MADISON & ADELINE experimental devices
Features and design challenges

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RJH
Réacteur Jules Horowitz
SÉCURITÉ HONNÊTETÉ RÉSULTATS ESPRIT D'ÉQUIPE

Content

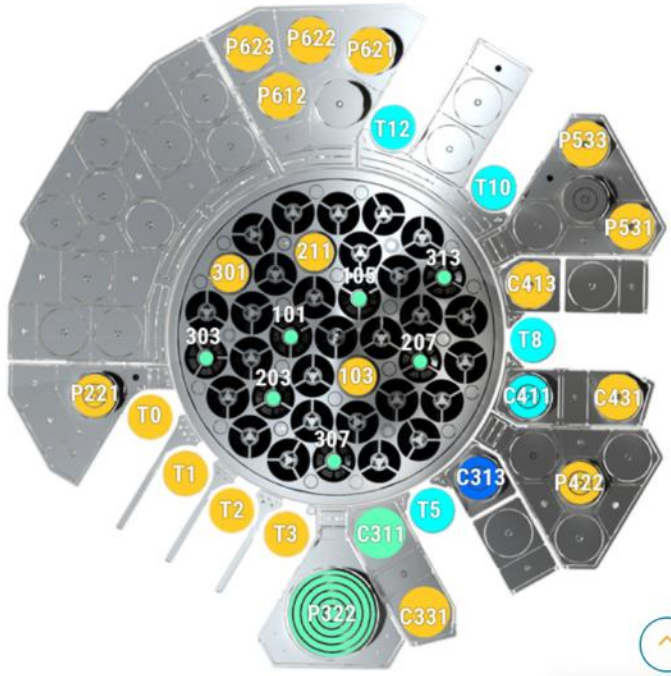
1. Jules Horowitz Reactor

Main charateristics and Experimental domain

Jules Horowitz Reactor (JHR)

- Material Test Reactor currently under construction at the CEA Cadarache Center

- Main Characteristics
  - Power : 70 to 100 MW_{th}
  - Fast and Thermal flux up to 5. 10^{14} $n.cm^{-2}.s^{-1}$
  - Displacement per atom (dpa/year) : Up to 11.5



- Purposes
  - Select, characterize and qualify nuclear fuels and materials,
  - Produce various radioelements for medical and Industrial applications

JHR : Experimental Domain

4 main families of experiments

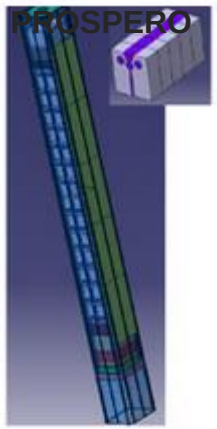
Up to 20 experiments simultaneously

Fuel test devices
- PWR loops : ***MADISON & ADELINE***
- Capsules **:** ***FUICA***

Material test devices
- Capsules **:** ***MICA, PROSPERO***

Radio-isotope production devices
- For other RI than MOLFI : ***REA***

Non Destructive Examination Benches
- Gamma, X-ray and neutron imaging : ***UGXR, SIN***



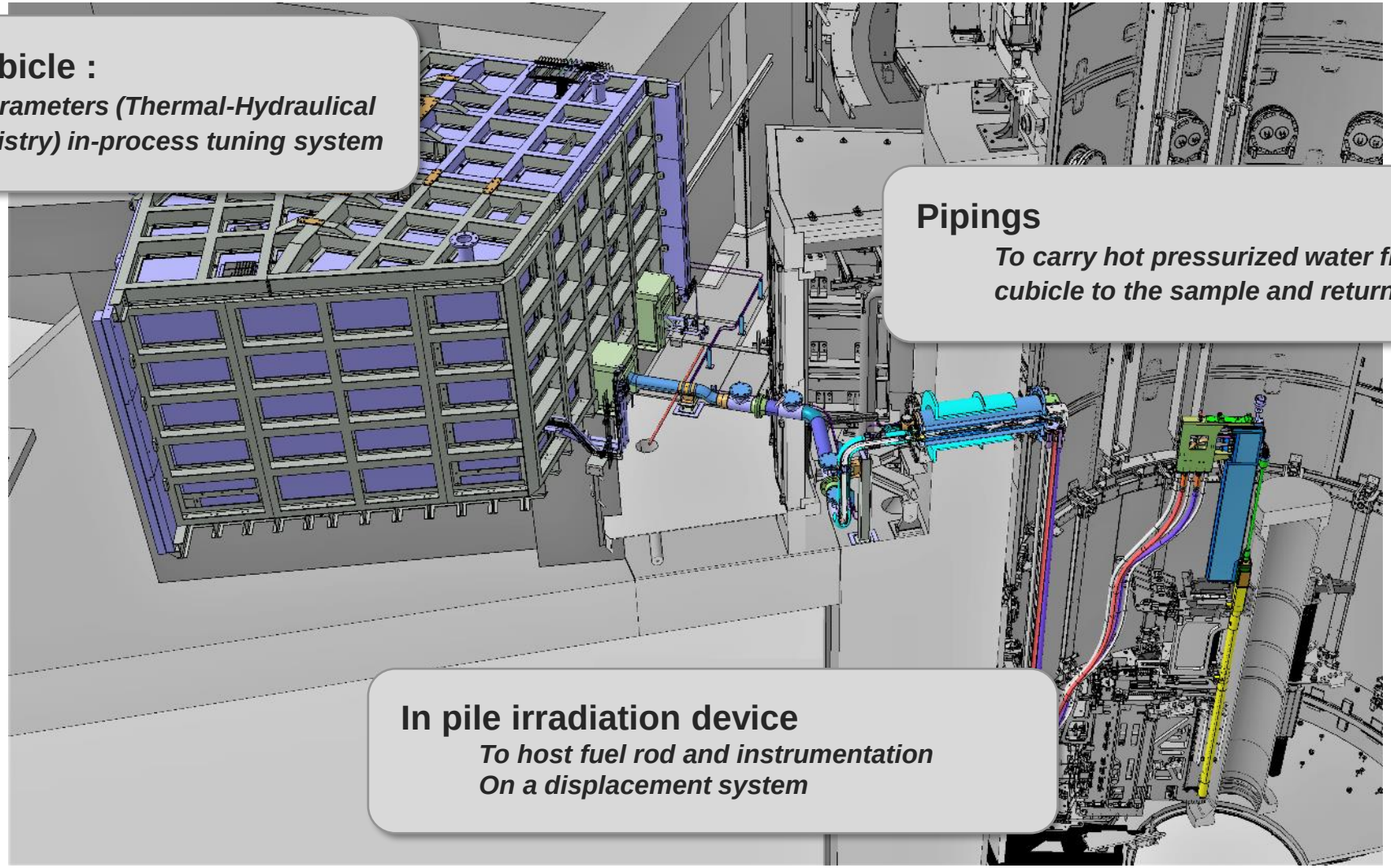
2. JHR : PWR fuel Experimental loops
MADISON and ADELINE

Global Architecture and Experimental goals

JHR : PWR fuel Experimental loops

MADISON & ADELINE devices

From bird eye view : Same architecture



A Shielded Cubicle :

To house the parameters (Thermal-Hydraulical and water chemistry) in-process tuning system

Pipings

To carry hot pressurized water from the cubicle to the sample and return.

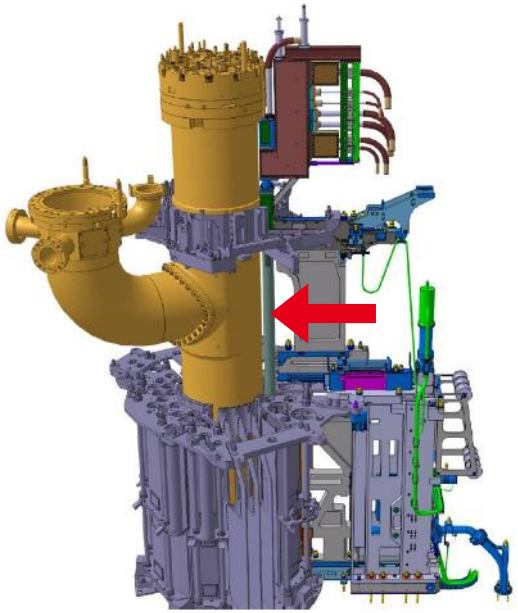
In pile irradiation device

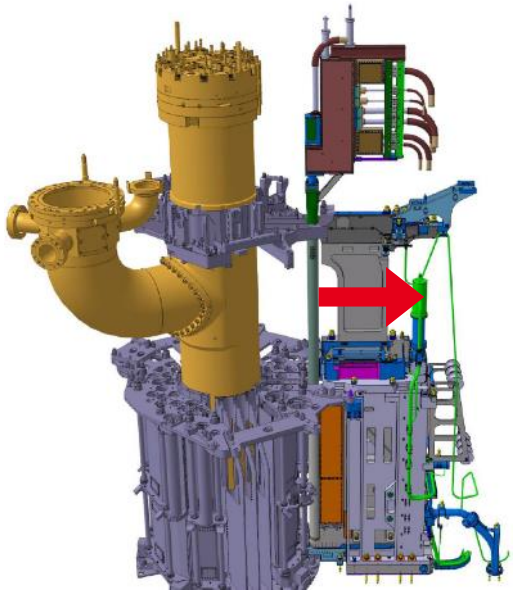
To host fuel rod and instrumentation
On a displacement system

JHR : PWR fuel Experimental loops

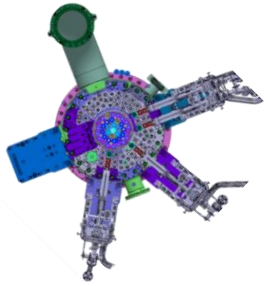
MADISON & ADELINE devices

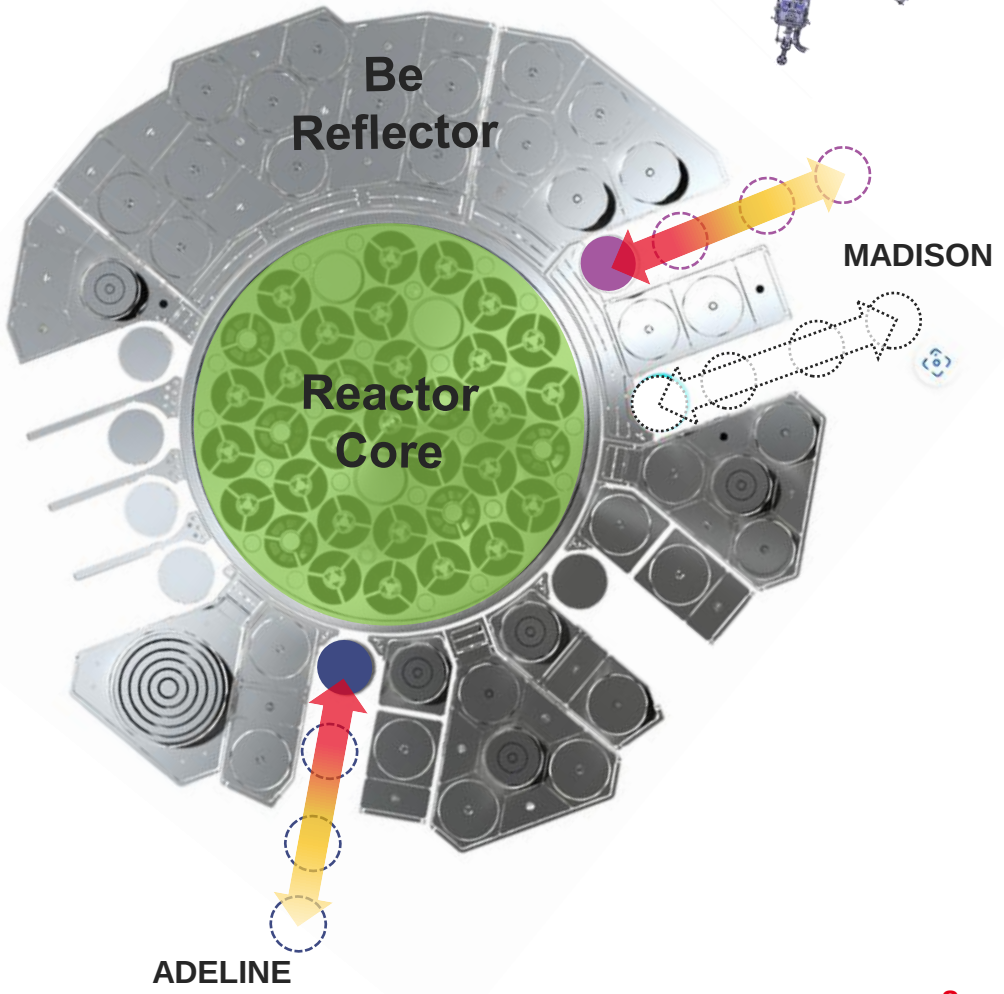
In pile part on a
Displacement System





Same principle to adjust fuel rod flux





MADISON : PWR fuel Experimental loops

MADISON and ADELINE devices

Experimental goals

MADISON

To investigate fuel behavior under nominal operational conditions

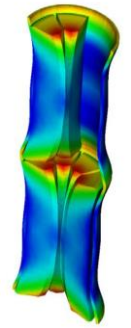
Fuel Selection
(Screening Test)

Fuel Characterization
(Properties measurement)

Fuel Qualification
(PWR conditions representativeness)

ADELINE

To test fuel under off-normal operational situations



Perform power ramps
(PCI studies)

Perfom power ramps
(Fuel behavior after cladding failure)

Perform power ramp to fusion
(Power threshold to fuel fusion)

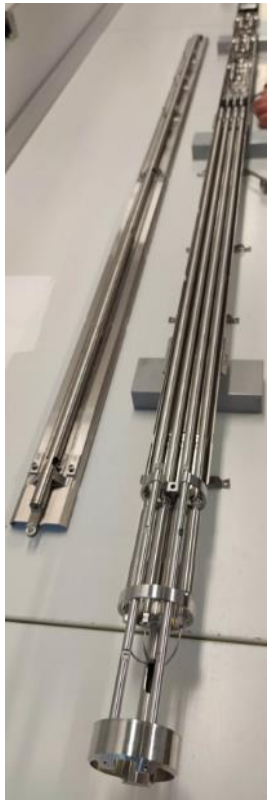
3. JHR : PWR fuel Experimental loops
MADISON and ADELINE

Requirement and Design features

MADISON : PWR fuel Experimental loop

Modulary device for investigate fuel behavior under nominal operational conditions

Experimental Goals	Requirements
Selection	Comparison of serval samples Limited monitoring on line
Characterization	Highly instrumented
Qualification	Irradiation, thermohydraulics and chemistry conditions representativeness



Specific Design solutions

Modular sample holder
- 2 to 4 fuel rods
- Spare plugs for instrumentation (thermocouples, pressure sensor, acoustic sensor, diametral gauge, LVDT…)

Pressurized tube : Large diameter needed + PWR conditions (320°C) load
- Stainless steel (316L) instead of Zircaloy

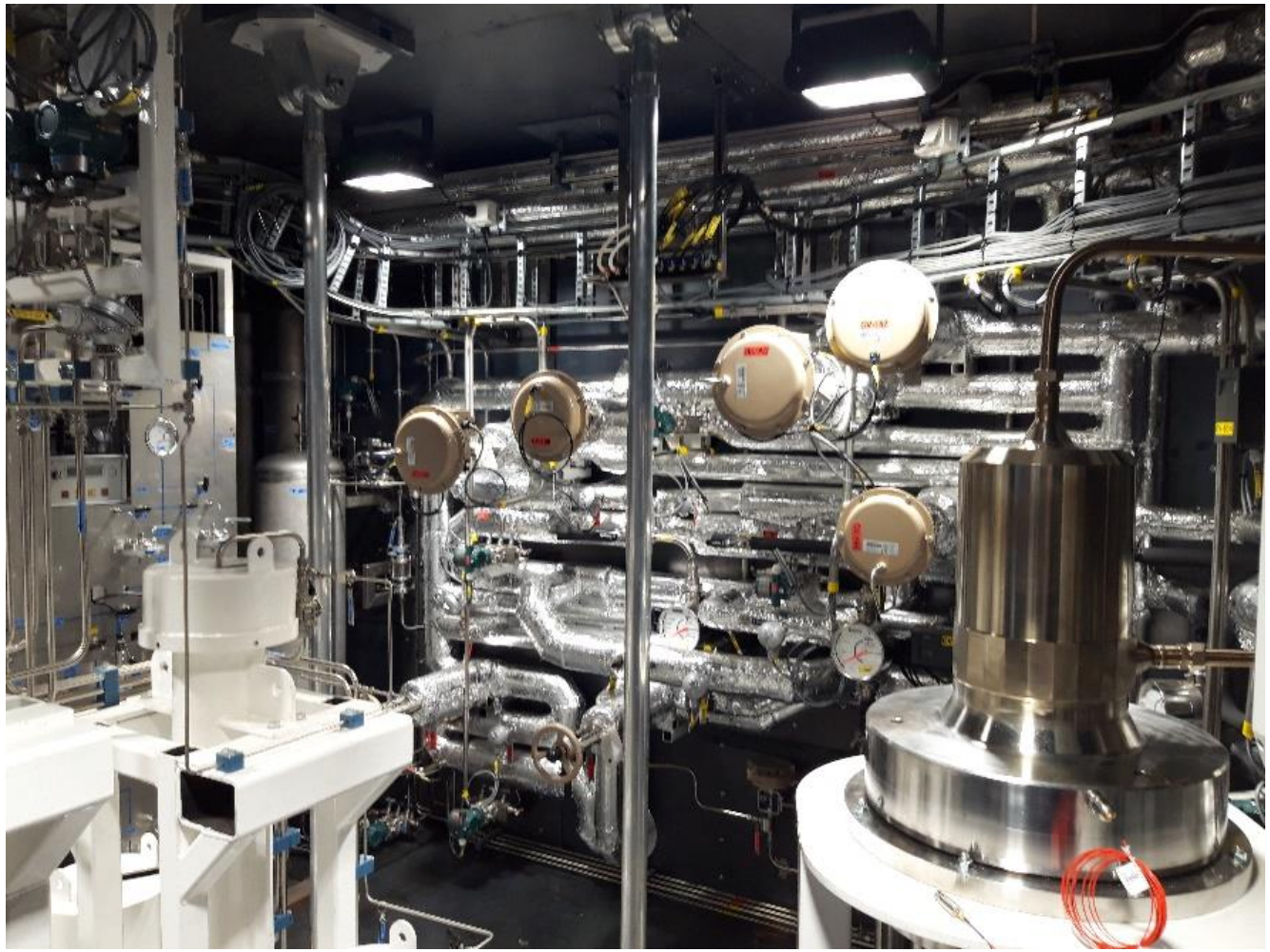
MADISON : PWR fuel Experimental loop

Design validation tests

Scale 1 Mock-up loop for process and design validation

See L. Costes et al presentation

MADISON experimental device dedicated to LWR fuels studies in JHR
Feedback on Mock Up Loop tests performed at IFE Halden



ADELINE : PWR fuel Experimental loop

To test fuel under off-normal operational situations

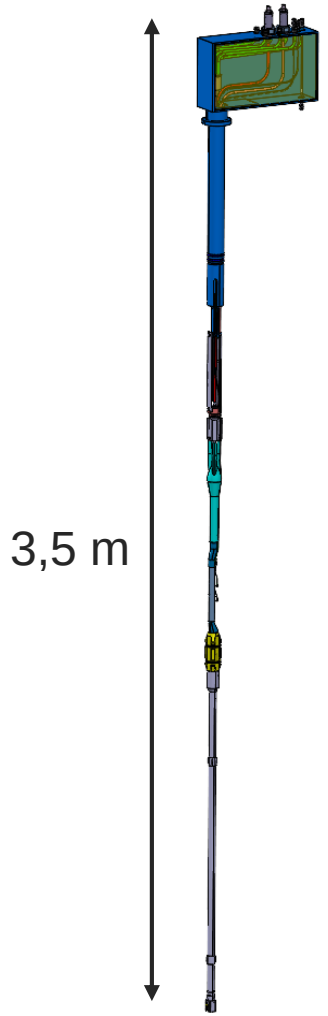
Experimental Goals

Perform power ramps up to cladding failure or fuel melting and PCI studies

Requirements

High performances : Power, kinetic and accuracy

Management of fuel leakage



Specific Design solutions

Sample holder :
- Single fuel rod
- Highly instrumented : flow rate, flux, temperature, elongation, …

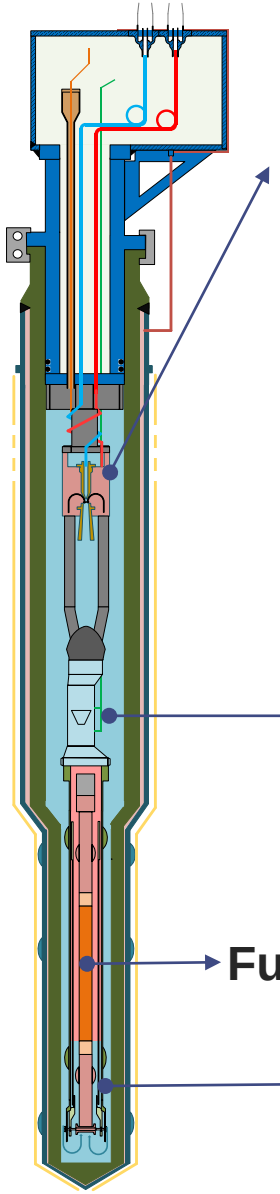
Pressurized tube :
- in zircaloy

→ Small Diameter : Φ 38 mm

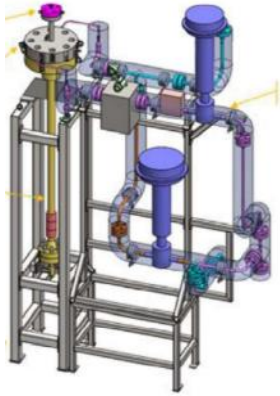
Radiological and confinement significant constraints

ADELINE : PWR fuel Experimental loop

Design validation tests



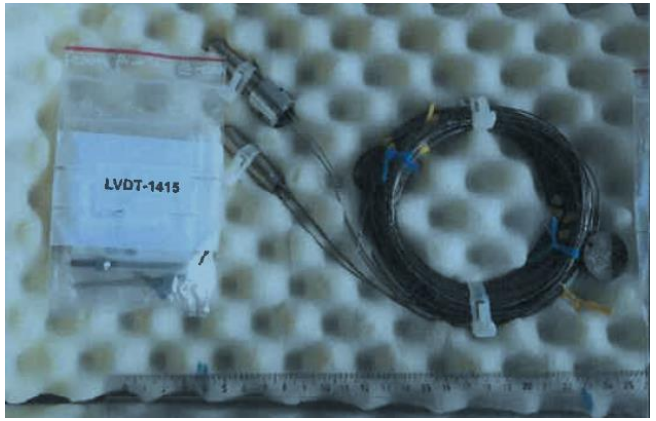
Jet pump
Water flowrate amplification around the experimental fuel rod



V-Cone
Water at LWR conditions flowrate monitoring

Fuel rod

LVDT
Sample elongation measurement



ADELINE and MADISON

Main performances synthesis

	ADELINE	MADISON
Experimental load	single fuel rod	up to 4 fuel rods
PWR conditions	up to 155 bar up to 285°C	155 bar 320°C
Themal balance accuracy	5,6%	~10%
Maximal Power	~600 $W.cm^{-1}$	~400 $W.cm^{-1}$
Ramp speed (Max)	Up to 700 $W.cm^{-1}.min^{-1}$	50 $W.cm^{-1}.min^{-1}$
Burnup Max (UO_2, MOX)	90 $GW.d.t^{-1}$	80 $GW.d.t^{-1}$
Experiment duration	3.5 days	days - months - years

4. Conclusion and next steps

MADISON and ADELINE : PWR fuel Experimental loop

- **Their Design is complex and challenging:**
  - Numerous professional competencies
  - Multiple « physics »
  - Lot of Requirements not always compatible: safety, performances, operation, regulation …
  - Difficulties of calculation and simulation Codes sometimes upon the limits of their validity

Detail Design Completion 2023-2024

- **Challenge for suppliers**
  - Numerous professional discipline
  - High level of precision
  - High level of quality : Safety, regulation, performances
  - First of a kind and single copy

Tendering Process 2024-2025