JULES HOROWITZ REACTOR. France

First Thermal hydraulic campaigns in support of Irradiation Devices Development

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IAEA-IGORR Conference. 2025 June. MITO.Japan

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JHR Project overview

The JULES HOROWITZ REACTOR is currently under construction at the CEA Cadarache centre (South of FRANCE).

It is a MATERIAL TESTING REACTOR (MTR) Type

It will be used to perform IRRADIATION TESTS

ON FUEL AND MATERIAL SAMPLES.

It will be a part of support Programmes for current Nuclear (GEN II AND III) and future (GEN IV AND FUSION) reactors.

The JHR reactor will also be used to produce RADIOELEMENTS (MAINLY Mo-99) for medical purposes and will meet 50% of the European demand in this field.

JHR Project overview

The JHR = Experimental Facility opened to the international community

Irradiation Reactor

+

Consortium

https://jhrreactor.com/

CPN (July 23)

French Government Agreement to complete the JHR by 2032-2034

JHR. Main characteristics of the reactor

Material Testing Reactor designed at 100MWth (starting at 70MWth)

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

  Closed primary circuit (12 bar pressurisation)

- **High materials damages capabilities (core)**

  15 dpa/year

- **High thermal neutrons flux** (reflector)

  8 x PWR th.neutrons flux

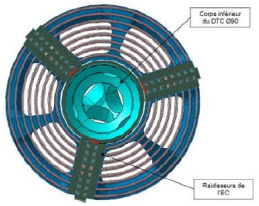
- **High Experimental Platform**

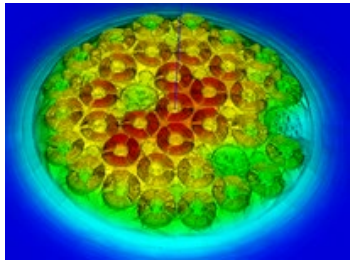
  Possibility to manage up to 20 irradiation devices

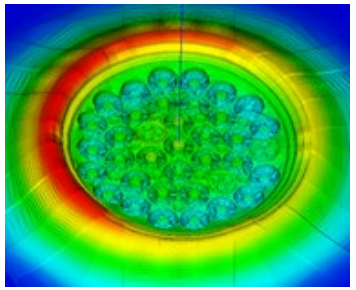
  (x10 in the core and x10 in the reflector)

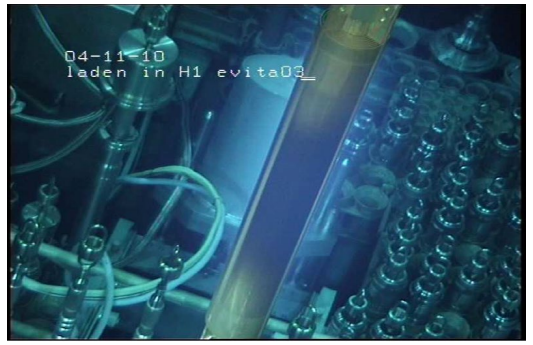
  Experimental and operation equipment's integrated in the facility

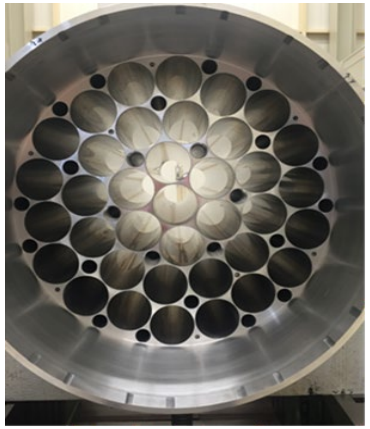
  NDE systems, + (not at the startup) FP laboratory, hot cell with specific one for failed rods conditioning,…





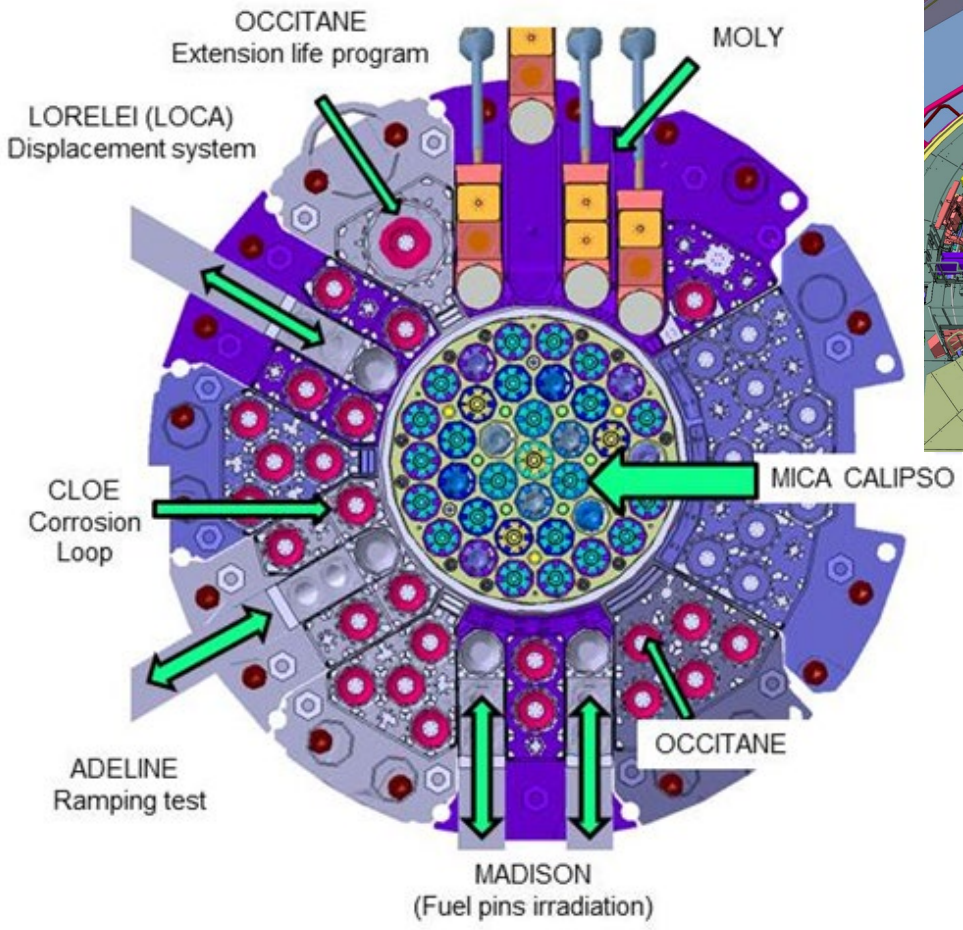


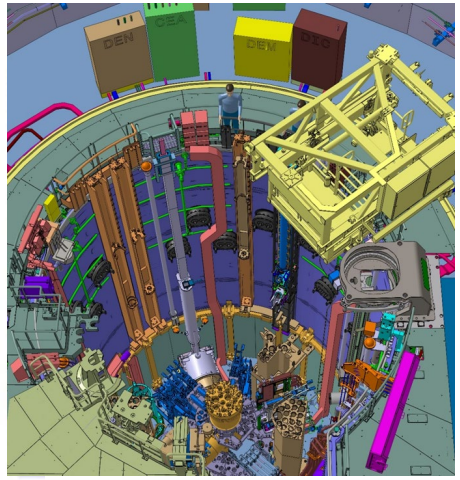




JHR Experimental fleet

- The core, Be reflector, the pool
- The hot cells,…
- Material devices,
- Fuel devices,
- Physical characterization devices (CARMEN,MONITOR,DOSI,…)
- MOLY devices (medical),
- REA (neutron activation), SND,
- NDT benches (UGXR,HGXR,NIS,.





Fleet 1 : Need for start up (T0)

Fleet 2 : T0+2y-> T0+5 y

Fleet 3: T0+5y -> T0+10 y

FUEL ADELINE loop

Expected performances

An experimental irradiation loop dedicated to rod irradiation functioning under LWR conditions in under detailed study.

This fuel irradiation loop is composed of an in-core part located in the reactor pool and of another part located in the operation zone of the experiments (BUR, CEDE).

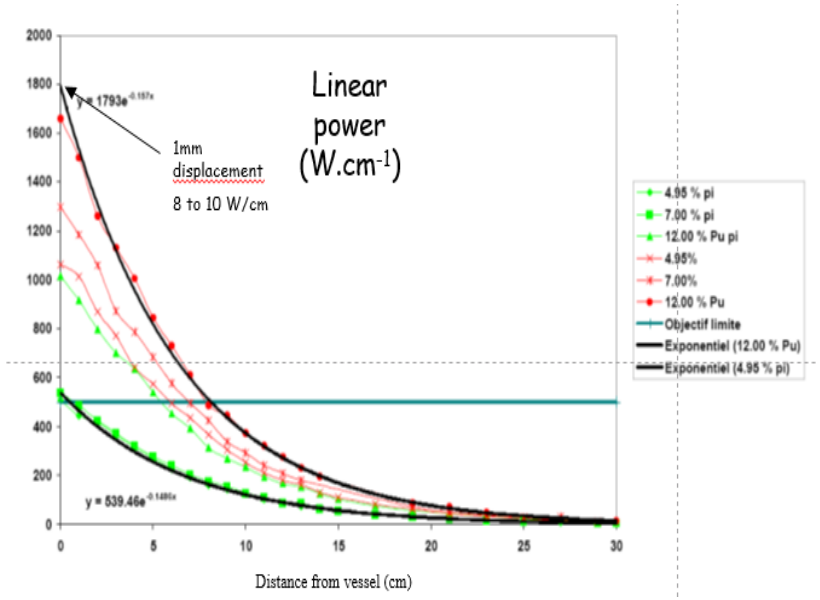


Figure 3a: Example of power evolution versus SAD displacement and fuel enrichment (analytical calculations).

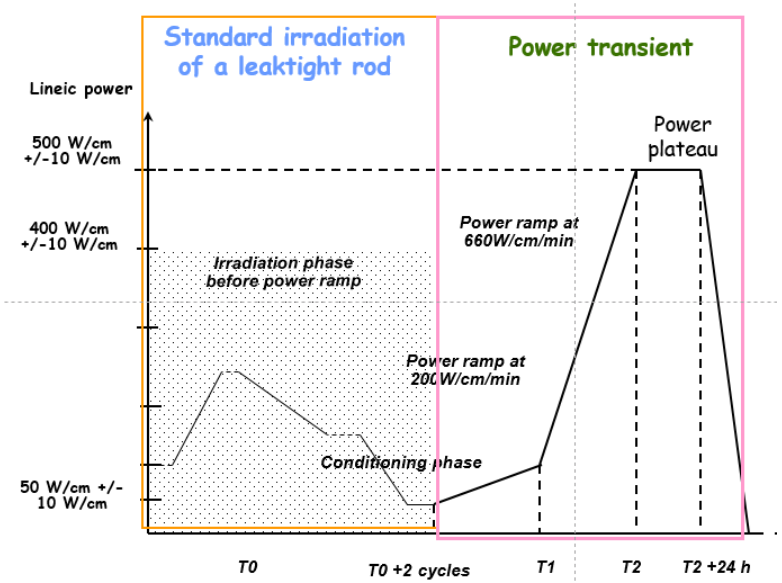
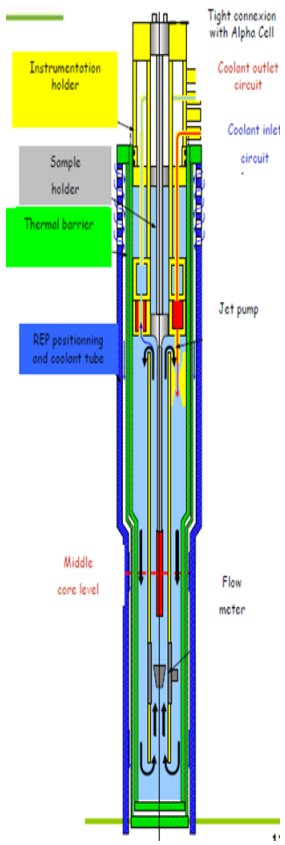


Figure 3b: Typical experimental scenario of a fuel power ramp test.

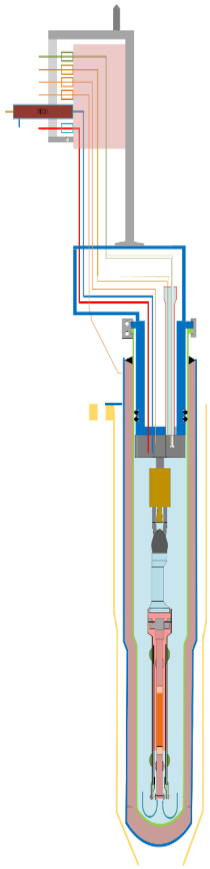
ADELINE. Irradiation Loop for fuel ramps tests

Main Features

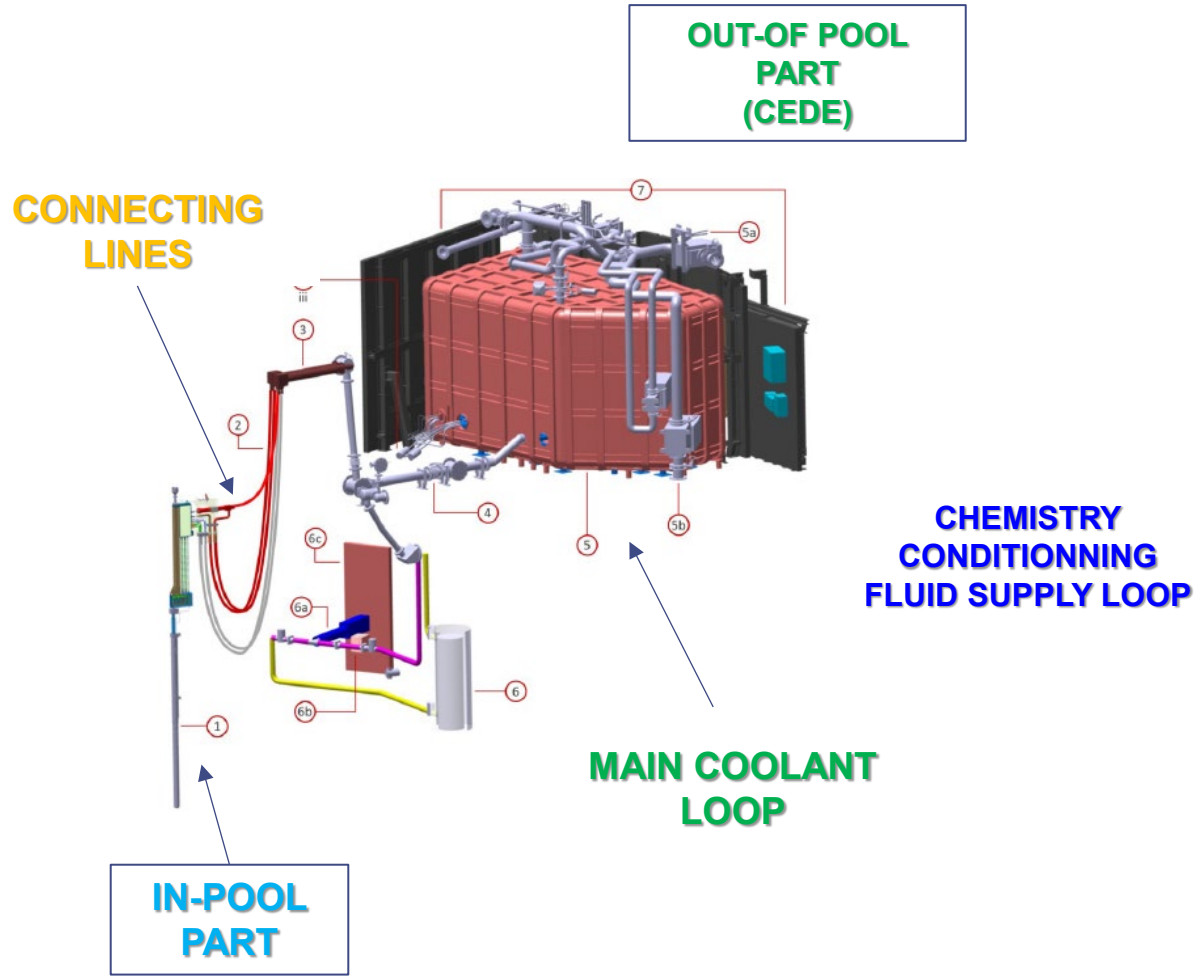
- **TH PARAMETERS** : LWR : 155b,320°C , BWR: 80b,280°C



ADELINE V0 design



ADELINE V2 design



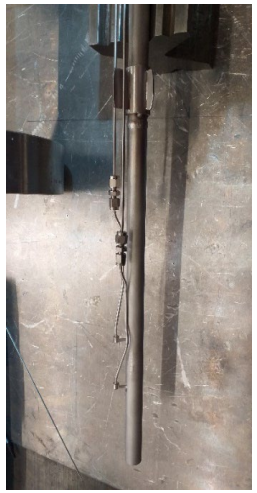
Qualification tests
Final objective reminder

The out of pile qualification activities permit to test some parts of a new device during the detailed design phase.

- ✓ It allow to verify the behaviour of some critical components in working environment, more or less representative in terms of pressure, temperature, flow, nuclear field,…
- ✓ It permit also to define some characterisation maps in working areas larger & stronger than the final use.
- ✓ It contribute to increase the robustness of the components.

In this context, different qualification tests are identified regarding for ADELINE device development such as calibration of VCône Flowmeter and also qualification tests of flow amplifying module in representative TH conditions (room temperature, BWR & PWR conditions).

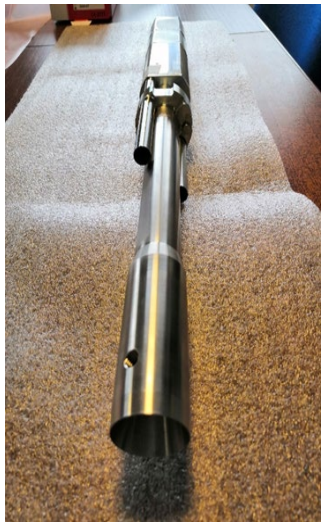
ADELINE device. Qualifcation Activities



- **Calibration of VCone Flowmeter**
  - Tests at Room Temperature, BWR & PWR conditions

- **Qualification of Flow Amplifying module**

  in representative TH conditions
  - Tests at Room Temperature, BWR & PWR conditions



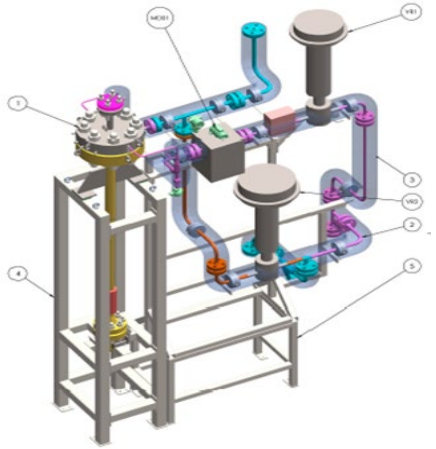
Support Qualification Loop

CORAIL TH LOOP IN CAD

- *TH conditions : P=190b, T=350°C, Q.tot=30m^3/h.*
- *Historically used for cladding corrosion tests then stopped since 2007.*
- *Restart in 2020 for JHR applications.*
- *Can work during long periods (few weeks).*
- *Used for Vcone flowmeter calibration (Room T, BWR,PWR conditions)*

INTERFACE BETWEEN CORAIL & TEST SECTIONS

- *Specific skid needed for test section flow driving*
- *Two valves used (main line, bypass) used to drive the flow inside the test section (from 15 to 45 g/s)*
- *+ one reference flowmeter on the main line (CORIOLIS type)*



Vcone flowmeter Calibration

The objective of this test is to improve the accuracy of the measurement of the cooling flow inside the irradiation channel. The flowmeter used is called VCône. It is a compact instrumentation comparing with a VENTURI type. The measurement principle is the same. It is based on pressure drop measurement around two points on the tube. The reference measurement is a Coriolis flowmeter

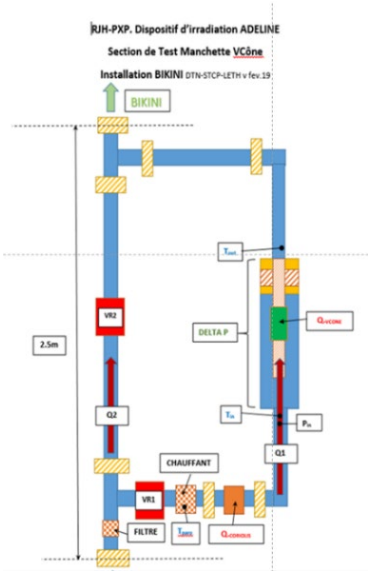
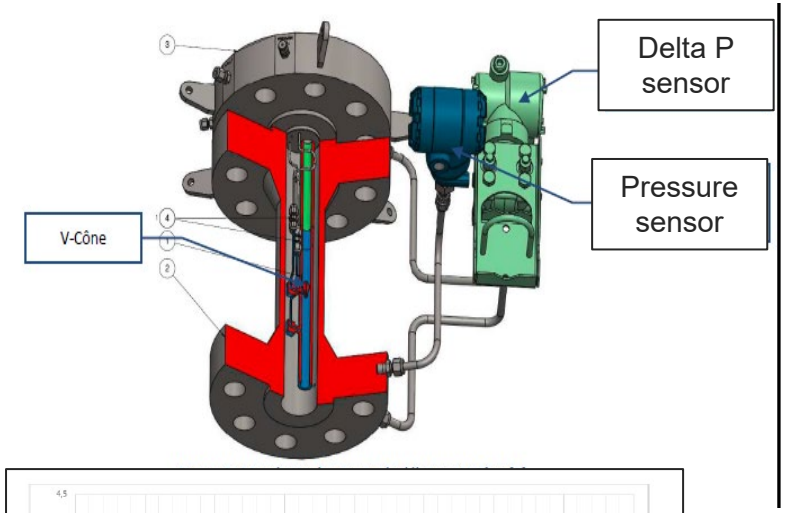
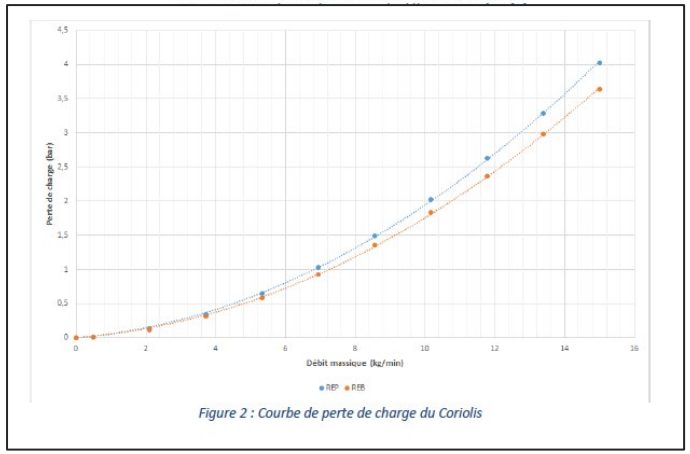


Fig.5a : General scheme of the test section

Fig.5b : Picture of the flowmeter & pressure tubings (VCone type)

Fig.5c : Test section overview (without thermal shroud)

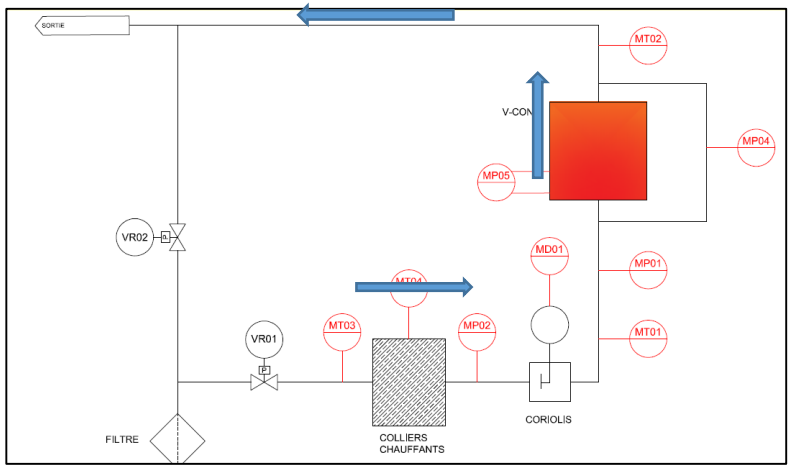




Reference CORIOLIS flowmeter (illustration)

Vcone flowmeter Calibration

Experimental Set-up



General Scheme of the VCône test section with instrumentation labels

Experimental Results

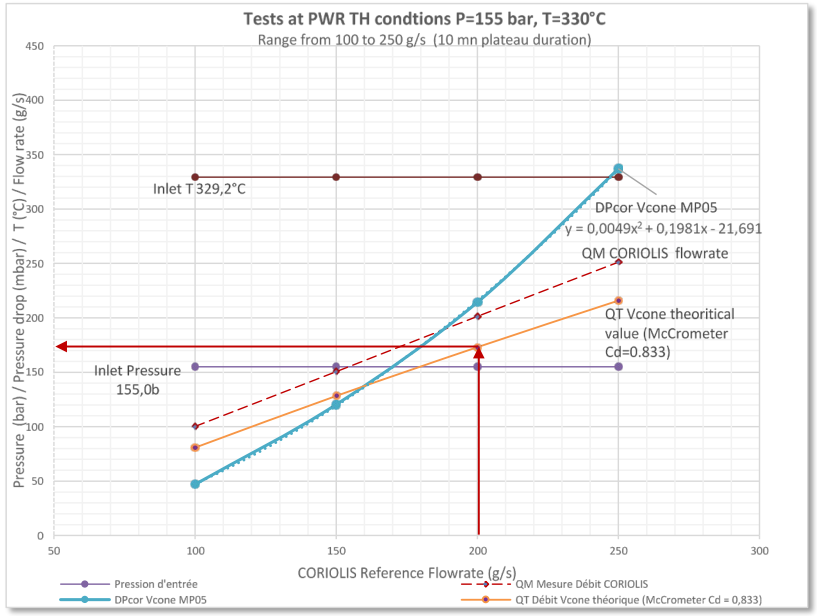
Fig.6 : Vcone Flowmeter

Calibration tests

Overview of the experimental

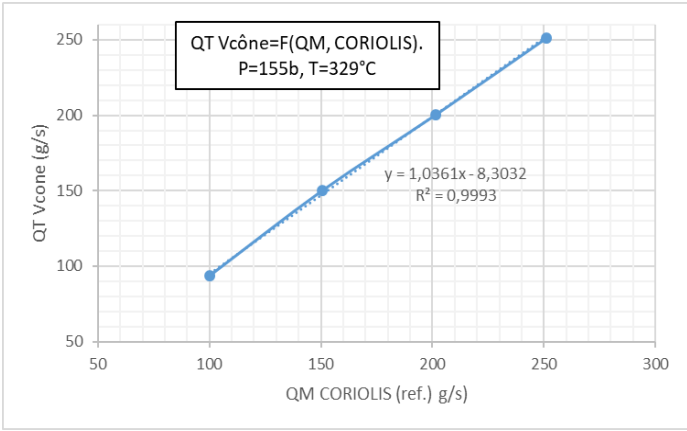
results obtained

at PWR conditions



After a first analysis, the tests carried out and the results obtained (comparison 1-QT/QM < 6, 5% using (3) for Cd).
these results are considered as acceptable for this campaign.

Correlation between Vcone & Coriolis flowmeters



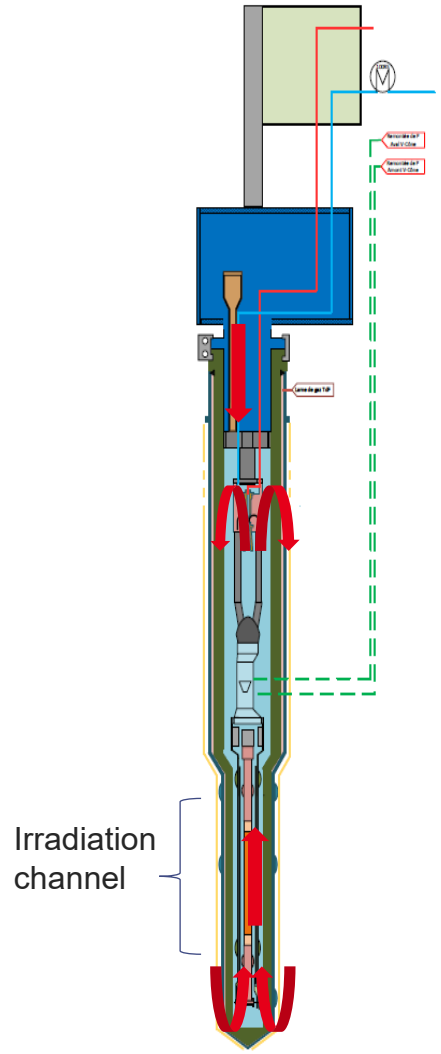
Flow Amplifying Module Test

Objectives & description

The objective of these tests are to verify the capability of the injectors-diffusors module to accelerate the cooling flow inside the device from 50g/s up to 200-300g/s.

The principle of the amplifying module is to inject inlet flow at high pressure flow throw small injectors. Then, this flow induce a flow recirculation inside the device. This system allow to reach the flow level requirement inside the irradiation channel.

The interest of this technology is to limit the inlet flow inside the device & consequently to limit also the size of components in the out of pool part (experimental cubicle, pumps, valves, heat exchangers).



Adeline In-Pile Scheme

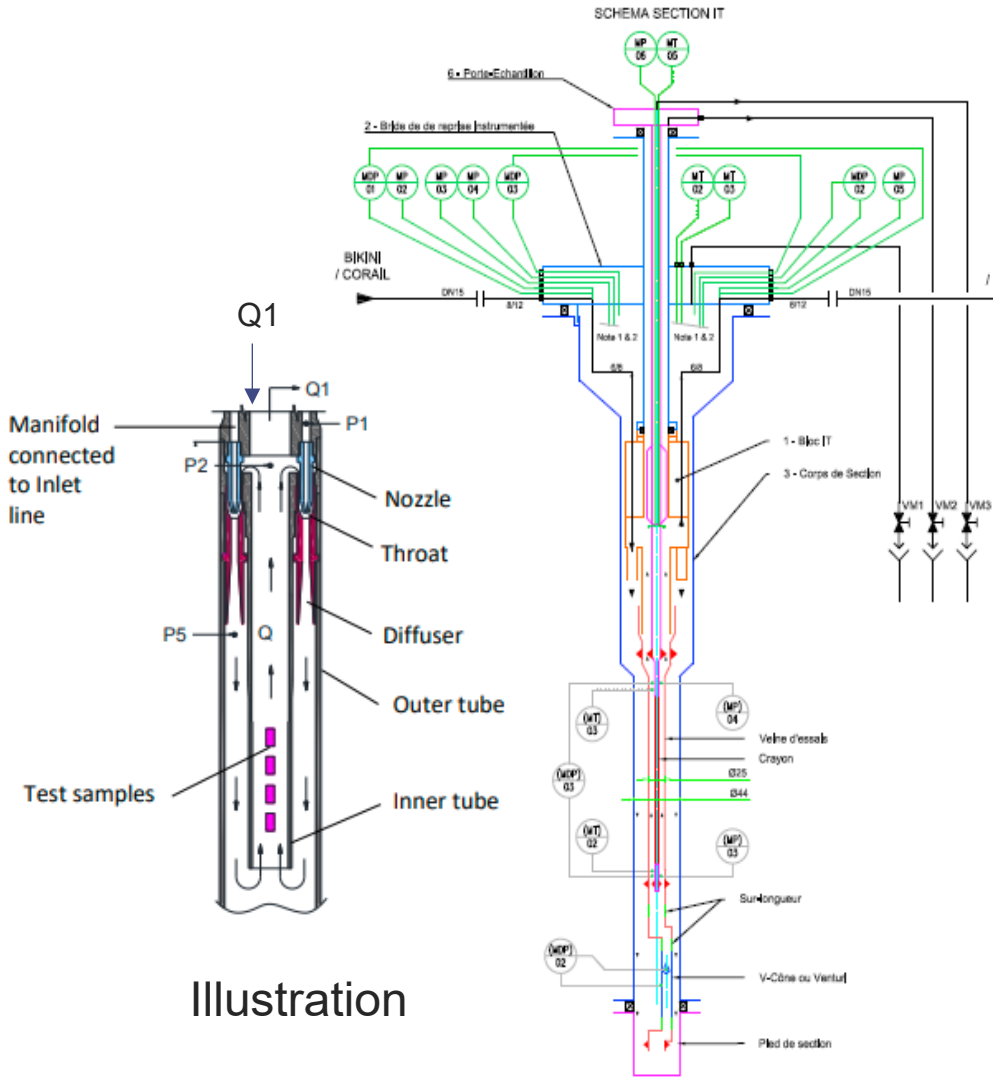
Flow Amplifying Module. Experimental set-up

Two designs of tests sections are considered (DESIGN 1 & 2)

DESIGN-1 *(TH tests done)*

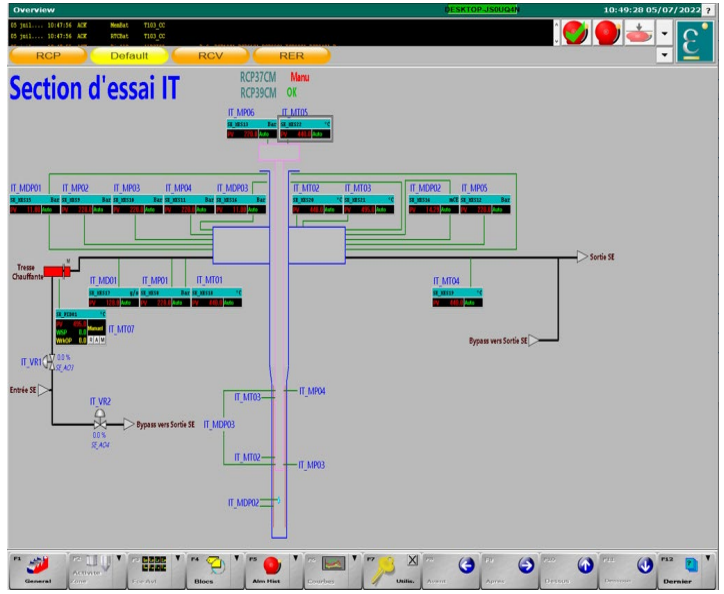
- *Test section representative of ADELINE-V0 concept (historical)*
- *Length shorter (2.8m) than ADELINE device*
- *Channel representative (rod 60cm length)*
- *Instrumentation (such as LVDT) represented by nuts around the experimental rod*
- *Flow amplifying module : 2 injectors D=0.9mm + 2 diffusors*
- *Three configurations tested :*

  1 rod 9.5 mm / 1 rod 12mm / 1 rod 15mm
- *VCone flow meter located inside the channel (in front of the rod)*



Flow Amplifying Module. Experimental grid

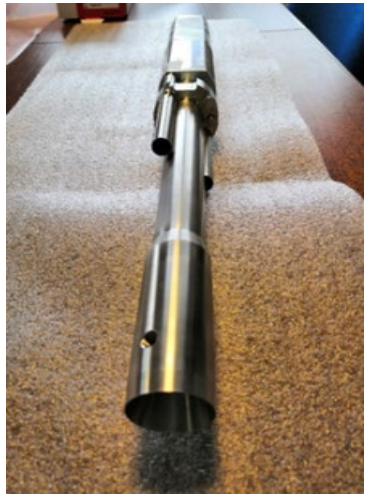
Case	Front IT	Downstream IT
PWR **(155b, 320°C)**	P = 1 à 190 b (*) T = 20 à 350°C $Q_{\cdot inducteur} = Q_{\cdot min}$ à 100g/s	P = 1 à 169 b (*) T = 20 à 350°C $Q_{\cdot induit} = Q_{\cdot min}$ à 300g/s
BWR **(80b, 280°C)**	P = 1 à 90 b T = 20 à 280°C $Q_{\cdot inducteur} = Q_{\cdot min}$ à 100g/s	P = 1 à 80 b T = 20 à 280°C $Q_{\cdot induit} = Q_{\cdot min}$ à 350g/s
Start up	P = 10 à 50 b T = 50 à 100°C $Q_{\cdot inducteur} = Q_{\cdot min}$ à 100g/s	P = 10 à 50 b T = 50 à 100°C $Q_{\cdot inducteur} = Q_{\cdot min}$ à 100g/s



Driving panel

Note : *For these tests , the flow inside the channel is obtained from VCone supplier calibration sheets*

Flow Amplifying Module. Experimental Results



Flow amplifying module

Main characteristics

Overall geometry of the component

L=373mm, D=54mm

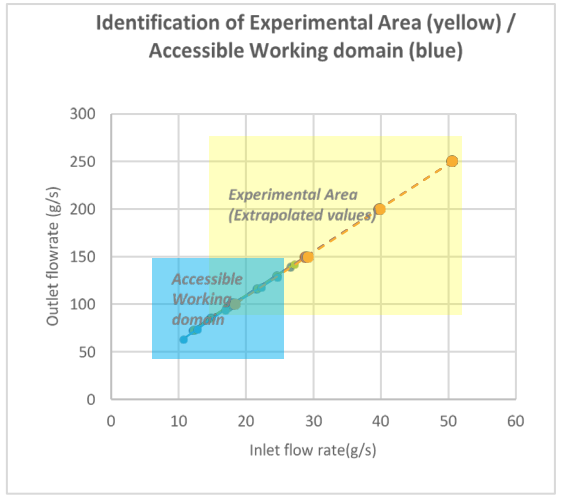
Equipped with 2 injectors d=0.9mm

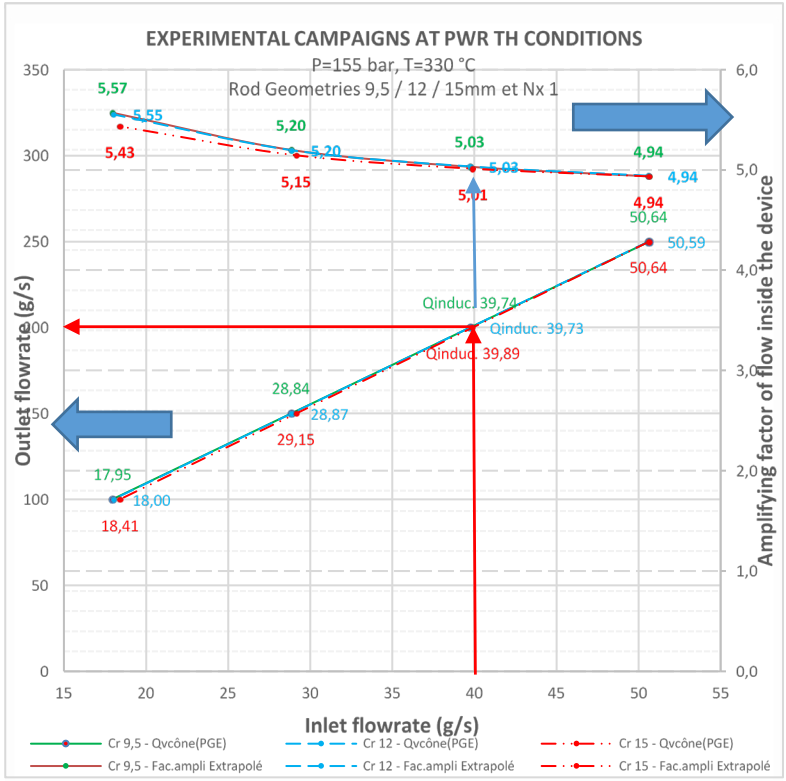
Fig.9:
ADELINE-V0 type
Test section

Overview of the TH results.

Rod geometry : 9.5 / 12 / 15mm

PWR TH conditions (155b,330°C)





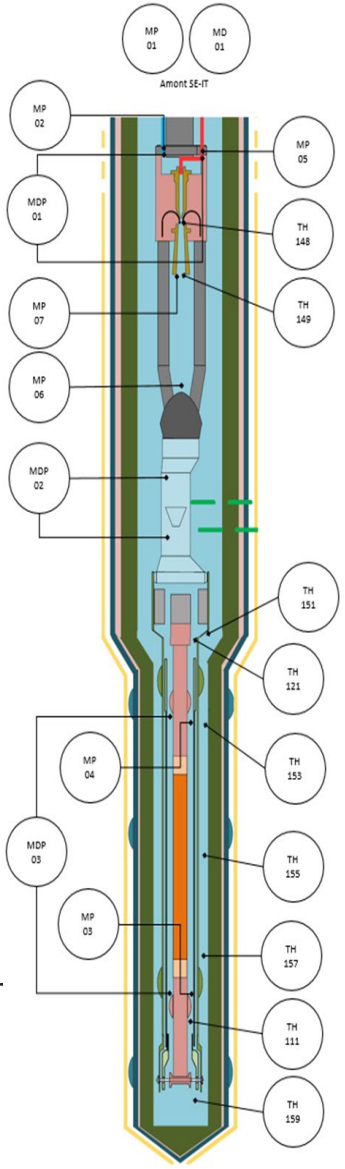
Flow Amplifying Module. Future Tests

DESIGN-2 *(test section manufacturing finalised)*

- *Test section representative of ADELINE-V2 concept (JHR objective)*
- *Length representative of ADELINE device (around 3.2 m)*
- *Channel representative (rod 60cm length)*
- *Flow amplifying module : 1 injector D=1.35mm + 1 diffusor (OSIRIS Feedback)*
- *One configuration will be tested : 1 rod 9.5mm*
- *Vcone flowmeter located inside the channel (downstream the rod)*

Note (Designs 1 & 2)

- *The Test sections are considered as Under Pressure Equipment (Cat 3).*
  Consequently, design & manufacturing phases have been controlled by Notify Body.
- *The test section is equipped with Thermal Shroud located around the components & line in or to limit thermal losses at high temperature*



Instrumented design

Experimental Set-up

3D Cad model

Conclusion & Perspectives

New irradiation devices development for JHR impose to test some critical components during detailed phase.

- ✓ In the case of JHR ADELINE device (fuel ramps tests),
- ✓ It concern, in priority, cooling flowmeter (Vcone) & amplifying flow module.
- ✓ The experimental set-up use for these tests has to work at PWR & BWR conditions.
- ✓ It was the case with refurbished TH existing loops.
- ✓ After a first set of TH campaigns, complementary tests will be performed in more representative configuration (Design 2)
- ✓ The objective is to cover all the TH working domain, larger than nominal conditions
- ✓ It allows also to test some off-normal scenario and to check the TH behavior of the system.
- ✓ At the end, these tests permit also to train future operation staff.

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