Nuclear Compact Reactors

TechnicAtome

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Hydraulic design and validated calculation tools of the Jules Horowitz Reactor (JHR) Reflector
Introduction

- **TechnicAtome** has designed the Jules Horowitz Reactor (JHR): a 100 MW Research Reactor on behalf of CEA

- Numerous experimental locations with high performances and a strong flexibility, especially, in the reflector

- JHR reflector requirements have led to design a complex reflector with several possible configurations

- Preliminary thermal hydraulic sizing allowed to define the hydraulic operating domain strongly reduced by:
  - The calculation uncertainties
  - The margins to be considered

- For final sizing, calculation tools have to be validated on the reflector geometry
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2 Constraints on JHR reflector thermal hydraulic sizing

3 Hydraulic description of the JHR reflector

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# JHR reflector requirements and design options

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<th>Requirements</th>
<th>Design options</th>
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<td>- Neutronic performances in-core and in-reflector</td>
<td>- Beryllium modular reflector</td>
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<td>- A wide range of neutron flux and spectra for irradiation devices</td>
<td>- A lot of irradiation locations available dispatched in 9 sectors</td>
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<td>- Isotopes production rigs</td>
<td>- Zircaloy® gamma shields installed in some reflector area</td>
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<td>- Simulate transients occurring in incidental or accidental situations</td>
<td>Displacement systems in different locations</td>
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<td>- Medical radioisotope production (MOLY)</td>
<td>- Reflector structures and irradiation devices cooled by the open pool cooling circuit</td>
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<td>Capability to load and unload experimental devices when reactor is operating</td>
<td>- Downward cooling flow rate adopted</td>
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![Diagram of JHR reflector](image)

- **Experimental devices**
- **Displacement systems (MOLY)**
- **Gamma shields**
- **Beryllium Blocks**
Constraints on the reflector thermal hydraulic sizing

- **Pool cooling circuit architecture:** redundant pump, plate-based heat exchanger, reflector located at the pump suction

- For the final thermal hydraulic sizing, two actions are undertaken:
  - Adjust the necessary cooling flow rate crossing reflector structures and experimental devices
  - Reduce the calculation tools uncertainties
Hydraulic design of the JHR Reflector

Hydraulic description of reflector

One sector

Active zone (core region)
High energy deposition

Cooling channels

Sector water box

Water box final

Other sector not shown

Cooling pump circuit

Zircaloy shields
Beryllium blocks
Experimental device
Aluminum plates
Guiding tube
Channels diaphragms
Sectors diaphragms
Flow rate circulation
Calculation tools

- **CATHARE (Code for Analysis of Thermal-Hydraulic during an Accident of Reactor and Safety Evaluation):**
  - Developed by CEA, EDF, IRSN and AREVA
  - Dedicated to thermal hydraulic analyses
  - Based on a “2 fluids 6 equations” model

  CATHARE is used to perform the reflector thermal-hydraulic sizing

- **STAR CCM+:**
  - Computational Fluid Dynamics (CFD) tool developed by Siemens PLM Software
  - Multidisciplinary platform, used by engineer to solve complex industrial problems
  - Reference CFD code at TA: support in safety studies, design assistance

  STAR CCM+ is used to characterize the hydraulics flows in the water boxes and to design the diaphragms
General process - Calculation tools validation

**Actions**

- **Experimental tests performed**
- **Validation of reflector modelling in CATHARE**
- **Experimental tests performed to get a predictive CFD calculation tool (STAR CCM+)**
- **CFD Calculation (no experimental tests)**
- **Channels diaphragms design**
- **Sectors diaphragms design**

**Purposes**

Active zone (core region) High energy deposition

Cooling channels

Sector water box

Water box final

General process - Calculation tools validation

Hydraulic design of the JHR Reflector - p. 9/12
Sectors water boxes – Experimental process

- The aim of experimental tests is to qualify a CFD calculation scheme (STAR CCM+)

- First step: mesh rules and turbulence models
  - One mock-up representing the most constrained geometry of water boxes
  - Different configurations have been tested

- Second step: validation of CFD calculation scheme based on a blind test
  - One mock-up representing a sector water box with a different geometry
Sectors water boxes – diaphragms sizing

CFD calculation results: two experimental configurations

Diaphragms diameters are well predicted with a maximum calculation uncertainty lower than 8% on the target head loss.

Without qualification of CFD code: 30% calculation uncertainties retained.
Conclusions

- JHR reflector is intended to provide high flux performances and a strong experimental flexibility

- The challenge of the thermal-hydraulic sizing is to ensure the reflector cooling with the expected flexibility

- For final thermal hydraulic sizing, it is important to define with accuracy the hydraulic operating domain

- All the actions undertaken for calculation tools validation have led to:
  - Reduce significantly the calculation uncertainties
  - Finalize the reflector design (all the diaphragms)