ALFRED

Improvement of ALFRED Thermal Hydraulics Through Experiments And Numerical Studies

Technical meeting on State-of-the-art of Thermal-hydraulics of Fast Reactors 26-30 September 2022, Brasimone, Italy

ANSALDO NUCLEARE
Ansaldo Energia Group

Corso F. M. Perrone, 25

16152 Genoa – Italy

Marco Caramello PhD

Fluid System Design Unit
Member of Expert Board, FALCON Consortium

Phone: +39 010 655 8236

marco.caramello@ann.ansaldoenergia.com

ALFRED

Acknowledgements

POLITECNICO MILANO 1863

UNIVERSITÀ DI PISA

SAPIENZA UNIVERSITÀ DI ROMA

UNIVERSITÀ DEGLI STUDI DI PALERMO

ALMA MATER STUDIORUM UNIVERSITÀ DI BOLOGNA

POLITECNICO MILANO 1863

CIRTEN CONSORZIO INTERUNIVERSITARIO PER LA RICERCA TECNOLOGICA NUCLEARE

POLITEHNICA UNIVERSITY OF BUCHAREST UPB 1818

IFIN-HH

UNIVERSITATEA DIN PITEŞTI

CITON

ACADEMIA ROMÂNĂ

C E S I N A

FALCON

ANSALDO NUCLEARE Ansaldo Energia Group

ENEA

RATEN ICN PITEŞTI

(*) Bilateral agreeement with ENEA

Supporting organizations (MOA)

CIRTEN CONSORZIO INTERUNIVERSITARIO PER LA RICERCA TECNOLOGICA NUCLEARE

walter tosto

NUCLEARELECTRICA

S.R.S. Servizi di Ricerche e Sviluppo S.r.l.

NRG

CRS4 IDEAS BECOME LIFE

EMPRESARIOS AGRUPADOS

GREENPUMPS (*) MAG - DRIVE SEAL- LESS PUMPS

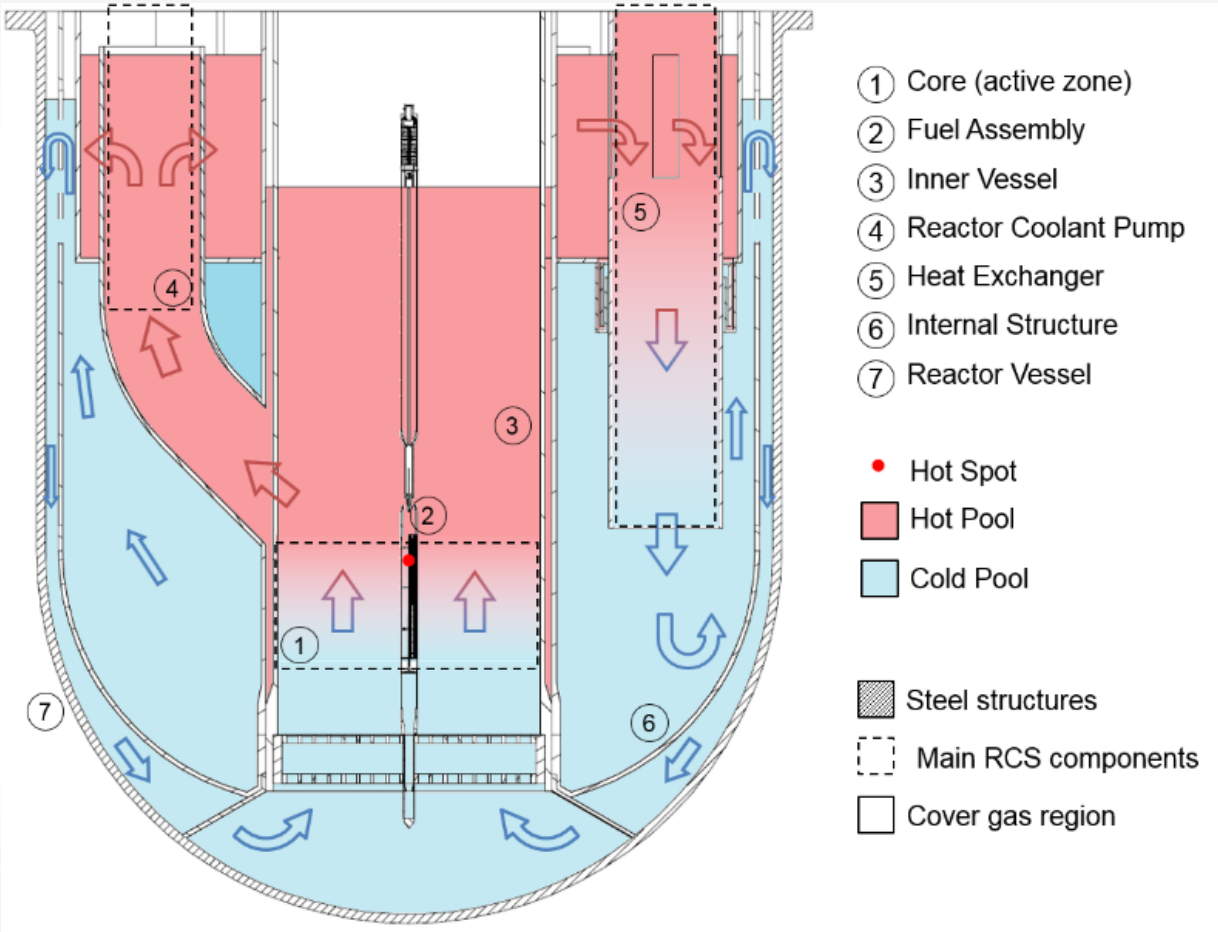
iit (*) ISTITUTO ITALIANO DI TECNOLOGIA

CHALMERS UNIVERSITY OF TECHNOLOGY

Outline

- ALFRED Overview
- Pool thermal hydraulics
- Core thermal hydraulics
- Safety systems thermal hydraulics
- A new research infrastructure

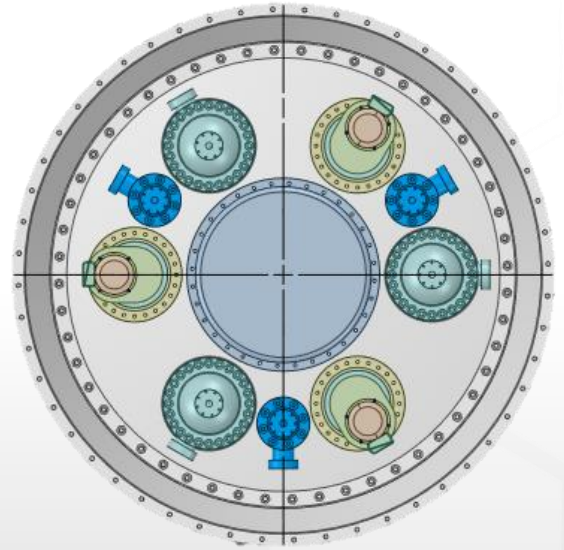
ALFRED Overview



Key parameters:
300 MW_{th}
Lead: 400 – 520°C
Water: 335 – 450 °C

Reactor coolant system:

1 Inner Vessel
1 Internal Structure
3 Steam Generators
3 Primary Pumps
3 Dip Coolers (DHR-2)

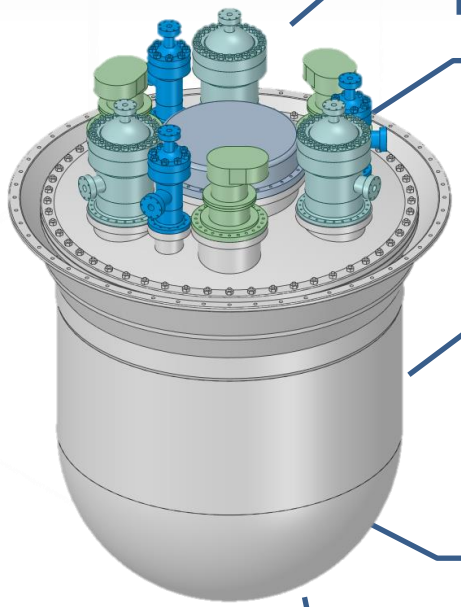


ALFRED Revised Concept

Driven by thermal hydraulic optimization

- A flow path without stagnant regions
- Separation between pumps and SGs
- Single tube SGs at high efficiency

ALFRED bases on lead technology to shorten time-to-market leveraging on SMR features



Relatively low power

Compact design

Removable components

Proven technologies

Simple flow path

Efficient natural circulation

Molten lead as coolant

Excellent intrinsic prop.

Manageable neg. prop.

Pool type Primary System

Pool Thermal Hydraulics – Full CFD Modelling

Challenge

Thermal stratification on reactor vessel causing thermal stresses

Proposed solution

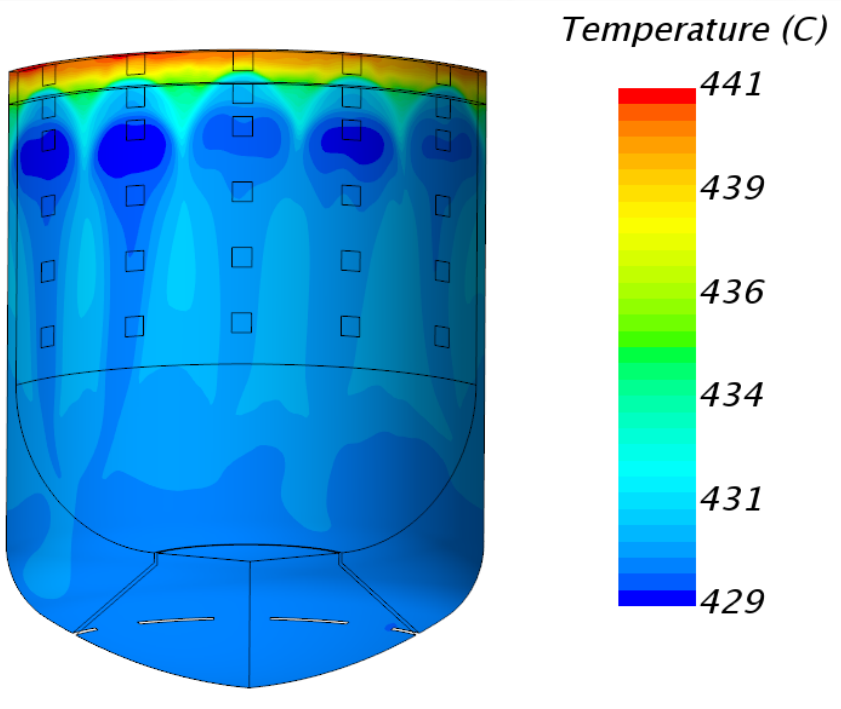
Adoption of internal structure to optimize flow path

Assessment method

High fidelity CFD modelling of ALFRED RCS

Results

Thermal gradients strongly reduced on reactor vessel both in normal operation and accidental conditions



Pool Thermal Hydraulics – High fidelity modelling

Challenge

Uneven temperature and pressure losses at core outlet

Proposed solution

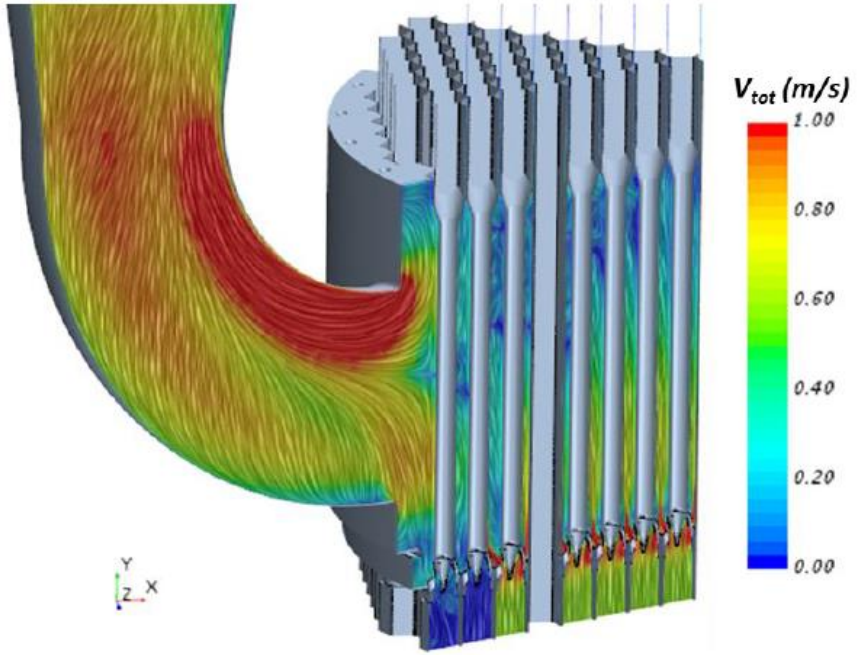
Optimized pumps arrangement and fuel assemblies

Assessment method

High fidelity CFD modelling of ALFRED inner vessel section

Results

Good mixing of outlet flow, reduced average velocity and pressure drops



Pool Thermal Hydraulics – Testing SGs

Challenge

Demonstrating bayonet SG capability as DHR

Proposed solution

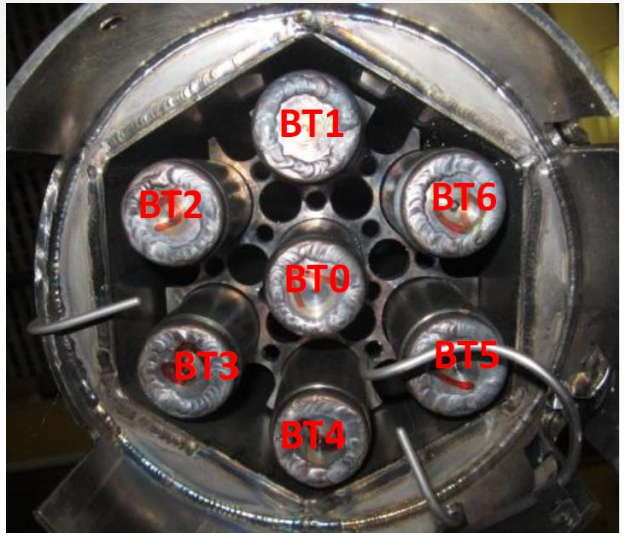
Testing in CIRCE facility ALFRED scaled SG

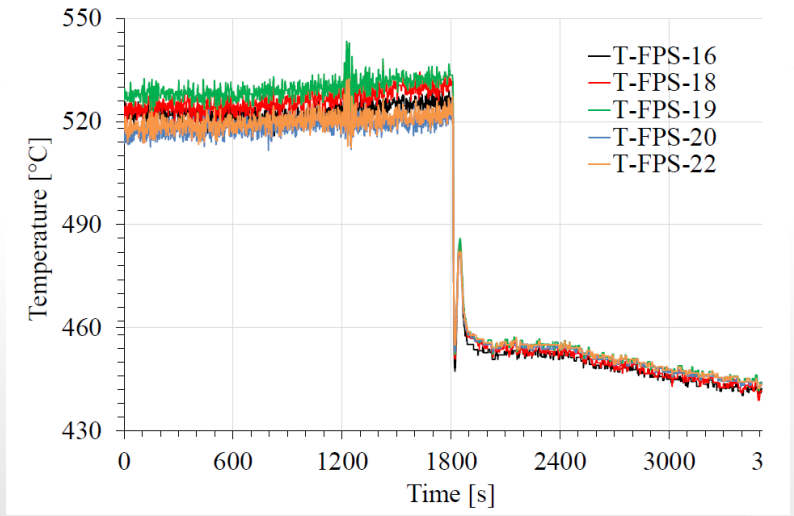
Assessment method

PLOFA Transient test

Results

No temperature peaks on both LBE and clad temperatures





Core Thermal Hydraulics – Subchannel codes

Challenge

Performance prediction of ALFRED fuel assembly

Proposed solution

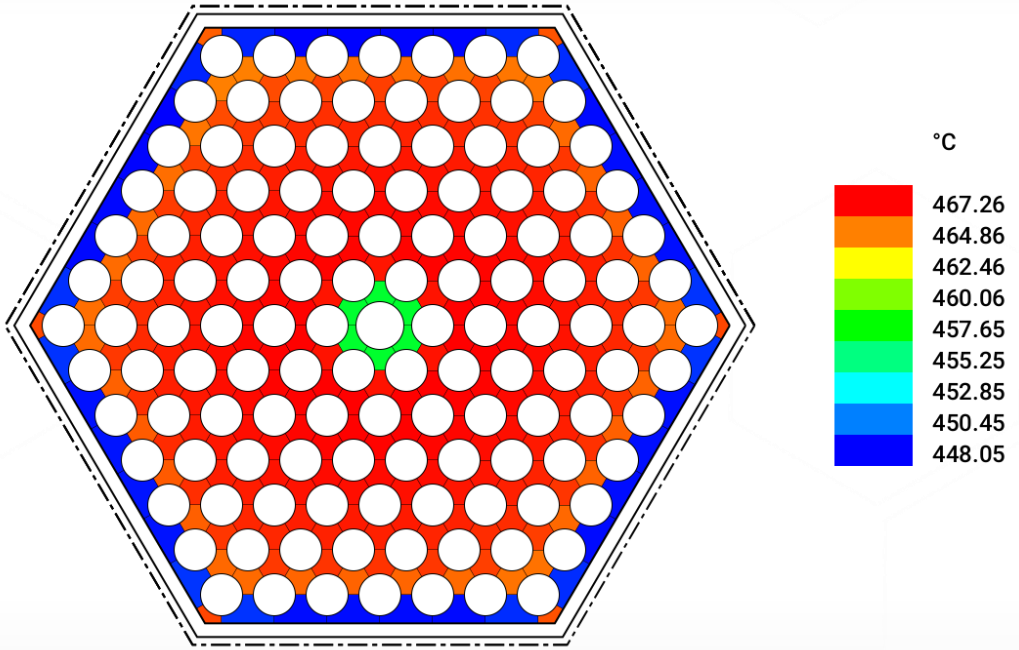
Development and use of comprehensive sub-channel model

Assessment method

Performance studies with ANTEO+

Results

Prediction of temperature field within ALFRED core



Core Thermal Hydraulics – Inter-assemblies

Challenge

Performance prediction of ALFRED whole core

Proposed solution

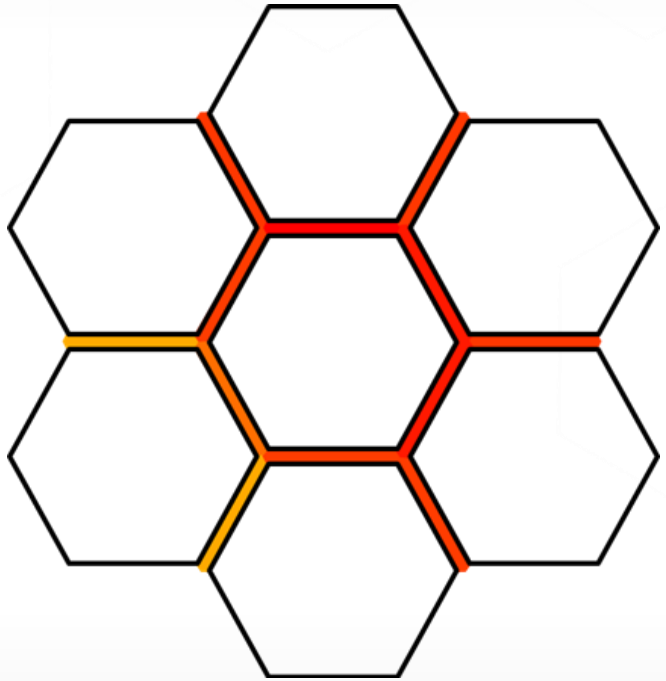
Development and use of comprehensive sub-channel model

Assessment method

Development of TIFONE code

Results

Prediction of inter-assembly (by-pass) temperature field within ALFRED core



Core Thermal Hydraulics – Fuel bundle performance

Challenge

Fuel assembly performance

Proposed solution

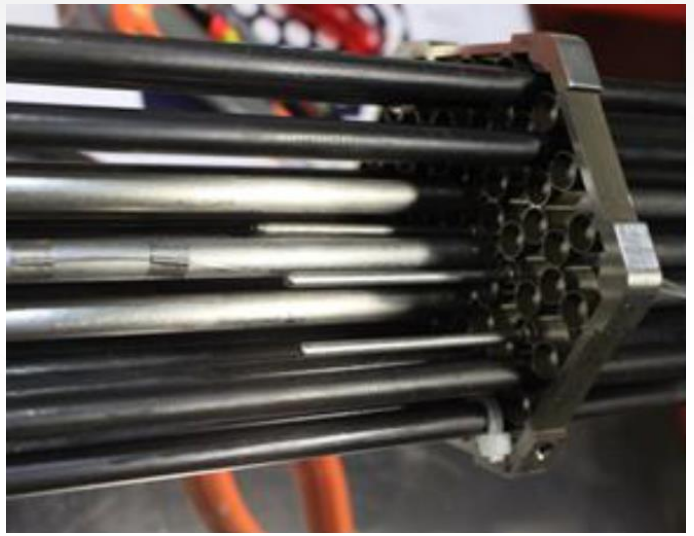
Testing core heat transfer in CIRCE

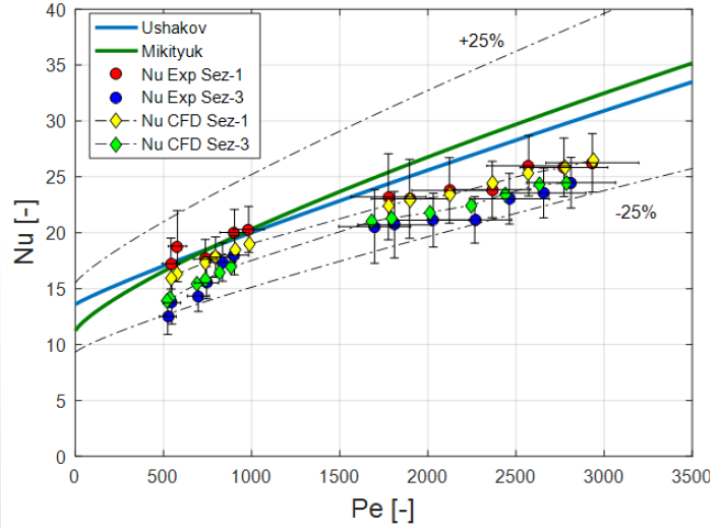
Assessment method

Heat transfer measurement in different operating condition

Results

Validation of empirical correlations





Safety Systems Thermal Hydraulics - DHR

Challenge

Reactor coolant freezing in long term accidental conditions

Proposed solution

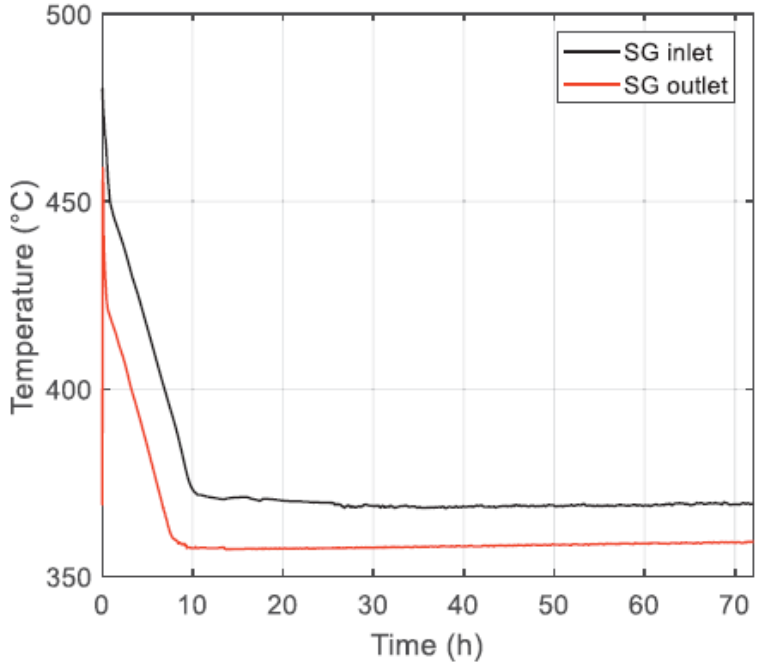
Innovative DHR system with passive power control

Assessment method

Numerical analyses by means of RELAP5-3D code

Results

Effective primary coolant freezing delay



Safety Systems Thermal Hydraulics – flow blockage

Challenge

Flow blockage within the core

Proposed solution

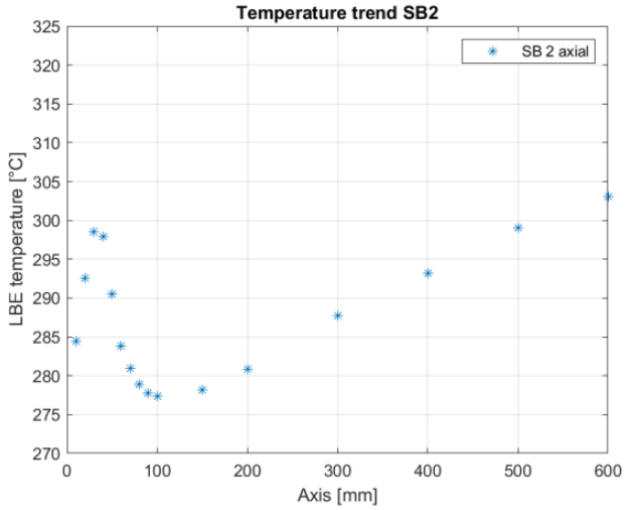
Testing accidental scenario in NACIE-UP

Assessment method

Dedicated test section with artificial flow blockages

Results

Prediction temperature surge within bundle



Safety Systems Thermal Hydraulics – SIRIO

Challenge

Demonstrating ALFRED DHR at relevant scale

Proposed solution

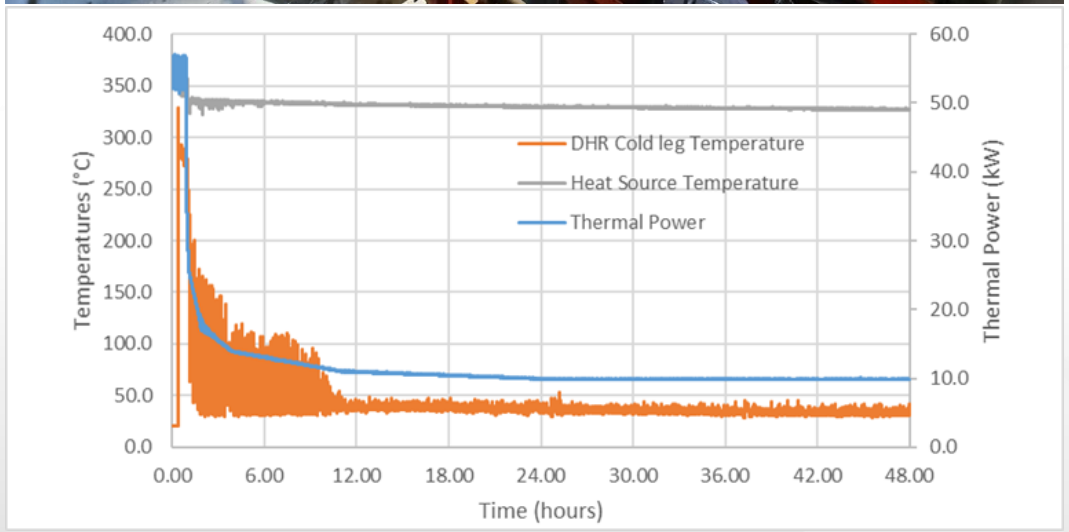
Testing in SIRIO facility ALFRED DHR

Assessment method

PSBO Transient test

Results

Promising results showing heat transfer control capability



Further challenges

In 2020 the FALCON consortium drew up a selection of R&D needs

The topics covered:

- Materials studies and coolant chemistry
- Core integrity
- SGs & HXs functionality and safety
- Fuel assembly transport system and spent fuel management
- Thermal hydraulics
- Pump corrosion & erosion
- Neutronics
- Fuel irradiation testing

The new research infrastructure

FALCON

The largest pool facility in the world, for large-scale components testing in representative conditions

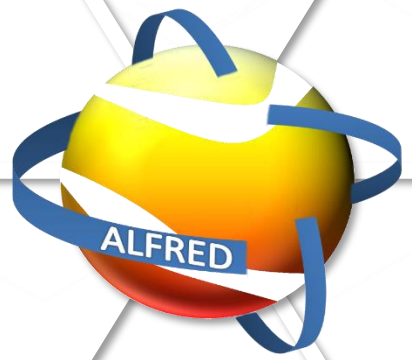
ATHENA

A broad-scope laboratory on the chemistry of HLMs and materials science

ChemLab

A hot facility to characterize radioisotopes behavior in Lead under accident conditions

Meltin'Pot



ELF

A pool facility for long-term experiments, to characterize the components and systems

HELENA-2

A loop facility for full-scale testing and complete thermal-hydraulic characterization of fuel and absorber assemblies

Hands-ON

A facility devoted to the testing and qualification of systems and procedures for the handling of core elements

The new research infrastructure

FALCON

The largest pool facility in the world, for large-scale components testing in representative conditions

ATHENA

Under Construction

A broad-scope laboratory on the chemistry of HLMs and materials science

ChemLab

A hot facility to characterize radioisotopes behavior in Lead under accident conditions

Meltin'Pot

ELF

A pool facility for long-term experiments, to characterize the components and systems

HELENA-2

Fund Requested

Hands-ON

A loop facility for full-scale testing and complete thermal-hydraulic characterization of fuel and absorber assemblies

A facility devoted to the testing and qualification of systems and procedures for the handling of core elements