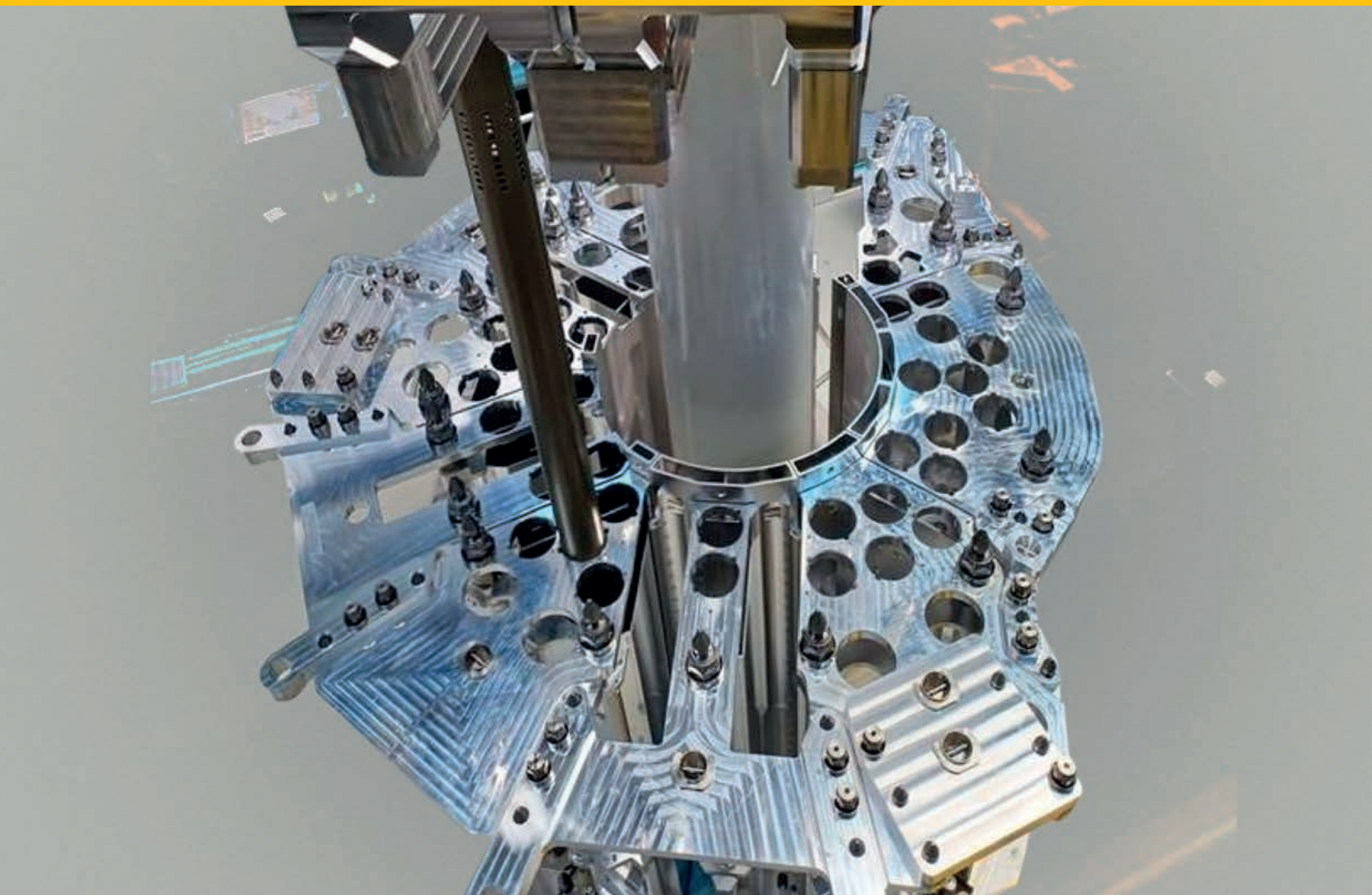
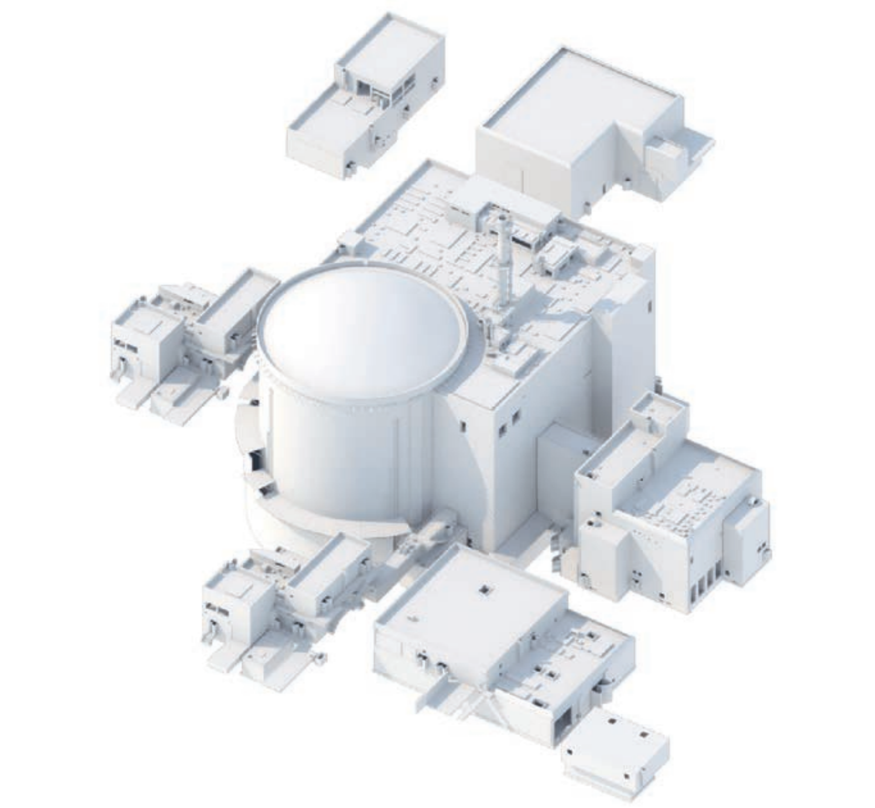
2022

Jules Horowitz Reactor
Status Report





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Please refer to pages 78/79 to find the signification of all the acronyms underlined in yellow

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

Foreword 1

Petri KINNUNEN
JHR Governing Board Chairman

The year 2022 was devoted to road mapping our common project. The CEA prepared plans for the French government laying out the completion of the construction project, while the consortium made plans for the operation phase. Even though the project experienced some "timeout" on the construction side, it did not bring the works to a halt as efforts focused on reassessment of the engineering studies. The JHR consortium has been very active, whether in terms of managing its in-kind contributions, establishing cost estimates for operations, or completing support actions all moving towards the same goal, i.e. the successful operation of the future reactor.

The delay in construction was announced with enough anticipation and the CEA was able to provide a solid justification for this delay. In 2022, the target was to ensure the capacity to finalise construction, which has called for thorough planning of the resources and time scales. Meanwhile, the consortium partners have continued the realisation of their in-kind contributions. For instance, the Finnish in-kind contribution was finalised after 17 years, in late 2022, while the first experimental devices were installed in the JHR earlier on in the year.

Operation planning is well under way. The European members of the JHR consortium have been planning the operation phase for EURATOM (Jules Horowitz Operation Plan 2040, JHOP 2040 project) in response to the request to explain how the European Commission can use its 6% access rights for the benefit of EU Member States. At the same time, the JHR International Advisory Group (JHR IAG), which was set up by the Governing Board, continued its work in assessing the experimental costs; this work is expected to be completed in 2023.

In addition, the OECD re-launched its FIDES framework (now FIDES II) under which part of design work for the future JHR experimental capacity was continued. The JHR consortium also progressed in its actions for the JHR Archive Material initiative that aims at selecting, characterising and testing a reference material for the lifetime of the JHR.

The JHR Consortium is committed to driving the project's progress to successful finalisation. In 2023, the final design for the reactor and the new schedule for construction are expected to be completed. Meanwhile, the Consortium will continue its actions in preparation of the future operation of the JHR, fully supporting the CEA along the way.

There are still numerous activities to be completed in many different fields, but our Consortium is strong and I am confident this work can be accomplished with a target that is clear to all of us.

David EMOND
JHR Project Director

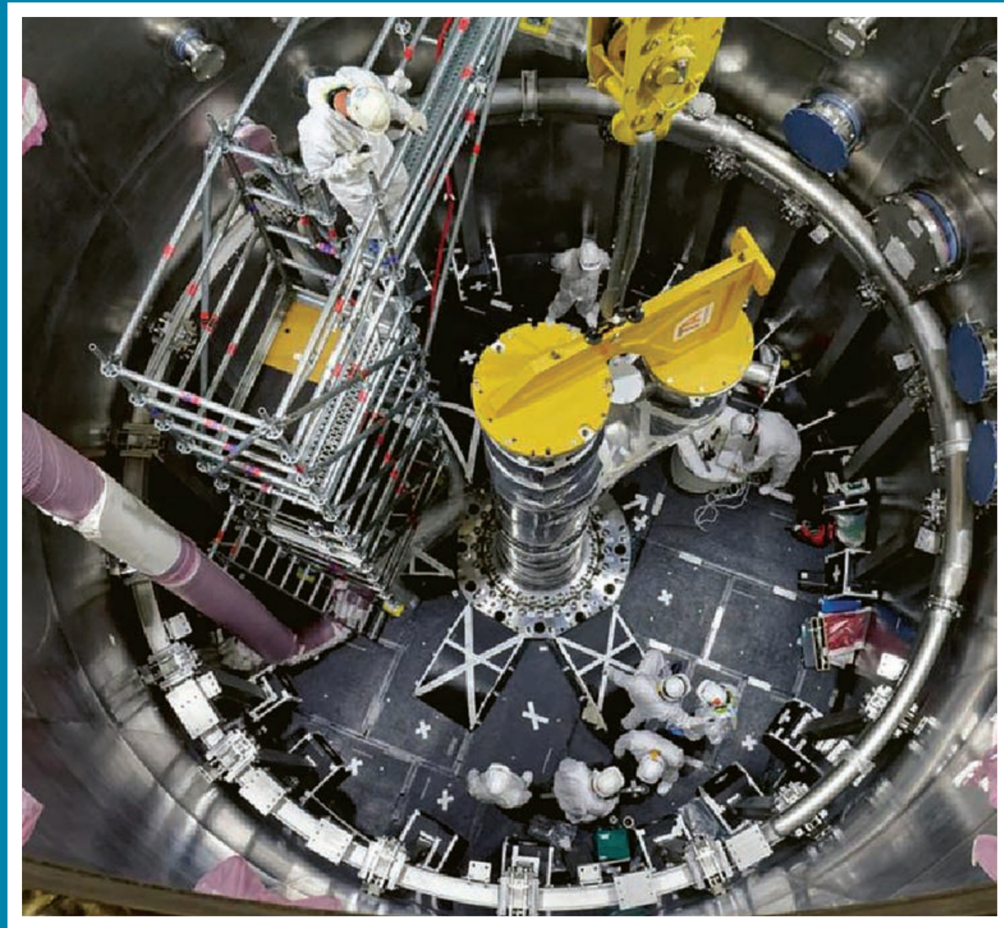
In the first days of 2023, the CEA sent the French government its roadmap for completing the JHR reactor and the first experimental devices, followed by a reassessment of the project schedule and cost.

Having achieved more than 2 years with no lost-time accidents and a 94% on-time delivery rate in 2022, the JHR project is now ready to start electromechanical installation at full speed. We expect to be welcoming dozens of workers to the construction site very soon.

The JHR project has reached a turning point. The credibility of our roadmap relies on the commitment of all stakeholders: the CEA is, of course, fully engaged in delivering a successful project; the support of the French authorities is also key during this phase; contractors who are willing to accelerate and achieve the project as would the Consortium members.

There is still a long path to completion and the CEA is counting on each Consortium member to continue supporting the JHR project to the very end. The JHR project will submit a revised frame addressing both the construction and the operations phases. We expect to reach a joint agreement that will secure the success of the JHR project and serve the interests of each member.

Auguste Escoffier, a famous French chef, used to say that his goal was perfection and the way to reach it was simplicity and honesty. Let us take this as a source of inspiration to finalize the roadmap that will lead the JHR project to a successful start-up and operation!



2 Safety

Guillaume Villard
Site Safety and Security 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 indicators

The accident frequency indicators remained at a good level: no accident with lost time occurred in 2022. The last accident with lost days occurred in October 2020.

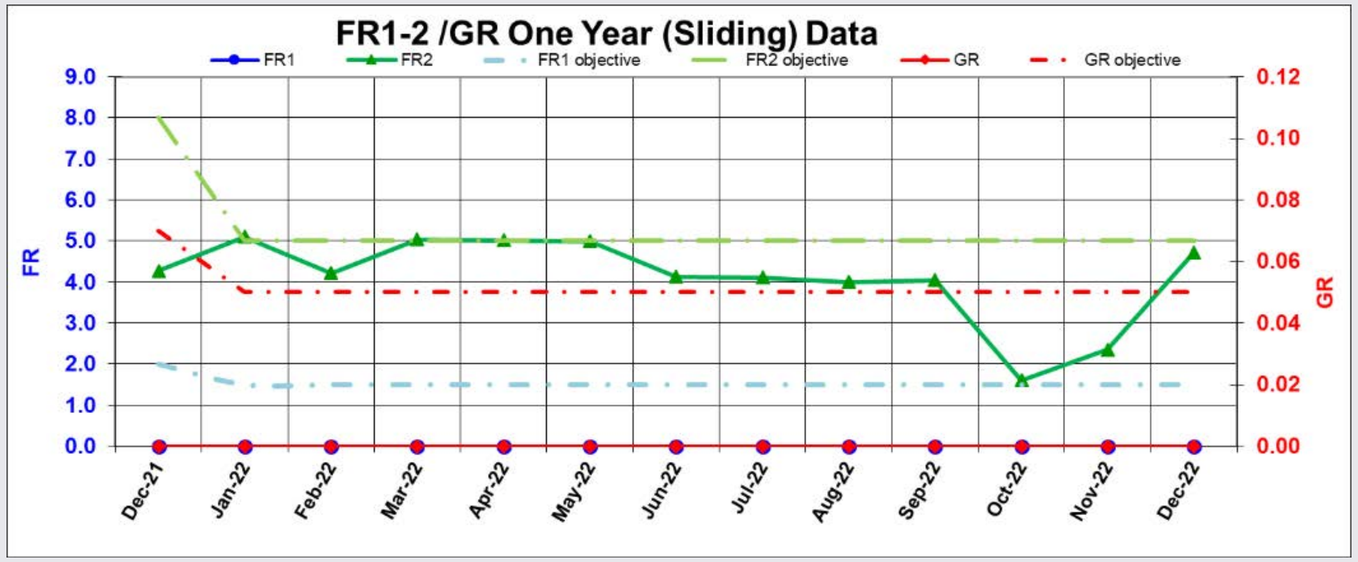
Two standing records were therefore reached in 2022:

- Milestone of 2 million working hours without any accidents with lost time as of June 2022
- Milestone of 2 years without any accidents with lost time as of October 2022.

However, the number of accidents without lost time remained at the same level as that of 2021. These accidents mainly occurred during the fourth trimester (4/6), with half of them being due to pedestrian movement on the construction site.

Safety Key Performance Indicators in 2022

FR1	FR2	GR
0.0	4.7	0.0



- *FR1 (Frequency Rate 1): 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 1): 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.*

THE MAIN EVENTS IN 2022 WERE:

- 0 accidents with lost time
- 6 accidents with no lost time
- 6 events requiring first-aid care

Average daily number of workers on the construction site per month in 2022:

Jan	feb	Mar	Apr	May	Jun	Jul	Aug	Sep	Oct	Nov	Dec
703	718	720	703	703	**730**	698	644	709	711	721	630

2.2 Industrial safety actions

2.2.1 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.

2.2.2 Industrial Safety and Environment Day

Industrial Safety & Environment Day took place on 4 October 2022 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 in this event, and several workshops were led by contractors, e.g. scaffolding safety or electrical risk detection.

A total of 65 visits were carried out in 2022, with 229 good practices observed and 101 hazardous behaviours corrected.

The following workshops were proposed:

- Safety escape game: 108 participants
- How to use a fire extinguisher: 102 participants
- Managing stress through yoga and breathing: 58 participants
- Seated massage: 75 participants
- Resitting the driving theory test: 66 participants
- Sport: 41 participants
- Conflict management: 48 participants
- Osteopath: 13 participants
- Lifting activities: 68 participants
- Electrical risks: 75 participants
- Well-being and personal development to enhance professional performance: 75 participants
- Safety buzz: 49 participants
- Safety theatre: 92 participants
- Road safety with policemen: 80 participants
- Safety risks' treasure hunt game: 10 participants
- Risk prevention' card games: 68 participants
- Ergonomics: 23 participants
- Scaffolding safety: 36 participants
- Electric mobility: 42 participants

2.3 Awards

2.3.1 Company industrial safety award

In 2022, 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:

Q1/2022: BOCCARD

Q2/2022: EQUANS

Q3/2022: MAINCO

Q4/2022: CLEMESSY

2.3.2 Employee of the month

In 2022, 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

2.4 Emergency drills

About 12 emergency drills are organised every year to train staff in how 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.

David EMOND
JHR Project Director

3.1 Consortium organisation for the operation phase

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.

* picture by Yves Gauthier

3.2 Project organisation

The project organization team, within the CEA, has the responsibility of leading the JHR project up to reactor start-up and the first experiments within the framework of 4 basic values and behaviours:

- Always give priority to safety
- Speak the truth
- Get results
- Promote team spirit

4 JHR COMMUNITY

Fabrice Carle
Clients and Consortium Manager

4.1 Governing board and support programmes activities

4.1.1 Consortium new members

The CEA is mandated by the governing board to enlarge the JHR International consortium by accepting new members. During the year 2022, the CEA continued to exchange with potential clients having shown interest in joining the JHR international consortium.

Nevertheless, the CEA has chosen to wait until the French government decision in 2023 before proposing any technical and financial offer to prospective clients.

4.1.2 JHR working groups

Following the Covid-19 pandemic, the three working groups (fuel, material and technology) were pleased to be able to meet again in person in 2022.

They met twice:

- At the 11th scientific and technical seminar in Aix-en-Provence (France) in April
- During a series of specific meetings in Rez (Czech Republic) organised by colleagues from CVR who also planned visits to the LVR15 research reactor and the SUSEN hot laboratory

The main activities of the three working groups involved:

- Providing information and deliverables in support of the JHOP 2040, a European project (see below)
- Issuing the summary document in mid-2022, describing the R&D needs for the first experiments in the JHR

This summary document represents an important milestone regarding the work performed by the working groups and inspires confidence with respect to the on-going development of the first fleet of experimental devices.

(private document)

JHR CONSORTIUM
FUEL, MATERIALS AND TECHNOLOGY
WORKING GROUPS

Synthesis Document on future R&D needs
updated as of Mid-2022

Work coordinated by

S. Gardey, EDF	Materials Working Group Convenor
M. Miklos, CVR	Fuel Working Group Convenor
R. Van Nieuwenhove, SCK CEN	Technology Working Group Convenor

With the contribution of

P. Guimbal, CEA	Materials Working Group Scientific secretary
S. Bejaoui, CEA	Fuel Working Group Scientific secretary
S. Gaillot, CEA	Technology Working Group Scientific secretary

and members of the three Working Groups

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.

4.1.3 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: UJV - 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 significant work was completed in 2022, including:

- Publication of the summary document from WP1 called the Strategic Research Plan: JHR years 1-4 (available on the JHOP 2040 sharesite)
- Publication of the summary document from WP2 called the Strategic Research Plan: JHR Years 5-15 (now available on the JHOP 2040 sharesite)
- Publication of the first deliverable from WP3 called the JHR Programme Structure and Governance,including resources, targeted costs and financing model for the first four years (now available on the JHOP 2040 sharesite)

4.2 JHR as an international facility

4.2.1 Scientific seminar

The 11th scientific and technical seminar on the JHR experimental capacity was held from 5 to 7 April 2022 in Aix-en-Provence, with the possibility of remote participation through videoconferences for colleagues not able to travel (China, India).

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

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

- JHR project and the new organization
- Design of the experimental devices (fleet 1 and fleet 2&3)
- In-kind contributions for experimental devices
- Secondee's work, which included a presentation
- Preparation of international joint programmes (OECD/NEA/FIDES, EURATOM, etc.)
- Updated version of the 2015 summary document on R&D needs

Half a day was dedicated to parallel sessions organised for each working group.

A technical visit of the JHR building site and the TOTEM facility (in which the non-destructive test benches by VTT were being tested) was organised and greatly appreciated by the participants.

4.2.2 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 first governing board meeting held in May 2021 endorsed the first four joint R&D projects (called JEEP), which will be implemented in the coming years.

The JHR consortium members are particularly involved in two projects: the 'Power to Melt and Manoeuvrability' (P2M) project that sets out to perform slow-power transients to reach partial fuel melting, and the 'In-Pile Creep studies of Accident-Tolerant Fuel cladding' (INCA) project.

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.

4.2.3 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 2022 on the specifications of the reference material and on identifying potential companies that could provide such a material.

During the last months of 2022, significant efforts were undertaken to encourage the Material working group members to incorporate the JAM initiative into a broader proposal on material within the FIDES-II framework called INCREASE, which is led by US organisations (DOE, NRC and EPRI).

This proposal was endorsed (programme and budget) in early 2023 and is now under way. The reference material for the JAM project was ordered in December 2022 and should be delivered to the CEA in spring 2023 for cold characterisation.

The first irradiation of the JAM samples is scheduled to take place in the Advanced Test Reactor (ATR) in Idaho sometime in 2025.

4.2.4 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 CEA 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.

During the 66th IAEA General Conference in September 2022, a successful side-event of this ICERR scheme was organised by the CEA to promote the initiative focused on the JHR.

4.2.5 Conferences

A presentation was given to the European conference on research reactors (RRFM) in June 2022 called 'JHR experimental capacity under development for the start-up of the reactor and the years after: updated status early 2022'.

During the same conference, the CEA participated in a panel discussion (with other key European contributors such as the SCK CEN Belgium nuclear research center, the NRG Dutch Institute, the Polish NCBJ nuclear research center, etc.). It discussed the foreseen production of radioisotopes for medical applications in the JHR within the framework of the European SAMIRA action plan on the security of supply of medical isotopes.

5 PROJECT PROGRESS

Guillaume Villard
Site Safety and Security Manager

5.1 Global overview

In 2022, all of on-time delivery milestones for site activities were achieved:

- Delivery of embedded feedthrough sections between the BMN gallery and the reactor building
- Installation of 6 RSS feedthrough in the reactor primary containment wall
- Development of general installation sequences for all JHR areas
- End of the drilling activities in the intermediate area between the reactor pool and the shielded cubicles
- 1st phase of BND channel constructions

MAIN ACHIEVEMENTS IN 2022

Each of these above 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.

Industrial safety, technical coordination and nuclear cleanliness teams worked hand in hand to ensure that all installation activities complied with the industrial safety and quality requirements.

In the meantime, lessons learned were implemented with respect to electromechanical activities in order to secure the schedule and improve installation processes.

As an example of the lessons learned:

- Management process was deployed to ensure the sealing of civil works penetrations
- Installation sequences were improved with the deployment of support structure installation campaigns for all contractors, rather than successive contractor operations on support structures and equipment erection
- Cleanliness tents and scaffolding were set up by the CEA for installation contractors in order to secure interfaces

KEY MILESTONES IN 2023

In 2023 the preparation of bulk installation works is the key challenge for JHR schedule implementation. The main detailed erection sequences will be issued with contractor cooperation, storage areas will be prepared, and installation processes will be further improved with lessons learned from BUA first-levels activities.

The on-time delivery milestones for site activities are:

- 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 some rooms at level -2 of the nuclear auxiliary building
- End of airlock sealing in the transfer pool
- End of DLC structural erection (structure above the reactor pool)

David EMOND
JHR Project Director

Philippe GAÏ
Project Control Manager

5.2 Project roadmap

For the JHR project, the CEA implements a roadmap that has been divided into two phases:

1st phase - 2021-2023:

- Completion of the detailed design and finalisation of layout (3D model)
- Resolution of remaining technical sticking points
- Manufacturing and qualification of critical equipment
- Small-scale installation test of components (electrical cables, pipes, ventilation, etc.) in critical areas to collect feedback

2nd phase – post-2023:

- Finalisation of quantities on the basis of the detailed design and the 3D model
- Ramp-up of equipment/system installation up to commissioning tests and start-up

A project review milestone is scheduled in 2023 with the French government to reassess:

- Remaining work with a low level of uncertainty
- Overall schedule based on the equipment/system installation times
- Cost at completion

5.3 Milestones and schedule 2022

In 2022, the reference schedule at completion was updated by the JHR project team and the main suppliers.

The management of key milestones has been closely monitored.

Thirty-six milestones have been identified in the new roadmap and 94% of them have been reached on time.

In particular:

- Reviewing the architecture of displacement systems for molybdenum[99]
- Defining the strategy for construction-related contracts
- Carrying out a detailed design review of the BND
- Reviewing the maturity of the reactor and its ancillary facilities design

5.4 Risks management

Risk and opportunity management is at the heart of project control, making it possible to anticipate key issues and implement mitigation actions in due time.

Key risks and opportunities for the JHR project have been compiled into a single portfolio that is managed at project level, improving the resolution of cross-disciplinary issues, and identifying risks and opportunities at each level of the organisation.

The status of actions is monitored on a monthly basis.

The risk portfolio includes approximately 100 main risks that are monitored at project level. These risks mainly concern:

- Technical issues (vibration) with core components
- Compactness of the design, which may impact feasibility in some areas and the progress of concurrent activities (known as 'coactivity' in France) during the assembly phase
- Delays in convergence on the detailed design, depending on the integration constraints of supplier equipment
- Delays in the validation of safety cases by the ASN

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 remit:

- 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)

Reflector

Philippe DAUBRIVE
Construction Manager

In 2022, the integrated project platform (PPI) set up in 2020 continued its activities using a collaborative working method with its contractors.

The main actions completed in 2022 were:

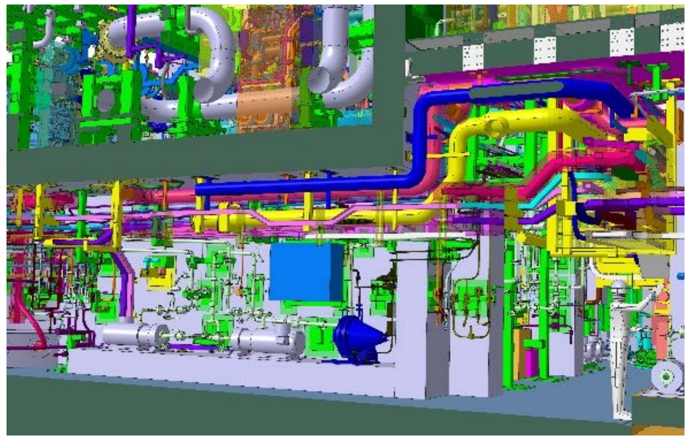
- Agreement on the numerical mock-up configuration of JHR rooms and areas
- Resolution of configuration issues in complex rooms
- Clarification of the electrical interfaces

Working together within an integrated technical platform (PTI), the CEA and its main contractors were able to agree on the configuration of four areas in the JHR facility through combined efforts on the numerical mock-up. As of 1 January 2023, the tasks remaining to be done by this platform are:

- Agreement on the numerical mock-up configuration of five more areas
- Incorporation of changes to cableways into the 'assembly' configuration
- Resolution of reservations
- And resolution of sticking points encountered during configuration finalisation

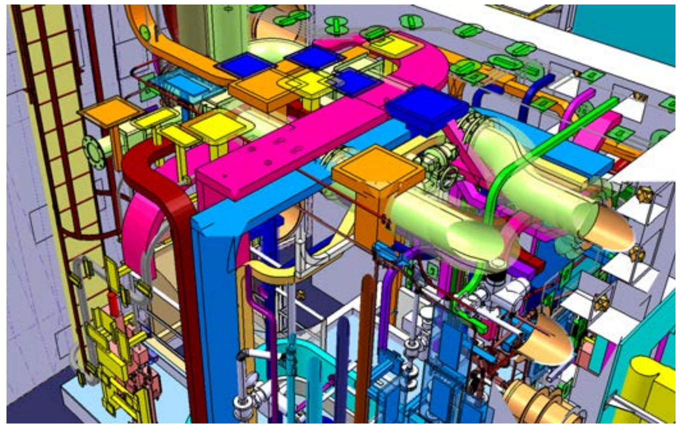
Several examples of validated configurations:

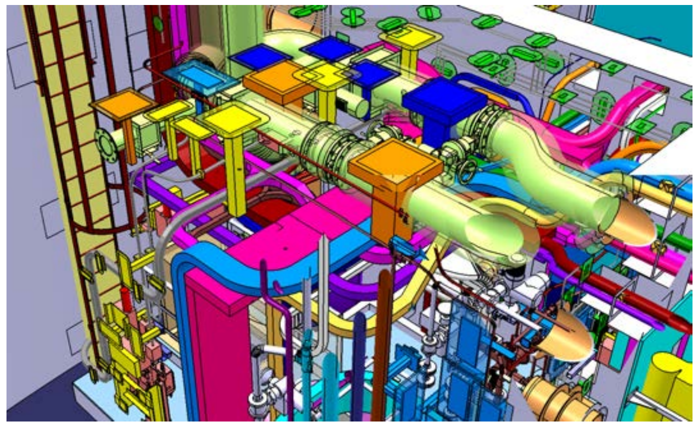

Example in BUA +1


Example in BUR -3

Working groups comprising both contractor and CEA staff have continued to work on resolving configuration issues (sometimes impossible situations) encountered in some very complex rooms. About fifteen such rooms have been analysed and their configuration finalised.

Example: major interference between cableways, ventilation ducts and fluid systems was resolved by reconfiguring the room layout and changing cable routes.


Problem


Solution

KEY MILESTONES IN 2023

In 2023, the JHR construction division set up a unit responsible for maintaining operational conditions onsite. This unit is tasked with carrying out preventive and corrective maintenance, and with conducting periodic tests on equipment and structures delivered onsite, to make sure they remain in good working order until their qualification and commissioning in the JHR facility.

This construction division also recently defined the organisation for another new unit called “construction site engineering” that will be set up onsite in early 2024. This purpose of this unit will be to resolve any issues that arise during the assembly phase. It will gradually replace the integrated technical platform team once all configurations have been finalised.

Antoine Dewavrin
Building, Pools & Cells Manager

7.1 Buildings, pools and cells

MAIN ACHIEVEMENTS IN 2022

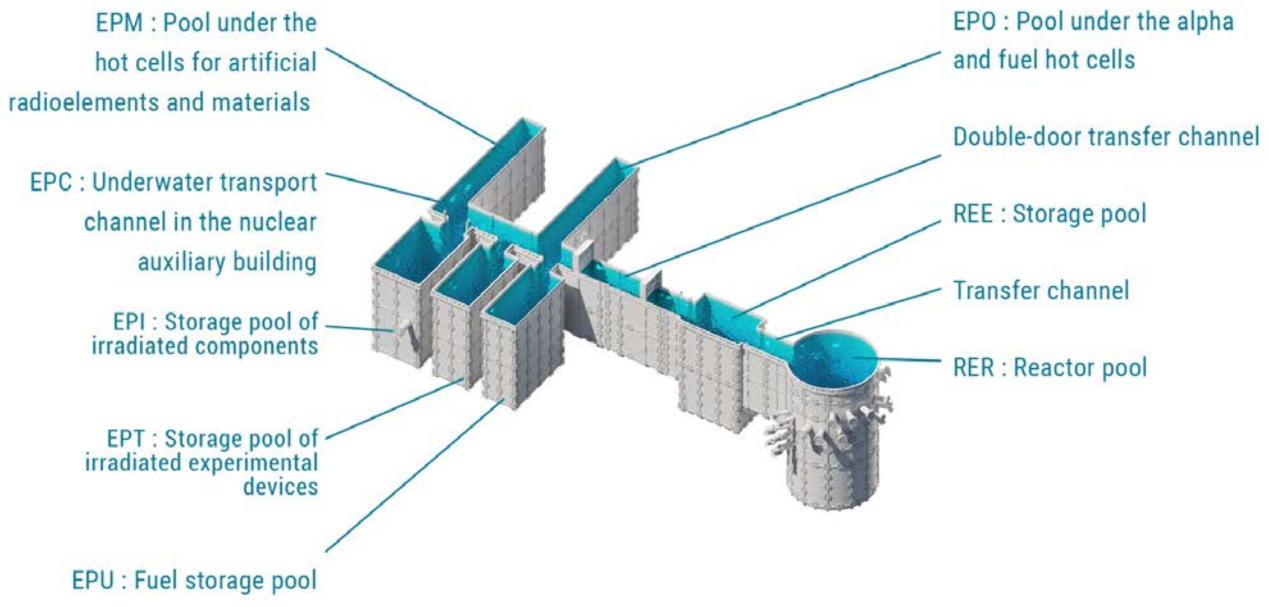
The year 2022 was marked by the following achievements:

- Start of erection of the DLC structure in BUR building
- Concrete cable troughing between nuclear building and the BND
- Creation of openings and preparation of these holes for the assembly of the HVAC and electrical systems in the BUR building
- Site assembly of the hot cell windows
- Finalisation of the EPT pool liners in the nuclear auxiliary building, including the bases
- Investigation regarding visible traces found on the RER pool liner: confirmation of local stress corrosion covering a section limited to 3 metres of the liner welding in ring 1, with no other evidence detected anywhere else in the RER pool. The repair procedures are in the process of being validated

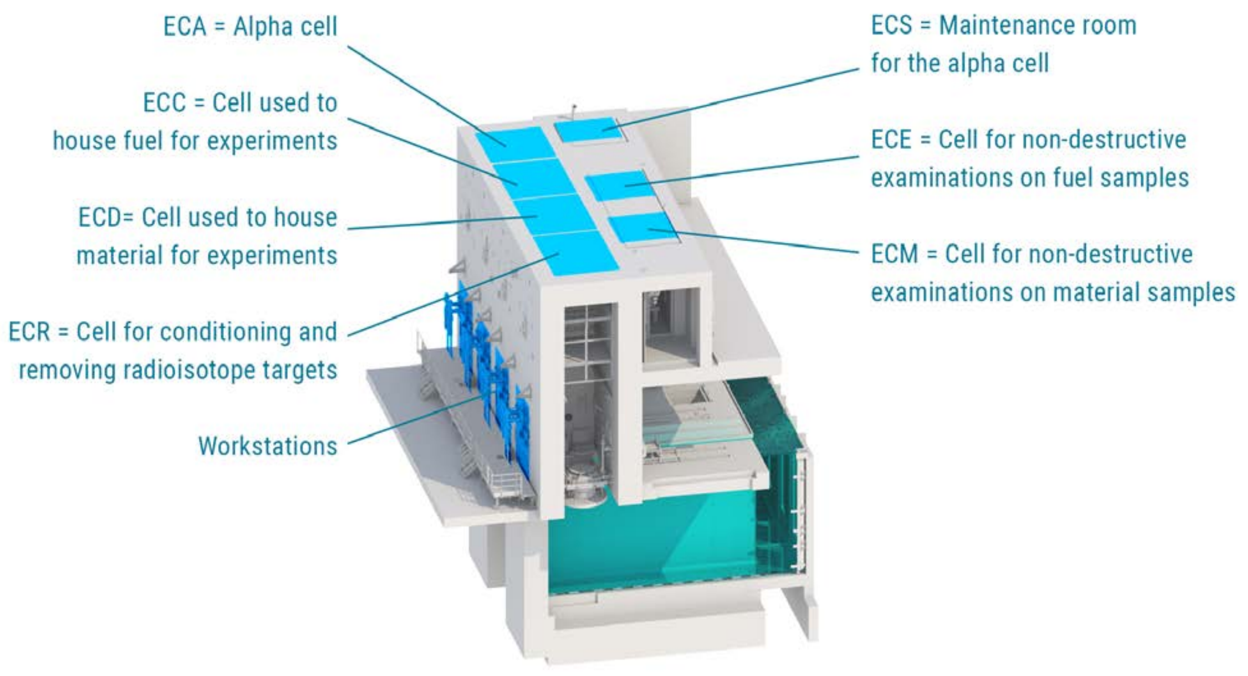
7.1.1 Engineering activities

- 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 on the conveyors for the electronic instrumentation system 2 (EIS2) dewatering prevention system

Pools



Building



7.1.2 Factory activities

7.1.2.1 Hot cells (Czech in-kind contribution)

- Continuation of manufacturing activities for the lifting units ECC (Large hot cell to house fuel experiments), 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)

7.1.2.2 Lightweight telemanipulators

Factory testing and acceptance of the telemanipulators.

7.1.2.3 Pool liners

The reactor pool complex has been divided into 5 pool areas:

- Two in the reactor building:
  - RER (reactor pool)
  - REE (intermediate pool)
- Three in the auxiliary building:
  - EPI (storage pool of irradiated components)
  - EPT (storage pool of irradiated experimental devices)
  - EPU (fuel storage pool)
- Three canals (in the auxiliary building):
  - EPC
  - EPO
  - EPM

The main 2022 achievements regarding the pools are:

- Factory acceptance of the EPI gamma penetration
- Factory acceptance and onsite delivery of the airlock underwater doors between the BUR and the BUA
- Start of manufacturing of the underwater conveyor

7.1.2.4 Secondary handling

- Beginning of tests on the mechanical assembly of the RMD bridge and the winding telescopic extension arm system
- Continuation of manufacturing for the conveyors and main EPO structures
- End of the manufacturing of a test bench to test screw-nut material combinations following the ACTEON (Nickel-based alloy enriched with chromium and molybdenum allows friction with all conventional stainless steels without lubrication and without seizing) nut seizing issue during underwater tests on the conveyors

7.1.2.5 Hot cell equipment

- Manufacturing finalised for the shielding doors of the automatic fire detection sensors
- Factory manufacturing continued for some equipment (trapdoors to canals, biological shielding plugs, ventilation systems, etc.)
- Factory acceptance of storage, washing and investigation pits

7.1.3 Onsite activities and acceptance procedures

7.1.3.1 Civil works and buildings

- Concrete cable troughing between the nuclear building and the BND

7.1.3.2 Experimental utilities and pools

Hot cells (UJV-CVR in-kind contribution)

- Shielded partitions for the sliding doors assembled between the small and large hot cells
- Installation of the inflatable seal completed for the docking pit in the hot cell used for radioelements (ECR)
- Installation of the ECR floor started
- Door installation operations continued in cells and hatches (mechanical adjustments, wiring, etc.)

Pool liners

- EPT pool liners completed (excluding the bases)
- Cutting and assessment of samples taken from the weld in the RER pool

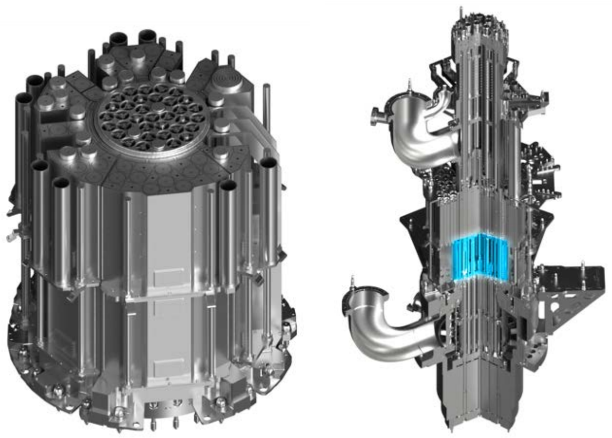
Secondary handling equipment

Modifications made to the EMT transfer crane (under the ECR hot cell) were taken into account: the EMT transfer crane repair procedure has been defined and the list of spare parts has been established.

Erection of the DLC structure in the BUR building has begun.

Pascal Pierre
Reactor Block Manager

7.2 Reactor block



In 2022, the main activities on the reactor block project are described hereafter.

7.2.1 MOLY displacement system project

MOLY project = project of the displacement system (4 irradiation positions) developped to optimize the molybdenum^{99} irradiation and production.

A review of the MOLY project architecture was initiated in March 2022. It highlighted opportunities for improving robustness and reliability by simplifying the MOLY process, mainly the refrigeration circuit (back-up pumps located in the shielded cubicle instead of immerged pumps in the reactor pool). A new configuration was studied and its design is under progress. Most of the MOLY contracts are affected by this general modification and a new industrial set-up is being defined.

7.2.2 Pile block unit

In 2022, most of the equipment for the pile block unit reached important milestones. Some of these facilities are still being studied, others are being built, and some are being finalised.

After acceptance, the thinner elements were lent to the 'Internal Structures Analysis' working group to improve their behaviour in the test loops.

Factory activities

Lifting beam

The lifting beam for the closure head was accepted in November. This is a very complex tool necessary for inter-cycle operations. It will be stored onsite at Cadarache pending site testing.

Reflector

On 29 July 2022, the milestone for completing the factory assembly of the reflector was achieved.

This very important step announces the end of the manufacturing process for this equipment. To make this reflector, the teams had to develop specific riveting processes on very thin aluminium parts.

Displacement system mock-up

Displacement system for irradiation devices. In 2022, in air tests have been launched on a representative mock-up of the displacement system and will continue in 2023 with underwater tests.

Monitoring mechanisms

Acceptance tests for equipment in the crypt performed on 16 November in the presence of the future operator

Lifting beam

Reflector

System mock-up

Monitoring mecanism

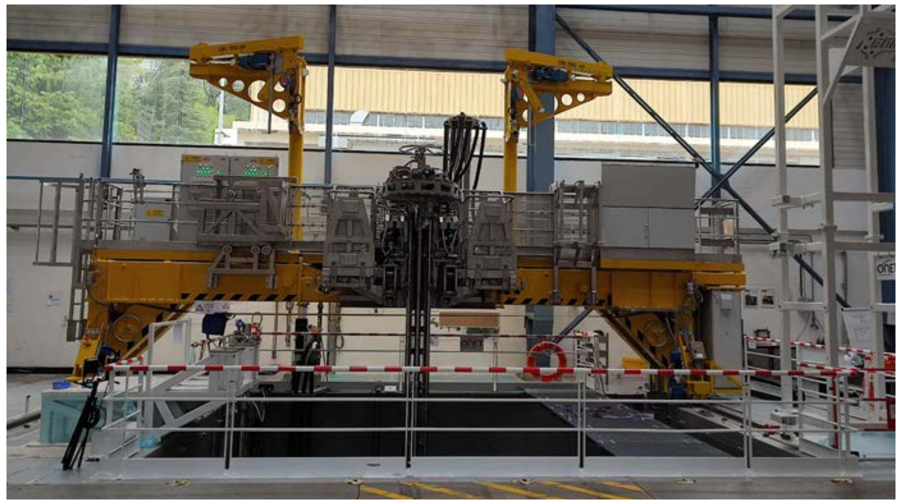
7.2.3 Loading/unloading machine

In the second half of 2022, interconnected tests both in air and in water made it possible to secure the unloading / rearrangement / loading of the core in semi-automatic mode.

Training sessions for the future operator have been scheduled to take place in 2023.

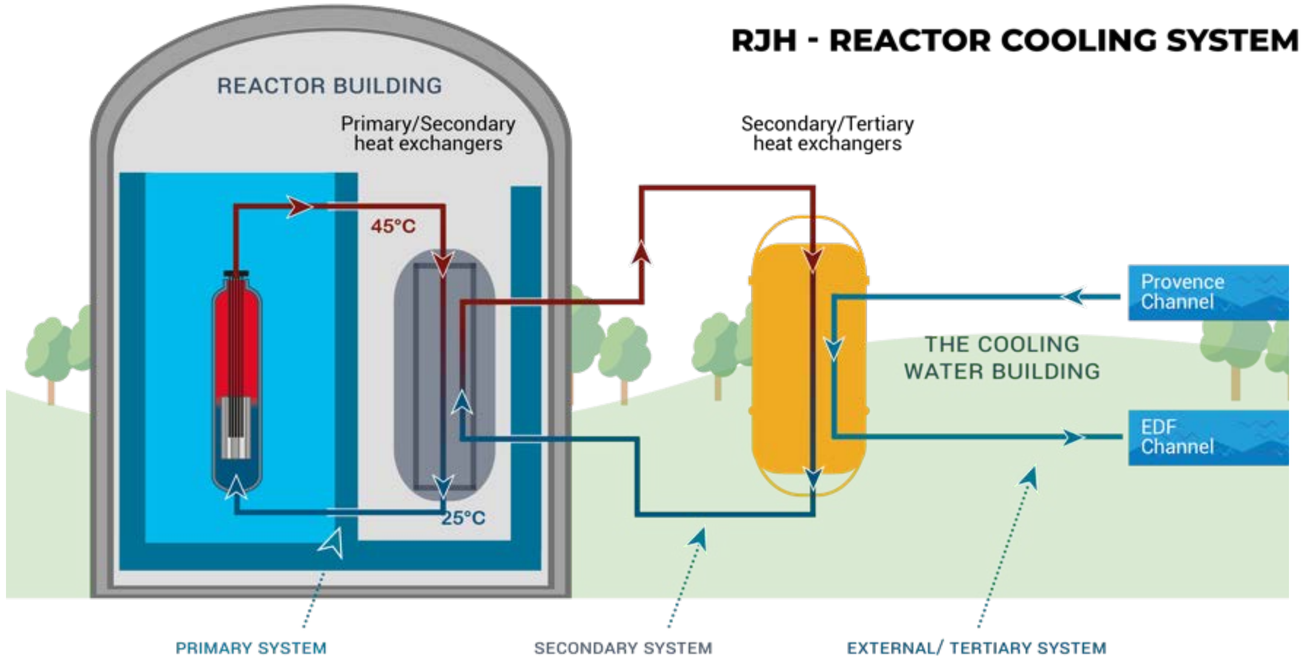
The core fuel element loading machine will then be stored for a few years before being remobilized for reactor operations.

Test of loading / unloading



Loading machine

7.2.4 Cooling system



7.2.4.1 Primary Circuit pumps

The contractor of the JHR primary pump contract carried out the functional tests on the primary pump, as were the endurance tests on pump No. 2.

The primary pump was successfully operated for 400 hours in December before being completely disassembled to check the condition of the components.

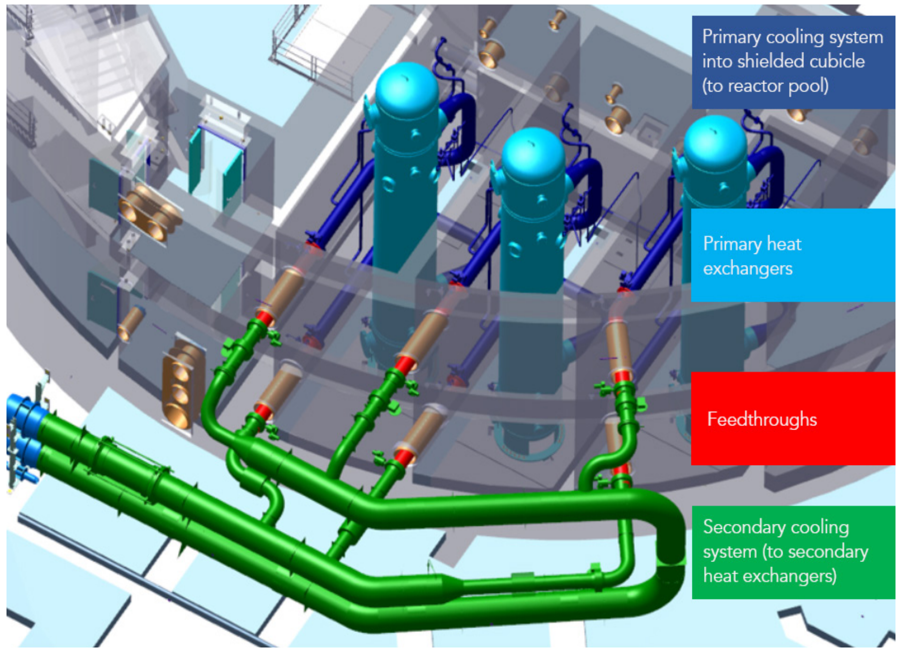
The work sequence will now continue with the assembly of the RSS in the ZRF, in accordance with the project schedule

Primary circuit pump

Feedthrough assembly

7.2.4.2 Primary system in the shielded cubicle

The six feedthroughs of the main secondary system were mounted on 3 February 2022. These feedthroughs form the connexion between the primary heat exchangers and the RSS circuit.



Feedthrough assembly

7.2.4.3 Progress

Onsite activities

The final assembly of the floor structure for the secondary shielded cubicles in the reactor block unit was accepted in June.

Factory activities

Fabrication of the bellows for the expansion joint (safety fluid) were launched in 2022.

Heat exchangers (Spanish in-kind contribution)

Following the detection of orange marks on the tubes of a primary heat exchanger (traces of surface oxidation were suspected inside the tubes), extensive visual inspections were carried out on the three primary heat exchangers in September 2022 and early 2023. These inspections confirmed the presence of loose material as well as oxidation which will need for specific treatment before the heat exchangers could be considered ready to be welded to the primary system.

Rémy Pommier
Fluids and HVAC Manager

7.3 Fluid and HVAC systems

7.3.1 Engineering

7.3.1.1 Fluid systems

MAIN ACHIEVEMENTS IN 2022

- 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 2023

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.

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

MAIN ACHIEVEMENTS IN 2022

The main achievements for the HVAC 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 in the reactor hall (BUR)

KEY MILESTONES IN 2023

The following main tasks planned for the coming year are:

- Update the functional system files to take into account major topics concerning the sub-configuration status
- Optimisation of the JHR 3D model on all levels to complete the launch of the detailed design documentation, except for the CEDE erection areas in the nuclear building

7.3.1.3 HVAC back-up building (BAS)

MAIN ACHIEVEMENTS IN 2022

Regarding the progress made in engineering for the HVAC back-up building (BAS), the design finalisation review was successfully completed based on configuration V3.2 corresponding to the erection configuration status.

KEY MILESTONES IN 2023

The main milestones identified for the coming year is the optimisation of on JHR BAS Buildings' 3D model to complete the launch of the detailed design documentation, except for part of the CEDE erection areas in the nuclear building.

7.3.2 Manufacturing

7.3.2.1 Fluid systems

MAIN ACHIEVEMENTS IN 2022

The main achievements in fluid system manufacturing are:

- Delivery of major components for the conventional auxiliary building (BMR)
- Manufacturing of pipe spools launched on a large scale during the first semester of 2022, before it was halted and then resumed in late 2022 after resolution of major quality issues in the manufacturing premises

KEY MILESTONES IN 2023

The key milestones for 2023 are to:

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

7.3.2.2 HVAC (except the emergency diesel generator building)

MAIN ACHIEVEMENTS IN 2022

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

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

KEY MILESTONES IN 2023

The key milestone for 2023 is to continue delivering key components and equipment for the conventional auxiliary buildings, as well as components for the nuclear auxiliary building.

7.3.2.3 HVAC back-up building (BAS)

MAIN ACHIEVEMENTS IN 2022

The main achievement of the year is the manufacturing of some tests components.

KEY MILESTONES IN 2023

The key milestone for 2023 is to continue production of the test components and their qualification process.

7.3.3 Assembly

7.3.3.1 Fluid systems

MAIN ACHIEVEMENTS IN 2022

In terms of construction, this year saw:

- Delivery of all major components in the BMR building
- Continued installation of the fluid systems in the nuclear unit building (level -2 and -3)

KEY MILESTONES IN 2023

In 2023, 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)

7.3.3.2 HVAC (except the BAS buildings)

MAIN ACHIEVEMENTS IN 2022

Progress made in the field of HVAC concerns:

- Installation work in the nuclear auxiliary building (level -2 and -3) and completion of duct installation on the mezzanine floor in the BUR reactor hall

KEY MILESTONES IN 2023

In 2023, the team will focus on:

- Completing the installation of all equipment in the auxiliary refrigeration and utility building (BMR)
- Installing the ventilation and air-conditioning systems on levels -1, -2 and -3 in the nuclear auxiliary building

Philippe GUILLEMOT
Electrical and I&C Systems Manager

7.4 Electrical and I&C system

7.4.1 Engineering

In 2022, the key progress made in electrical and I&C system engineering are:

- Design revues in configuration 3.2 for:
  - Electrical equipment (90 % of reviews completed). Some examples include:
    - Electrical panel (50 switchboards)
    - Fire detector system in the control rooms
    - High- and low-voltage (HV and LV) electrical short circuit units
- Update of I&C system studies in configuration 3.2 (80% of studies completed)
- Qualification testing for electrical equipment:
  - Electrical penetration with two solutions

Figure 1

Figure 2

  - Thermal testing of safety electrical panels

  - Earthquake testing of:
    - Electrical panel for the radiation monitoring system
    - HV short-circuit units

Monitoring system

HV short circuit units

- Qualification of industrial sensors:
  - 27 types of sensors representing 1120 sensors:
    - Flow measurements, temperature measurement, and hygrometry station

Sensor for flow mesurements

Sensor for temperature mesurements

Hygrometry station

KEY MILESTONES IN 2023

The main milestones for the year will involve:

- Continued design reviews in configuration 3.2 for:
  - Electrical equipment (100% of electrical distribution equipment reviews completed)
- Completion of installation studies for the upper levels of the nuclear unit to ramp up assembly operations in 2024
- Start of final qualification for electrical equipment:
  - Electrical penetrations, electrical safety panels, high-voltage short-circuit units, transformers, cables, fire systems and small equipment (e.g. lighting)
  - Earthquake testing of the automation platform for safety-class 3 I&C systems
- Creation of the object libraries for the human-machine interface (HMI) and automation software development
- Factory test of safety-class 2 I&C system software

BMR *+0*

BUA*-2 S14*

7.4.2 Construction

MAIN ACHIEVEMENTS IN 2022

The main construction achievements for the year were:

- Manufacturing of safety radiation sensors
- Continued manufacturing and installation of cable tray supports on the lower levels of the nuclear unit
  - 1500 cable tray supports manufactured and 1200 mounted

KEY MILESTONES IN 2023

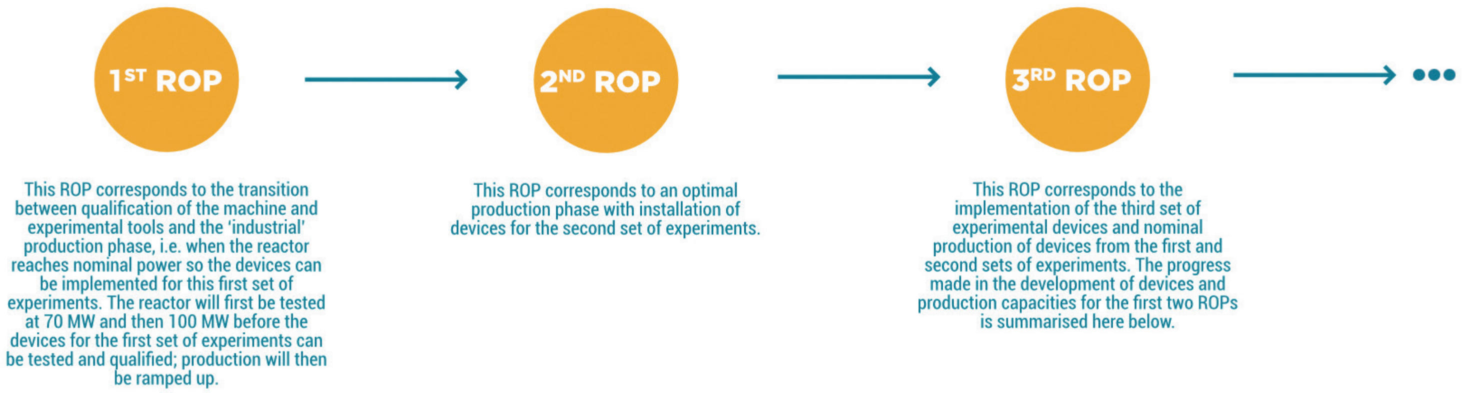
The year 2023 will focus on:

- Continued manufacturing of cable tray support structures
- Continued installation of cable tray supports on the lower levels of the nuclear unit
- Manufacturing of the process simulator for the current JHR configuration

Raphaël PALHIER
Experimental Devices Manager

7.5 First-phase experimental devices and associated utilities

During the operational phase, the JHR will be managed in periods of four years, with each period being defined in a reference operating plan (ROP). The first period will therefore require a first set of experimental devices, dubbed the 'first fleet'. The JHR project directorate is currently working on all the experimental devices, equipment and tools that will be needed for these first four years.



One of the JHR objectives is to carry out material and fuel experimental irradiations. To do so, the project is developing experimental devices that can be used as either simple capsules or complete loops.

The JHR project is expected to offer the following range of experimental devices with their related utilities:

The other objective of the JHR is to produce radioisotopes for the medical and industry sectors, as well as for any other applications.

The first radioisotope objective for the JHR is to ensure between 25% and 50% of the European production of molybdenum^{99} required in nuclear medicine for a wide variety of tests (e.g. bone cancer diagnosis).

The MOLY device will be irradiated in the JHR reflector using U^{235}-enriched targets to produce molybdenum^{99} (LEU target).

The production system and its associated equipment and tools are managed by the reactor block project whose progress is detailed in Section 7.2. This production system is embedded in the reactor block project and therefore progresses at the same pace. The JHR is also expected to produce other radioisotopes, both from fission and neutron capture reactions. In accordance with customer needs, feasibility studies are being conducted to develop the equipment to be able to produce other radioisotopes. In order to start JHR production quickly and to carry out all the experiments and irradiations programmed, some activities are scheduled to take place as soon as possible after criticality has been reached in the JHR.

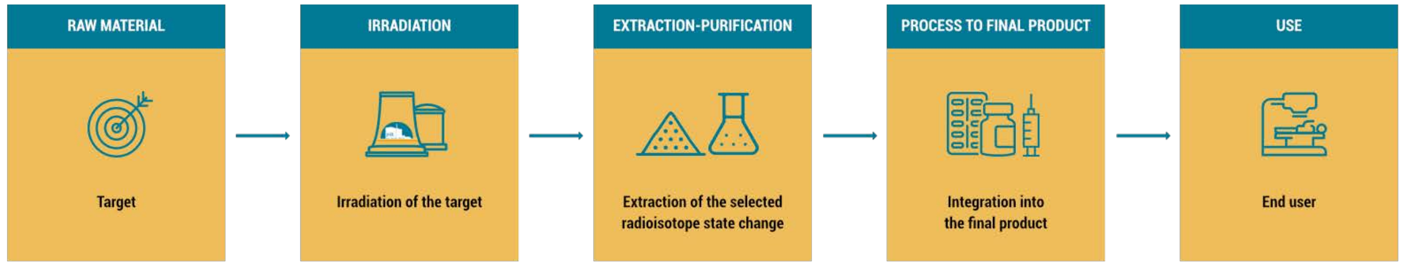
The following equipment has been identified:

- Neutron start-up sources and specific devices needed to ensure the subcritical loading of the core and to manage the subcritical approach to divergence
- Neutron poison absorbers
- Start-up instrumentation devices used for JHR acceptance tests (safety and technical performance)

  Several types of instrumentation (neutronic, photonic, hydraulic, thermal and mechanical) are transitioning from feasibility studies to manufacturing, with some of them involving dozens of systems. The results of in-core and ex-core irradiation monitoring devices recorded at different power levels will be used to check data in compliance with the nuclear safety authority (ASN) requirements.
- Some specific devices for the JHR vessel and reflector monitoring will also be installed
- Irradiation devices for the production of radioisotopes

7.5.1 Development of devices and tools for radioisotope production

This supply chain can be succinctly illustrated as such:



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

MAIN ACHIEVEMENTS IN 2022

The preliminary design studies of the multi-radioisotope devices were completed in 2022 and a review was organised. External experts examined the technical studies carried out during the year to give the green light to continue the engineering design studies.

Different concepts of sealed and reusable irradiation containers were studied to limit the production of nuclear waste (especially aluminium waste for the future customers). Mock-ups of irradiation containers were used to test their leatktightness after several opening/closing cycles.

Figure 1: Bayonet-and screw-type locking systems tested

In parallel, the mechanical design of the irradiation devices was defined for the different production locations, according to the type of radioisotope. Radioisotopes with a relatively short half-life such as ^{177}Lutetium for example will be produced in a short basket-type device in the reflector or in MOLY devices. The others radioisotopes will be produced in a standard long device in core or reflector locations.

KEY MILESTONES IN 2023

The engineering design studies will take place in 2023-2024. The main objective of 2023 is to consolidate the kinematics of radioisotope operating system in the reactor in order to define the optimal solution to manage the daily production of radioisotopes with relatively short half-lives. These studies will also make it possible to design the tools needed to carry out the operating operations in the hot cell.

7.5.2 ADELINE

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.

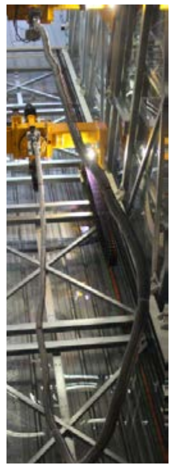
To do so, the device will be placed on a displacement system that travels through the reflector towards to the reactor core in order to subject the samples to power ramps. The main components of the device are given below.

MAIN ACHIEVEMENTS IN 2022 AND FOCUS ON RISK MITIGATION IN 2023

Underwater line prototype test on a special bench

Underwater lines are used to lead process systems and utilities from the shielded cubicle to the PWR rod sample through the reactor pool and the pipe penetration.

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 2500 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.

2023: Regulatory qualification

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

V-cone calibration tests and design validation of the jet pump system

These systems are located in the in-pile irradiation device and part of the process water loop. The V-cone monitors the water under LWR flowrate conditions and the jet pump amplifies the water flowrate around the experimental fuel rod.

V-cone calibration tests under PWR conditions (up to 155 bar and 330°C) were successfully completed in 2022.

The jet pump system experimental rig was fabricated in 2022 and the design validation tests under PWR conditions (pressure and temperature) will be conducted in 2023.

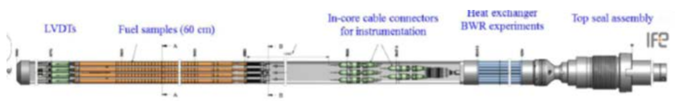
7.5.3 MADISON

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

The CEA plans to make this device available soon after the JHR start-up as a part of the first fleet of experimental devices. A device pooling 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 de vices, Halden experiments performed in 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.)



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 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 2022

The main roadmap is still progressing well and is consistent with the new milestones.

The experimental conditions have been updated with the future end users' needs and the project team in order to check the compatibility of these needs versus the design studies in progress.

Installation of the cubicle in the JHR facility was expected to end in 2023, but difficulties were encountered with welds between the cubicle structure and the steel inserts in the concrete floor. This issue is now being resolved.

The 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.

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

The CEA has delivered the main pump to IFE in order to perform the final test programme. The primary pump has been connected to the loop without any difficulties.
The second phase of the test was performed in 2022.

The MADISON test loop was started with the pump in May 2022 for cold tests, then 120°C hot tests were conducted on 25/05/22, followed by tests under PWR conditions (320°C) on 16/06/22.

The first step was to operate the pump focusing on the following points:

- Vibration monitoring (audible & felt by hand) by trained staff members
- Monitoring of the electrical parameters (isolation resistance, voltage, and current monitoring at start-up)
- Pump instrumentation monitoring (internal pressure and stator / bearing temperatures)
- Leak monitoring, pressure monitoring, level monitoring

Then cold tests were performed and the mock-up loop finally reached PWR conditions at nominal flow and full operating conditions.

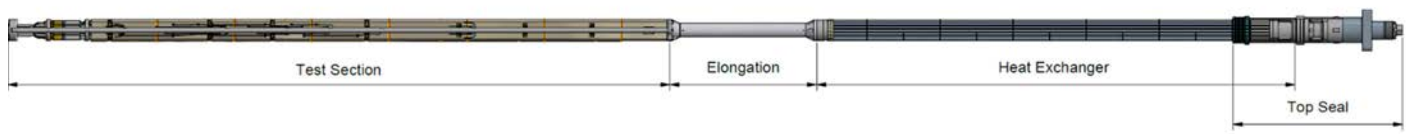
The main tests were aimed at verifying the general behaviour of the MADISON mock-up loop in terms of the stability of the main parameters (pressure, flow and temperature) during normal transients and relevant abnormal operating conditions for the loop.

In particular, tests were carried out to validate the normal operation of the loop; these tests mainly concerned the transients for starting and stopping the loop, as well as variations in the primary flow, cooling and electrical power.

The tests of the abnormal transients concerned the loss of heating elements and the untimely movements of actuators (e.g. inadvertent opening of the bypass valve on the flow control valves of the main exchangers, inadvertent closing of the relief valves to the low-pressure circuit (LPC), the closing of the secondary valves of the main exchangers, and the main pump flow decay measurements in the case of loss of power supply).

The goal was also to validate the design (thermohydraulic performance, chemistry, control systems and adjustments), but also to validate maintenance operations in a full-scale mock-up before manufacturing the final loop.

These tests made it possible to train JHR experimenters and JHR project design staff on the mock-up loop.



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

The main function of the irradiation rig is to maintain integrity at all operational pressures and temperatures under boiling water reactor (BWR), PWR and water-water energetic reactor (VVER) conditions and to house fuel samples and instrumentation.

A full-scale test bench was installed in a specific the TOTEM test facility to run the first test to validate 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

With the support of an engineering company, the CEA carried out studies to manufacture the final loop in order to reach the maturity milestone.

KEY MILESTONES IN 2023

The work to be carried out in 2023 is to:

- Continue detailed design studies on the main components of the experimental device
- Carry out the second validation test for the underwater lines
- Carry out the first handling tests on the IFE dummy rig
- Continue the setting-up of the shielded cubicle in the JHR

7.5.4 Gamma and X-ray non-destructive examination devices (Finnish in-kind contribution)

Gamma and X-ray examinations systems (NDE) will be implemented in the JHR to examine experimental samples by high-resolution X-ray imaging and by quantitative measurements of the spatial distribution of gamma emitters.

Three benches were manufactured and commissioned:

- 2 underwater gamma and X-ray scanning systems (UGXR) for examinations of samples in an integral device: one for the reactor pool and one for the storage pool
- 1 hot cell gamma and X-ray scanning system (HGXR) for in-air examinations on samples in a hot cell. In parallel to the in-kind contribution, the CEA entrusted a French company (ORIATRON) with the design and manufacturing of a 6 MeV linear accelerator.

7.5.4.1 UGXR systems (VTT in-kind contribution)

The underwater benches were transported to Cadarache in early 2021. The first bench (A) was tested at VTT's sub-contractor laboratory, then transported to Cadarache, and accepted by VTT and CEA. The second bench (B) was fully tested at Cadarache. Unfortunately, during the second bench site acceptance tests, some support structural components were damaged in the bench, which caused a delay of several months in the acceptance of the bench. The damaged components were replaced in autumn and the final tests were successfully performed thereafter. The second bench (B) was accepted in December 2022. It was also noted in the tests that some cables needed to be replaced as they were not flexible enough, but this will be in the warranty period in 2023.

Installation of bench B installation in the CESARINE pool of the TOTEM facility

In parallel with the UGXR benches, the underwater collimators and biological shielding were also manufactured. The final assembly of the collimator structures in their final positions in the JHR was started with one of the collimator devices in 2021 and was finalised in early 2022, with these devices being the first experimental devices installed in the JHR. For the other collimator devices, only the handling crane was installed but not the collimators themselves as the area is not yet ready to host the collimator systems. The CEA will test this equipment before using it for training purposes in the Totem facility. Access to the JHR site requires very thorough planning and the time windows for carrying out installation operations are quite small. The installation of the collimators and handling devices to the JHR was a good pilot project for the CEA in terms of learning just how much time and effort is needed to install the experimental devices.

Collimator installation in the reactor pool feedthrough of the JHR

The Finnish in-kind contribution reached its goals in late 2022 as the experimental equipment was successfully delivered. In the early 2023, the final reporting and the delivery of all necessary documentation from VTT to the CEA will be completed and the project will come to an end regarding VTT's in-kind contribution.

The CEA will carry on testing and qualifying these different systems in the TOTEM facility before preparing for their integration into the JHR.

7.5.4.2 HGXR system

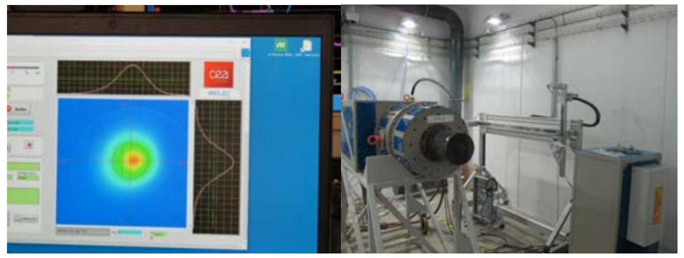
Delivery of the hot cell gamma measurement and X-ray radiography bench, together with the collimators (HGXR), was finalised in early 2020. The equipment is now installed in the TOTEM facility at Cadarache where the CEA is using it for training purposes, while defining the experimental protocols for future operations in the JHR.

In order to address the specific nature of the remote handling control and maintenance operations required for this hot cell bench, the design and manufacturing of a hot cell mock-up was launched by the CEA in 2022. It will be installed in the TOTEM facility in 2023.

Hot cell bench and collimators in the TOTEM facility

7.5.4.3 Linear accelerator ORIATRON

Factory acceptance of the ORIATRON accelerator was completed at the end of 2022. The test results highlighted its excellent performance specifications that are unique worldwide, both with regard to the size of the reduced focal spot (0.37 mm) and self-shielding (better than 7 decades). In addition, the latest adjustments have made it possible to achieve excellent operating stability, suitable for high-resolution X-ray imaging in the JHR, which requires operating times lasting several consecutive hours.



ORIATRON factory acceptance tests

7.5.5 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 on 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.

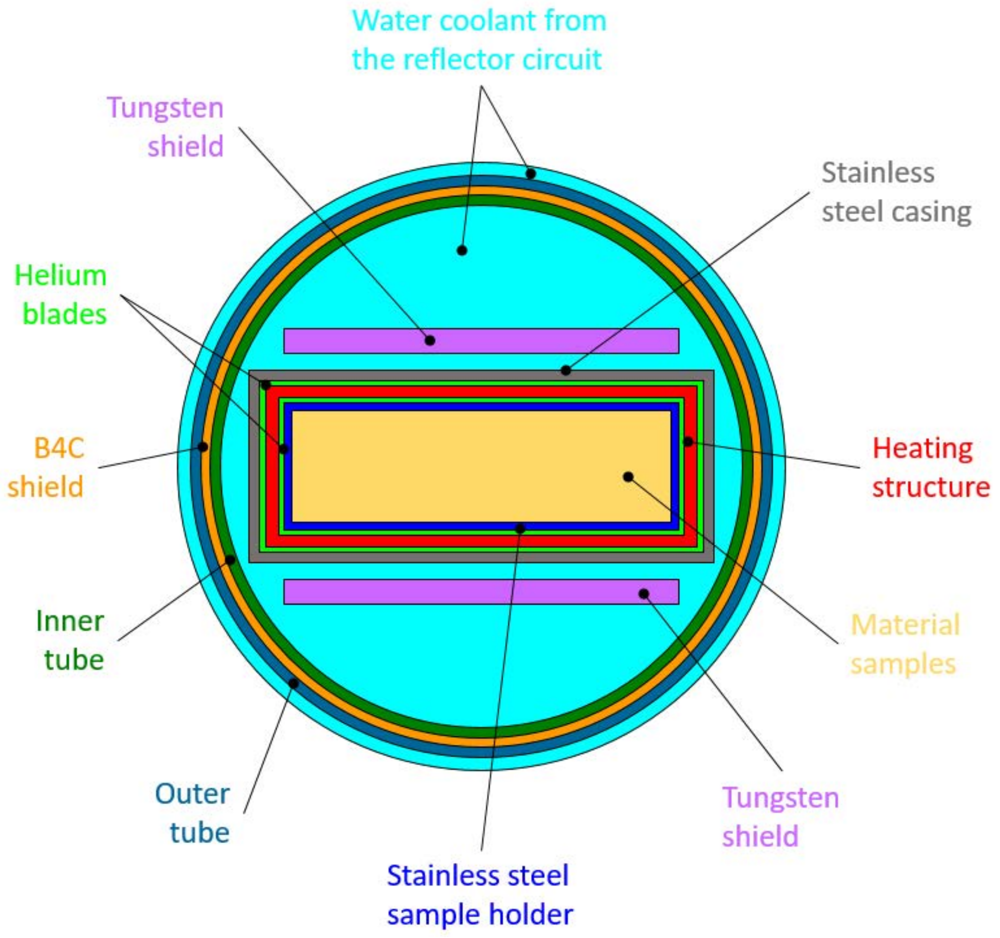
CEA staff were able to travel to India in November 2022 for a one-week meeting, which was profitable for in-depth technical exchanges following the Covid-19 pandemic.

The very good work and progress of the CLOE detailed design phase has been acknowledge by the CEA and the detailed design review is now planned for autumn 2023.

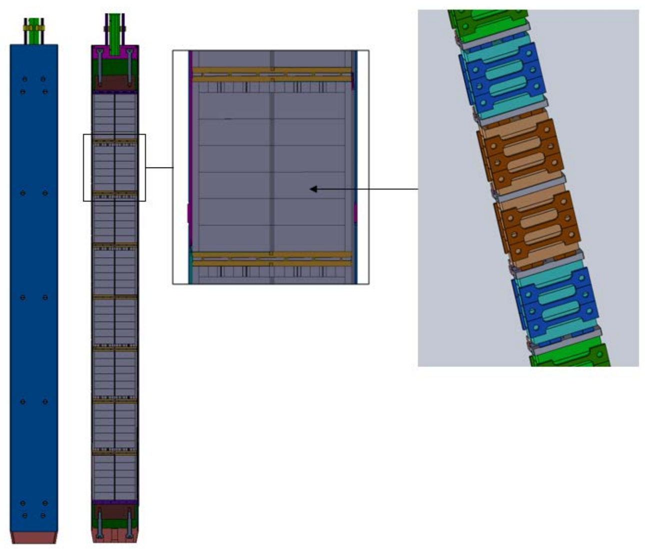
To support these efforts, Anil Pathrose, a BARC engineer, was seconded to the JHR team at Cadarache last November 2022 and is focusing on the publication of documentation for the equipment's specifications.

7.5.6 OCCITANE

In the field of vessel steels for PWRs, irradiation experiments are carried out to substantiate the safety case of this second containment barrier and to improve its lifetime, thus the lifetime of the reactor itself.



The CEA is designing an out-of-core hosting system called OCCITANE for neutron ageing tests, making it possible to perform irradiation experiments in an inert gas from at least 260°C to 330°C.



The OCCITANE experimental device will be placed in the first ring of the JHR reflector. The neutron characteristics (a best estimate at the maximum flux plane, 100 MW, 27% 235uranium, and the core at equilibrium in mid-cycle) are expected to be:

- Fast flux (E > 1 MeV) – about 8.1012 n/cm^2.s
- Fast flux (E > 0.1 MeV) – about 2.1013 n/cm^2.s
- mdpa/EFPD: 1.0

The neutron fluxes and the dpa must be multiplied by 0.7 to reach 70 MW.

The ratio between the neutron spectrum Rs = (E > 0.1 MeV) /(E > 1 MeV) and nuclear heating in the samples can be adapted by using neutron and gamma shields.

Various types of samples (creep, tensile, Charpy and microstructure) can be irradiated if they do not exceed 25 x 60 mm^2 in size. Samples can be stacked on top of each other up to 55 cm (see the figure below), with an axial damage gradient due to variations in the fast neutron flux. The sample holder is rotated 180° in the device between each cycle to homogenise the damage in the experimental samples.

The multi-zone furnace controls the required irradiation temperature between 260°C and 330°C and compensates the axial thermal gradient due to the axial nuclear gradients mentioned above.

The related instrumentation includes at least several thermocouples and dosimeters positioned as close as possible to the samples.

MAIN ACHIEVEMENTS IN 2022

The main achievements of the year are:

- Metallisation (aluminium) of short furnace mock-up

- Design optimisation to meet the specifications of the reference irradiation experiment so vessel steel experiments can be performed in the JHR

KEY MILESTONES IN 2023

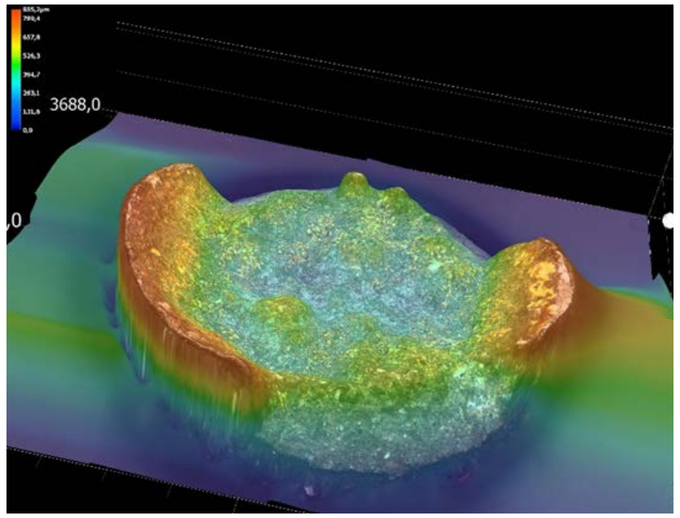
The key milestones of the coming year are:

- Continuation of final preliminary design studies
- Mock-up of the deep furnace using an electric discharge machine
- Mock-up of cooling tube with integrated shields

7.5.7 Hot cell non-destructive examination bench (HNDE)

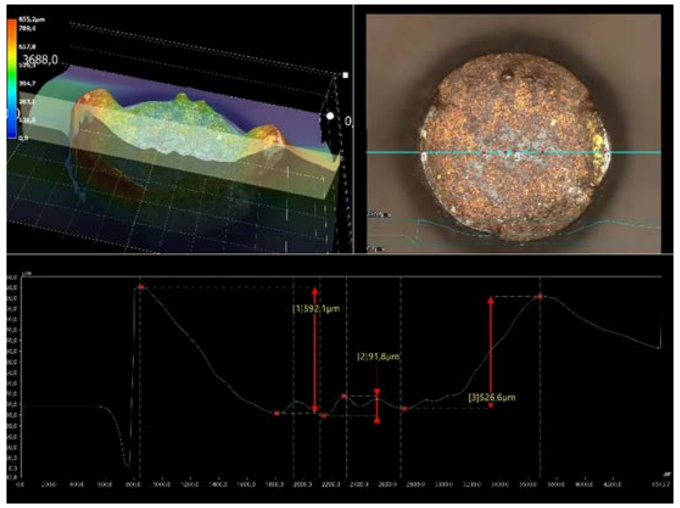
Two types of non-destructive tests will be carried out in a hot cell environment:

- Firstly, this bench will be used to weigh, measure the size and photograph the samples from a material perspective



The fracture surface of a traction specimen (digital macroscope currently being qualified) reconstructed from data collected by a hot-cell non-destructive test bench

The fracture surface of a traction specimen reconstructed from data collected by a hot-cell non-destructive test bench (digital macroscope)



3D imaging measurements of a traction specimen using data collected by a hot-cell non-destructive test bench

- Secondly, the following tests will be performed for fuel observation purposes:
  - Visual examinations by camera with photographs and video recordings
  - Geometric measurements (before and after irradiation) of the diameter of cylindrical fuel rods/pins as a function of the height (elevation), with different rod/pin orientations and heights (Deflection measurements can also be performed)
  - Corrosion thickness measurements to determine the corrosion thickness profiles of the cylindrical fuel (e.g. PWR type) as a function of the height (altitude) and different orientations, or on each side in the case of fuel plates
  - Health check to detect any internal or external cladding defects on cylindrical fuels. Drafting of the functional needs and performance specifications of the HNDE fuel non-destructive test bench for the JHR

MAIN ACHIEVEMENTS IN 2022

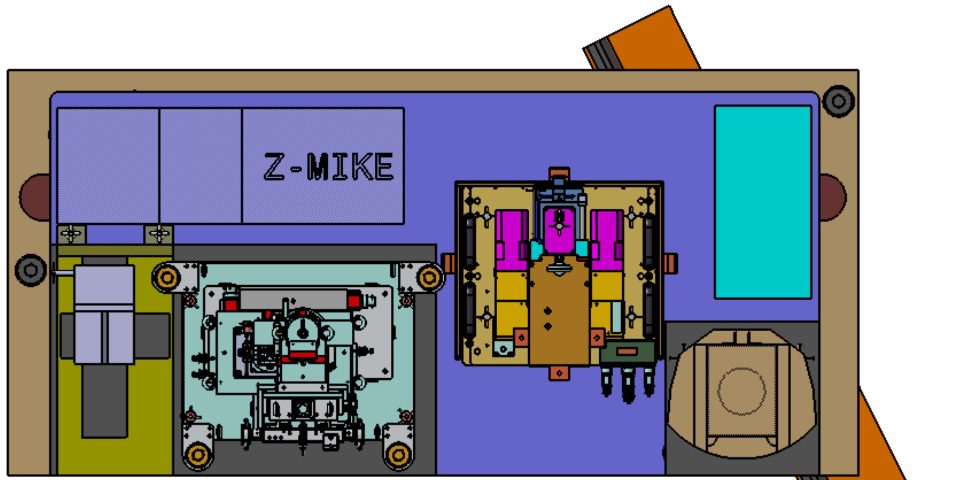
The main achievements of the year are:

- Drafting of the functional needs and performance specifications for the HNDE fuel non-destructive examination bench in the JHR
- Drafting of the requirements for the non-destructive examination bench in the JHR
- Drafting of the specifications for the preliminary studies associated with the installation of HNDE benches in the JHR hot cells

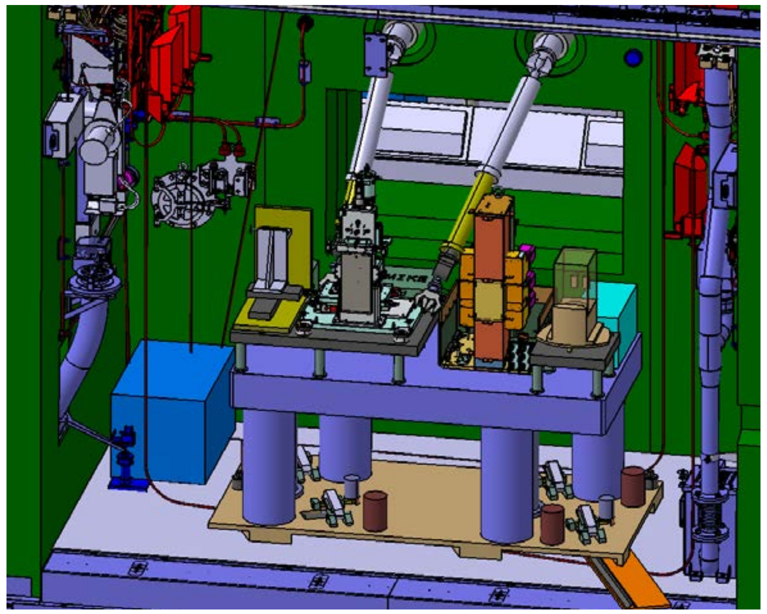
KEY MILESTONES IN 2023

The key milestones of the coming year are:

- Launch of the preliminary studies associated with the installation of HNDE benches in the JHR hot cells for acceptance in 2023
- Launch of the studies needed to develop the hot-cell non-destructive measuring device/appliance for materials in 2023



Bench used taking for non-destructive measurements in hot cells



Set-up for non-destructive measurements in the ECM (Small hot cell for non-destructive tests on material samples) of the JHR

Franck PILLOT
Manager in charge of preparing JHR operation

8.1 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.

The plates for the first two cores manufactured in 2021 were finally not assembled in 2022 pending the conclusion of the fuel element wear issue.

The year 2022 was devoted to completing contractual tasks, manufacturing activities and skills preservation.

8.2 Training process

The future JHR operator is responsible for developing and implementing the training programme, which must ensure that the operating team is correctly trained and qualified to carry out their functions, from commissioning through to nominal operation.

A training sequence for the future operator was carried out in late 2021 – early 2022. A total of 24 training modules were provided, ranging from the general role of the JHR to its operation and maintenance specificities; this represented 65 hours of training and a cumulative total of 402 attendees. The JHR project employees could also receive this training.

8.3 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 2022, several important documents were produced, such as the JHR accident operating procedures. These procedures focus on the safety systems that are triggered in such situations to bring the reactor back to a safe state.

Several periodic test procedures were also elaborated; these procedures were elaborated for a number of complex operating systems chosen in order to analyse their feasibility as part of the maturity review led by the JHR project.

8.4 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 2022, no new equipment was handed over to the future operator. Operating activities focused on the systems that have already been handed over: interim storage building, operator building, electrical power supply, polar crane, and load lifts.

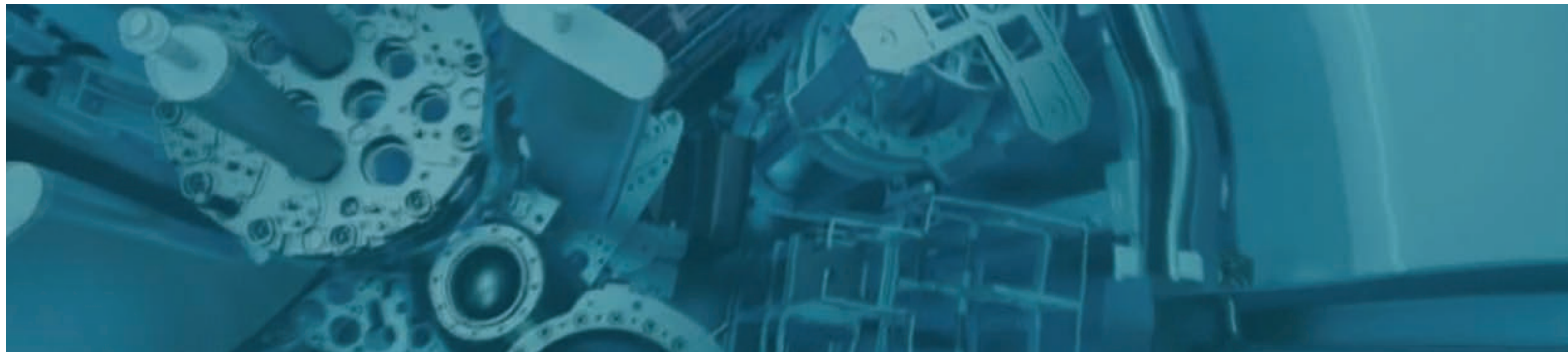
8.5 Operation preparation

In 2022, work continued to focus on the organisation of annual outage for maintenance, as well as on periodic tests. The transfer of experimental devices between the different workstations was further refined (irradiation, pools, channels, hot cells, etc.), which made it possible to validate some components and to identify items to improve.

Regarding studies, the future operator contributed its expertise to help define the operating point of the newly designed ADELINE (see § 7.5.2) hydraulic loop.

Tests were also carried out on mock-ups of experimental devices to validate their behaviour during some handling operations.

MADISON (see§7.5.3) head handling tests at the JHR cold test facility in 2022



The CORALIE loop intended to measure the hydraulic characteristics of the experimental devices (in core and reflector areas) was also assembled and tested onsite at Cadarache in 2022. With this step completed, it will now be possible to perform the hydraulic tests in 2023 (PROSPERO).

CORALIE Loop at the TOTEM facility (2022)

ASN	French Nuclear Safety Authority
BARC	Indian consortium member
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
CEA	French Alternative Energies and Nuclear Energy Commission, JHR Host and French consortium member
CEDE	experimental shielded cubicle room
CIEMAT	Spanish consortium member
CVR	Czech Republic consortium member
DLC	support structures for experimental tools
DOE	US Department Of Energy
ECR	Large hot cell used to condition and remove radioisotope targets
EDF	Electricité De France, French consortium member
EFPD	Effective Full Power Days
EI&C	Electrical, Instrumentation and Control
EPC, EPO, EPM	Canals
EPI, EPT, EPU	Pools (BUA)
EPRI	US Electric Power Research Institute
EURATOM	European Atomic Energy Community supporting the development of the European nuclear industry
FIDES	Framework for IrraDiation ExperimentS
HFDS	High Level Defence and Security
HNDE	Hot cell Non-Destructive Examination
HVAC	Heating, ventilation and air-conditioning
IAEA	International Atomic Energy Agency
I&C	Instrumentation & Control
ICERR	International Centre based on Research Reactors
IFE	Institute For Energy technology, Halden
IMS	Integrated Management System
INB	Licensed nuclear facility
IRSN	French Institute for Radiation Protection and Nuclear Safety
JAEA	Japan Atomic Energy Agency
JAM	JHR Archive Material project

JHOP 2040	Jules Horowitz Operation Plan 2040
JHR	Jules Horowitz Reactor
JRC	Joint Research Centre, European consortium member
LVR15	Czech Republic research reactor
LWR	Light Water Reactor
MTR	Material Test Reactor
MW	A unit of power in the International System of Units (SI); it is equal to one Million Watts.
MeV	Energy unit representing one million times the energy of an electron accelerated by a potential difference of 1 Volt
NDE	Non-Destructive Examination
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
PWR	Pressurised Water Reactor
REE	Intermediate pool
RER	Reactor pool
RMD	Reactor pool polar crane bridge
RSS	Reactor cooling secondary system
R&D	Research and development
SAMIRA	European Strategic Agenda for Medical Ionising Radiation Applications
Studsvik	Swedish consortium member
SCK CEN	Belgian consortium member
TOTEM	CEA cold test facility
TSO	Technical Support Organisation
VTT	Finnish consortium member
WP	Work Package
ZRF	Intermediate area between BUR and BUA

April 2023

Jules Horowitz Reactor

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