2023

Jules Horowitz Reactor

Status Report

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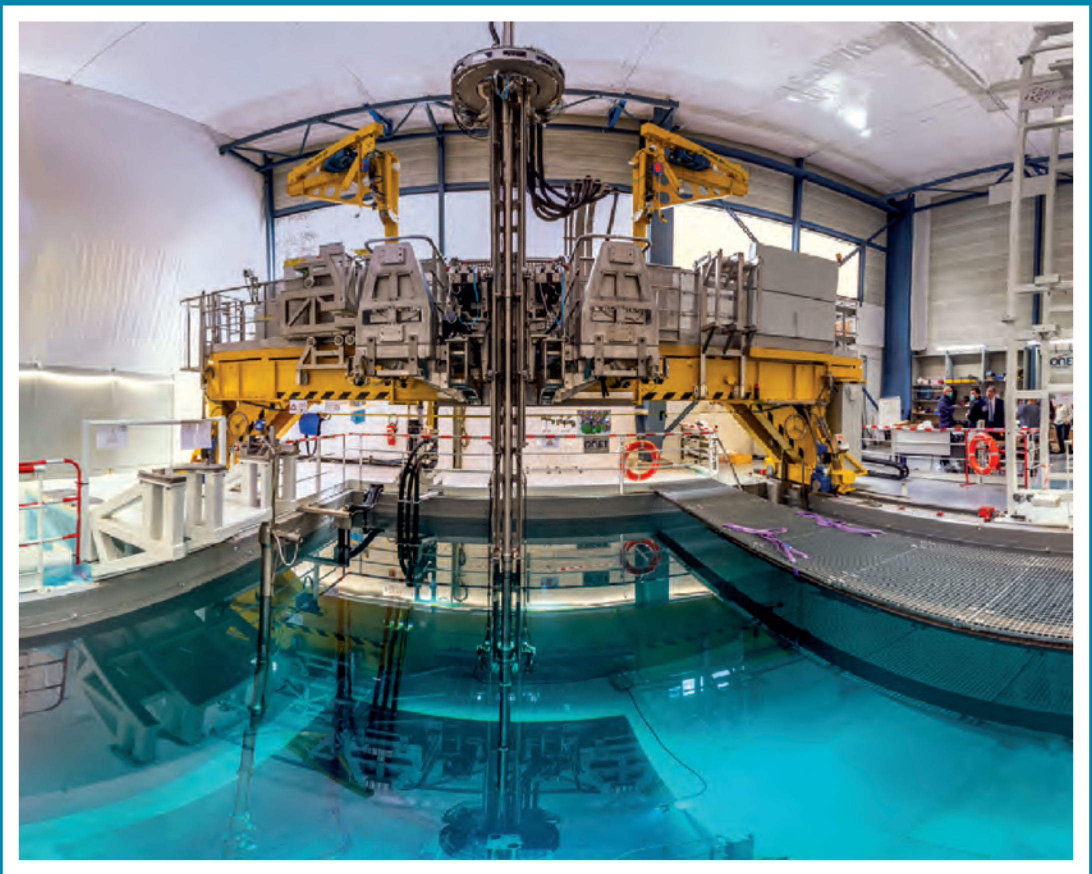
Please refer to pages 74/75 to find the meaning of the acronyms underlined in yellow

Words underligned in blue contain a link to specific pages of the new JHR website



Petri KINNUNEN
JHR Governing Board Chairman

When the year 2022 was a year for roadmapping, the year 2023 turned out to be the year of decisions for the construction of the JHR. The French State associated to the nuclear industry has decided to pursue the investments in this project, endorsing the roadmap elaborated by CEA to finalize the installation of the reactor by 2032-2034. This was very positive and long-awaited step in the project giving lots of boost for the realisation of our common project. New planned start-of-operation should take place during the first half of 2030's. The French State set goals and targets that the JHR Consortium needs to take into consideration in its future activities. One of those activities will be the renewal of the JHR Consortium Agreement being equivalent to the current consortium composition and its targets.

The JHR project management has openly communicated the observed challenges in the construction but been also able to provide technical and organisational solutions for them. Consortium members have had the opportunity to discuss the construction challenges with the project management and gained confidence that the work is now progressing as planned. All members have recognised and shown understanding to the challenges in such a large scale project.

At the same time when the construction works are running again with full power, the operation planning took also major leaps forward. The operation planning for the first 15 years of operation for the Euratom purposes was finalised in autumn 2023 by the EU-JHOP2040 project. The target was not only to write open the technological goals for experimental programmes but also to figure out possible ways for Euratom to take the maximal advantage of their share in the reactor capacity ; several options were presented how Euratom could organise itself towards the operation of the JHR. Also, the operation cost model was sketched by the JHR International Advisory Group giving the foundation on which the future detailed cost structures can be created.

Outside the JHR construction and operation planning, several consortium members have been active in the OECD FIDES II framework continuing the common efforts to design the future experimental capacity also for JHR purposes. The JHR Working Groups have recognised and listed several technological and scientific topics which are of utmost importance to the JHR operation, e.g., different sensor development needs. In addition, the JHR Archive Material initiative was taken to the testing phase targeting to produce reference data for future purposes with a material relevant for the JHR.

The JHR construction project is now in progress again after major decisions. The last couple of years have been very active in many fronts. I have had a personal privilege to be in the core of these activities for the last eight years as the Governing Board (GB) chairman. Now it is time for me to thank the Governing Board, the project personnel and all the great colleagues for their co-operation in this demanding project. After the next GB meeting, the next step in the project takes place again with the new GB chairman.

David EMOND
JHR Project Director

On July 19th, 2023, the French Nuclear Policy Council validated the achievement roadmap of the Jules Horowitz reactor and confirmed the need for putting it in operation by 2032-2034.

The acceleration of site activities has already started with a focus on the electromechanical installation. Safety remains the utmost priority. Despite a loss-time accident occurred in November 2023, the site has reached the record milestone of 3 years without loss-time accident.

In the next months, ramping-up of the workforce will trigger the increase of activities all over the site. By the end of 2024, the Cooling Building will be the first building to be fully completed.

Meanwhile, the first experimental devices will switch from design to manufacturing.

With more than 1 500 km of cables and 40 km of piping, there is still a lot to install but 2024 will show strong progress and will be a new step towards the completion of the JHR. In 2029 the reactor will enter in a testing phase with a first criticality scheduled in 2032.

With the daily commitment of the project team, the contribution of all industrial partners and the support of the consortium members, the Jules Horowitz reactor is now on its path to completion and start-up: 2024 is the year of acceleration and the project team intends to make it visible at site.

As Benjamin Franklin pointed out, “energy and persistence conquer all things”.

2 TOWARD A ZERO ACCIDENT CONSTRUCTION SITE

Guillaume Villard
Safety and Construction Site Manager

The JHR Project team values the health and safety of its employees, contractors and third parties involved in its construction and commissioning activities. Preventing accidents, injuries and ill health while protecting the environment is one of the JHR Project's primary concerns, which is why all the work throughout construction and commissioning has and will continue to be carried out in the safest possible conditions. All of the project's contractors, including the CEA, have signed the industrial safety policy and are committed to making industrial safety their main concern.

The JHR Project strives to provide a safe and healthy working environment for employees and contractors alike; its managers, supervisors, engineers and operatives, as well as its contractors, are all encouraged and expected to proactively contribute to improving its health and industrial safety indicators.

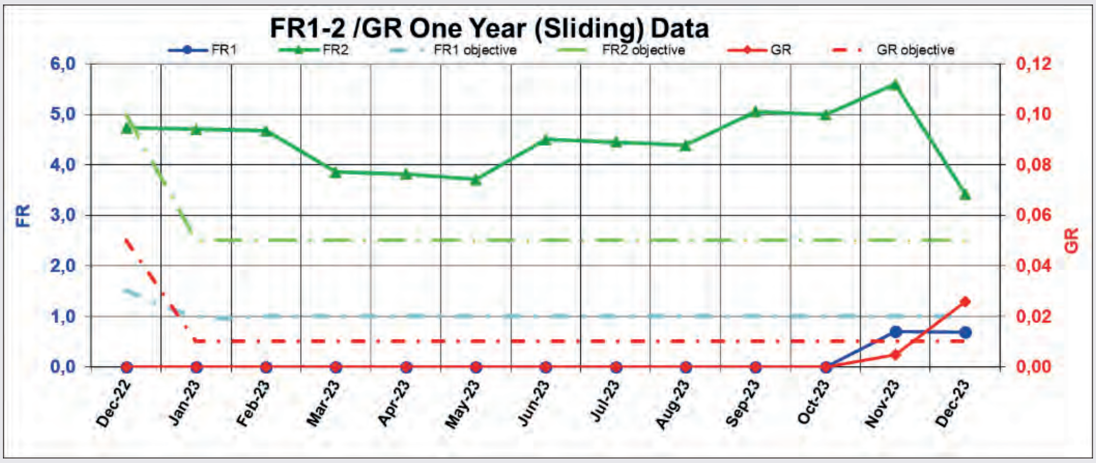
All health, safety and environmental risks are systematically managed as an integral part of the project; accordingly, the behaviour of employees and contractors must reflect the highest industrial safety standards when going about their daily activities.

2.1 Occupational safety

2.1.1 Indicators

The table hereafter shows the main safety key performance indicators for 2023:

Safety Key Performance Indicators in 2023		
FR1 0.7	FR2 3.4	GR 0.03



- *FR1 (Frequency Rate 1 - LTIR): this industrial safety performance indicator defines the number of occupational accidents with lost time over a 12-month period per million hours worked*
- *FR2 (Frequency Rate 2 - TRIR): this industrial safety performance indicator defines the number of accidents with and without lost time over a 12-month period per million hours worked.*
- *GR (severity rate): this industrial safety performance indicator defines the ratio between the number of days lost multiplied by 1,000 and divided by the number of hours worked over a 12-month period.*

Even if these rates remain low for a construction site activity, we unfortunately had, end of 2023, 1 accident with 38 days away from work.

This event put an end to an ongoing record of 1 148 days (more than 3 years) without Lost Time accident.

4 other accidents occurred within the year without lost time.

2023 accident list

Accident with lost of time:

- 23/11 A worker felt pain at his calf while he was pulling a wheeled trolley of cylinder gas

Accident without lost of time:

- 21/11 A worker twisted his ankle while walking backward on a pipe in order to move a safe ladder
- 12/09 A worker crushed his finger between 2 hinged doors
- 07/06 A worker crushed his finger between 2 side of a safe ladder while he was closing it
- 11/01 A worker twisted his ankle walking on the pedestrian path on construction site

This year, 10 events required first-aid care.

Average daily number of workers on the construction site per month in 2023:

Jan	Feb	Mar	Apr	May	Jun	Jul	Aug	Sep	Oct	Nov	Dec
787	793	814	810	809	831	832	785	847	855	878	860

2.1.2. Actions

2.1.2.1 Industrial safety behaviour visits

The JHR project has implemented informal inspections to observe the industrial safety behaviour in the workplace. This involves observing employees (JHR project personnel and contractors) 'in the field' to find solutions to improve occupational safety and the working conditions.

Employees are asked to think about the situation themselves so they can resolve their own industrial safety issues and improve their workplace conditions.

This approach actively engages employees in the implementation of actions that have been decided together.

A total of 74 visits were carried out in 2023, with more than 200 good practices observed and 100 hazardous behaviours corrected.

2.1.2.2 Industrial Safety and Environment Day

The Industrial Safety & Environment Day took place on 3 October 2023 at the JHR construction site. This day was dedicated to well-being at work, industrial safety training and meetings between managers and employees to discuss health and safety matters. All the project contractors were invited to participate to this event, and several workshops were led by contractors, e.g. scaffolding safety or electrical risk detection.

The following workshops were held:

- Local biodiversity awareness: 56 participants
- Stress management through yoga and breathing: 84 participants
- How to use a fire extinguisher: 74 participants
- Slip and trip hazards: 45 participants
- Resitting the driving theory test: 60 participants
- Psychosocial risks at work: 45 participants
- Lifting activities: 47 participants
- Electrical risks: 75 participants
- Safety theatre: 71 participants
- Drugs and alcohol / Road safety with policemen: 56 participants
- Risk prevention card games: 11 participants
- Work at height risks: 50 participants
- Scaffolding safety: 18 participants
- Rollover car: 114 participants
- Shock test car : 115 participants
- Office risks in virtual reality: 33 participants

2.2 Site safety community

2.2.1 Company industrial safety award

In 2023, four company safety awards were presented at the general safety assembly for the implementation of good practices, deployment of new industrial safety initiatives, and ownership of industrial safety issues.

The following companies were rewarded:

- Q1/2023: GTM SUD
- Q2/2023: CVR
- Q3/2023: EUROVIA
- Q4/2023: WSP

2.2.2 Employee of the month

In 2023, twelve staff members were presented with an 'employee of the month' award for the following reasons:

- Zero industrial safety non-conformity events observed over a period of 3 months (compliance with the JHR safety fundamentals)
- Model behaviour with respect to the industrial safety rules (wearing safety equipment, following procedures, etc.)
- Good safety initiatives and safety proposals
- Polite and open communication in safety and environmental matters
- Proactive warnings about hazardous situations

2.2.3 Emergency drills

17 emergency drills were organised in 2023 to train staff to react correctly in the case of an accident and to benefit from lessons learned. Hazardous situations are analysed and 'victims' are evacuated from areas considered difficult to access in order to test the emergency preparedness set-up.

In december, the JHR Project organized an important safety event involving more than 50 firemen highly specialized in hazardous environment, occupational doctors, Radiation Protection Department team members (SPR) and part of the CEA rescue team.

The purpose was to test our capability to rescue victims in 6 highly difficult-to-access areas into JHR buildings.


WEIGHT
1195 KG
IDOM
IDOM
IDOM

Fabrice CARLE
Client and Consortium Manager

3.1 Consortium organisation

The JHR Project is steered and financed by 15 partners within an international consortium; the consortium agreement states the rights and obligations of each member, providing a model for governance during the construction and operation phases.

The consortium is managed by the governing board. Each member of the Consortium appoints a representative to attend the governing board meetings.

Petri KINNUNEN
JHR Governing Board Chairman

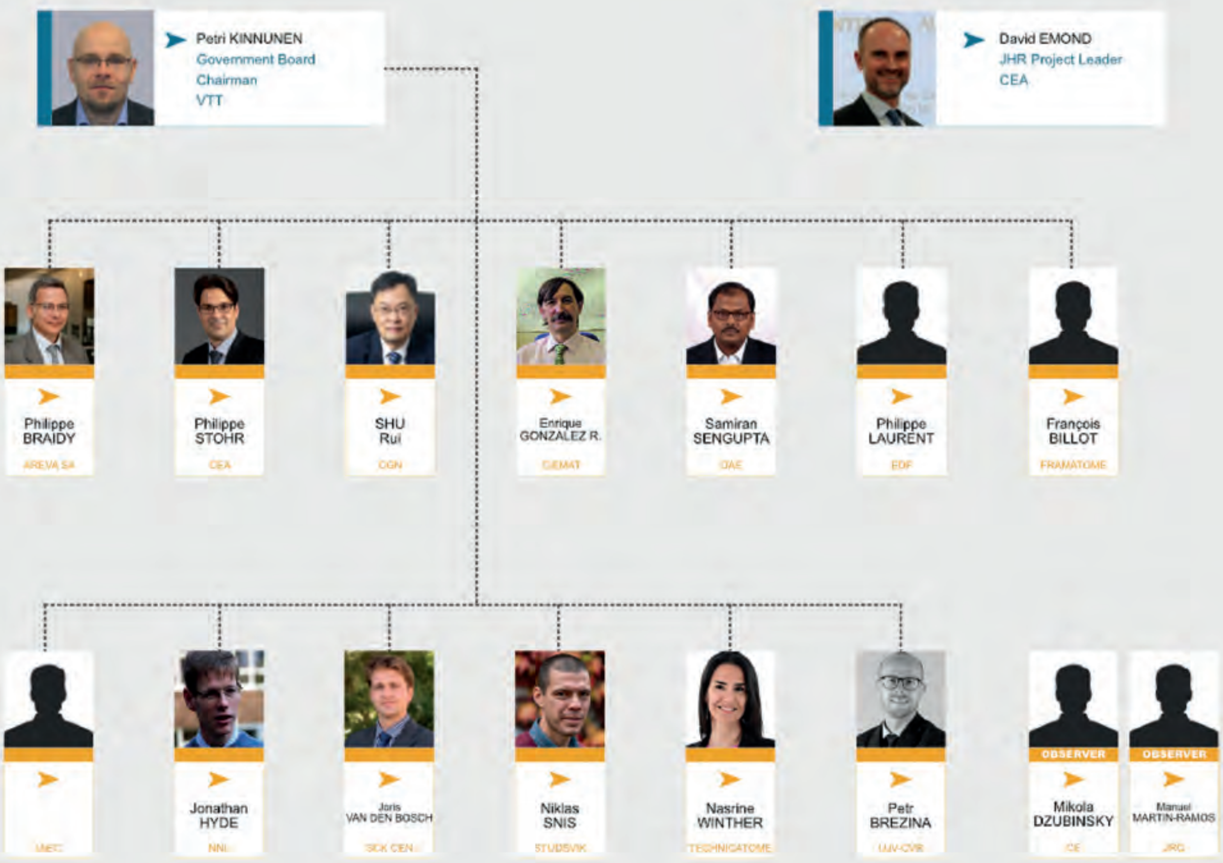
The governing board is responsible for defining the policy and strategic orientations of the consortium.

The governing board members appoint a chairperson to manage the meetings and duties for a period of four years. The current chairman was re-elected for a second 4-year term in 2020.

David EMOND
JHR Project Director

A project leader, appointed by the CEA and approved by the governing board, is responsible for the construction phase. This involves managing the day-to-day activities associated with construction.

ORGANISATION CHART



3.2 Governing board and consortium activities

3.2.1 Consortium new members

The CEA is mandated by the governing board to enlarge the JHR International consortium by accepting new members. During the year 2023, the CEA continued to exchange with potential clients having shown interest in joining the JHR international consortium. Following the important decision made by the French Nuclear Policy council in July 2023, CEA is now in a position to propose to some "targeted countries" to enter the JHR consortium. (Up to now, CEA's efforts are focused on Japan and Republic of Korea).

3.2.2 JHR working groups

The three JHR working groups (fuel, material and technology) were pleased to meet twice in 2023:

- At the 12th scientific and technical seminar in Aix-en-Provence (France) in June
- During a series of specific meetings in Madrid (Spain) organised by colleagues from CIEMAT who also planned visits to the ENUSA fuel fabrication plant

The main activities in 2023 of the three working groups involved were to:

- Provide information and deliverables in support of the JHOP 2040, a European project (see below)
- Exchange on several key topics strongly linked to JHR experimental capacity (for example LOCA tests for FWG, JAM samples for MWG, LVDT supply for TWG…)

It also underpins the importance of launching the 'pre-JHR' phase through several joint research programmes in operating MTRs (see OECD/NEA FIDES framework, EURATOM framework, etc.) in order to be able to optimise the experiments in the JHR.

3.2.3 JHOP 2040

The goal of JHOP 2040 is to bring the JHR consortium members together with the key players involved in the project, as well as all relevant European nuclear research associations and EU Member States not represented in the JHR consortium. The ultimate goal is to produce strategic research roadmaps for JHR operation during the first four years and then for the following 11 years of operation.

JHOP 2040 includes the following members / countries:

- European Commission: JRC
- Finland: VTT
- France: CEA, EDF
- Czech Republic: CVR
- United Kingdom: NNL
- Sweden: STUDSVIK
- Belgium: SCK CEN
- Spain: CIEMAT

The main objectives are to:

- Structure the financial aspects of the project and provide a framework for EURATOM, taking into account governance and cost breakdowns for each programme.
- Identify and review the current and future needs for fuel, materials and technology, both within and outside the current JHR consortium.
- Guarantee the extensive use of the JHR facility via EURATOM access rights and fully exploit the planned JHR capacity by promoting and enhancing collaboration between potential users.

The project started in September 2020 and was fully completed in September 2023. All the documents originally scheduled in the project have been published (available on the JHOP 2040 sharesite) after an ultimate external review done by the International Scientific Advisory Group of the project and after the endorsement of all of it by the JHOP 2040 members during the final general assembly hold in Madrid in September 2023.

For 2024, discussion around the conclusion of the JHOP 2040 project will be held between the General Directorate of Technologies and Research Development (DGRTD) of the European Commission, the CEA and VTT (the JHOP 2040 Project Leader).

3.3 JHR an international facility

3.3.1 Scientific seminar

The 12th scientific and technical seminar on the JHR experimental capacity was held from 7th to 9th June 2023 in Aix-en-Provence, with the possibility of remote participation through videoconferences for colleagues who were not able to travel (China, India).

Some dedicated non-members of the consortium were invited to participate (US-NRC, IRSN).

Around 80 people attended the seminar (around 50 in person, the other half remotely), during which the JHR community was given an update on the progress of:

- JHR project
- Design of the experimental devices (fleet 1 and fleet 2&3)
- In-kind contributions for experimental devices (as CLOE loop from BARC) but also experimental devices developed by JHR partners (such as RISHI loop from IGCAR and Pb-Bi caspule from CGN)
- Secondee's work, which included a presentation
- An embedded 2nd JHOP 2024 Workshop in line with the completion of this European project end of September 2023
- Preparation of international joint programmes (OECD/NEA/FIDES EURATOM framework especially the CONNECT-NM initiative under finalisation, etc.)
- Feedback from the JHR WGs synthesis document issued mid-2022 (R&D needs and joint projects for "pre-JHR phase")

Half a day was dedicated to parallel sessions organised for each working group.
A technical visit of the JHR building site and the CABRI research reactor was organised and greatly appreciated by the participants.

3.3.2 OECD FIDES framework

After the phase-out of the Halden reactor (mid-2018), the OECD decided to launch a new initiative called FIDES, i.e. the Framework for IrraDiation ExperimentS.

This initiative federates a broad scientific community around material test reactors to propose several joint R&D programmes on fuel and material behaviour studies under irradiation.

The CEA and its partners from the JHR consortium have been actively working on the FIDES legal framework agreement, as well as preparing the first joint experimental programmes based on topics proposed by the JHR working groups. The CEA has also confirmed that once the JHR starts operating, the OECD-NEA community will be able to perform important research programmes on innovative fuel and structural materials.

The FIDES legal framework was officially launched in March 2021, gathering 27 organisations whether nuclear operators, fuel manufacturers, R&D organisations, or TSOs.

The year 2022 saw an overall increase in the number of activities led by the joint research project. Nevertheless, due to the international context and the fact that the OECD council suspended the Russian members from taking part in all activities in May 2022, a new framework called FIDES-II was created; it is similar to the original framework but no longer includes the three Russian members in the first FIDES. The new framework for FIDES-II with 24 organisations was officially endorsed at the governing board meeting in October 2022, and there has been no impact on the progress of the R&D projects thanks to the excellent responsiveness of all members.

The fall 2022 governing board meeting endorsed an additional joint R&D projects (called JEEP) to the four already on-going : it is called INCREASE and is aiming to study behaviour of structural material (outside cladding material) under neutron irradiation in the MIT-R (USA) firstly and then in the HFR in Netherlands. This INCREASE joint project embarks sample from the JAM initiative (Jules horowitz Archives Material) with strong support from the Material WG.

The United Kingdom enter officially the FIDES-II framework as a new member in October 2023.

Hence, the JHR consortium members are particularly involved in three projects: the 'Power to Melt and Manoeuvrability' (P2M) project that sets out to perform slow-power transients to reach partial fuel melting, the 'In-Pile Creep studies of Accident-Tolerant Fuel cladding' (INCA) project and this last INCREASE project led by INL from the USA.

3.3.3 Jules Horowitz Archive Material (JAM)

The Material working group is currently focusing on an important topic linked to the specific neutron spectrum in the JHR.

The group is studying the behaviour of reference materials in different neutron spectra; firstly, in operating MTRs such as the HFR in the Netherlands and LVR15 in the Czech Republic, and later in the JHR to build a data bank on reference materials (stainless steel) that will be used for the entire service life of the JHR.

Significant work continued in 2023 on supplying the reference material from a Belgium company, delivering the Stainless Steel plates at CEA-Saclay and by starting cold characterisation before sending some of these reference samples for irradiation. This cold characterisation greatly benefits from the deputation in Saclay of a young material scientist from VTT.

Following the efforts made by the Material working group members, this JAM project is now embedded into the INCREASE joint program quoted above. These JAM samples will be integrated with other samples in a capsule type device that will be installed for irradiation in the MIT-R. The beginning of irradiation is foreseen mid-2025

3.3.4 IAEA ICERR

The CEA was named an International Centre based on Research Reactors (ICERR) by the IAEA in 2015 for 5 years. Such international recognition has led to successful collaborative actions with several IAEA member states. In late 2019, the CEA decided to submit its candidacy for the next 5 years with a new scope including the CABRI research reactor and the JHR. After a rigorous assessment process carried out by the IAEA in 2020, the CEA and its partner IRSN were chosen in December 2020 to be an ICERR for the next 5 years.

Within this ICERR framework, the main highlight were the following:

- Preparation of hands-on training staff from Federal Authority for Nuclear Regulation (Regulator of the United Arab Emirates) on fuel & material sciences
- Preparation of an experimental campaign in the Jordan Research and Test Reactor owned by JAEC (Jordan Atomic Energy Commission) for precise core characterisation (postponed due to the international context)

3.3.5 Conferences

JHR and CEA were attending International and European events regarding fuel and material experiments or dedicated to material and test reactors during while several presentations on the JHR project were given to communicate on an update of the JHR project, the preparation for operation, experimental devices under development and the main outcomes of the European Project JHOP 2040.

- 5th edition of the Device Material Test Reactor, a privileged time to exchange on MTR issues
- International Group On Research Reactors (IGORR)
- International Conference on Advancements in Nuclear Instrumentation Measurement Methods and their Applications (ANIMMA)
- European research reactor conference (RRFM)
- IAEA International conference on research reactor

This year, JHR direction aslo welcomes national and local elected representatives with the objective to sensibilized the decision-makers to the central role the JHR will play in support to the nuclear industry and to nuclear medicine.

The CEA and JHR client and consortium directorate also participated to many events related to the medical radioisotope production in order to communicate on the new schedule.

3.3.6 French Decision makers visits

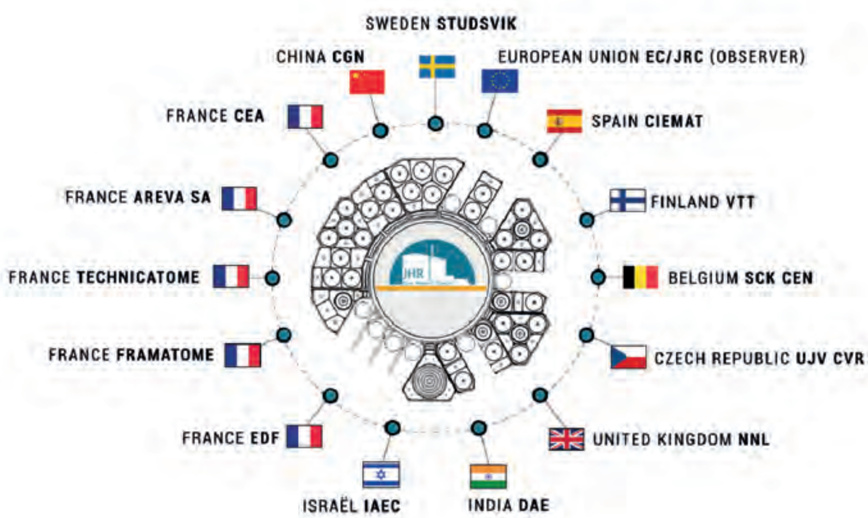
In order to support the roadmap proposed by CEA to the French State for the JHR completion, JHR Direction organised JHR visits with French decision makers as:

- International French parlementarians
- French local parlementarians
- Local representatives

3.4 Renewal of the consortium Agreement

The French government approved further investment in the JHR project last July. One of the resulting actions is the revision of the original consortium agreement of 2007, which regulates the rights and obligations of each consortium member, taking into account the updating of outdated data (cost at completion, schedule, governance, etc.) as well as the methods of additional contribution to the reactor construction costs and contribution to the annual operating costs.

To this end, the consortium's customer management team gave a verbal presentation to each member on the main issues involved in updating the agreement. Following the board meeting in October 2023, a roadmap was communicated to all members with the aim of signing the new agreement by the end of 2025.



4 DELIVERING THE JHR REACTOR AND EXPERIMENTAL DEVICES

David Emond
JHR Project Director

4.1 Project roadmap and overall schedule

During the Nuclear Policy Council of 19 July 2023, the French State decided to pursue the investments in this project to finalize the installation of the reactor by 2032-2034.

To do so, the project needs to implement the validated roadmap based on the following challenges:

- Sustain results in the field of occupational safety
- Erect, install, commission and start-up in quality according to schedule
- Sign variation orders and new purchase orders according to site needs
- Anticipate licensing process
- Continue deploying best project management standards
- Secure resources
- Prepare for technical and commercial operation

Regarding the schedule, the project management team, along with all contractors, target that JHR shall be ready by the end of 2032.

The main milestones that structure this new schedule are as follows:

2024	Finalize the 3D model of the lay-out. End of preparatory work in the reactor hall (bridge walkway, feedthrough ducts machining, pool gutters)
2025	End of the detailed preliminary design phase of the 1st fleet of experimental devices Ramp-up of the electromechanical assembly of the Reactor Building
2026	Start of Experimental area assembly
2027	End of assembly in Annex Building
2028	End of assembly of the primary circuit
2029	Commissioning of electrical distribution and start of system tests
2030	Filling of Annex Building pools
2031	Filling of Reactor Building pools
2032	Fuel loading and First Criticality (start-up)

Philippe GAÏ
Project Control Manager

Pascal Pierre
Reactor Block
and Moly system Manager

4.2 Milestones in 2023 and 2024

The management of the 2023 key milestones has been closely monitored. Thirty-five milestones have been identified and 86% of them have been reached on time.

In particular:

- Implementing the monitoring of assembly activities with the main suppliers
- Defining the industrial strategy for the realisation of the experimental devices
- Finalizing the detailed design of the Building containing the "hard core" set of safety equipment BND
- Validation of the optimized configuration for the control rod guide tubes
- Negotiating the contract amendments for fluids, ventilation and electricity at completion
- Defining 85% of the detailed sequences to enable the ramp-up of the assembly phase

In July 2023, the completion roadmap has been approved following the review of schedule, costs and risks by the French government.

Thirty four milestones have been identified in order to implement this roadmap. They will be monitored during this year 2024, with 3 of them considered as risky that will be monitored more closely.

4.3 Reactor block and Moly production

In 2023, the main activities on the reactor block project are described hereafter.

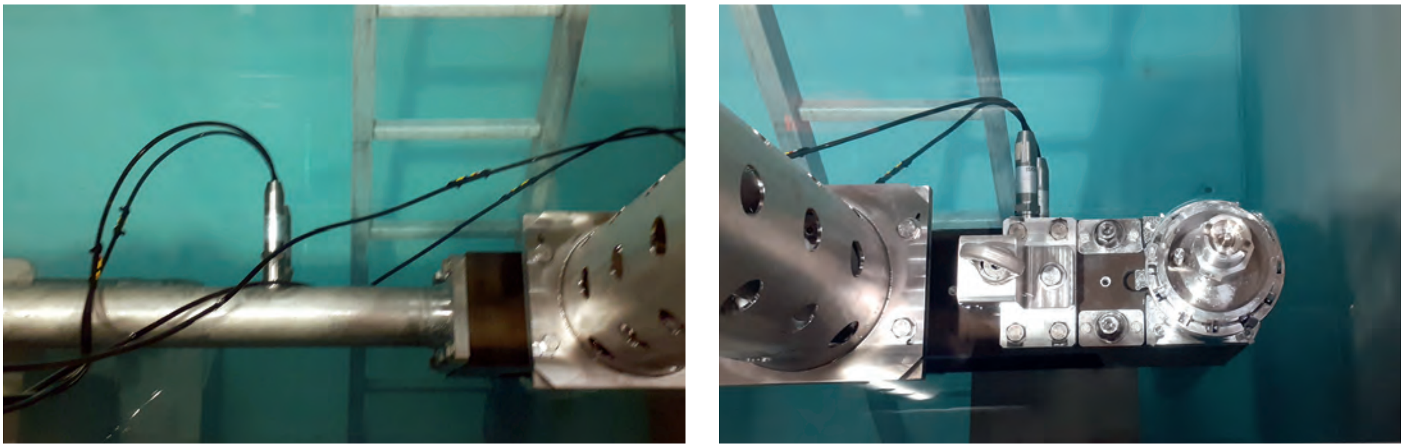
4.3.1 MOLY displacement system project (MOLY project)

The new configuration of the MOLY refrigeration circuit, to improve its robustness and reliability has been studied, leading to news specifications for the MOLY contracts.

Additional hydraulic tests were performed in December 2023 to assess the performance of the MOLY disposal and bypass system with respect to the pressure and flowrate requirements.

The part of the MOLY equipment not affected by the new configuration is under completion.

Hydraulic test system



Bypass with upstream/downstream pressure sensors

4.3.2 Pile block unit

Factory activities

In 2023, the factory activities concerning the pile block equipment continued in a nominal way except for the displacement system, where a flaw was identified during qualification tests on a mock-up.

Monitoring mechanisms

- Leak test of Junction Boxes successfully completed

Launch of thermal aging tests planned during the 1st quarter 2023

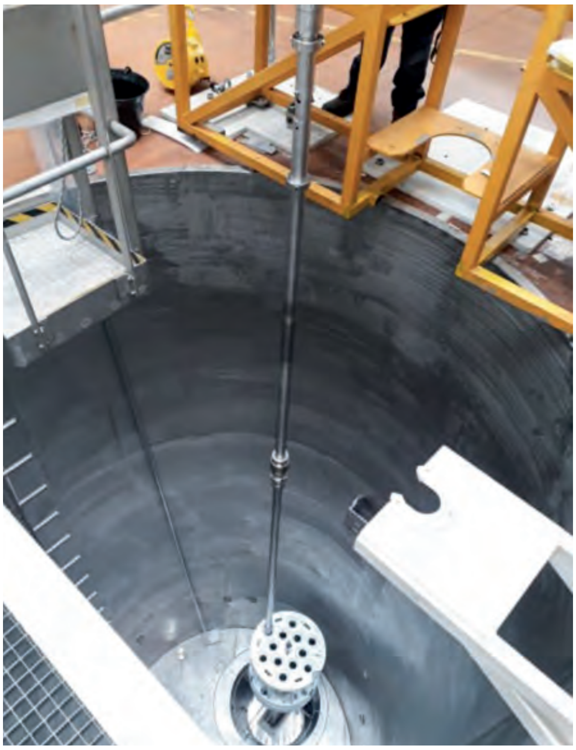
- Calibration of hydraulic loop sensors for mechanism acceptance tests
- Nominal operation of the factory tests of the backup and shutdown neutron absorbent mechanisms following the resumption of detector target assembly

Displacement system mock up

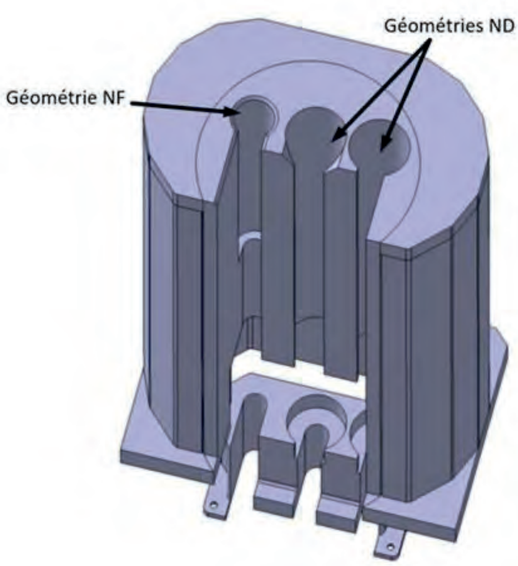
Integration of the new mechanical seal on the V2 mock up allowing the start of water tests

Other equipments

- Factory tests of rack tools

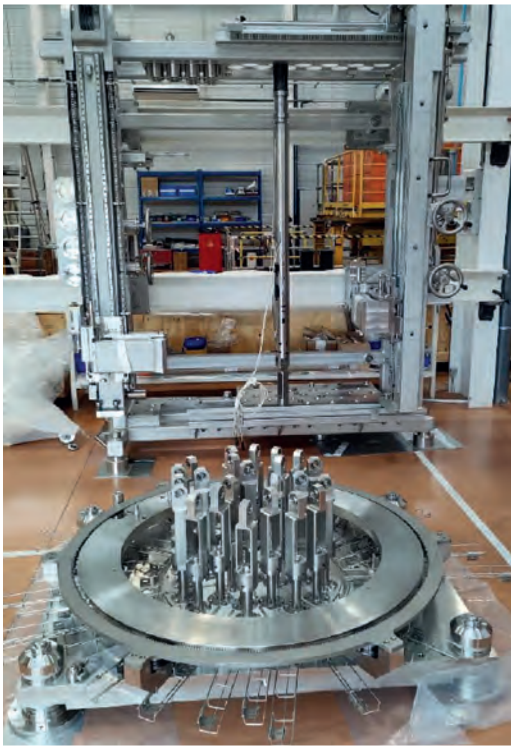


- Prototype of neutron starting and power chain frames of ex-Core launched in manufacturing



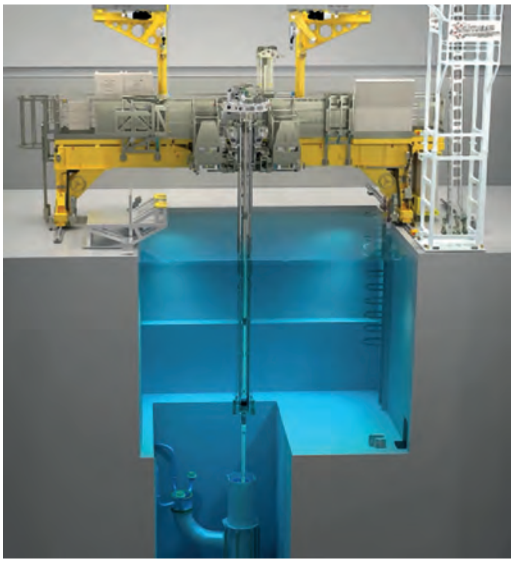
On site activities

- End of the cleaning of the feet of the floor in reactor pool and stop in rotation of the screws M100
- Delivery on 07/12/23 of equipment used for handling in crypt mechanisms

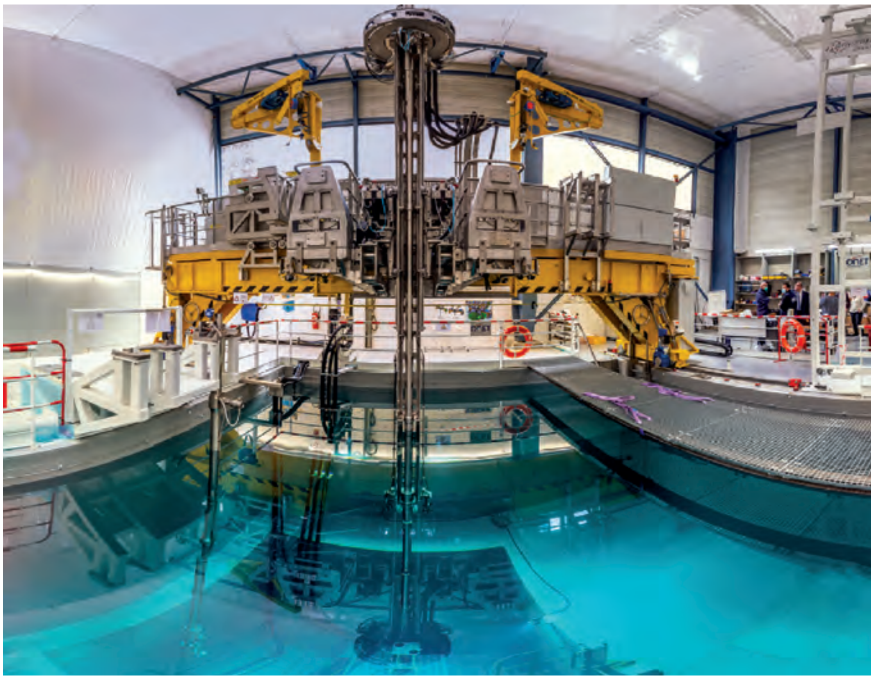


4.3.3 Loading/unloading machine

In the second quarter of 2023, the final factory tests were successfully completed, enabling the future operator to finalize his training.



Design view of the loading test



View of the loading test realized with the JHR machine on the factory site

At the end of 2023, the subcontractor's workshop was fitted out to enable long-term storage of the equipment.

Storage of the loading machine at the subcontractor facility

4.3.4 Cooling systems

4.3.4.1 Primary Circuit pumps

Qualification tests on pump n°2 showed the need for implementing some technical improvements. They were also implemented on pumps n°1 and 3.

Pumps n°1 and 2 were successfully retested and pump n°2 was disassembled to check all components. Tests of pump n°3 are scheduled in 2024: the last factory tests will be realizes before site delivery.

4.3.4.2 Primary circuit

At the end of 2022, a discrepancy between the calculation requirements and the geometry of the already supplied DN 400 elbows of the primary circuit was detected.

It was decided in 2023 to repair or change the impacted elements.

Extrusion of the elbows of the primary circuit

4.3.4.3 Progress

Onsite activities

Heat exchangers (Spanish in-kind contribution)

After completed visual inspections on the 3 heat exchangers (between January to August 2023), different types of indication were founded (cf. pictures here under for example).

After theses inspections, a root cause analysis has been realized, in order to understand the origin of the phenomena and to choose the best way to repair the heat exchangers.

To complete this analysis, CEA has extracted 12 tubes on the heat exchanger n°1 in order to do some chemical analysis.

The tubes have been extracted at the end of 2023. The results of the expertise will be available at the beginning of 2024, and after that, the decision to repair the heat exchangers will be made between :

- "Mitigation solution A": realize a mechanical brushing inside the tubes and flushing on the secondary part
- "Mitigation solution B": replace the primary tube bundle in factory

Here under some pictures of the extracted tubes:

KEY MILESTONES IN 2024

- Modification and qualification tests of the displacement system
- Reparation of the heat exchangers according to the mitigation solution chosen
- Finalization of the clamping of the Central Fixed Point of the primary circuit

Jean-Pierre MUNOZ
Fluids Manager

4.4 Fluid systems

4.4.1 Engineering

MAIN ACHIEVEMENTS IN 2023

The main achievements for the fluid systems are:

- Successful completion of the design finalisation reviews for configuration V3.2 corresponding to the erection configuration status
- Ongoing work on the detailed design of the lower floors (level 0, -1, -2 and -3) in the nuclear auxiliary building (BUA), and lower level of the nuclear reactor building (BUR except the experimental areas) to secure the estimated erection timeline

KEY MILESTONES IN 2024

The main milestone identified for the coming year is the optimisation of the JHR 3D model on all levels in order to complete the launch of the detailed design documentation (isometrics), except part of the CEDE erection areas in the nuclear building.

4.4.2 Manufacturing

The main achievements in fluid system manufacturing are:

- Delivery of major components for the conventional auxiliary building (BMR)

Compensators

Pumps installed in the BMR level +1

- Manufacturing of pipe spools and supports for the auxiliary refrigeration and utility building

Manufacture of piping

KEY MILESTONES IN 2024

The key milestones for 2024 are to:

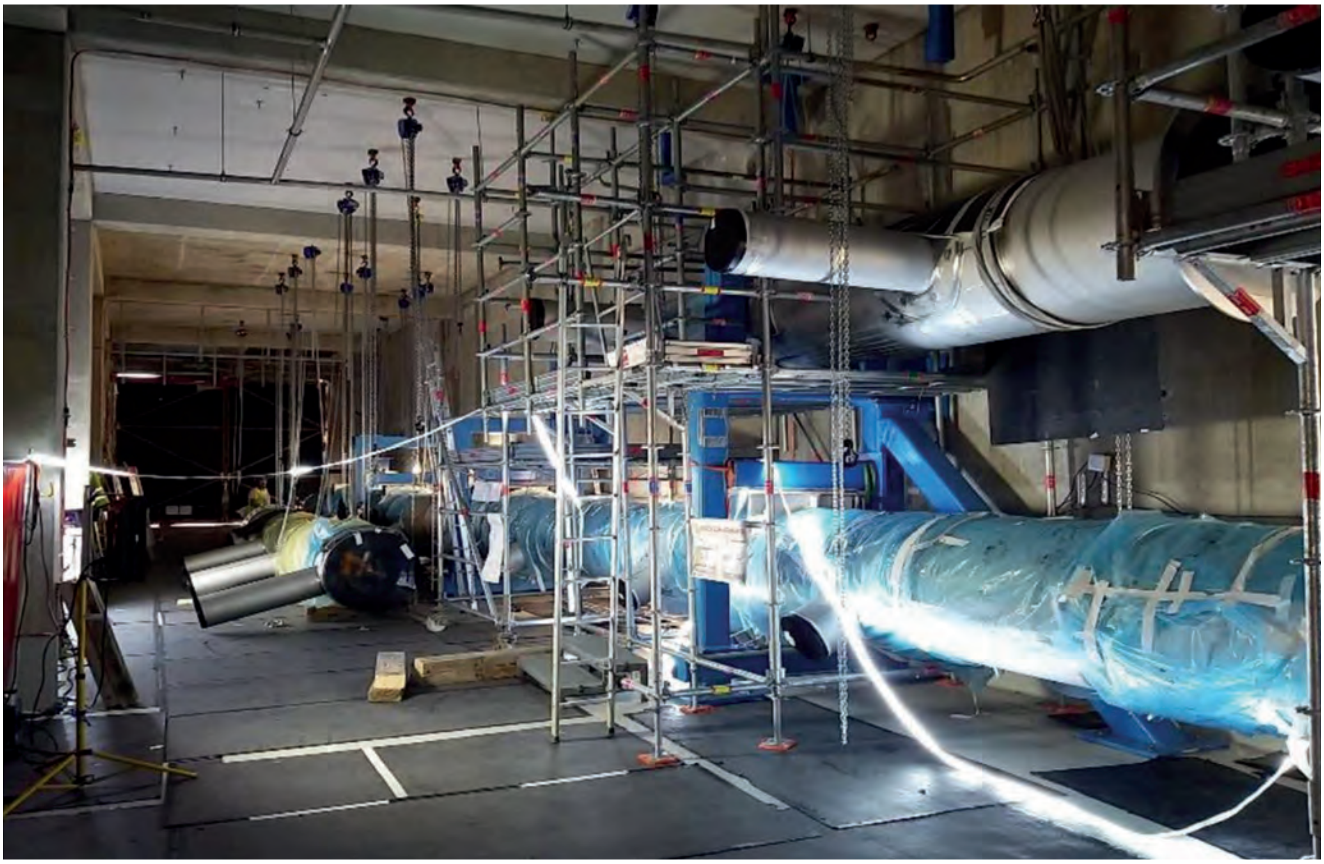
- Continue the delivery of key components and equipment for the auxiliary refrigeration and utility building, as well as components for the nuclear auxiliary building
- Secure the piping spool production according to the estimated erection timeline

4.4.3 Assembly

MAIN ACHIEVEMENTS IN 2023

In terms of construction, this year saw:

- Delivery and installation of all major components in the BMR building



Mounting of brackets and piping in the BMR level +0

- Continued installation of the fluid systems in the nuclear unit building (level -2 and -3)

KEY MILESTONES IN 2024

In 2024, the team will focus on:

- Finalising the piping installation on level -2 and -3 of the nuclear auxiliary building (BUA)
- Making progress in installing the plant's secondary and tertiary system components and piping parts from the nuclear building (BUA) up to the auxiliary refrigeration and utility building (BMR)

David Angebaud
HVAC Manager

4.5 HVAC systems

4.5.1 Engineering

4.5.1.1 HVAC (excluding the emergency diesel generator building, BAS)

MAIN ACHIEVEMENTS IN 2023

The main achievements for the HVAC systems are the freeze of the erection references of the JHR 3D model on all levels of the BUA and of the BUR. Detailed design documentation production was launched accordingly.

For the CEDE erection areas, the specification for the update of the functional requirements has been finalised.

KEY MILESTONES IN 2024

The following main tasks planned for the coming year are:

- Update the functional system files and 3D model for CEDE -1, -2 and -3
- Production of the detailed design documentation to secure the erection phases schedule

4.5.1.2 HVAC safeguard building (BAS)

MAIN ACHIEVEMENTS IN 2023

For the HVAC safeguard building (BAS), the completed design review allowed the finalisation of the 3D model arrangements.

The freeze of the erection reference of the 3D model permitted the launch of the detailed design documentation.

The main activities will be to finalize the design and go through the on site installation.

4.5.2 Manufacturing

4.5.2.1 HVAC (except the emergency diesel generator building)

KEY MILESTONES IN 2024

The main manufacturing achievements of the year are:

- Manufacturing of components and equipment to be installed on the lower floors (level -1, -2 and -3) of the BUA building, the conventional auxiliary building (BMR) and the mezzanine floor of the BUR reactor hall

- Manufacturing of non-safety-classified equipment

Refrigerating Unit

HVAC Electrical Distribution Panel

- Launch of prototype manufacturing for most important safety-related equipment in order to launch qualification and consequent "in-series" manufacturing processes

KEY MILESTONES IN 2024

The key milestone for 2024 will be to continue delivering key components and equipment for the auxiliary refrigeration and utility building, as well as components for the BUA and BUR.

4.5.2.2 HVAC safeguard building (BAS)

MAIN ACHIEVEMENTS IN 2023

The main manufacturing achievements of the year were:

The manufacturing of some major components such as the fans:

KEY MILESTONES IN 2024

2024 will secure the finalisation of all major equipment qualifications and execute the site deliveries of the components and equipment according to erection schedule requirements.

4.5.3 Assembly

4.5.3.1 HVAC (except the BAS buildings)

MAIN ACHIEVEMENTS IN 2023

In 2023, installation work were focused in the BUA (level -2 and -3) and completion of duct installation on the mezzanine floor in the BUR reactor hall.

KEY MILESTONES IN 2024

In 2024, the team will focus on:

- Completing the installation of all equipment in the auxiliary refrigeration and utility building
- Driving the completion of the ventilation and air-conditioning systems on levels -2 and -3 in the BUA and starting the installation the ventilation and air-conditioning systems on levels -1 and +1 in the BUA

Pierre Yves Boivin
Electrical Systems Manager

4.6 Electrical systems

4.6.1 Engineering

MAIN ACHIEVEMENTS IN 2023

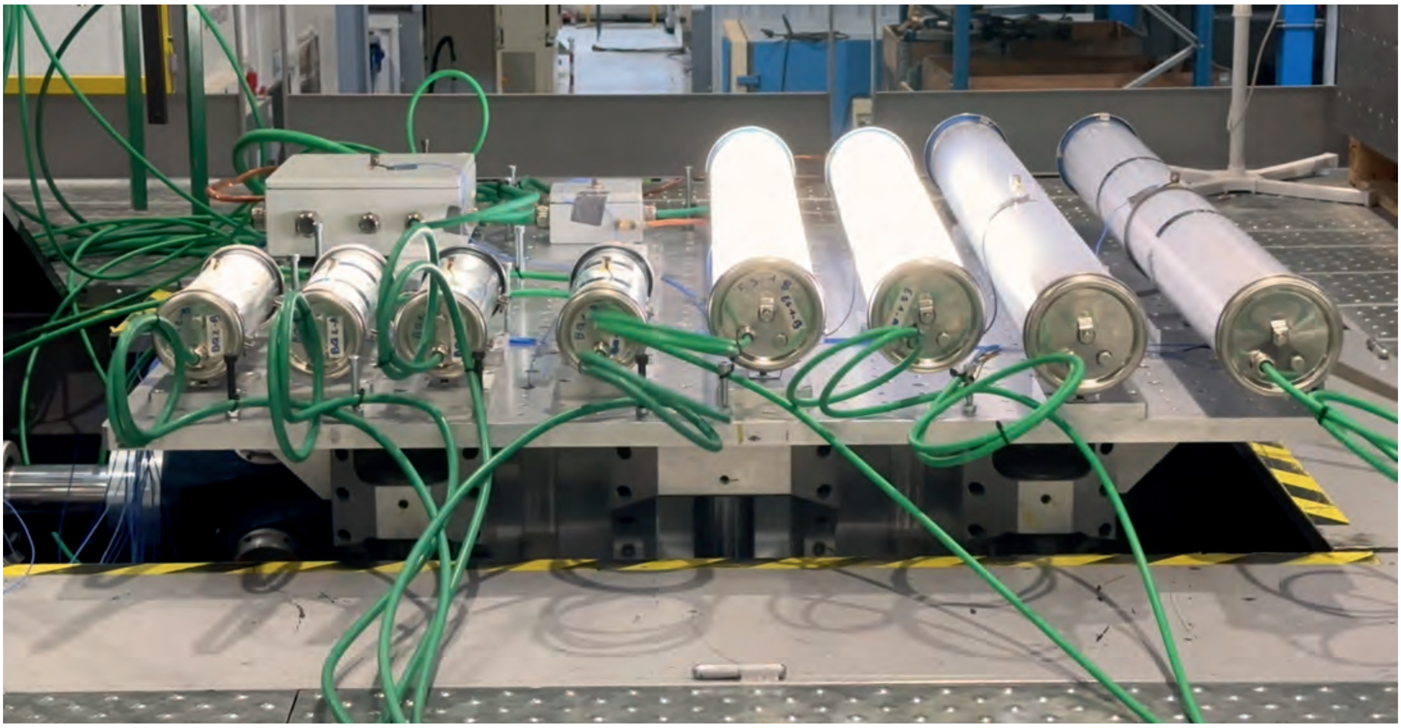
In 2022, the key progress made in electrical system engineering are:

- Design reviews for the following equipment important to safety:
  - Uninterruptible Power Supply system
  - Electrical transformers

90% of the review has been completed.

- Qualification studies for electrical equipment:
  - Through-wall video system enabling the surveillance of the hot cells
  - Medium-Voltage Switchgear

The qualification studies began in 2023, and will increase in 2024.



Earthquake testing : light projector and flame / smoke detector

KEY MILESTONES IN 2024

The main milestones for the year will involve:

- Update of electrical (High and Low Voltage) system studies
- Update of the detailed design (CATIA model), and joint work with the construction team in order to minimize impacts
- Qualification studies for electrical equipment:
  - Main low-voltage board
  - Central fire alarm system
  - Electrical transformers
- Seismic tests of:
  - Uninterruptible power supply system
  - Medium-Voltage Switchgear
- Underwater testing of the main electrical cable

4.6.2 Construction

MAIN ACHIEVEMENTS IN 2023

The main construction achievements for the year were:

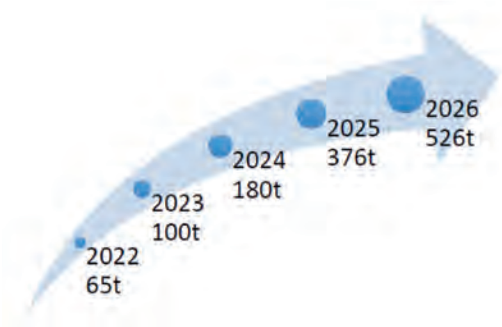
- Production of support brackets, and cable trays (~100 tonnes)

- Assembly of 3 km of cable tray in the nuclear units

KEY MILESTONES IN 2024

The year 2024 will focus on:

- Delivery of the 370km of electrical cables
- Acceleration of the supports bracket production from 65 to 526 tonnes:



- Fabrication of the first electrical penetrations
- Machining of penetration sleeves (the work began in 2023), in order to mount the first electrical penetrations
- Acceleration of the assembly: Drilling of 4 000 supports brackets in the nuclear unit and installation of 1 500 support brackets

Michel Trevisiol
Instrumentation & Control Systems Manager Including emergency diesel generators

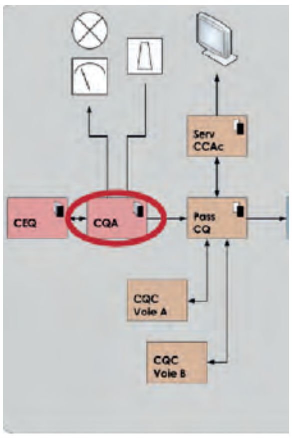
4.7 Instrumentation and Control (I&C) systems

4.7.1 Engineering

MAIN ACHIEVEMENTS IN 2023

Many good results have been obtained by the I&C team in 2023, such as:

- Software testing, verification and validation (V&V), factory acceptance for safety class C1 software



Delivery of the JHR's simulator to the CEA is the result of a 3-year collaboration between the different teams which were involved in the software development.

The simulator will be used to model physical phenomena of circuits and instrumentation and control systems, to define reactor operating procedures and to train future operators.

- Qualification review of the Radiation Monitoring System / Sensors

The system has been developed to monitor gamma dose rate during accident and post-accident conditions. Seismic monitor beta/gamma radiation detection and gamma ambient radiation has been developed to sample air in discharge stacks or ventilation ducts.

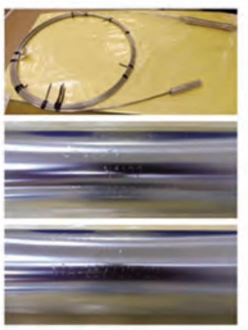
- Completion of the physical/chemical metrology review completed in November 2023
- Successful qualification of the industrial control systems cabinets (class C3)

- Successful design review of the ultimate backup diesel generator

KEY MILESTONES IN 2024

The 2024 main objectives for I&C engineering activities are:

- Acceptance of software part of control systems in configuration 3.2
- Acceptance of the V1.1 issue of the JHR simulator coupled with command and control emulator
- Preparation of the Ex-Core neutron detectors tests on an experimental reactor



- Qualification tests for Pressure sensors & Thermostats (Georgin)
- Verification and validation (V&V) factory acceptance for nuclear temperature sensors
- Ultimate backup diesel generator qualification review

4.7.2 Manufacturing

MAIN ACHIEVEMENTS IN 2023

- Manufacturing and delivery of radiation protection systems to the JHR

- Manufacturing of the pressure sensors & thermostats

- Manufacturing and delivery to the JHR of emergency diesels generators

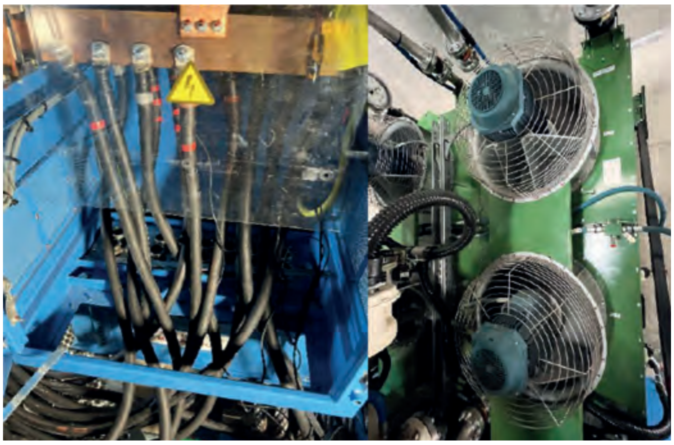
KEY MILESTONES IN 2024

The main key milestone for 2024 will be to manufacture the cable tray brackets, non-radiological equipment (electrical and connexion boxes and cabinets).

4.7.3 Installation

MAIN ACHIEVEMENTS IN 2023

In 2023, the main achievement has been the successful periodic maintenance of the emergency diesels generators.



KEY MILESTONES IN 2024

The main key milestone for 2024 will be to install the cable tray brackets for radiation protection systems.

Antoine Dewavrin
Building, Pools & Cells Manager

4.8 Buildings, pools and cells

MAIN ACHIEVEMENTS IN 2023

The year 2023 was marked by the following achievements:

- Erection of the supporting structure for experimental tools in the reactor hall
- Creation of openings and preparation of these holes for the assembly of the HVAC and electrical systems in the BUA and BUR building
- Factory acceptance of the underwater conveyor
- Finalisation of the EPT pool liners in the nuclear auxiliary building, including the floors
- Repair of 2 welds (section limited to 3 meters) in the RER pool after local stress corrosion cracks were found
- Site delivery of first set of hot cells' lifting units

4.8.1 Engineering activities

MAIN ACHIEVEMENTS IN 2023

- Continuation of design studies for dimensioning the tools required to install and remove the derivation pipes for fission product analysis
- Continuation of design studies on the tilting frame for the isolation doors
- Incorporation of changes made to the inter-locking device on the isolation doors:
  - Review of the EI&C design studies
  - Review of the drawings for the isolation doors
- Manufacturing of the I&C system for the isolation doors and conveyor in progress
- Leaktightness of the interface between the engineered structures and the isolation door frames
- Continuation of design studies on the conveyors for the Electronic Instrument System 2 dewatering prevention system
- Design and layout of additional anchors in cells. Support for the mechanical strength of the new anchors and hot cell lining.
- Design of Hot cells and hatches' doors adjustments according to build features

4.8.2 Factory activities

4.8.2.1 Hot cells (Czech in-kind contribution)

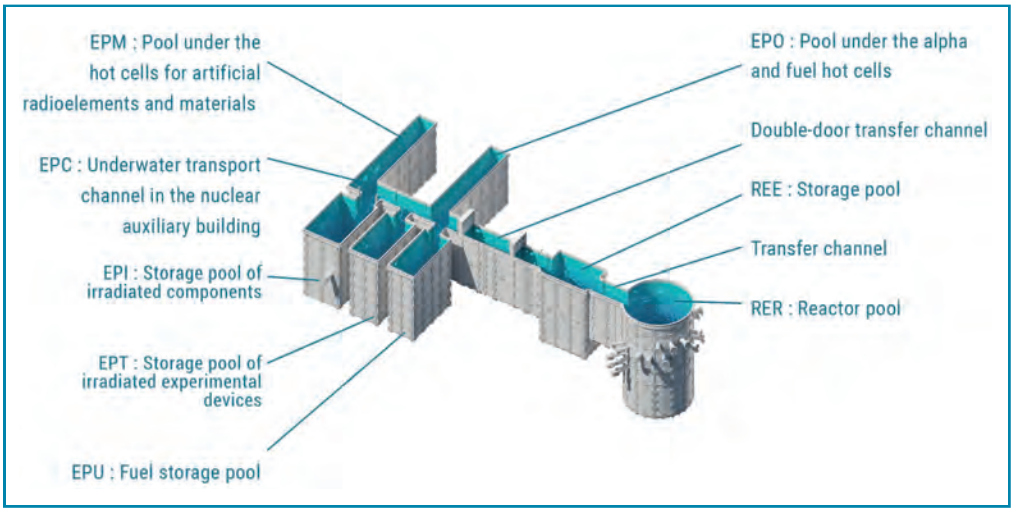
MAIN ACHIEVEMENTS IN 2023

The main achievements of this year regarding the hot cells are:

- Completion of the fabrication of 6 lifting units out of 9. Continuation of manufacturing activities for the lifting units ECE (Small hot cell for non-destructive tests on fuel samples), ECS (Small hot cell dedicated to alpha contamination) and ECE-ECS airlock.

- End of construction of the floor for the ECR (hot cell for artificial radioelements)

4.8.2.2 Pool liners



MAIN ACHIEVEMENTS IN 2023

The main 2023 achievements regarding the pools is the factory acceptance of the underwater conveyor.

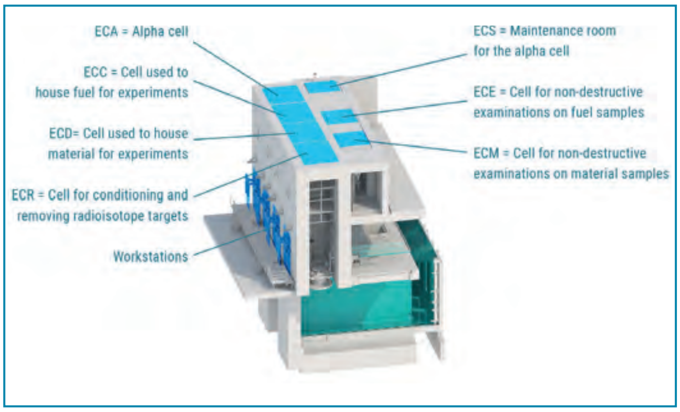
4.8.2.3 Secondary handling

MAIN ACHIEVEMENTS IN 2023

The main achievements of the year in terms of secondary handling are:

- Launching of the last tests on the mechanical assembly of the RMD bridge and the winding telescopic extension arm system
- Continuation of manufacturing and tests of the conveyors and main EPO structures
- End of qualification tests for the screw-nut material combinations following the ACTEON nut seizing issue during underwater tests on the conveyors

4.8.2.4 Hot cell equipment



MAIN ACHIEVEMENTS IN 2023

The main achievements of the year in hot cell equipment's are:

- Factory acceptance of heavy doors to be installed in rear zone of large cells
- Factory manufacturing continued for some equipment (trapdoors to canals, biological shielding plugs, ventilation systems, etc.)

4.8.3 Onsite activities and acceptance procedures

4.8.3.1 Civil works and buildings

MAIN ACHIEVEMENTS IN 2023

The main achievements of the year in civil works is the creation of openings and preparation of these holes for the assembly of the HVAC and electrical systems in the BUA and BUR building

4.8.3.2 Experimental utilities and pools

HOT CELLS (CZECH IN-KIND CONTRIBUTION)

The main achievement in 2023 regarding the hot cells has been:

- Installation of the ECR floor
- Door installation operations continued in cells and hatches (mechanical adjustments, wiring, etc.)

POOL LINERS

The main achievement in 2023 regarding the pools are:

- Erection start of the airlock underwater doors frames between the BUR and the BUA
- Repair of 2 welds (section limited to 3 meters) in the RER pool after local stress corrosion cracks were found.

SECONDARY HANDLING EQUIPMENT

The main achievement in 2023 regarding secondary handling are

- Completion of EMT heavy cask lorry installation and tests
- Start of the installation of the operation platform in the front zone of the large hot cells

Raphaël PALHIER
Experimental Devices Manager

4.9 Experimental devices

The year 2023 was mainly devoted to the continuation of the detailed studies for all experimental components (irradiation loops and capsules, measurement benches, I&C equipment, mechanical equipment, start-up equipment for the JHR), the aim being to complete the studies in 2024. Nearly a hundred people are involved in these studies, divided between the JHR project team at CEA Cadarache (on site), the CEA laboratories at Cadarache and Saclay, and partners for studies on irradiation facilities.

The design of the ADELINE, MADISON, OCCITANE and MICA devices has now been finalised and some remaining design items still need to be validated through further studies and tested on mock-ups or prototypes. The CEA test facilities at Cadarache (TOTEM & HRT platforms) and Saclay (TAXY loop) will continue to be used to carry out the tests required to validate the studies. These facilities have already produced significant results this year, including fatigue tests in the HRT hall for the underwater cables, hydraulic qualification on the TAXY loop for the source-holder mandrel dedicated to the JHR start-up neutron source, and hydraulic qualification of the components of the ADELINE and PROSPERO devices on the CORAIL loop in the TOTEM facility. Other test programmes are being developed, in particular to qualify the prototype measuring cell for CARMEN in the Belgian BR2 reactor and to characterise the NaK Water reaction for the MICA device in a CEA Cadarache facility (VAUTOUR cell).

In addition to the components in the study phase and the associated tests, 2023 also saw the "concretisation" of the first experimental elements with:

- The transfer of the first experimental component to the future JHR operator, the collimator of the UGXR bench installed in the RER pool
- The launch of the first tender for experimental equipment to provide biological protection for the corridor separating the pool liner from the experimental casemates

These two examples illustrate the growing importance of experimental construction and installation activities. As part of this process, an initial project for the subdivision of the construction contracts has been prepared and a procurement process launched with the manufacturers likely to produce the experimental equipment.

2024 will therefore be a transition year between the end of the studies and the launch of the first contracts for the construction of the experimental facilities.

4.9.1 Development of devices and tools for radioisotope production

According to prospective feedback, the demand for artificial radioisotopes is expected to increase in the coming years, especially for nuclear medicine where radioisotopes are used for examination purposes (diagnostics) and cancer treatment (therapy).

The JHR has the following objectives:

- Produce radioisotopes for diagnostics and therapy in the medical sector
- The JHR will be able to produce numerous radioisotopes not only for medical purposes, but also for industrial and R&D purposes (e.g. non-destructive testing, sterilisation of equipment, etc.)
- Secure the production of medical radioisotopes:
- Production to meet between 25% (about two billion of patients diagnosed) and 50% of the yearly European requirements for molybdenum[99]
- Production from start-up of therapeutic radioisotopes to sustain development (e.g. vectorised internal radiation therapy). Securing this medical production for the next fifty years is a key issue across the world. This is why JHR is looking to use the most versatile industrial production approaches.

This activity is important to help to secure the worldwide supply of medical radioisotopes and to contribute to equilibrate the JHR business model.

MAIN ACHIEVEMENTS IN 2023

The main achievement of the year was to consolidate the kinematics of radioisotopes operating circuit in the reactor in order to set up the optimal path to manage the daily production of relatively short half-life radioisotopes such as for the ^{177}Lutetium. Feasibility has been acquired for installing a dedicated radioiso-topes shielded box in a nuclear unit room.

KEY MILESTONES IN 2024

The engineering design studies continue in 2024. Priority is given to radioisotopes which can be managed in the shielded box after irradiation, such as ^{177}Lutetium. The main objectives this year will be to design the devices and all the tools associated with this production process, including studies of the shielded box.

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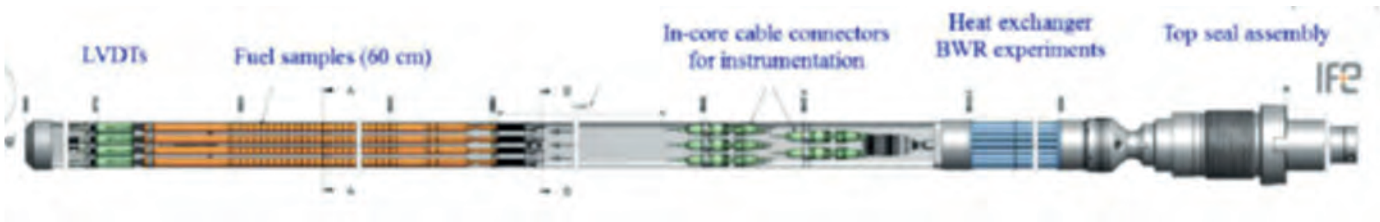
4.9.2 MADISON

The MADISON device (Multirod Adaptable Device for Irradiation of LWR Fuel Samples Operating in Normal conditions) will provide the nuclear industry (utilities, research institutes, fuel vendors, etc.) with a facility dedicated to testing LWR fuel samples under normal operating conditions existing in nuclear power plants:

- An in-core part located on a displacement system, in the JHR reflector will provide the neutron flux conditions required for any type of experimental programme. The fuel linear power and transient scenarios will be representative of conditions that do not lead to cladding failure.
- A water loop implemented in the JHR reactor building will supply the in-core part with the thermohydraulics and chemical conditions required by customers.



Madison design inspired from the IFE model

The CEA plans to make this device available right after the JHR start-up as a part of the first fleet of experimental devices.

This device pooling took feedbacks from CEA/OSIRIS and IFE/Halden knowledge and best practices.

The CEA is integrating feedback from both the OSIRIS reactor (France) and Halden reactor (Norway) in the MADISON device. For this reason, the CEA has subcontracted the detailed design of the first irradiation rig (including instrumentation), the water loop and I&C system to IFE/Halden.

This experimental device will ensure the continuous use of most of the experimental devices existing in these experimental reactors: OSIRIS experiments performed in GRIFFONOS and ISABELLE4 test devices, Halden experiments performed in an IFA's irradiation device with a single or multi-rod irradiation rig.

The first MADISON device will use most instruments currently employed in these two reactors, and specific changes to the MADISON irradiation rig will make it possible to use all of them (counter-pressure sensors, diameter gauge, etc.).

MAIN ACHIEVEMENTS IN 2023

With the support of an engineering company, the CEA carried out studies to achieve basic design studies and to provide specifications for manufacturing of the final loop and MADISON device. Engineering has provided studies of the basic design of the main components of the loop and the experimental device. The design is updated in accordance with French regulatory rules.

As planned in 2022, IFE Halden has performed the tests of the loop 17 (a full-scale mock-up loop fully representative, including I&C), but without the actual fuel rods (nuclear power simulated by electric heaters).

The MADISON test loop was started with the pump in May 2022 for cold tests, then 120°C hot tests were conducted, followed by tests under PWR conditions (320°C) until end of January 2023.

These tests aimed to make preliminary assessment that the loop will have a large capacity and could provide a wide range of experimentations:

- Wide range of flow, pressure available for experimentations and most configuration, making the loop a device able to respond to multiple experimental needs in the future
- I&C intuitive allowing a loop easy to control
- Robustness to transients is a goal achievable

LOOP MOCK-UP

In addition, this mock up is a quasi scale 1 mock-up of the future MADISON loop. This loop initially under IFE property was shipped to Cadarache in summer 2023, and will be re-operated in the Cadarache TOTEM facility.

This loop is a mock-up, which will help CEA teams for multiple needs during the design phase, and the manufacturing of the MADISON loop, such as the successful validation of the mock-up loop under the normal operating conditions and under different scenarios where the mockup demonstrated its robustness. The tests provided valuable insights for the design and operation of the MADISON loop.

Re operating this mock-up loop will allow support safety, reliability, efficiency, and pre-design validation. It will be useful to explore and test future experimental needs.

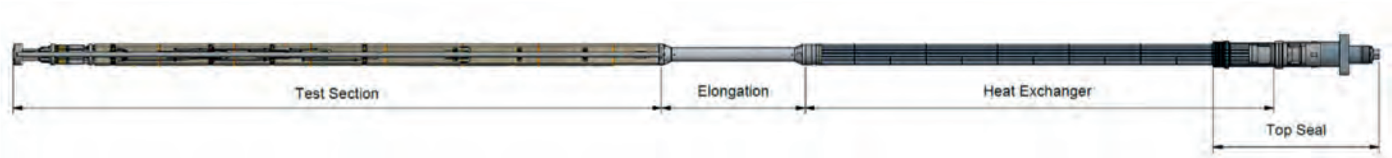
In 2023, CEA and IFE have organized the transport back to Cadarache of the loop 17, his cubicle and utilities. The whole components have been delivered to Cadarache in August 2023.

SAMPLE HOLDER

The first experimental rig (dummy rig) was manufactured by the IFE workshop teams.

The CEA has performed the first tests of this dummy rig at Cadarache in the UO2 laboratory facility.

These tests aimed to get a first feedback on the handling and design of the sample holder. The results of these tests are useful for the design update. In 2024 is foreseen to perform specifications for the MADISON sample holders manufacturing.



UNDERWATER FLEXIBLE HOSES/CONNECTIONS

The tests to validate flexible hoses on the full-scale test bench have shown a good behaviour of the flexible hoses. The goal is to be able to experimentally demonstrate that the fatigue of these components largely exceeds the number of cycles expected during their lifetime. The first campaign has been done with a number of iterative tests in order to validate the flexible expected lifetime duration.

MADISON CUBICLE

Installation of the cubicle in the JHR facility was expected to end in 2023, but difficulties were encountered with the cubicle structure linked to the steel inserts in the concrete floor. This issue is now being solved in order to restart assembly work of the cubicle in the reactor building.

The main function of the cubicle (a 40-tonne stainless steel liner reinforced with steel beams and able to withstand an internal overpressure of 1 bar and equipped with biological shielding) is to mitigate consequences in the case of a hypothetical accidental breach in the high-pressure primary system.

KEY MILESTONES IN 2024

The work to be carried out in 2024 is to:

- Achieve the phase related to detailed design studies of the experimental device and of the MADISON loop and his components
- Contract with IFE sensor laboratory for an expertise during the end of the studies of the MADISON experimental device
- Continue the validation test program for the underwater flexible hoses
- Prepare the call for tenders phase for the studies and manufacturing of the MADISON experimental device
- Continue the assembly of the shielded cubicle in the JHR CEDE

4.9.3 ADELINE AND MADISON

The ADELINE experimental device is dedicated to single fuel rod studies in light water reactor (LWR) conditions.

It aims at investigating the fuel behaviour under off-normal irradiation conditions up to cladding failure.

To do so, the device will be placed on a displacement system that travels through the reflector towards to the reactor core in order to subject the samples to power ramps. The main components of the device are given below.

MAIN ACHIEVEMENTS IN 2023 (and focus on risk mitigation in 2024)

2022: Design validation

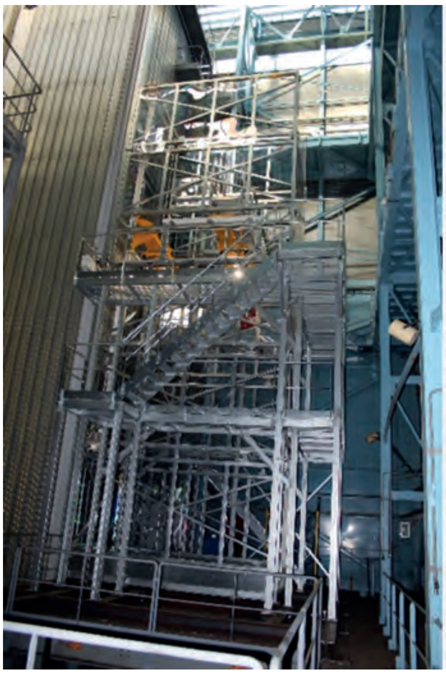
A full-scale line (around 11 m in length and diameter of 0.1 m in diameter) was successfully tested for more than 2 500 cycles on a specially designed bench. One cycle covers all possible displacements of the underwater line during normal operation. The water pressure inside the underwater line was also cycling from 1 to 310 bar during a cycle in order to simulate the PWR pressure and temperature. As no issue or damage occurred, the design of this line was validated.

In 2023: Regulatory qualification

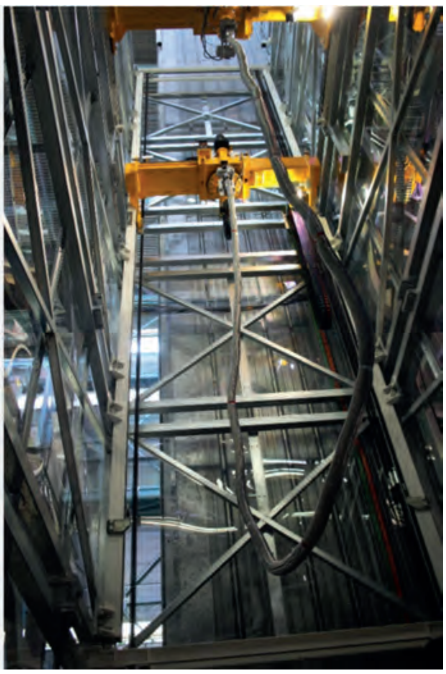
Another full-scale prototype has been fabricated and tested on the bench in order to qualify its design to comply with regulatory requirements.

FLEXIBLES LINES FATIGUE TESTS

The connections between the device and the out of pool parts of the ADELINE and MADISON devices are made with metallic flexible line in order to accommodate the kinematics of the devices inside the reactor pool on the displacement systems as well as to carry out the displacement of the devices in the reactor pool (before & after irradiation phases).



Flexible lines fatigue bench



MADISON flexible line

For ADELINE device, the underwater lines used are composed of small diameter metallic tubes. The inlet flow rate is 50 to 100g/s from the out of pool part.

For MADISON device, the lines are corrugated metallic hoses. The maximum inlet flow rate is about 1kg/s. The tests carried out are fatigue tests simulate the operating cycles of underwater lines during all the working phase in the reactor.

A specific fatigue test bench was carried out for these verifications. The working conditions of this bench are following: room T, P=300b inlet pressure.

The results obtained are:

- For the ADELINE lines, 2 600 cycles carried out without observed degradation
- For the MADISON lines, 400 cycles carried out without degradation

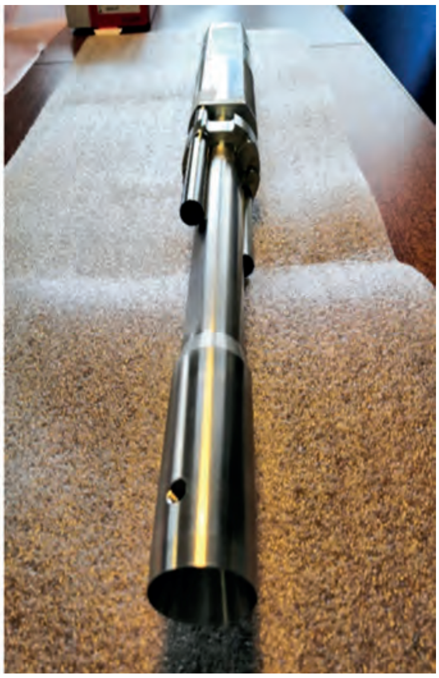
These experimental results will be used in the JHR ADELINE and MADISON technological support files.

ADELINE VCONE FLOWMETER CALIBRATION TESTS

The JHR-ADELINE device will be used to perform power ramps on irradiated fuel rods. The experimental measurement is based on the thermal balance in the test channel. In addition to the delta T measurement, the flow rate of the test channel is required to perform this measurement. In order to improve the accuracy of the thermal balance, the innovative VCone flowmeter is calibrated with a reference flow meter (CORIOLIS type). These tests are carried out of pile on the CORAIL loop of the CEA in Cadarache. At the end, the calibrated flow meter and its delta P instrumentation will be integrated into the ADELINE-JHR device.

Note: Action supported by CEA (test section, experimentation) & IAEC-BGU (Israel) for Thermal Hydraulic simulation

Testing section
Injector-nozzles



Amplification bloc
Injector nozzles

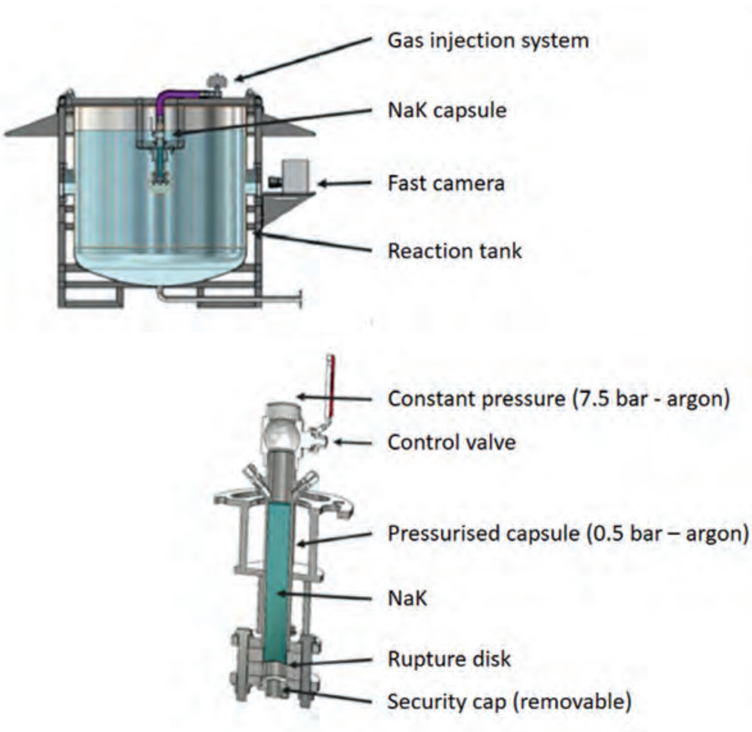
4.9.4 MICA

WATER-NaK INTERACTION IN THE EVENT OF A MICA FALLING DURING HANDLING

The MICA experimental device is designed to irradiate structural materials in the JHR inside a fuel element. The sample holder is immersed in liquid metal (NaK eutectic), which ensures optimal thermal homogeneity thanks to its high thermal conductivity.

In the event of a MICA falling during handling, the mechanical strength of the experimental device structure is not guaranteed. An explosive reaction due to the interaction of NaK with pool water can therefore take place under water with the risk of damaging nearby important component for safety. A dedicated technical open point was opened in 2022 to address this subject.

In order to define precisely loads to be used to study mechanical behaviour of nearby structures, it was decided to carry out an experimental campaign representative of the conditions of such an incident. CEA is in charge to design and manufacture the facility aimed to perform such tests. Equipped with fast cameras and pressure sensors, the objective is to monitor the pressure wave during the reaction and evaluate kinetic. Different volumes of NaK will be tested to evaluate the influence of such parameter. This new facility is called NaKRE.



Design of the future NaKRE facility

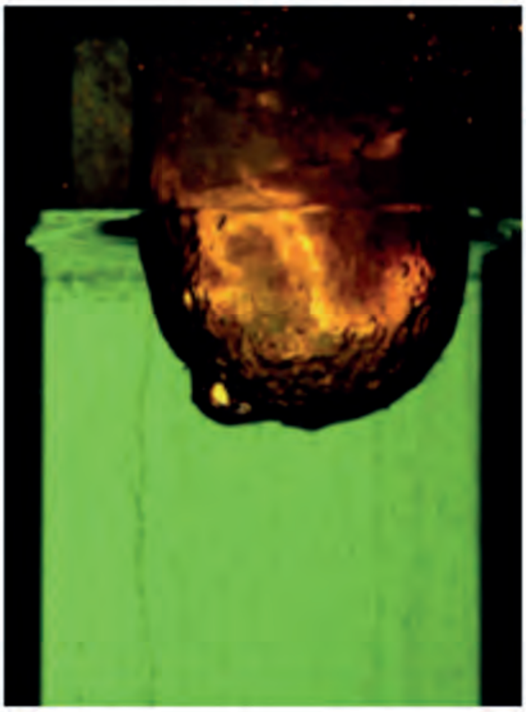


Illustration of the water-NaK interaction (CEA)

MAIN ACHIEVEMENTS IN 2023

The main achievements of the year on the MICA development were:

- Establishment of the roadmap to address the sticking point
- Reaction bench design and launch of calls for tenders

KEY MILESTONES IN 2024

The main activities to be realized in 2024 are:

- Machining of the reaction bench
- Integration of the components in CEA VAUTOUR cell
- Carrying out technological tests before the end of 2024 (with coloured water)

4.9.5 CARMEN

CARMEN is a multi-detector measuring device able to acquire the neutron and photon fluxes and the specific power deposited by nuclear heating over the full height of the core and in the different experimental locations of the JHR.

Continuation of engineering studies in 2023-2024 with the following highlights:

MAIN ACHIEVEMENTS IN 2023

- Vertical displacement system – Full scale endurance testing:

  Test results made it possible to validate the sizing of the motorization and the design of the kinematic chain. The spiral is resistant to cycling fatigue (continuity, insulation, wear). The entire mechanism resists corrosion. Overall, any major issues with design and process choices have been ruled out. Very local cable sheath perforation and traces of corrosion were observed but they can be dealt with without much difficulty (*).

(*) See the paper "CARMEN measuring device for the Jules Horowitz reactor: status of development" TRTR & IGORR, June 18-22, 2023, University of Maryland, USA, M. Antony et al.

- Validation of the calorimeter for high nuclear heating in BR2:

  The objectives and the preliminary description of the device were presented to the SCK CEN experiment study committee in the phase 1 (conceptual design) report in February 2023.

- Multichannel Online Neutron Acquisition system in Campbell mOde:

  Know-How License Agreement concluded between the CEA and a Slovenian company. This technological licensing agreement concerns the industrialization of an electronic data acquisition system for fission chambers called MONACO (Multichannel Online Neutron Acquisition system in Campbell mOde). This collaboration between gave birth to the product called "Libera MONACO 3". This multimode, multichannel and unique product on the market is now marketed by the partner company.

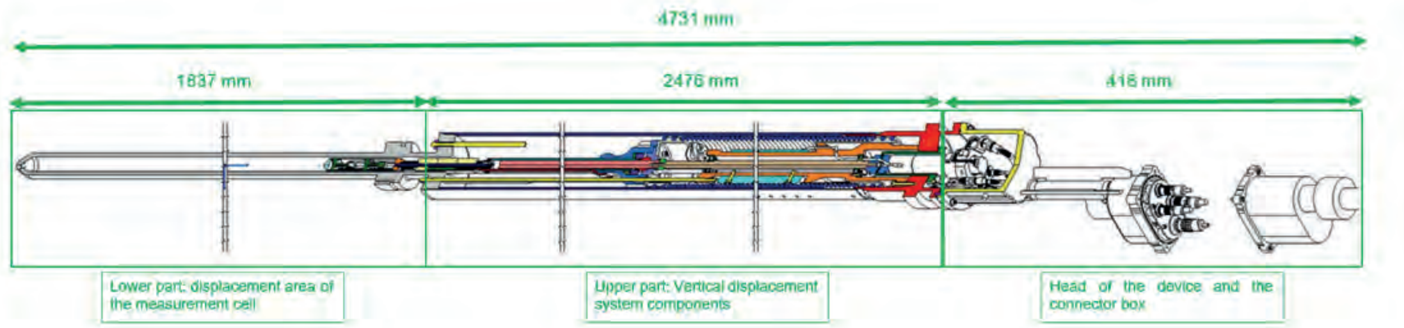
- Thermohydraulic studies in core and reflector

KEY MILESTONES IN 2024

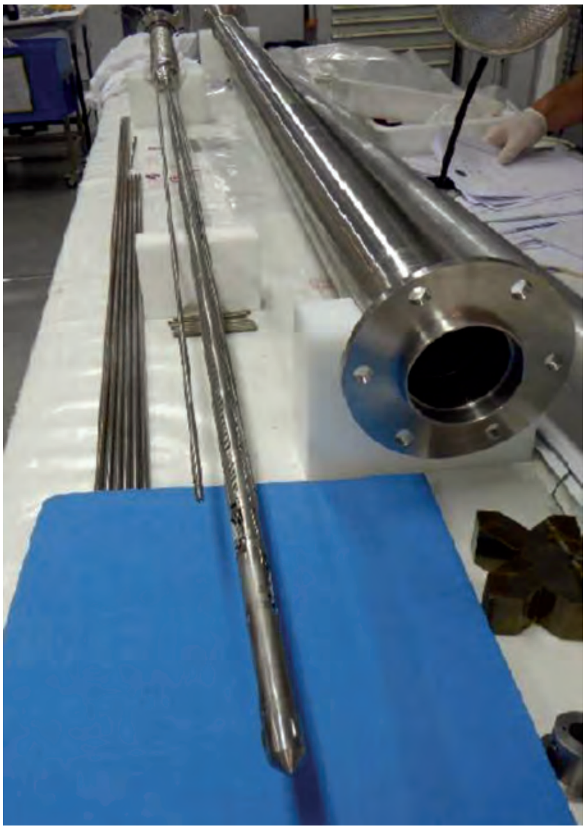
- Validation of the calorimeter for high nuclear heating in BR2:
  The detailed studies will be presented to the SCK CEN experiment study committee in the phase 2 (detailed design) report in March 2024. Following acceptance by the committee, it should be possible to manufacture the device in 2024.

- Mock-up of the head and leak testing:
  Validation of the assembly process of the connectors in the device head given the restricted space for assembly. The mock-up will be assembled and leak tested in the first quarter of 2024.

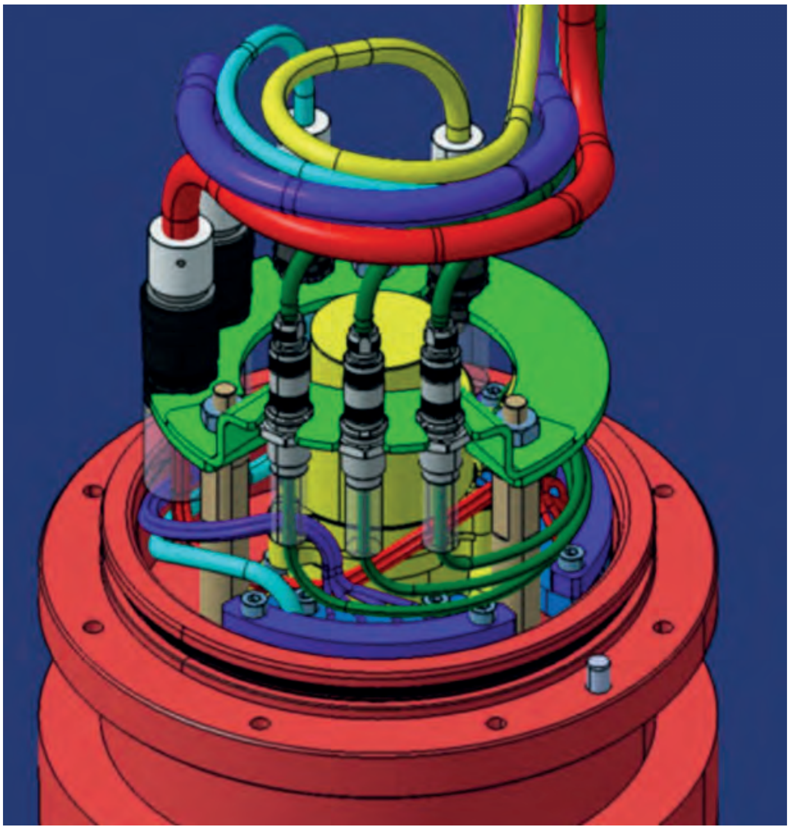
- Rad-resistant motors:
  Call of tender is planned in the first quarter of 2024 for the development and production of rad-resistant motors which will be integrated into the CARMEN head.



CARMEN device



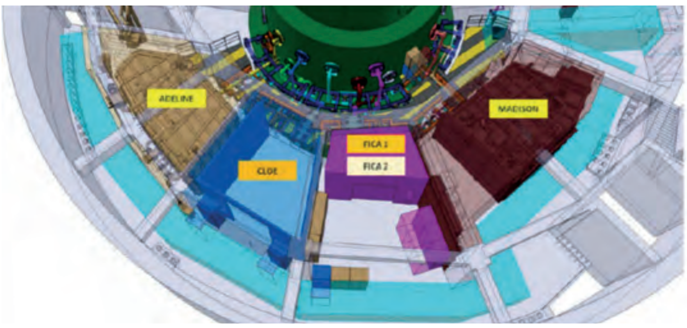
Vertical displacement system mock-up



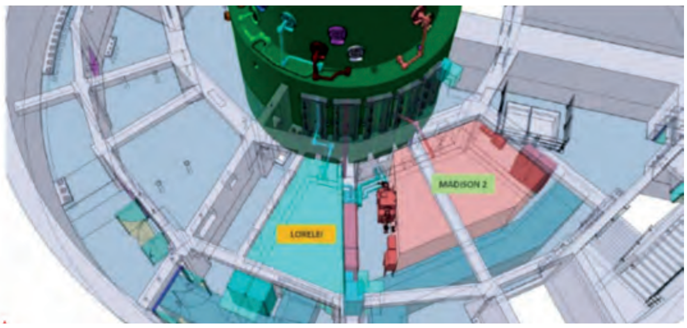
Illustrative view of the integration of components in the CARMEN head mock-up

4.9.6 Biological Protection

The experimental loops and utilities for the experimental devices are located in the three levels of the "CEDE" area. In this area, the experimental loops cross the reactor pool and move towards these casemates.



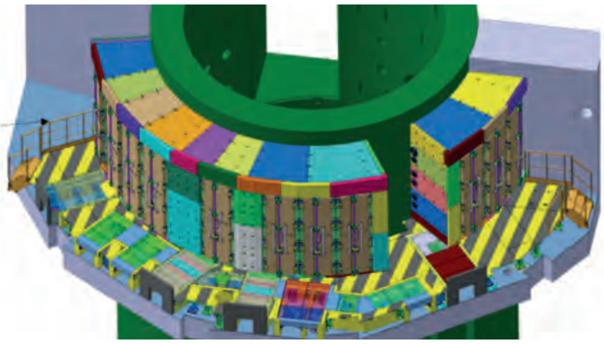
CEDE-1 area



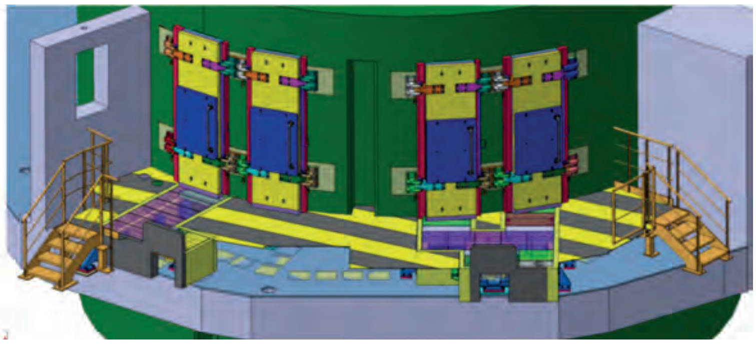
CEDE-2 area

In order to protect operators who works or circulate in this area, the JHR Engineering team has designed two kind of equipment around all these loops:

- The first one is a kind of locker all around the reactor pool who integrates doors that allow the access to the pool plugs
- The second one is a worker circulation platform with biological protection below who absorb ionizing radiation from the experimental loops



Biological protection in CEDE-1 corridor



Biological protection in CEDE-2 corridor

These two items of equipment will be manufactured in steel and lead. A lot of special handling tools will be needed for on-site assembly.
In 2023 the JHR team launched the first call for tenders for manufacturing these biological protections. Due to the on-going design studies of the experimental devices and other utilities contractors, it was decided to finalise the final design by the JHR engineering team before contracting with the manufacturer.

MAIN ACHIEVEMENTS IN 2023

Consequently, the work realized in 2023 to prepare the biological protections has been to:

- Launch the first call for tenders for the experimental devices and collect feedbacks
- Finalise the design of the biological protection in the three levels of CEDE area

KEY MILESTONES IN 2024

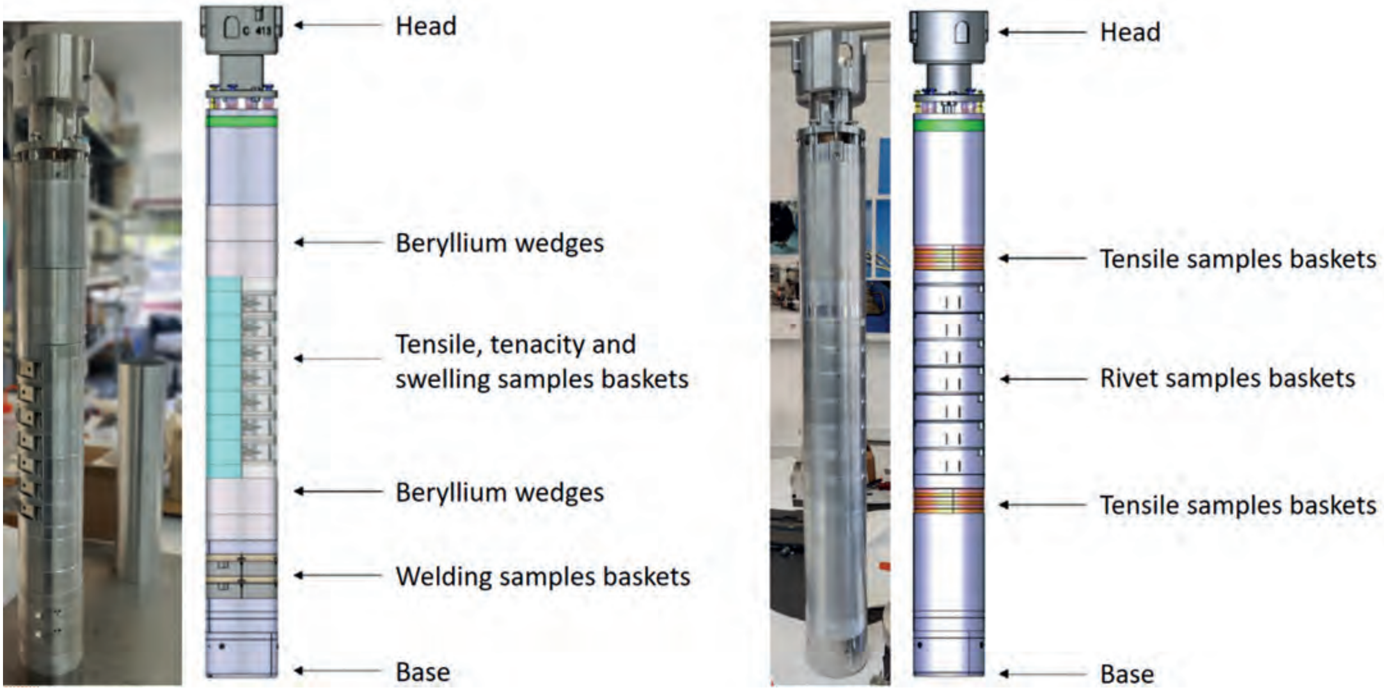
The remaining work for 2024 will be to:

- Establish contract with the manufacturer
- Start the work on site to install the anchoring plates for biological protection

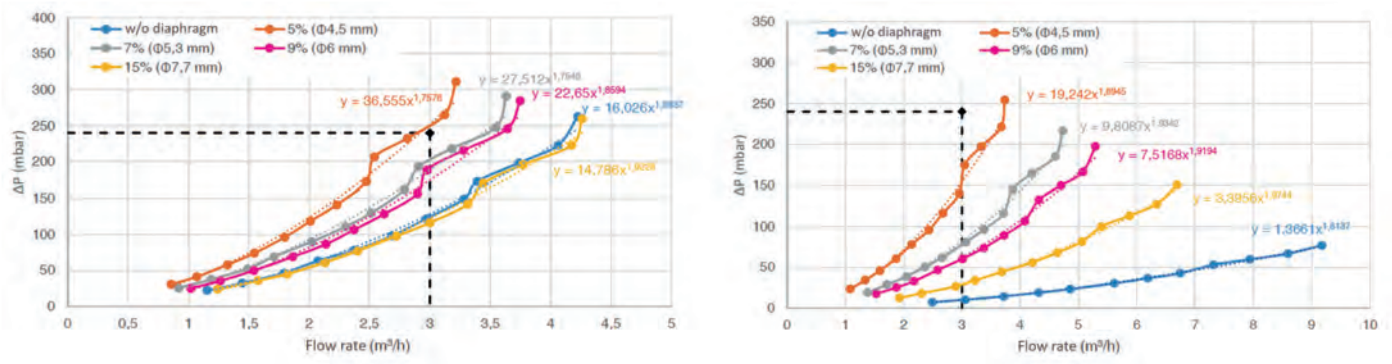
4.9.7 PROSPERO Mock-up

In the framework of the radiation monitoring program of the JHR reactor, the project team has designed an out-of-core hosting system called PROSPERO for neutron ageing tests on aluminium 6061 T6 samples issued from JHR reactor block. Two different components (PROSPERO SURETE & PROSPERO SUPPORT) make it possible to irradiate various samples necessary for the monitoring program. In order to validate the hydraulic characteristics and the design related to the hot cells manipulation, two full-scale mock-ups have been manufactured and tested.

PROSPERO SURETE **PROSPERO SUPPORT**



Mock-up preview and main characteristics



Measured hydraulic characteristics

MAIN ACHIEVEMENTS IN 2023

The main 2023 progress regarding the PROPSERO mock-ups were:

- Machining and assembly
- Hydraulic characterizations on CORALI-COR facility
- Tests in dummy hot cell

KEY MILESTONES IN 2024

The main steps for 2024 will be to:

- Finalize of the hydraulic characterization of the PROSPERO support with an optimized diaphragm
- Integrate into the PROSPERO design the feedbacks from the tests realized on the mock-ups

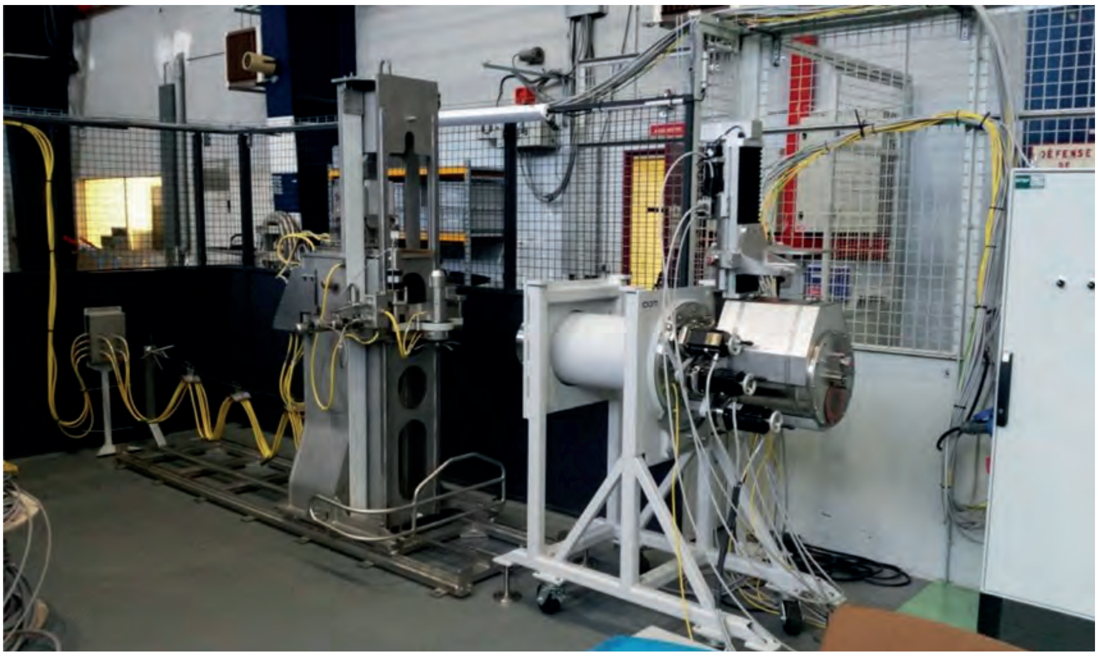
4.9.8 Non Destructive Examination devices (Finnish in-kind contribution)

Within the frame of JHR construction, Non Destructive Examination (NDE) systems have been required for:

- Underwater examinations on integral devices (in-pools)
  - Neutron imaging system (reactor pool)

- Gamma and X-Ray scanning systems (UGXR system), one for reactor and one for storage pools

- In-air examinations on samples (hot cells)
  - Gamma and X-Ray scanning system (HGXR system)



Two underwater benches reached the site acceptance test phase in Cadarache in early 2021 followed by an extensive test period in 2022. Unfortunately, one of the two benches failed the tests due to a damage in one mechanical component that needed to be replaced. This failed test bench got its final acceptance in late 2022. However, it was also noticed in the tests that some cables needed to be replaced due to their too high stiffness and this replacement was finally done in 2023 within the warranty period.

The other parts of the Finnish in kind contribution were earlier successfully finalized.

The Finnish in kind contribution was finally accepted by CEA in early 2023 after 17 years since the start of co-operation. Of these 17 years the first six years were dedicated to defining and properly specifying the in kind content. The remaining 11 years were dedicated to manufacturing and testing the devices. After the final acceptance, VTT gave the operation authorization to CEA to start learning working with the devices and making their own experimental protocols for the JHR. The Finnish in kind contribution devices were the first experimental devices to be fully completed. The installation of the benches within the JHR was a very important and interesting step as this installation turned out to be a complex step in the project. This first experiemental equipment installation feedback within JHR indicated the need to set up a good organisation when more devices will be installed in the reactor.

4.9.9 CLOE (Indian in-kind contribution)

Following the successful completion of the preliminary design phase for the CLOE loop, the work performed by BARC colleagues in India over the past few years has focused in 2023 on the continuation of the detailed design studies and the drafting of several engineering documents. Such work is closely related to the experimental qualification of key components (e.g. the pump) performed on the BARC premises in Mumbai. The documentation is currently being reviewed by the CEA and its engineering partner. In support of this work, CEA was happy to welcome for 9 months a Secondee form BARC whose main activities was to issue the technical specifications of key-components of the loop that will be supply by BARC in the coming years.

CEA staff traveled to India in November 2023 (Kalpakham and Mumbai) for a one-week meeting, which was profitable for in-depth technical exchanges on the different topic of collaboration (RISHI loop for Sodium environment developed by IGCAR, innovative sample holder for material capsule type by BARC, development on specific device for measuring smart properties of fuel also by BARC).

The very good work and progress of the CLOE detailed design phase has been acknowledged by the CEA and the full detailed design review is now planned for autumn 2024.

Components of PPL-CLOE facility

Transmitter rack
of PPL-CLOE facility

Control Room of PPL-CLOE facility

Guillaume Villard
Safety and Construction
Site Manager

4.10 Construction Management and site activities

MAIN ACHIEVEMENTS IN 2023

In 2023, 100% of the On-Time Delivery milestones dedicated to site activities preparation and realization were achieved:

- Development of the detailed installation sequences for 85% of JHR areas
- Set up of a 'war room' dedicated to site installation preparation and coordination
- Electromechanical installation in selected rooms at level -2 of the nuclear auxiliary building
- End of DLC structural erection (structure above the reactor pool)
- End of airlock sealing in the transfer pool

Each of these milestones were met thanks to the strong commitment of the CEA and contractor site teams, including tight follow-up of the schedule, and several technical and organisational improvements.

The definition of the installation sequences provides an operational schedule built with the contractors. It enhance our capacity to anticipate procurement needs, to pilot site erection in accordance to the project schedule and to react strongly to site hazards.

All the JHR project team work hand in hand to ensure that all installation activities complied with the industrial safety and quality requirements.

KEY MILESTONES IN 2024

In 2024, twelve On-Time Delivery milestones are dedicated to site activities preparation and realization:

- End of penetration of the concrete within the channel between the BMR and the BUA
- End of drilling implantation in the BUA for HVAC equipment
- Development of the operational schedule for the BMR and commissioning of the utility building
- End of civil work preparation activities in the BAS buildings
- 50% of drilling activities completed in 3 levels of the auxiliary building for electrical equipment
- Decide and implement the mitigation solution regarding the heat exchangers
- End of machining works on electrical penetrations sleeves in reactor building
- End of the in site assembly of the moving underwater conveyor assembly part
- End of the molybdenum target storage cabinets and fuel element rack installation
- End of Installation of the 1 900 electrical supporting structures
- Installation of the crane tracks
- End of the BMR and utility building installation

In 2024, the main issues in order to reach schedule objectives are:

- Maintain high safety standards and reinforcement of tasks preparation
- Maintain high installation follow-up level in order to insure quality at each step and to anticipate site hazards
- Strengthen capacity to insure equipment supply and manpower staffing according to operational schedule

Nathalie VEDRENNE
Nuclear Safety, Quality
and Licensing Manager

Since the establishment of the new JHR Project organisation with new entities, the Nuclear Safety, Quality and Licensing Division has the following mission:

- Define and implement the JHR nuclear safety policy
- Elaborate regulatory documents and submit them to the ASN's technical support, the Institute for Radiation Protection and Nuclear Safety (IRSN), to obtain approval for fuel loading and plant operation
- Maintain good working relationships with the ASN and IRSN
- Manage oversight of JHR contractors in compliance with the French ministerial order of 7 February 2012 defining the general rules governing licensed nuclear facilities (INB)

Preparing for licensing

Nuclear safety licensing

The application for an operating agreement must be submitted to the ASN in order to obtain regulatory authority approval to load fuel. This application includes the JHR project's nuclear safety standard and associated documents.

A request for updating the creation authorization decree (DAC) was also submitted to the ministry of energy transition.

In application of the licensing roadmap discussed with ASN and IRSN in 2022, an early examination of the Safety Report was proposed by ASN through 4 successive examination batches. The first batch of this anticipated examination is underway and is to be completed in October 2024.

Franck PILLOT
Manager in charge of preparing JHR operation

6.1 Fuel manufacturing

In 2020, wear on the fuel elements was detected during hydraulic tests, which was shown to be caused by vibration phenomena. This is because the JHR core is highly specific with very little space for water flow, leading to high flow velocities and pressure differences along the fuel elements. A working group analysed the situation and then proposed a solution that involved redesigning the fuel element's top and bottom ends.

In 2023, the last LEU (Low Enriched Uranium) plates were manufactured. These plates will be used for the assembly of the 100 first fuel elements, as soon as the design of their top and bottom is finalized.

6.2 Operation preparation

In 2023, regarding studies, the future operator contributed given its expertise in the field of thermohydraulics and neutron physics to perform studies supporting the design of several experimental devices such as MADISON, ADELINE, CARMEN.

Hydraulic tests were performed with the new CORALIE loop, to characterize the experimental device PROSPERO, which aims to validate vessel lifetime under neutron flux.

Introduction of PROSPERO model in the CORALIE hydraulic loop

6.2.1 Operation documentation

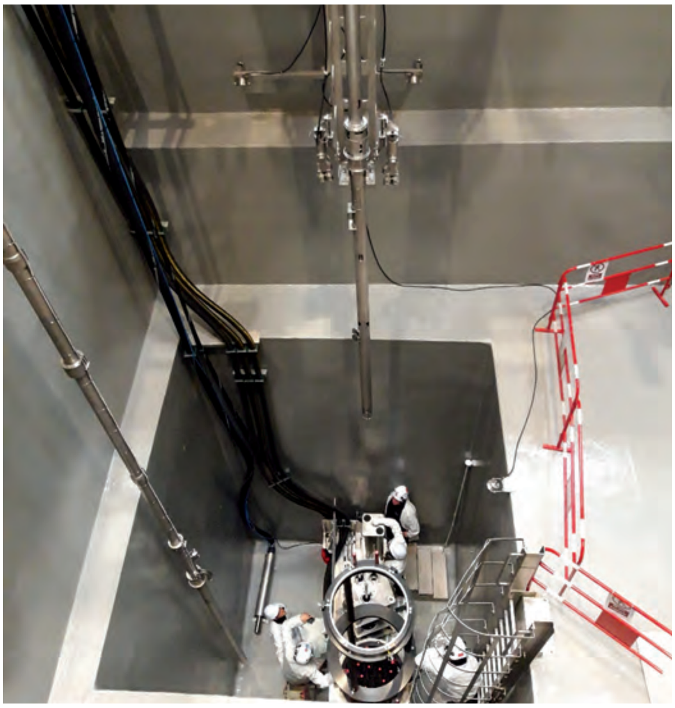
All the documentation has to be ready for the commissioning test programme and the related milestones. This represents more than 3600 operating documents, without taking into account documentation on the experimental devices.

In 2023, a huge work regarding the general operating rules was performed : 20 chapters (over 29) are on-writing, 3 were finalized : the ones regarding periodic tests of safety equipment, the incidental and accidental situations, and the waste management, the other chapters will be written in 2024.

6.2.2 Operating activities

The future JHR operator will progressively start up all the systems so the commissioning tests can proceed. Thereafter, it has to organise and follow the maintenance operations for keeping the systems in good operational conditions.

In 2023, new systems, such as a lift dumper, the electrical fence and the guard post, were handed over to the future operator.



6.2.3 Training

The elaboration of the training baseline continued, with the analysis of each operating working position, the identification of the necessary skills and attitudes, their conversion into training objectives, and the creation of training materials.

Simultaneously, in 2023, the future operating team received training to appropriate the functioning of the fuel loading device, and some handling tools.

Docking test of an experimental device on the work table in TOTEM pool

2023 – training of the future operator by manufacturers, on the loading machine

Reflector

7 ACRONYMS

ADELINE	JHR Advanced Device for Experimenting up to the Limits of the Nuclear fuel Element
ASN	French Nuclear Safety Authority
BAS	Safeguard building
BARC	Indian consortium member
BMR	Auxiliary refrigeration and utility building
BND	Building containing the "hard core" set of safety equipment (reactor monitoring in the case of an emergency)
BUA	Nuclear auxiliary building
BUR	Nuclear unit reactor building
BR2	Belgian Reactor
CARMEN	JHR device that measure neutron and gamma fluxes, gamma heating in order to precisely characterise irradiation locations , for better modelling and improvement ofexperimental results
CEA	French Alternative Energies and Nuclear Energy Commission, JHR Host and French consortium member
CEDE	Experimental shielded cubicle room
CGN	China General Nuclear Power Corporation – Chinese partner in the JHR Material Test Reactor international consortium
CIEMAT	Spanish consortium member
CLOE	JHR Corrosion LOop Experiment
CORAIL	Thermohydraulic loop within the TOTEM facility
CORALIE	CEA loop placed on the TOTEM facility to measure the hydraulic characteristics of the experimental devices (in core and reflector areas)
CORIOLIS	The Coriolis force is an inertial (or fictitious) force that acts on objects in motion within a frame of reference that rotates with respect to an inertial frame
CVR	Czech Republic consortium member
DLC	Support structures for experimental tools
ECR	Large hot cell used to condition and remove radioisotope targets
ECE	Small hot cell for non-destructive examination son fuel samples
ECS	Maintenance room for the alpha cell
EDF	Electricité De France, French consortium member
EI&C	Electrical, Instrumentation and Control
EMT	Hot Cell converyor transfer table
EPC, EPO, EPM	Canals
EPI, EPT, EPU	Pools (BUA)
EURATOM	European Atomic Energy Community supporting the development of the European nuclear industry
FIDES & FIDES-II	Framework for IrraDiation ExperimentS
FWG	Fuel Woring Group
HFDS	High Level Defence and Security
HFR	High Flux Reactor of Netherlands
HVAC	Heating, Ventilation and Air-Conditioning
I&C	Instrumentation & Control
ICERR	International Centre based on Research Reactors
IFE	Institute For Energy technology, Halden
IGCAR	Indira Ghandi Center for Atomic Research
IMS	Integrated Management System
INB	Licensed nuclear facility
INL	Idaho National Laboratory (USA)

IRSN	French Institute for Radiation Protection and Nuclear Safety
JAEC	Japan Atomic Energy Commission
JAM	JHR Archive Material project
JEEP	Joint ExpErimental Programs within FIDES II program
JHOP 2040	Jules Horowitz Operation Plan 2040
JHR	Jules Horowitz Reactor
JRC	Joint Research Centre, European consortium member
HGXR	Finnish In-Kind Hot cell Hamma and X-Ray scanning system
HRT	Research and Technology CEA Cadarache Hall
INCREASE	In-Core Real-Time Mechanical Testing of Structural Materials of the FIDES-II JEEP program
LOCA	Loss-Of-Coolant Accident
LVDT	IFE laboratory devoted to sensor studies.
LVR15	Czech Republic research reactor
LWR	Light Water Reactor
MADISON	JHR Multirod Adaptable Device for Irradiation of LWR's Fuel Samples Operating in Normal conditions
MICA	JHR Material Irradiation CApsule
MIT-R	Massachussetts Intitute of Technology Reactor (USA)
MOLY	Name of the JHR project for the development of the displacement system dedicated to the production of molybdenium
MTR	Material Test Reactor
MW	A unit of power in the International System of Units (SI); it is equal to one Million Watts.
MWG	Material Working Group
NEA	OECD Nuclear Energy Agency
NNL	British consortium member (Nuclear National Laboratory)
NRC	American Nuclear regulatory Commission
OECD	International Organisation for Economic Co-operation and Development
PROSPERO	JHR device to monitor changes in the reactor material at the beginning and vessel material behaviour under irradiation during its lifetime
PWR	Pressurised Water Reactor
RISHI	Research facility for Irradiation studies in Sodium at HIgh temperature -Sodium lopp designed and built by IGCAR
RER	Reactor pool
RMD	Reactor pool polar crane bridge
R&D	Research and development
STUDSVIK	Swedish consortium member
SCK CEN	Belgian consortium member
TAXY loop	CEA Saclay loop for hydraulic characterizations of JHR components (ex : flow measurements, pressure drop) and "fatigue" tests
TOTEM	CEA cold test facility
TWG	Technical Working Group
TSO	Technical Support Organisation
UGXR	Finnih in-kind of an Underwater Gamma and X-Ray scanning systems
VAUTOUR	CEA Cadarache cubicle casemate dimensioned to resists to explosure from Nak/water reactions
VTT	Finnish consortium member
WG	Working Group

JHR
Jules Horowitz Reactor
SAFETY HONESTY GET RESULTS TEAM MINDSET

April 2024

Jules Horowitz Reactor

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