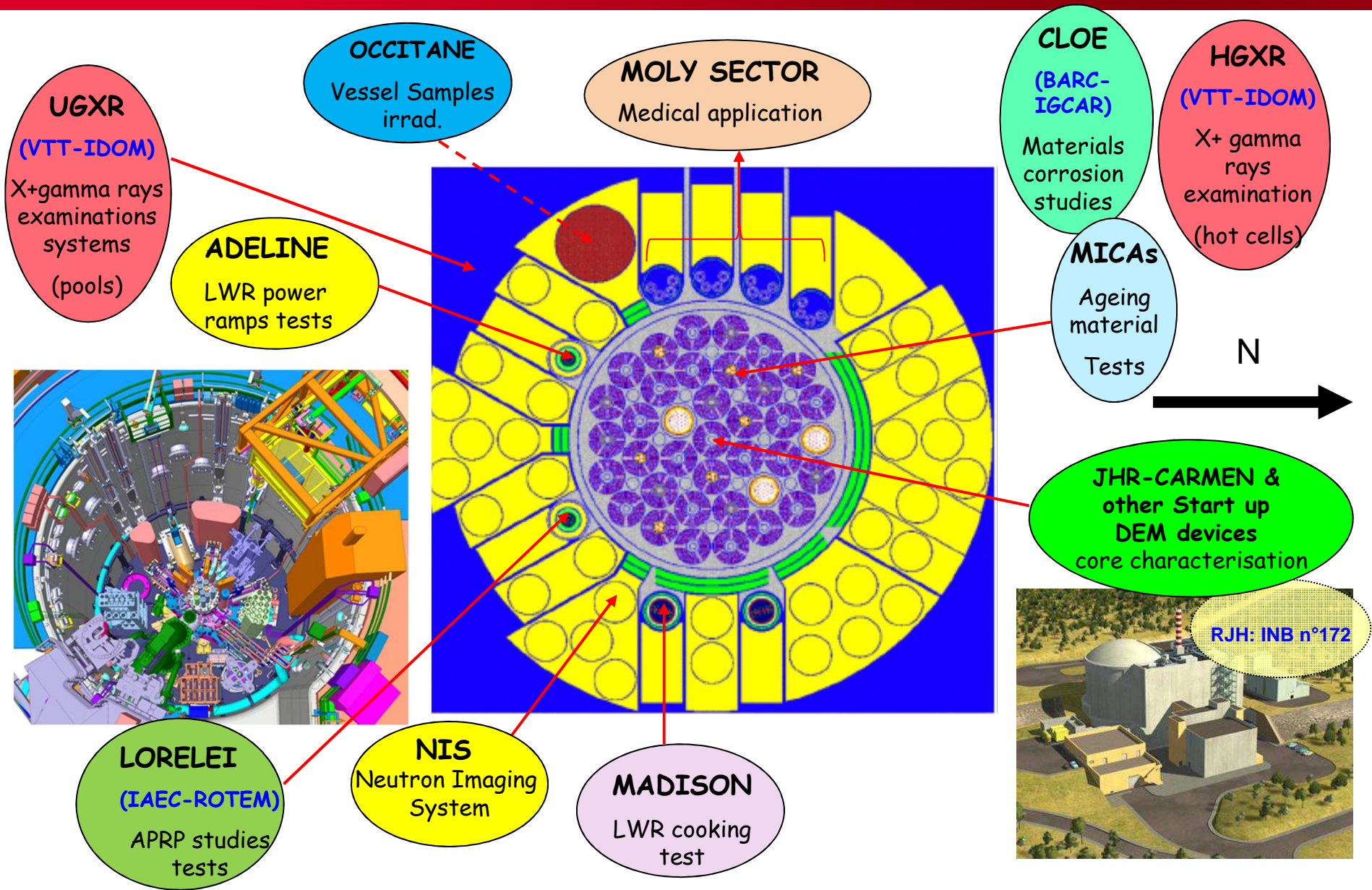
- High materials damages capabilities:
15 dpa/year (core),
- High thermal neutrons flux (reflector):
8 x PWR th. neutrons flux,

- **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).





JHR: EXPERIMENTAL CAPABILITIES

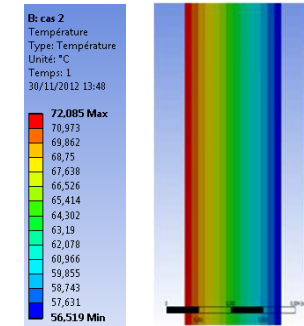
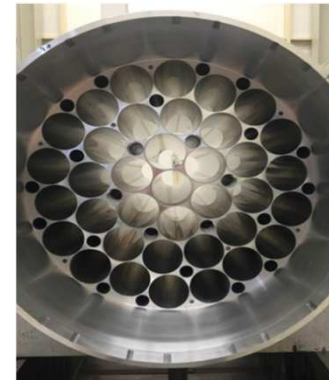


cea JHR: CODIFICATION , REGULATION , QUALITY

❖ CODIFICATION RCC (SAFETY BARRIERS , EIPS) :

Thermo-mechanical studies respecting RCC-MRX rules

(N2 level for pressure , high pressure & high T components,...).

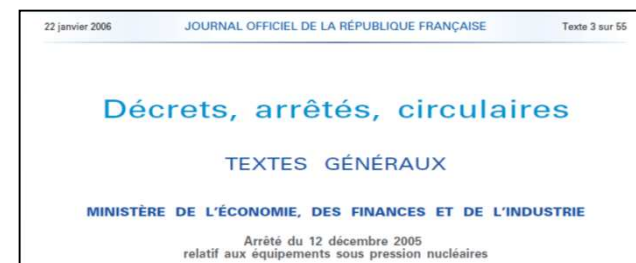
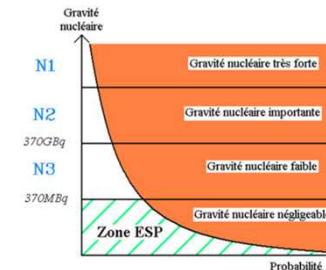


❖ DESP, ESPN REGULATION :

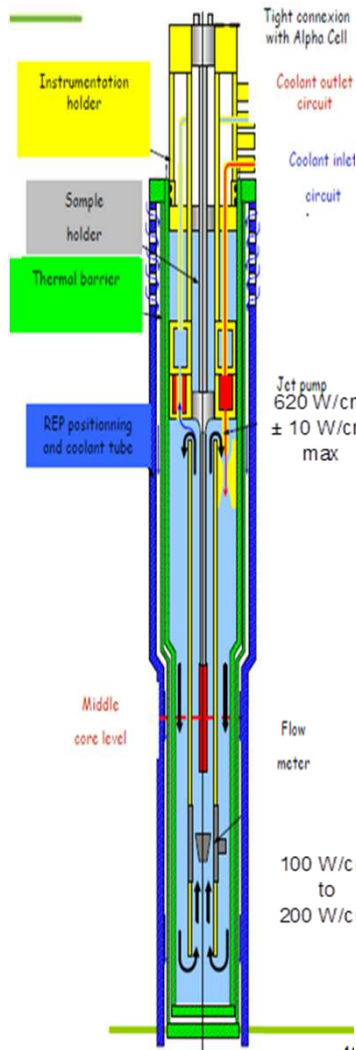
- data elaboration for ESPN regulator inspection(EPDM, risk analyses,...)
- regulation 3rd part support (ex:APAVE) during detailed design phase.

❖ 2012 BNI ORDER , ISO 9001 QUALITY EXIGENCES,...:

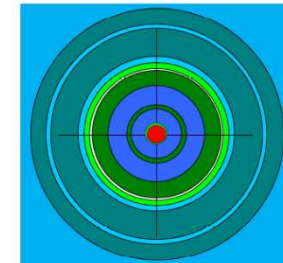
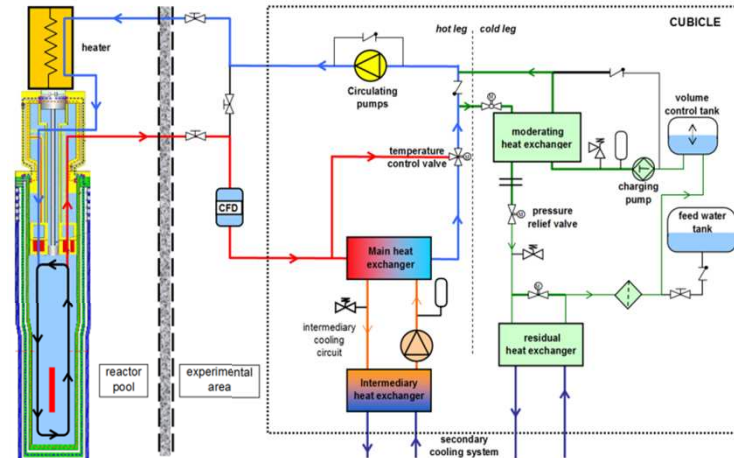
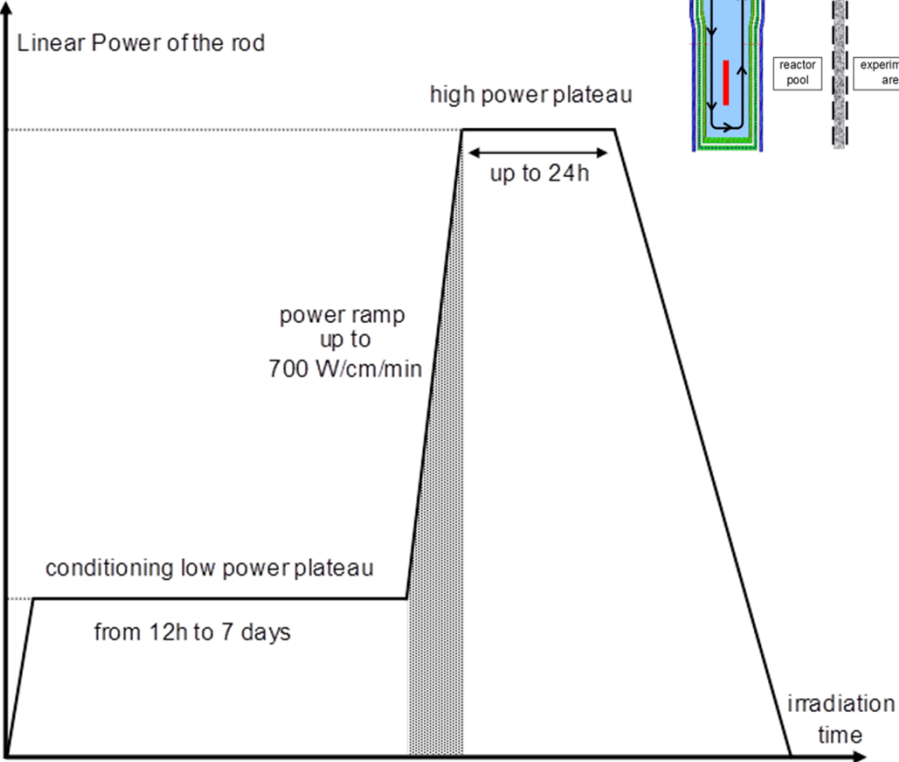
130 EIP (Equipments important for the protection) identified for ADELINE irradiation loop. Surveillance actions declinaison (CEA, manufacturer, suppliers,...)



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.



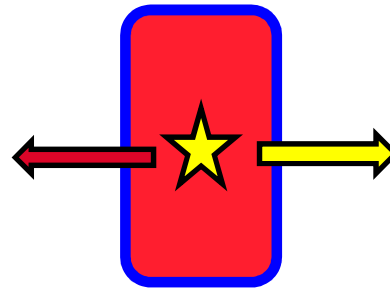
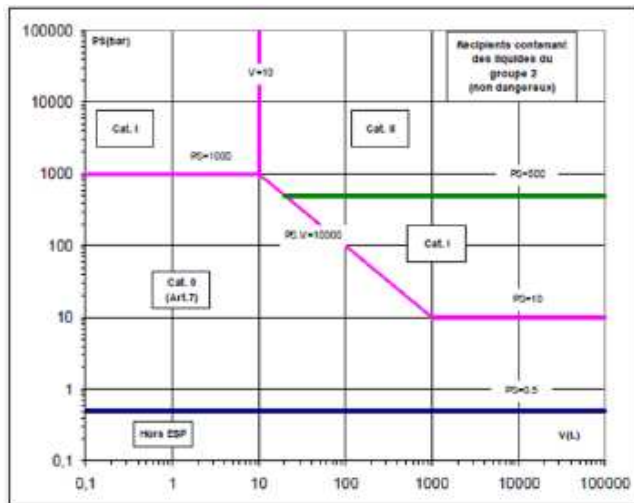
- ✓ 1 fuel rod (UO₂,PuO₂)
- ✓ Be Reflector zone
- ✓ Power plateau : 620W/cm
- ✓ Power ramp test up to 700W/cm/min

NPE: NUCLEAR PRESSURE EQUIPMENT REGULATION

European Pressure Equipment Directive (PED)

-> transposed into French law Nuclear Pressure Equipment

-> requirements governing the level of activity inside in the containers



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

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 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).



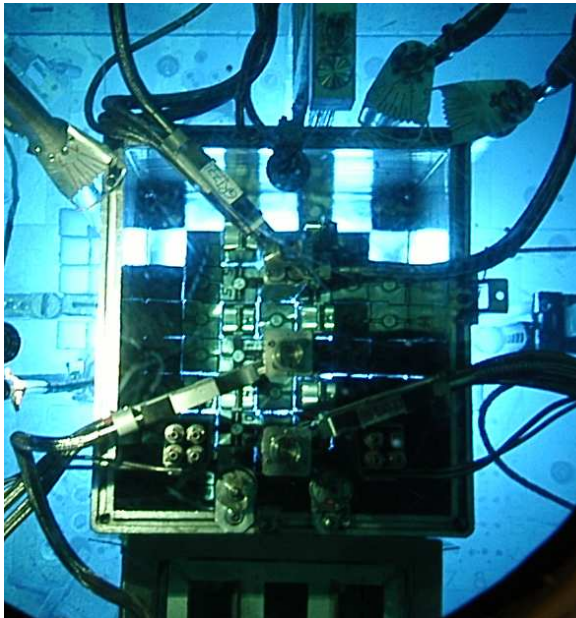
☐ **Once IN SERVICE,**

NPE must be monitored and maintained by the operator, undergo **PERIODIC TECHNICAL CHECKS BY AN ASN-APPROVED BODY.**

NPE-IP: FRENCH OSIRIS MTR FEEDBACK (1/2)



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

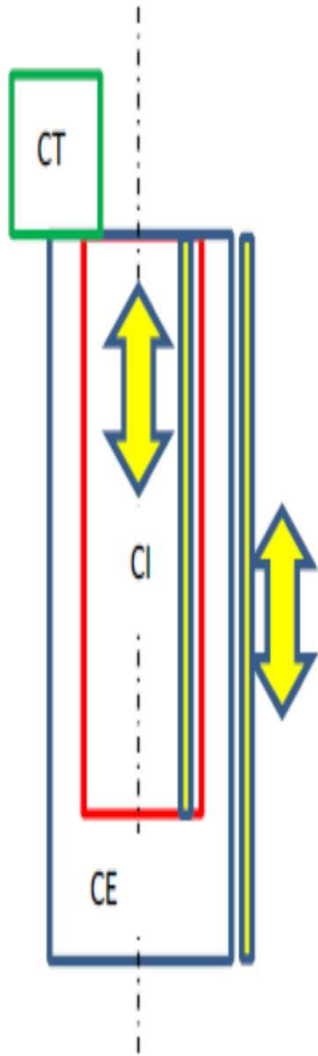
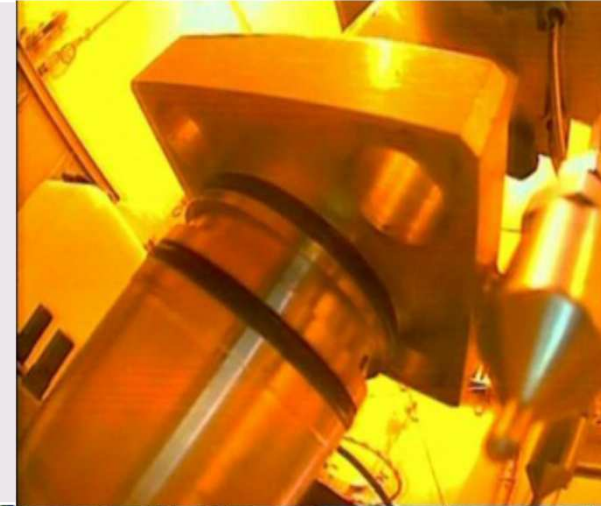
newly subjected to ESPN order

Multi-compartment container

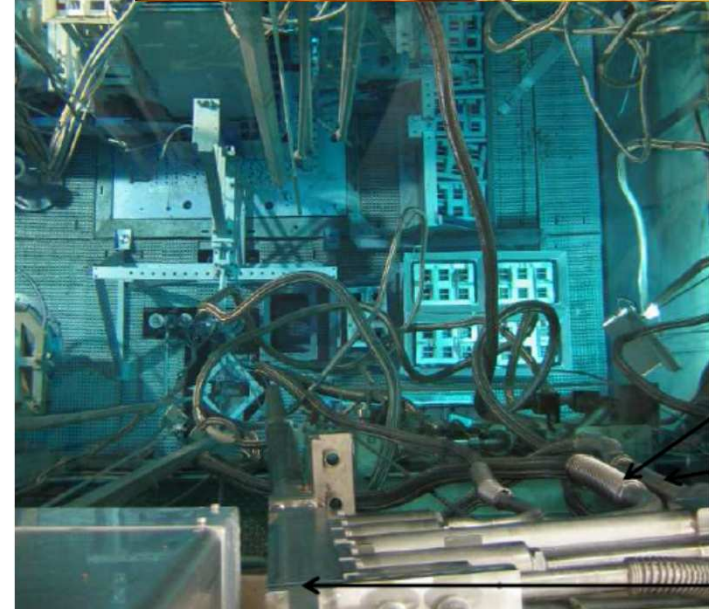
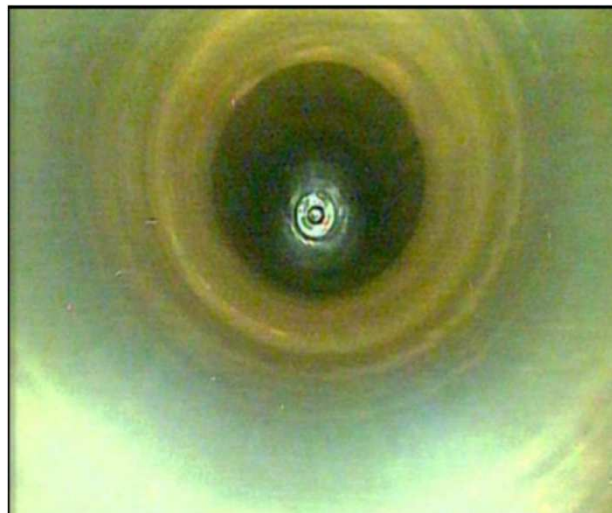
(CI-CE-CT)

Pressure tube: Zircaloy

RCCM-N2

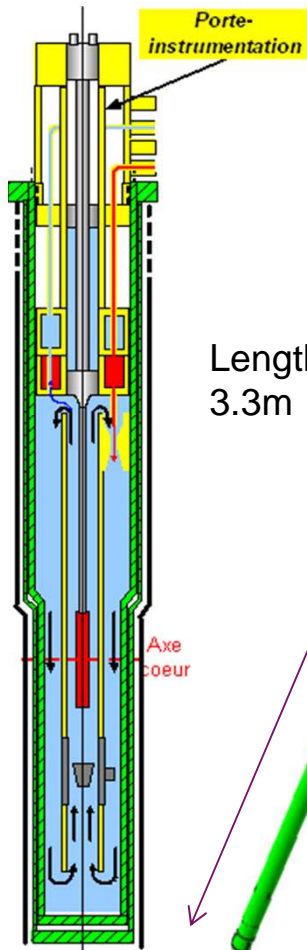


Type of inspection:
visual in a hot cell

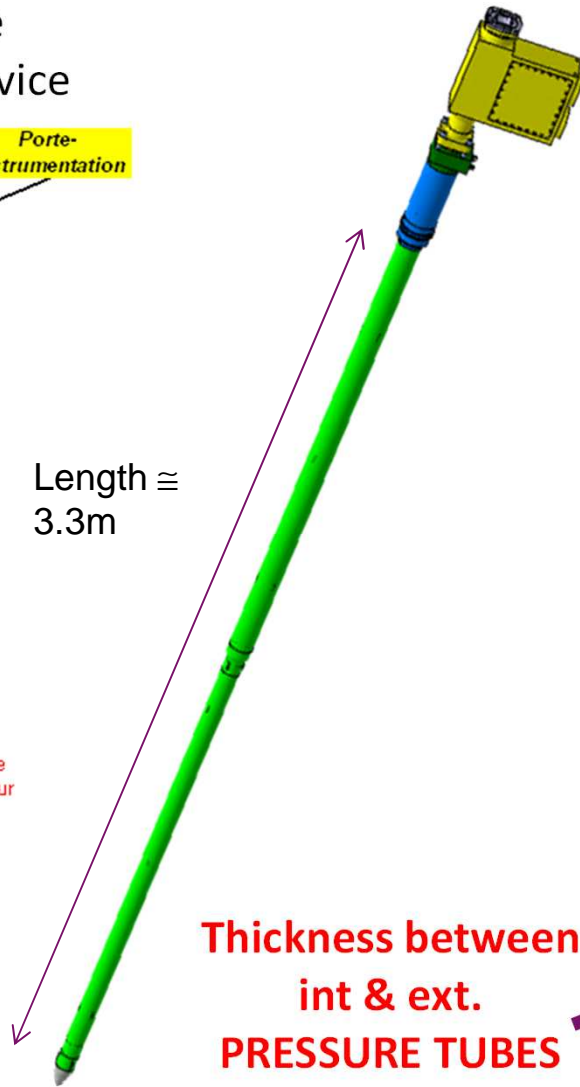


NPE-IP: APPLICATION TO JHR IRRADIATION DEVICES

JHR device
Irradiation device



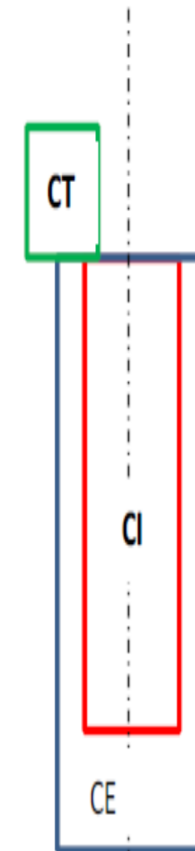
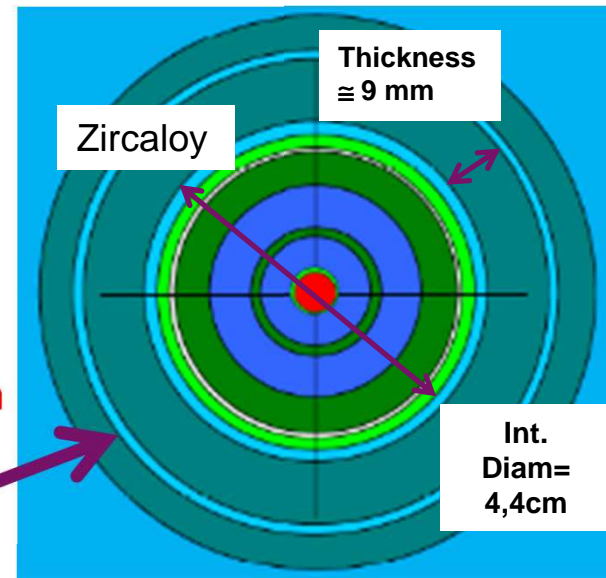
Length \cong
3.3m



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

JHR device from a Nuclear Pressure
Equipment approach

CI = internal compartment
CE = external compartment
CT = top compartment



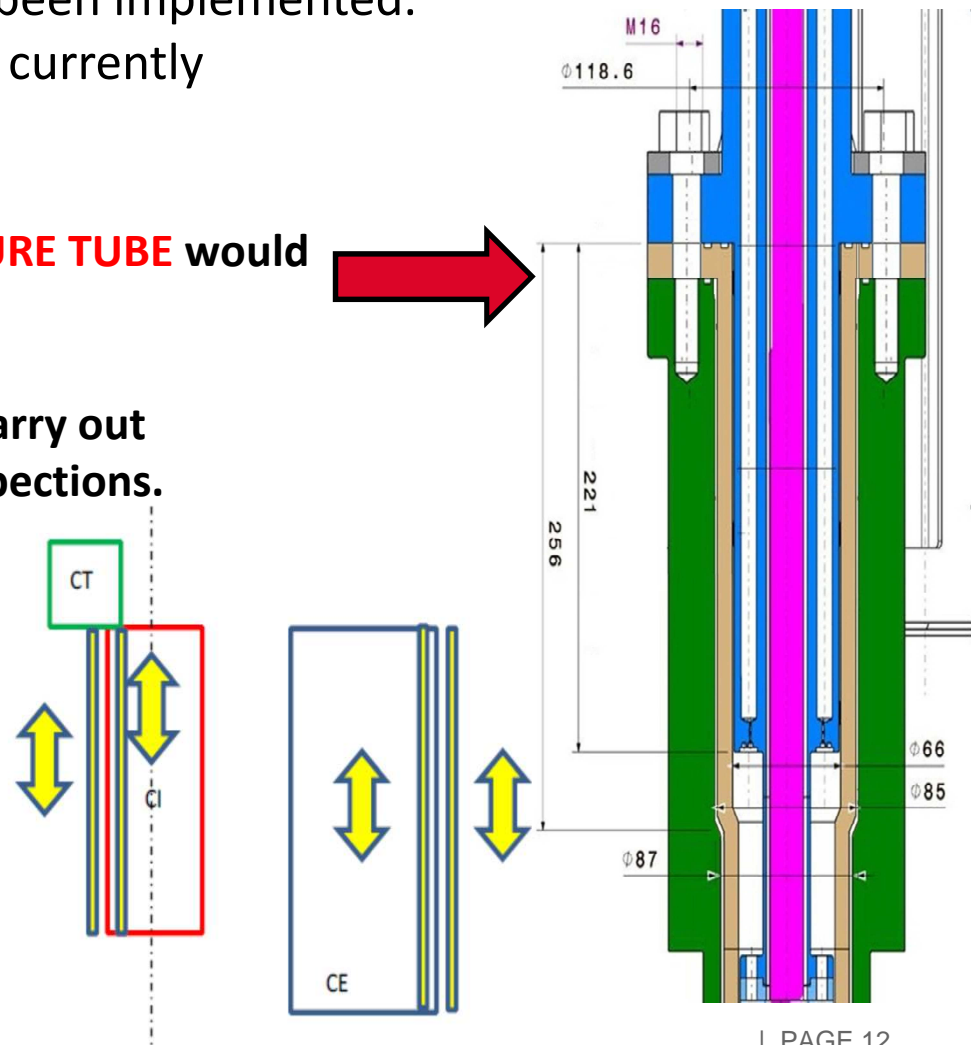
NPE-IP: INCORPORATING PERIODIC INSPECTION INTO DESIGN

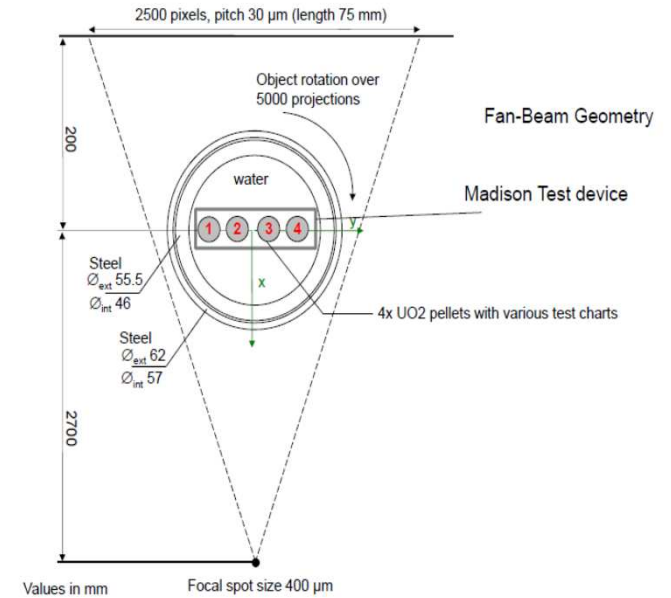
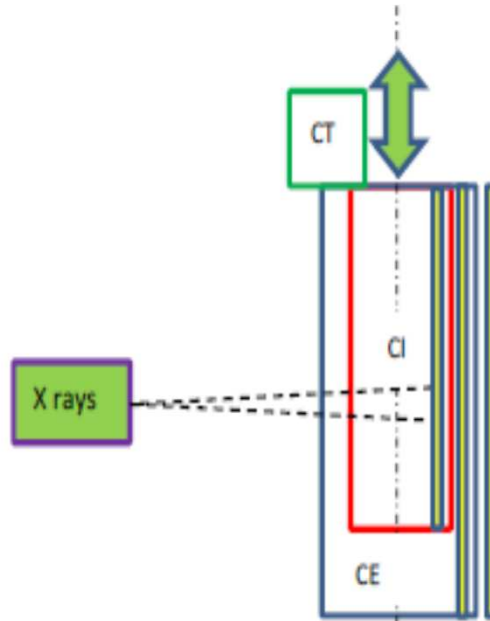
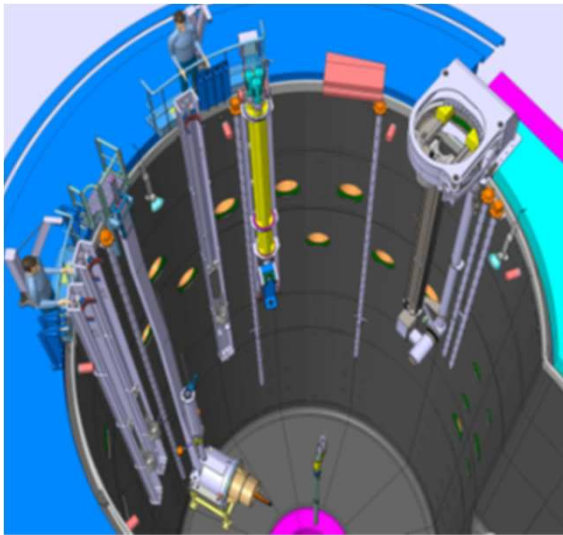
To meet the regulations requiring the periodic inspection of NPE, a number of constructive measures have been implemented. Concerning the Adeline irradiation device currently in its design phase,

- 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

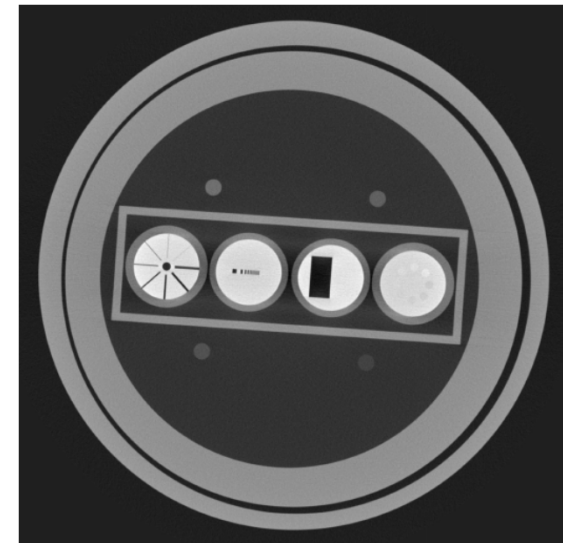




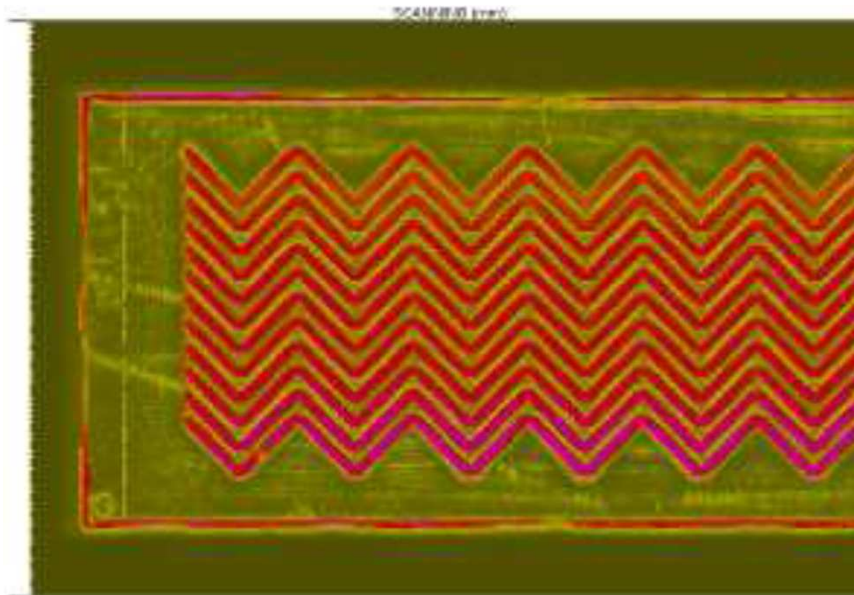
Numerical simulation (MODHERATO SOFTWARE) of an X-ray examination is given below for a structure of device with typical defects

(radial cracks of variable thicknesses ranging between 10 and 300 microns).

Full 3D inspection



Examples of NDT using ultrasounds and X-rays on heat exchanger plates.

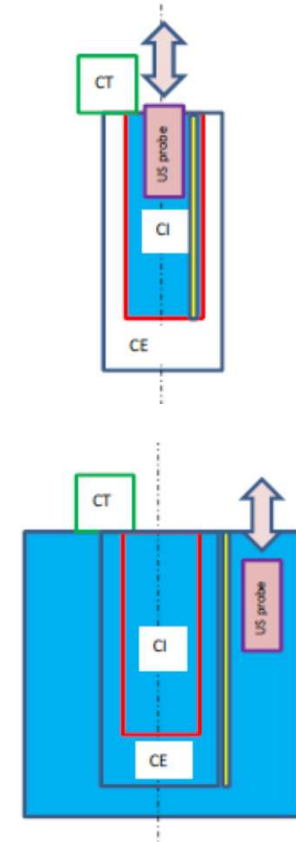


Non-destructive test using an ultrasonic bar comprising 64 elements at 20 MHz by means of XY scanning of a plate with millimetric-sized channels



resolution of about 100 microns in the steel

2-3D inspection



Main principle :

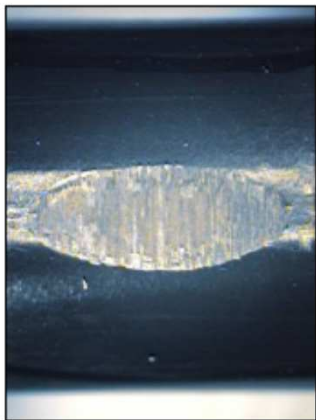
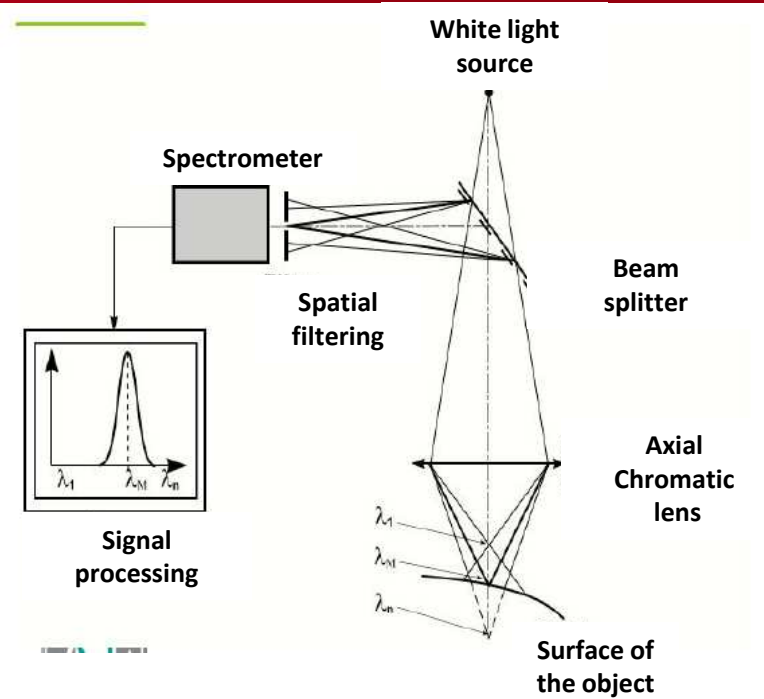
- polychromatic source
- + chromatic lens
- + spatial filter + spectrometer

Range : few microns to mm
Resolution: few 1/10 microns

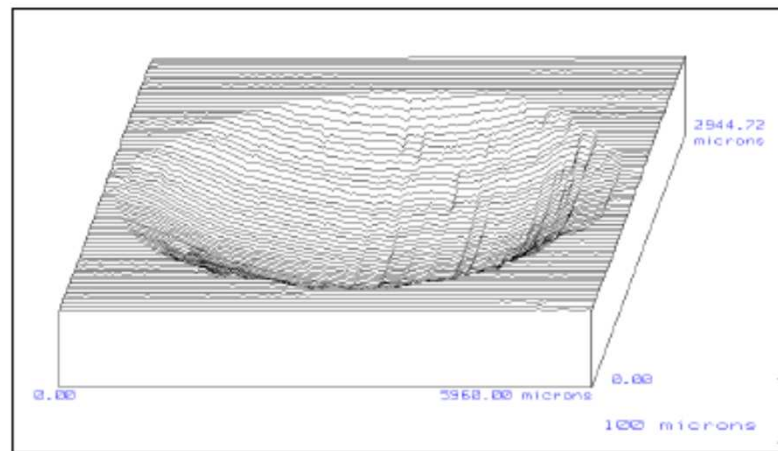
Applications :

- Surfaces defects
- fuel rod screening

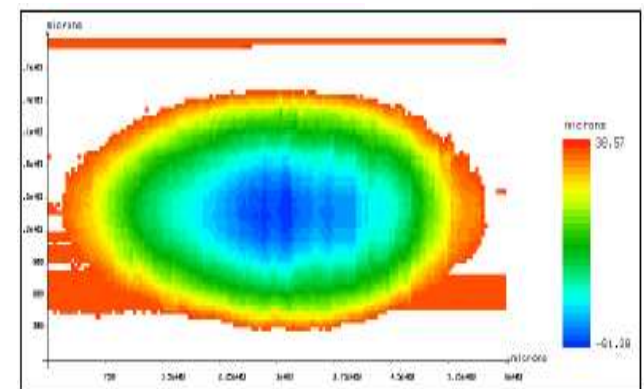
2D inspection



VISIBLE
DEFAULT

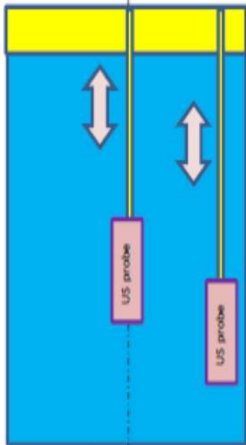


LEVELS
MAPPING



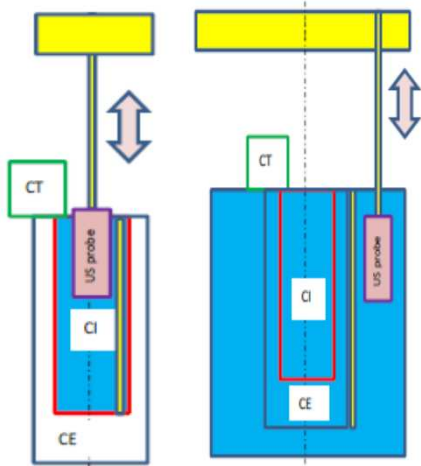
COLORISED
MAPPING

NPE-IP: INSPECTION CARRIER HOLDER SPECIFICATIONS



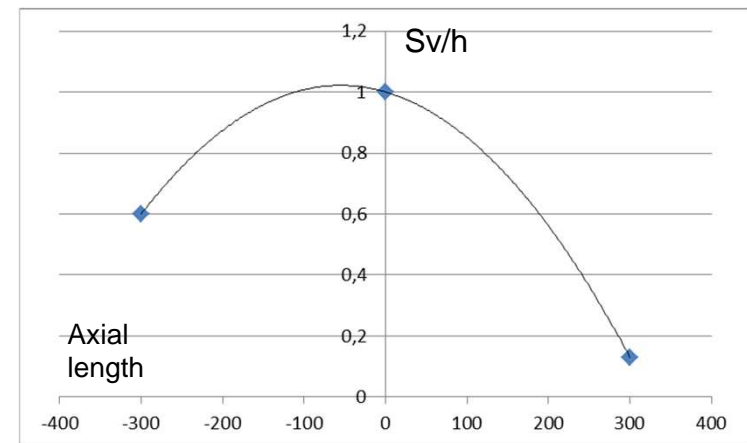
Mechanical holder for Ultrasonic detector

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.



INNER TUBE	6.5 mm
OUTER TUBE	5.5 mm
TYPE OF DEFECT	RADIAL NOTCH
GEOMETRY	L = 10 MM, W = 1 MM THICKNESS = 320 MICRONS

INSTRUMENTATION GAMMA DOSE RATE BEHAVIOR REQUIREMENT



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.

