2021

Jules Horowitz Reactor

Status Report

JHR
Jules Horowitz Reactor

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Please refer to pages 64/65 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

Petri KINNUNEN
JHR Governing Board Chairman

For the second year running, the Covid-19 pandemic somewhat impacted the JHR construction site. In 2021, however, the impact was much smaller than expected and sound progress was made in many areas.

The new project organisation has highlighted different working methods and placed more emphasis on rescheduling and planning construction. Despite the announced construction delays, the newly organised project has reassured the consortium on the project's progress and the scientific community's commitment to finalise the reactor. Accordingly, the consortium has gained a better understanding of the JHR's design specificities.

In 2021, several major milestones were achieved in reactor construction, among others completion of the liners for the three pools in the nuclear auxiliary building and completion of the beryllium reflector blocks. Concerning the in-kind deliveries e.g. extensive work was performed in TOTEM facility for the underwater and hot cell NDE bench tests, and the detailed design of the LORELEI loop by IAEC was completed and delivered to the CEA with all associated documents.

The JHR Consortium gained a new member in 2021 when China General Nuclear Power Group (CGN) joined the ranks. CGN brings valuable insight from one of the most active countries in nuclear new build. The consortium is looking forward to co-operating with CGN and attracting new partners to further expand the consortium.

The co-operative actions outside the construction project were also continued in 2021. The OECD FIDES programme was started, including two projects (P2M and INCA) that are directly connected to JHR operation. The FIDES framework provides an excellent tool for the JHR community to collect data that will eventually support JHR operations. Set up by the JHR governing board, the International Advisory Group (JHR IAG) also continued its work in assessing the experimental costs of the JHR programme. The Euratom-funded Jules Horowitz Operation Plan 2040 (JHOP 2040) has progressed well, resulting in the definition of the experimental matrix for the first 4-year period. Communication with European stakeholders outside the JHR consortium has equally been active in defining the common needs and preferences for future experiments.

Though JHR operations are not set to start for a few more years, the JHR consortium maintains active co-operation on several fronts. As existing co-operation progresses, the consortium is seeking for new ways to increase co-operation and to ensure continuum with the pre-JHR era. One of the keys to do this will be getting the entire European nuclear community involved in the JHR.

We shall keep up the good spirit and continue to progress effectively in 2022.

David EMOND
JHR Project Director

In October 2021, the Jules Horowitz Reactor project met a historical milestone when it completed a whole year without any lost-time accidents. In the context of the Covid-19 pandemic where health is our primary concern, this achievement proves how much safety is a major focus of the JHR roadmap. I congratulate those who have contributed to this success.

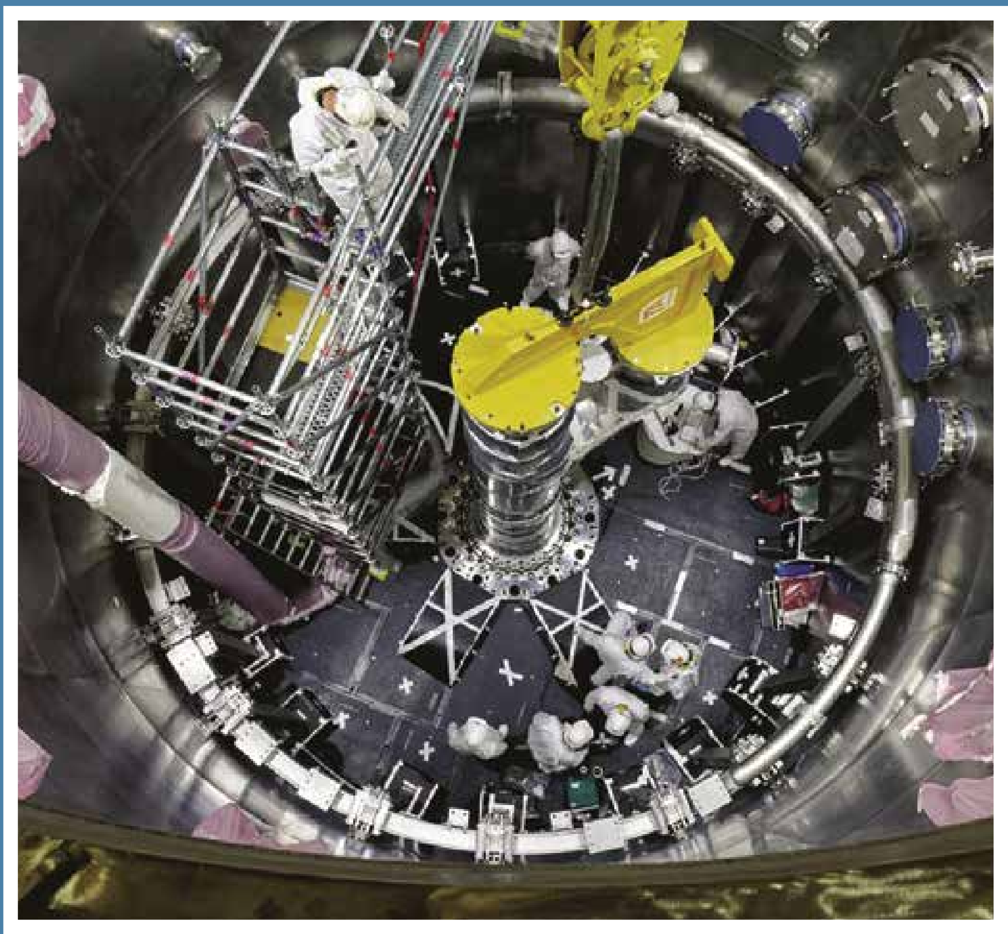
Approval of our roadmap by the French authorities has validated our strategy for continuation of the project, which involves completing design studies before fast-tracking the Mechanical, Electrical and HVAC (MEH) phase.

The year 2022 will focus on resolving some major design issues, preparing erection of the components and reviewing the overall schedule before submitting the JHR completion roadmap in 2023.

The JHR Safety Report was submitted at the end of 2021, with the licensing process set to start in early 2022.

In 2022, the JHR Consortium members will be able to count on the commitment and the passion of the JHR Project team in meeting the project's milestones and steering the JHR to completion.

Ninety years ago, James Chadwick irradiated beryllium with alpha particles, demonstrating that the resulting radiation did not produce gamma rays but uncharged particles whose mass was close to the proton mass. This was how the neutron was discovered. James Chadwick called it a "difficult catch" in an interview by the New York Times in February 1932. Ironically, he also said: "I am afraid neutrons will not be of any use to anyone." We now know his great discovery largely benefits science and industry. This legacy will continue with Jules Horowitz Reactor!



2 Safety

Alexandre LAGARRIGUE
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.

CHARTE POUR LA SECURITE DU PROJET RJH : Objectif « zéro accident »

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.

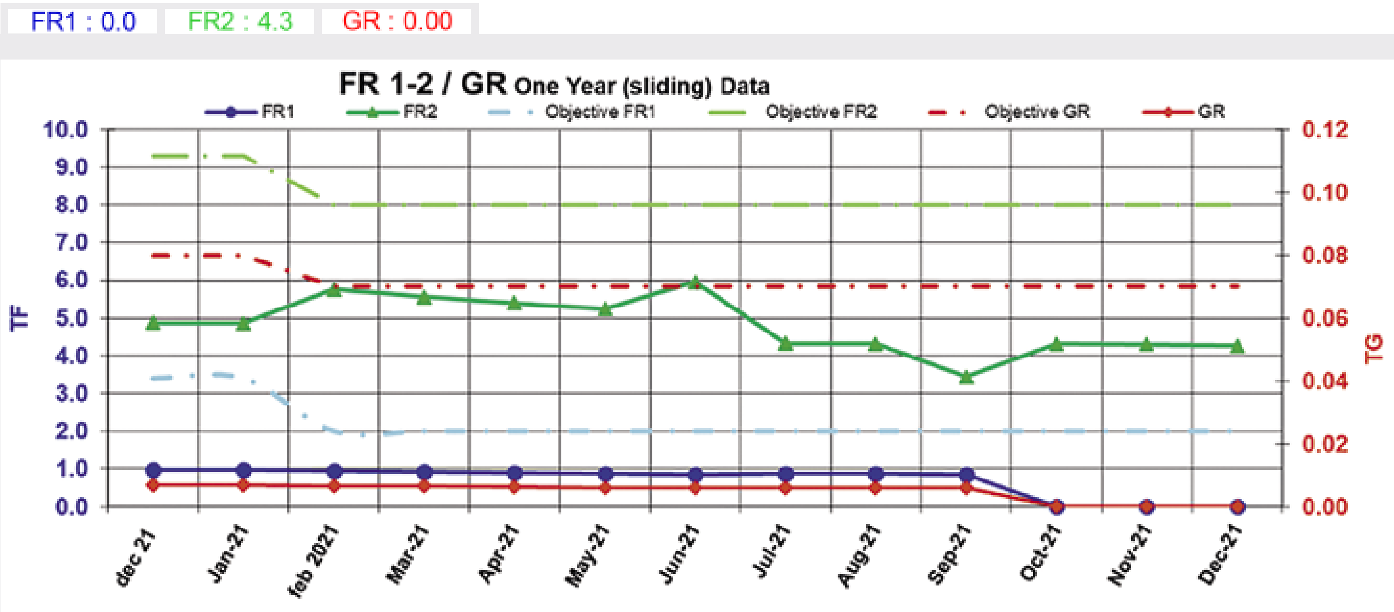
All health, safety and environmental risks are systematically managed as an integral part of the project; accordingly, the behaviour of employees and contractors must reflect the highest industrial safety standards when going about their daily activities.

2.1 Industrial safety indicators

The different accident frequency indicators improved significantly over the course of the year. This was not only due to the decrease in activities onsite during the first lockdown, but also to the rollout of sustained industrial safety awareness actions targeting JHR employees.

The last accident with lost days occurred in October 2020.

The standing record of 1 year without any accidents with lost days was broken on October 2021 and 1 million of hours without any accidents with lost time was reached in June 2021.



- *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 2021 WERE:

- 0 injuries with lost time: 7 days off
- 5 accidents with no lost time
- 7 events requiring first-aid care

Average number of contractor staff on the construction site per month in 2021:

Jan-21	feb 21	Mar-21	Apr-21	May-21	Jun-21	Jul-21	Aug-21	Sep-21	Oct-21	Nov-21	Dec-21
700	700	714	694	684	698	777	589	655	649	717	567

2.2 Covid-19

In 2021, there were three successive Covid-19 waves, which impacted the organisation of JHR construction site. Health and safety measures were once again implemented to prevent any outbreaks on the JHR construction site.

The main health and safety measures were:

- At the entrance to the construction site: compulsory hand washing
- Circulation on the construction site: on foot where possible (number of people in a group kept to a minimum)
- Social distancing: a distance of 1 metre between people
- Daily basis: regular hand washing + compulsory face mask
- Informing the medical centre if any symptoms appear.

Since the beginning of the pandemic, there have been 217 cases reported for the JHR Project (project team and contractors):

- 72 people tested positive for Covid-19
- 106 people were contact cases
- 39 people were showing symptoms.

2.3 Industrial safety actions

2.3.1 Industrial safety behaviour visits (SBV)

The JHR project has implemented informal inspections to observe 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 81 visits were carried out in 2021, with 298 good practices observed and 140 hazardous behaviours corrected.

2.3.2 Industrial Safety and Environment Day

Industrial Safety & Environment Day was celebrated on 12 October 2021 at the JHR Project. This is a special day where people focus on wellbeing at work, industrial safety training and meeting with their manager to discuss health and safety matters.

In 2021, construction site companies attended the Industrial Safety Day opening speech and one workshop (team escape game).

The following workshops were proposed:

- Seated massage: 71 participants
- Escape game: 101 participants
- First-aid beginner's course on how to detect a stroke: 68 participants
- How to use a fire extinguisher: 56 participants
- Managing stress through breathing: 63 participants
- Resitting the driving theory test: 80 participants 33 participants passed the theory test, i.e. a success rate of 41.25 %!
- Car-pooling: 15 participants and new volunteers for car-pooling pick-up points
- Sport: 26 participants
- Non-violent communication: 44 participants
- Managing waste: 25 participants
- Information on electric cars: 30 people stopped at the stand

2.4 Awards

2.4.1 Company industrial safety award

In 2021, four company safety awards were presented at the general safety assembly for:

- Implementation of good practices
- Deployment of new industrial safety initiatives
- Ownership of industrial safety issues.

2.4.2 Employee of the month

In 2021, twelve staff members were presented with an "employee of the month" award for the following reasons:

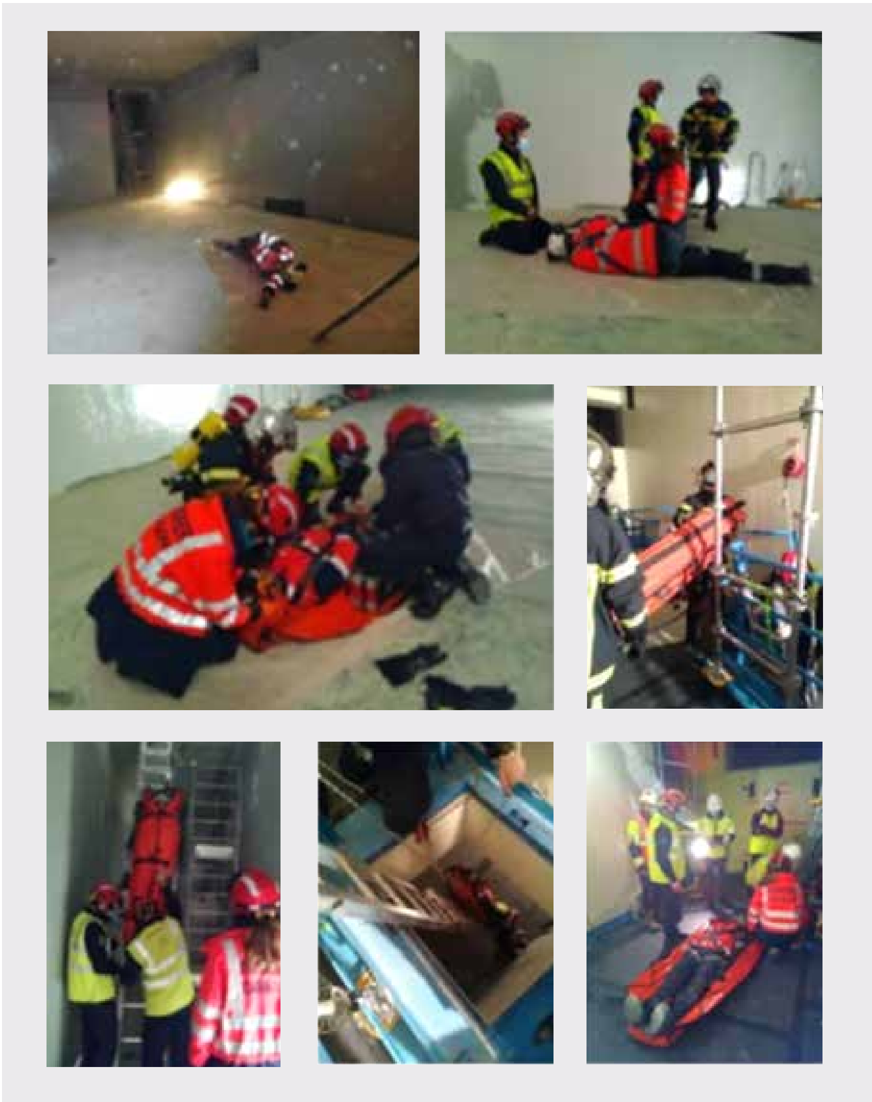
- Zero industrial safety non-conformity events observed over a period of 3 months (compliance with the JHR safety fundamentals)
- Model behaviour with respect to the industrial safety rules (wearing safety equipment, following procedures, etc.)
- Good safety initiatives and safety proposals
- Polite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

2.5 Emergency drills

About 12 emergency drills are organised every year to teach staff 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.

In 2021, one of the most spectacular emergency drills involved evacuating a victim after an anoxia event.



A victim of an anorexia event

1st care given to the victim

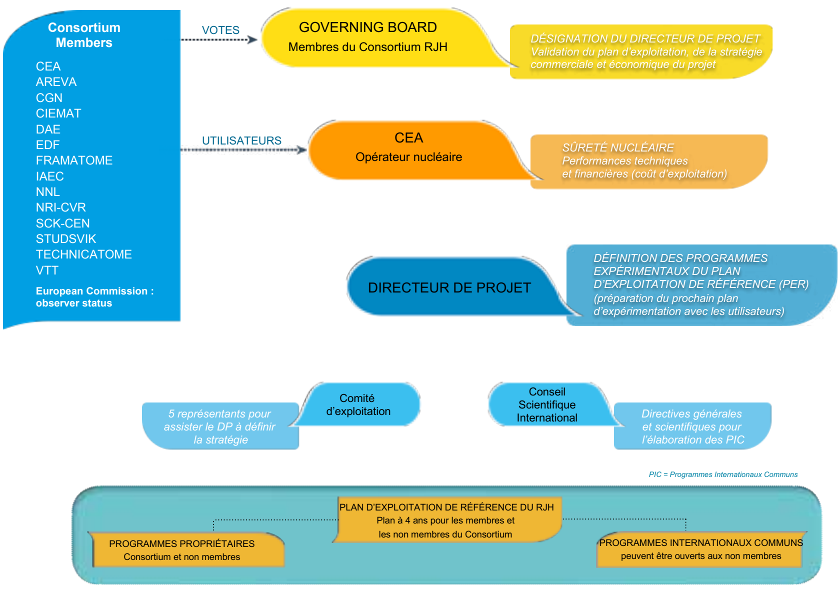
victim implementation into stretcher

Evacuation of the victim

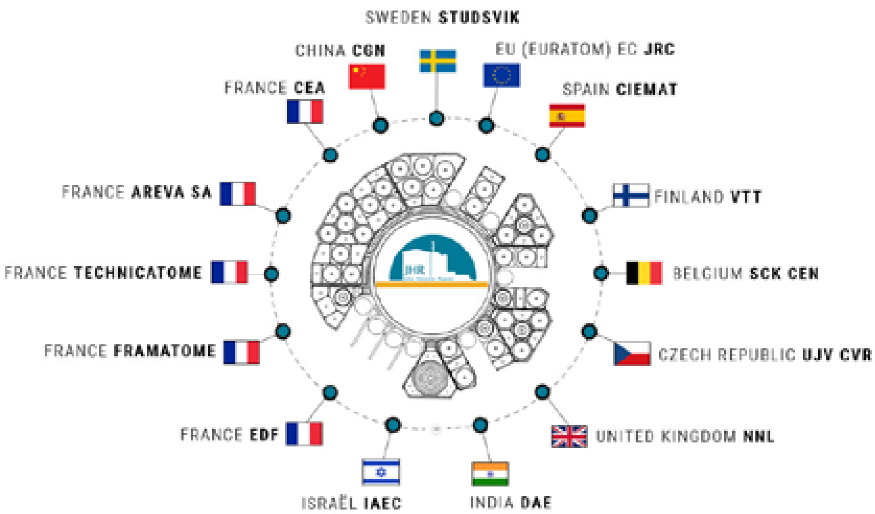
End of the exercise

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, which is composed of representatives from each member. Each member 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.

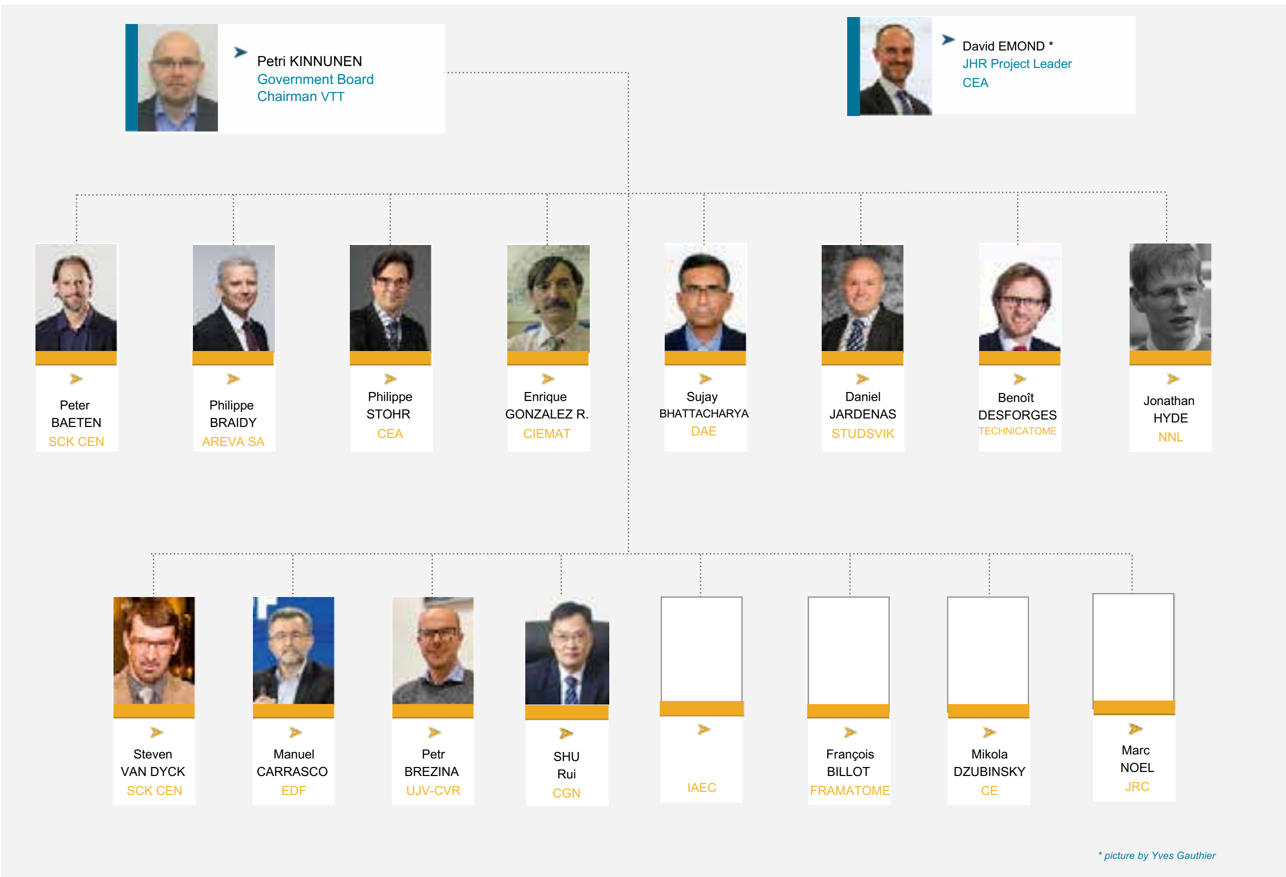
The governing board members appoint a chairperson to manage the meetings and duties for a period of four years. The current chairman has been endorsed for a second four-year period.

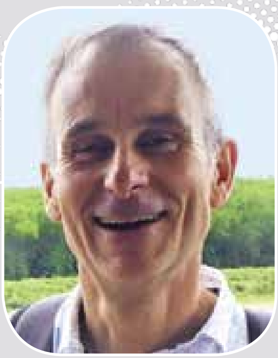
David EMOND

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





Jean-Pierre COULON
Clients and Consortium Manager

4.1 Governing board and support programmes activities

4.1.1 Consortium new members

The CEA has been mandated by the governing board to expand the scope of membership to the JHR International consortium. After several years of discussions and negotiations, the CEA has launched the process to officially make CGN (a major Chinese nuclear utility) a member of the consortium. This process was fully finalised during the first semester of 2021 and CGN became an official consortium member in July 2021. CGN now owns 2% of access rights (from CEA shares with no dilution regarding the other consortium members) and was given the opportunity to its reasons for wanting to join the consortium during the last Governing Board (June 2021).

4.1.2 JHR working groups

Due to the Covid-19 pandemic, it was not possible to organise the annual meetings for the three JHR working groups (i.e. Fuel Working Group, Material Working Group and Technology Working Group).

Nevertheless, each WG held its individual WGs remotely and discussions were continued to prepare the first international workshop of the European project JHOP 2040 (September 2021).

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 member states not represented in the JHR consortium. The ultimate purpose is to produce strategic research roadmaps for JHR operation during the first 4-year period and then for the following 11 years of operation.

JHOP 2040 comprises the following members/countries:

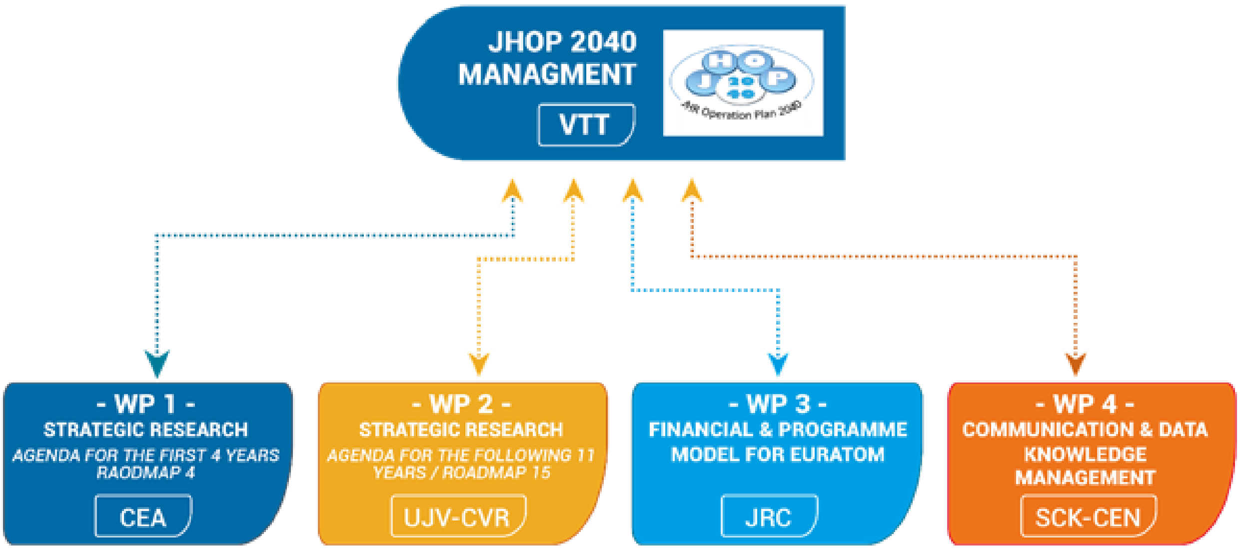
- European Commission: JRC
- Finland: VTT
- France: CEA, EDF
- Czech Republic: CVR, UJV
- United Kingdom: NNL
- Sweden: STUDSVIK
- Belgium: SCK CEN
- Spain: CIEMAT.

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 following figure indicates the structure of the JHOP 2040 through its work packages (WP):

JHOP MANAGMENT ORGANISATION



The project started in September 2020 and significant work was completed in 2021, including:

- First meeting of the International Scientific Advisory Group (ISAG) in March 2021, with design recommendations for the JHR experimental devices
- Publication of first deliverables from WP1 (now available on the JHOP 2040 sharesite)
- First international workshop in September 2021. Some European partners were able to attend the workshop at Cadarache, while others joined in remotely. This workshop provided the opportunity to discuss the future use of the reactor within a broader approach than the restricted JHR consortium.

4.2 JHR as an international facility

4.2.1 Scientific seminar

Due to the Covid-19 pandemic, the 10th scientific and technical seminar initially planned for March 2020 was held virtually from Tuesday 20th to Thursday 22nd April 2021.

Around 70 people attended the seminar, during which the JHR community was given an update on:

- JHR project and the new organization
- Progress on the design of the experimental devices
- Progress on the in-kind contributions concerning experimental devices
- Secondee's work via a presentation
- Preparation of international joint programmes (OECD/FIDES, Euratom, etc.)
- Halden sensor technology transfer.

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, the Framework for IrraDiation ExperimentS. This initiative federates a large 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 has 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 (nuclear operators, fuel manufacturers, R&D organisations, TSO, etc.). The first governing board (May 2021) meeting endorsed the first four joint R&D projects (called JEEP) that will be implemented in the coming years.

The JHR consortium members are particularly involved in two projects: the P2M (Power to Melt and Manoeuvrability) project that sets out to perform slow-power transients to reach partial fuel melting, and the INCA project that focuses on in-pile creep studies of ATF cladding.

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 has been done on the specifications of the reference material and on identifying the industrial company that could provide such material.

Following several meetings held in 2021 within the Material working group, it was decided to investigate the possibility embedding the JAM project in another JEEP proposal from US (INL) within the FIDES framework.

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 directorate decided to submit a new candidacy for the next 5 years with a new scope including the CABRI research reactor and the JHR. After a rigorous assessment process in 2020 by the agency, the CEA and its partner IRSN were chosen in December 2020 to be an ICERR for the next 5 years.

4.2.5 Conferences

Several presentations on the JHR were given in 2021:

- Presentation on installing the reactor block at the IGORR conference (held online in early June 2021 in collaboration with the IAEA)
- Presentation on the JHOP 2040 project at the RRFM2021, the European Nuclear Society conference on Research Reactors in Helsinki in September 2021.

Alexandre LAGARRIGUE
Site Safety and Security Manager

5.1 Global overview

MAIN ACHIEVEMENTS IN 2021

In 2021, 100% of On Time Delivery milestones for site activities were achieved:

- Introduction and erection of the steel structures in the secondary bunkers
- Erection of the Madison bunker floor
- Electromechanical installations in BMR level 1 and in the BUA level -2
- Installation of HVAC supports in the experimental area level +3
- Welding of EPI/EPT/EPU pools walls.

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.

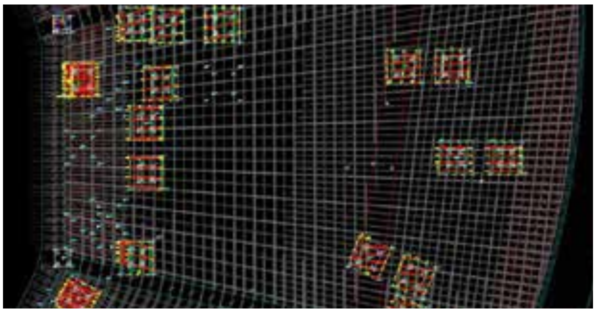
Industrial safety, technical coordination and nuclear cleanliness teams worked hand in hand to ensure that all installation activities complied with the industrial safety and quality requirements.

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, a new steel detection method was developed by the CEA site teams, providing a better view of reinforcement bar positioning inside concrete for drilling activities. This method was shared with contractors through PPI meetings.

Relevant site processes, exchanged with the ASN, were also introduced to shorten quality registration times for drilling activities.

KEY MILESTONES IN 2022

The year 2022 will be a challenge for site teams, especially with respect to the approval of the remaining erection sequences and the implementation of the lessons learned during the BUA-3/BUA-2 Mechanical, Electrical and HVAC (MEH) installation activities.



Supports location validated after analysis of the reinforcement

Drilling activities secured by steel detection using radar equipment

David EMOND
Project Leader

5.2 Control action plan

The control action plan for the project decided in 2019 has been discussed in detail with the French State and the following main conclusions were validated in mid-March 2021:

- All stakeholders acknowledged the positive outputs of the new organisation (simplification of inter faces, better efficiency, focus on delivery), the technical configuration for installation, the alignment of the main subcontractors on project goals, and the start of the licensing process (Safety Report submitted at the end of 2021).

- The basic design has been finalised from a technical viewpoint, while the detailed design process is still ongoing with the main subcontractors and the last review highlighted the specific features of the JHR (interface topics, high density of equipment, complex lay-out, etc.) leading to the following topics:

    - Uncertainty on quantities pending finalisation of the 3D model
    - Some technical risks that remain to be resolved
    - Uncertainties on installation times due to the complexity and high level of co-activity
    - Need for feedback on the installation of equipment in some specific areas.

The CEA has decided to implement a roadmap 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 implementation test in critical areas, to get 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 tests and start-up.

A project review milestone has been planned for mid-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.

This two-phase roadmap was validated by the French government having endorsed the continuation of JHR project led by the CEA under the following conditions:

- A review milestone in mid-2023
- A reinforced reporting process and follow-up of the project by the French state.

Philippe GAÏ
Project Control Manager

5.3 Milestones and schedule 2021

In early 2021, the roadmap for 2021-2023 was shared with the suppliers and within the project team. The priority is on finalising the design and implementing risk mitigation measures before ramping up the main Mechanical, Electrical and HVAC (MEH) installation work.

Schedule management is based on weekly and monthly routines at team and project manager level. "2 Months Look Ahead" (2MLA) routines have been set up to review which tasks of the month have not been performed on time and why, as well as to analyse the pending tasks and their prerequisites.

The management of milestones was another specific focus point in 2021. Twenty-five key milestones have been identified in the new roadmap, with the objective of reaching 80% of them on time. Risk analysis, detailed scheduling, action plans and close monitoring at project leader level have been implemented, allowing us thus far to reach 88% on-time delivery for these key milestones.

The 2021 schedule had to accommodate the ongoing Covid-19 crisis, but the project team and its suppliers are now organised accordingly, having managed to keep in line with the main objectives:

- **Management**
  - Roadmap 2021-2023 defined and implemented
- **Engineering**
  - Completion of 3D mock-up for BUA+2 level
  - Design review for BND
  - Tests and simulations conducted by the technical working group on vibration
  - Safety report submitted to French Nuclear Safety Authority (ASN) for assessment
- **Assembly**
  - Finalisation of "pools liner of the auxiliary building for EPI/EPT/EPU"
  - Installation of level 1 of the cooling water building completed

5.4 Risks management

Risk & 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 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 65 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 pr ogress 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 French Nuclear Safety Authority (ASN).

The project roadmap will focus on the design convergence in 2021-2022 to reduce uncertainties and risks during the assembly phase.

6 NUCLEAR SAFETY, QUALITY AND LICENSING

Nathalie VEDRENNE
Nuclear Safety, Quality
and Licensing Manager

Since the establishment of the new JHR Project organization with new entities, the Nuclear Safety, Quality and Licensing Division have the following missions:

- 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).

Philippe DAUBRIVE
Construction and Installation Manager

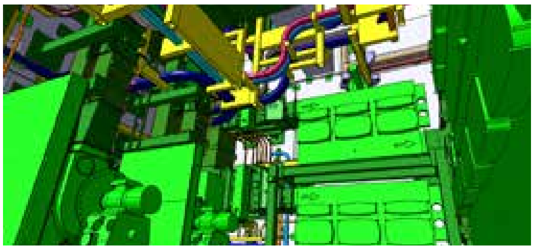
In 2021, the 'Integrated Project Plateform' (PPI) continued its activities using a collaborative working method with its contractors.

MAIN ACHIEVEMENTS IN 2021

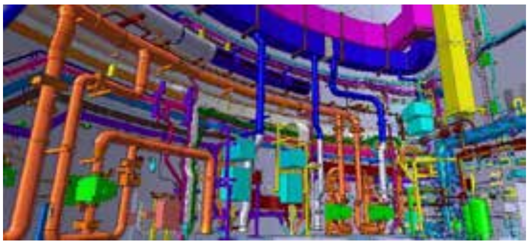
- Harmonisation of the layout arrangement
- Resolution of layout arrangement issues in complex rooms
- Clarification of the electrical interfaces

The CEA and its main contractors - brought together on the Integrated Technical Plateform (PTI) - were able to finalise the layout of 9 areas in the JHR facility thanks to joint efforts on the numerical mock-up.

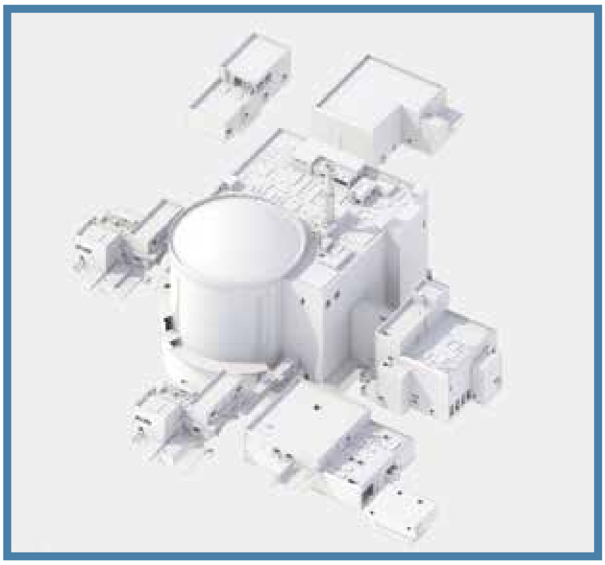
Examples of converged layout arrangements:



BUA +2 (room UA +2S08)



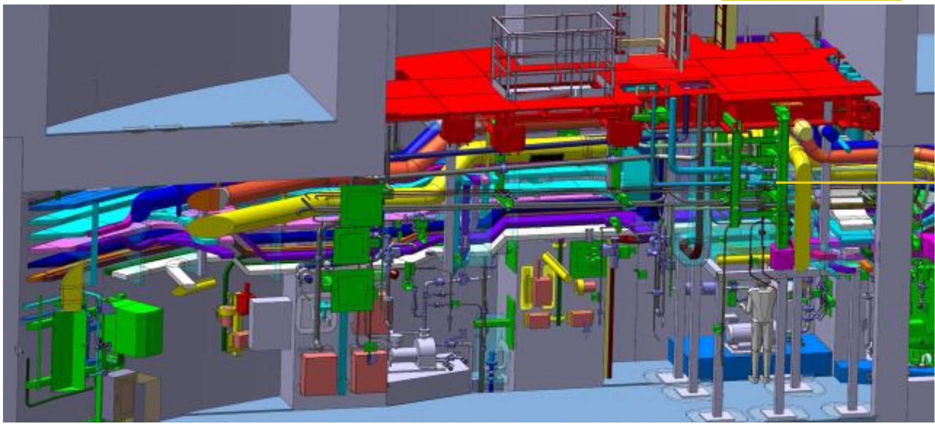
BUR hall



JHR buildings

Working groups were set up to find solutions for the layout arrangement issues encountered in some complex areas (about 10 rooms have been covered). Solutions were found either by implementing modifications or defining specific equipment.

Example of a layout arrangement in a complex area:



Definition of a frame to support the networks

Definition of support structures used for several work packages

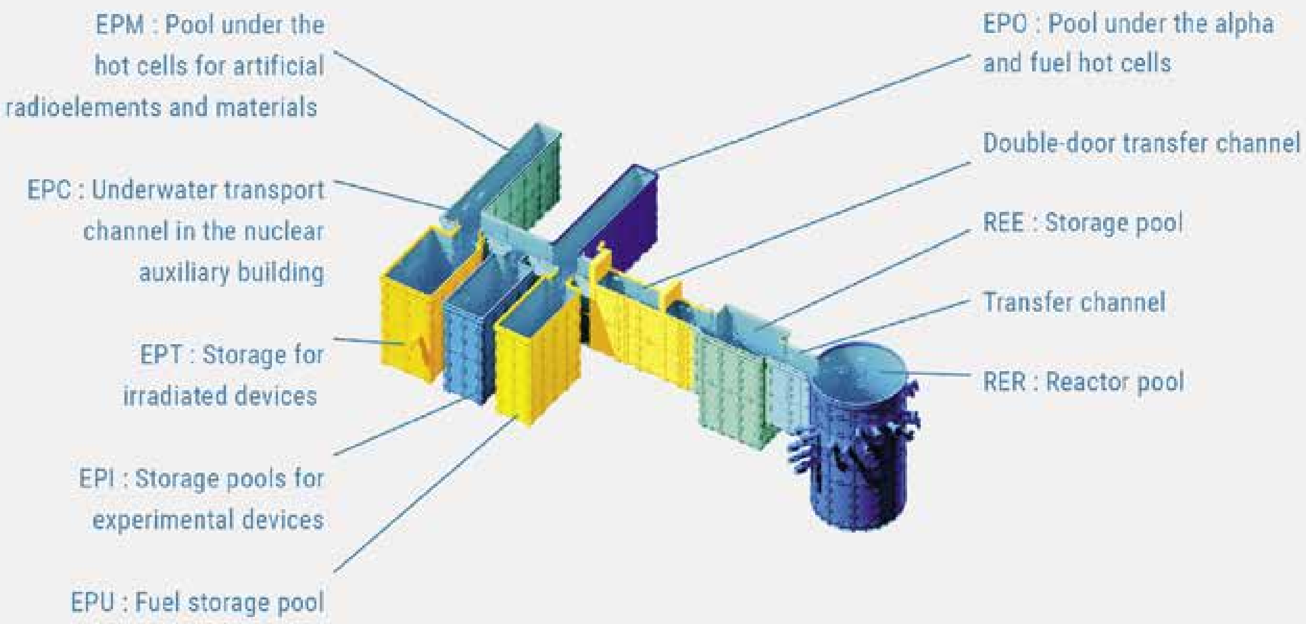
Guillaume TALHOUARN
Building, Pools
& Cells Manager

7.1 Buildings, pools and cells

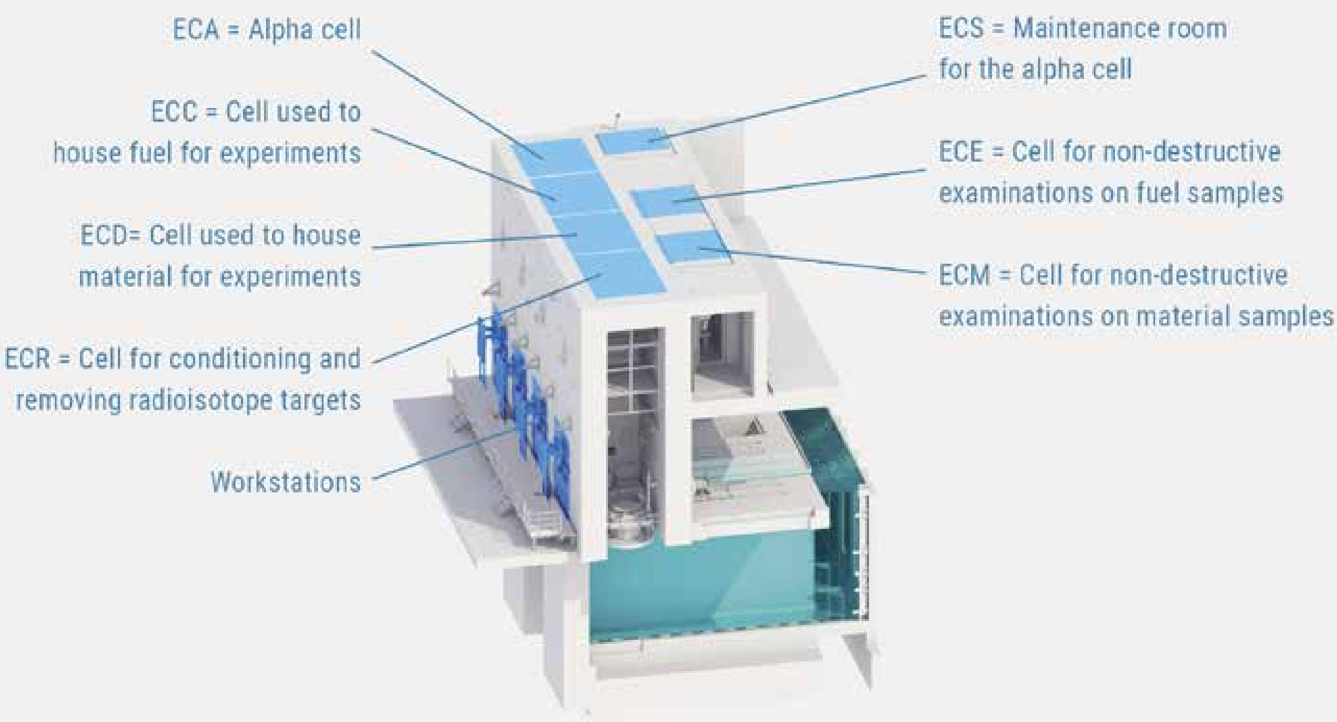
MAIN ACHIEVEMENTS IN 2021

This year has been marked by the following achievements:

- Mechanical factory acceptance of the DLG winding bracket and RMD bridge
- Assembly of the 'hat-shaped' peripheral structure in the BUR building
- Creation of openings and preparation of these holes for the assembly of the HVAC and electrical systems in the BUR building
- Testing of the JHR and PGZ electric fences
- Site assembly of the hot cell windows
- Finalisation of the EPI, EPT, EPU pool liners in the nuclear auxiliary building (excluding the bases)
- Detection of stress-induced corrosion cracking in a RER pool liner weld



Pools



Building

7.1.1 Engineering

Design studies

- Continuation of design studies on tools needed to install and remove experimental and fission product penetration
- 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
- Finalisation of the design for the I&C system for the isolation doors and conveyor
- Leaktightness of the interface between the engineered structures and the isolation doors frames

7.1.2 Factory activities

7.1.2.1 Hot cells (UJV-CVR in-kind contribution)

Factory manufacturing:

- Continuation of manufacturing activities for the lifting units ECC (standard fuel hot cell), ECE (fuel non-destructive examination hot cell), ECS (alpha maintenance hot cell) and ECE-ECS airlock
- End of construction of the floor in the ECR (hot cell for artificial radioelements).

ECR floor in the factory

7.1.2.2 Lightweight remote manipulator arms

Factory manufacturing:

Factory testing and acceptance of practically all the MT120 and MT200 remote manipulator arms.

End-of-manufacturing report

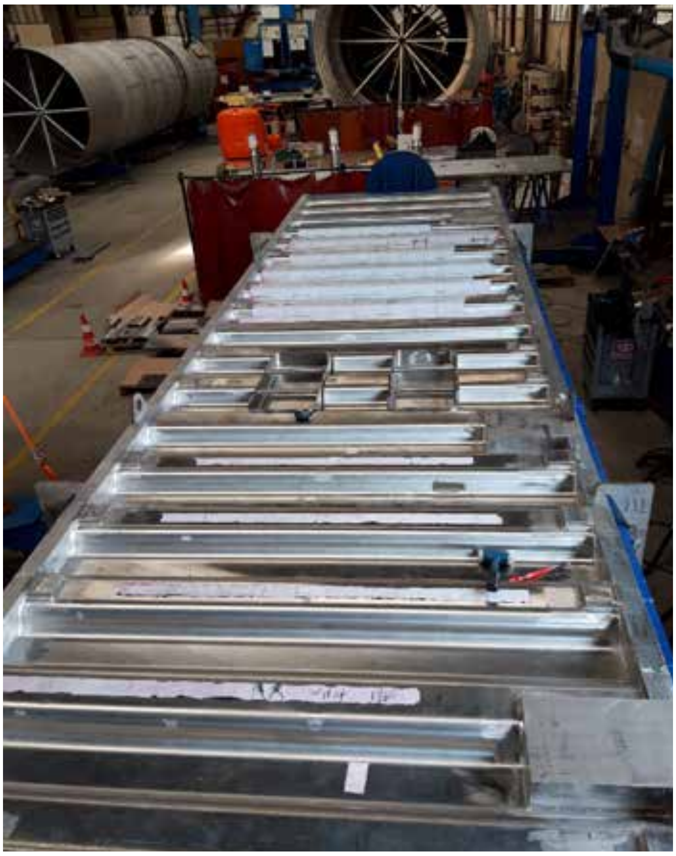
7.1.2.3 Pool liners

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 (irradiated component storage)
  - EPT (storage for irradiate experimental devices)
  - EPU (irradiated fuel element storage)
- Three canals (in the auxiliary building):
  - EPC
  - EPO
  - EPM

Factory manufacturing:

- Resolution of any manufacturing issues with the door frames and acceptance of the last door frame (RES) and 4 door leaves
- Factory acceptance of the EPI gamma penetration
- Continuation of manufacturing of the airlock doors (preliminary machining finished, electron beam welding finished) - airlock between the BUR and the BUA
- Industrial-scale studies for the underwater conveyor (welding operating procedures) and start of procurement.



Machining of the airlock door

7.1.2.4 Secondary handling

Factory manufacturing:

- Acceptance of the mechanical assembly of the RMD bridge and the DLG telescopic extension arm
- Continuation of manufacturing for the conveyors and main EPO structures
- Design and manufacturing of a test bench to test screw-nut material combinations following the ACTEON nut seizing during underwater tests on the conveyors.

Photos of the DLD and then RMD

EPM canal structure

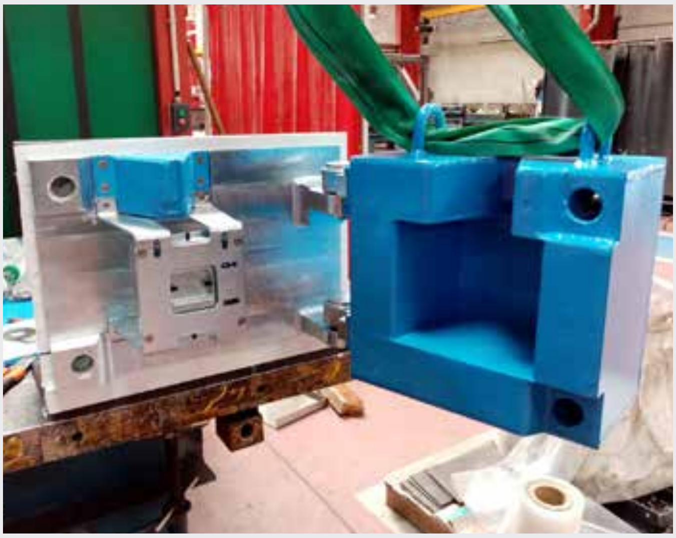
Tests on the EMI conveyor in water (seizing problem revealed)

7.1.2.5 Hot cell equipment

Procurement and factory manufacturing:

- Manufacturing finalised for the support structures of the automatic fire sensors (DAI)
- Factory manufacturing continued for some equipment (storage and scrawling hole, biological shielding plugs, ventilation systems, etc.)
- Factory acceptance of several biological shielding plugs and airlocks used for passing small equipment into the facility
- Manufacturing of the washing pit completed.

Photo of the DAI sensor support structure

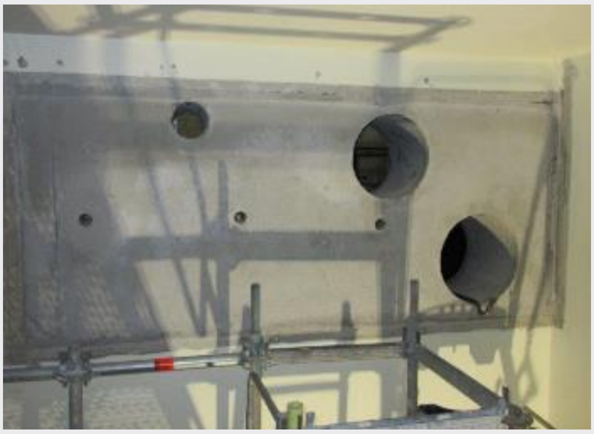


Hatches in the process of being manufactured

7.1.3 Onsite building and acceptance

7.1.3.1 Civil works and buildings

Creation of openings and preparation of these openings prior to the assembly of the HVAC and electrical systems in the reactor building



■ Assembly of the framework for the containment cover over the nuclear unit

7.1.3.2 Experimental utilities and pools

Hot cells (UJV-CVR in-kind contribution)

Site works:

- Assembly of the shielded partitions for the sliding doors between the small and large hot cells
- Transfer of 17.5-tonne monorail in the temporary operations area
- Installation of the inflatable seal for the docking pit in the hot cell used for radioelements (ECR)

ECR pit

Shielded partitions in the sliding doors

Shielded windows for small and large hot cells

Site works:

End of assembly and leak tests for the first seven windows and their alpha frame

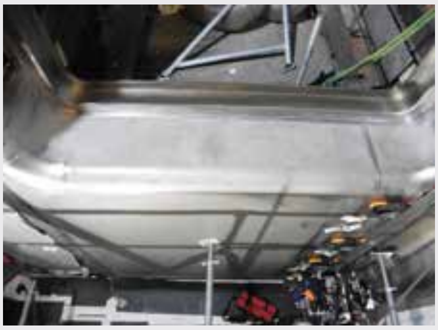
Insertion of the windows

Windows in place and protected

Site works:

- Assembly of the EPI gamma penetration finalised
- EPI, EPT, EPU pool liners completed (excluding the bases)
- During the year 2021, indications were detected on one of the reactor pool liner weld. Ultrasonic tests and sample analyses confirm these are stress-induced corrosion cracks. Investigations are on-going to understand the origin of the phenomenon as well as controls of adjacent welds.

Assembly of EPI gamma penetration



'Suitcase corner' lining completed

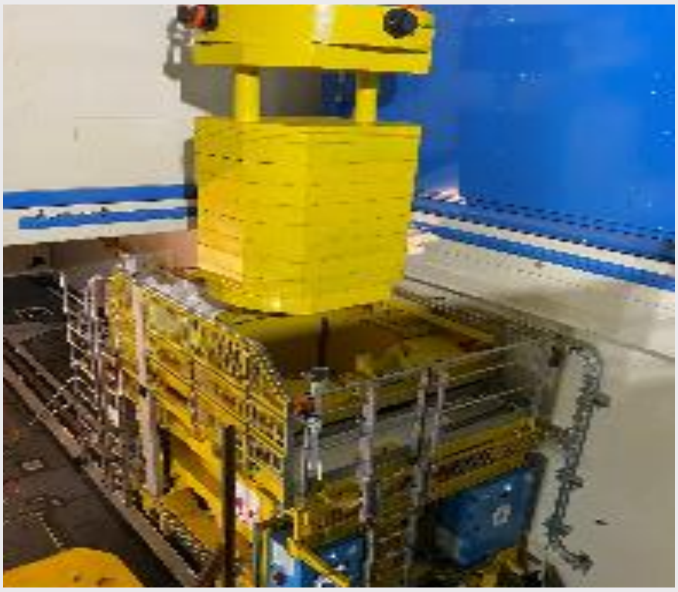
Installation of the gate frame

Finalisation of the lining

Secondary handling

Site works:

Functional tests on the EMT transfer crane (under the ECR hot cell): EMT transfer crane repair procedure defined and list of parts for replacement established.



Georges THOMINE
Reactor Block Manager

7.2 Reactor block

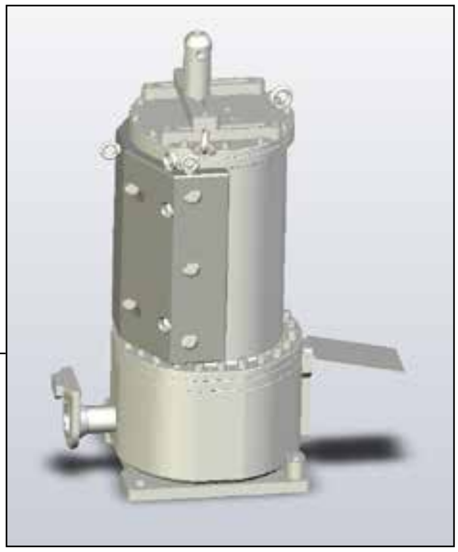
In 2021, the main activities on the reactor block project are described hereafter.

7.2.1 Engineering

MAIN ACHIEVEMENTS IN 2021

In 2021, the MOLY project made progress in several areas:

- In-core part: construction of the key components and definition of the emergency pumps.
- Out-of-core part (normal cooling system for the targets and loop I&C): definition of the equipment for the normal cooling system.
- Supply chain equipment: the design studies continued on equipment not interfacing with the transport casks for irradiated targets.



7.2.2 Assembly

7.2.2.1 Onsite activities

Fuel rack

The fuel rack is designed to hold fuel elements, inter-element mandrels, irradiation test specimens, and core pressure loss and output pressure measurement devices.

The first equipment to be installed in the core vessel was the fuel rack.

This operation was completed on 26 January 2021.

Closure head

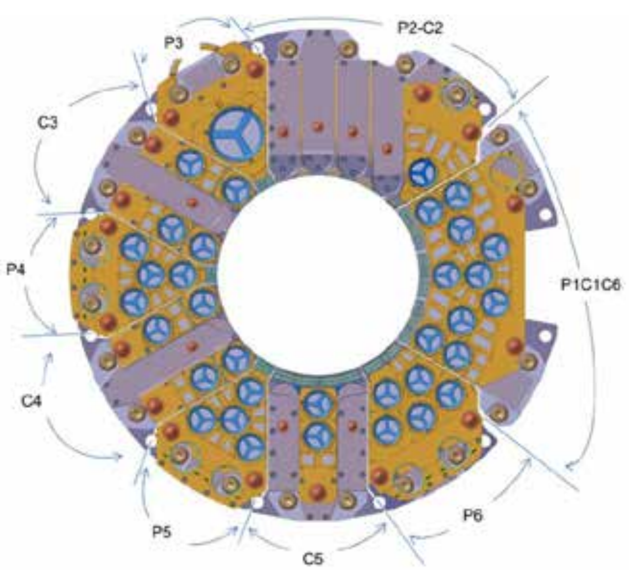
The closure head (nuclear pressure equipment category: N II) installed on the top of the vessel must guarantee the confinement of the primary coolant during operation. It maintains and positions experimental devices, as well as providing an anti-blow-out with a double lock. The closure head consists of several solid mechanical parts and precision mechanisms, which all have reduced definition tolerances. The plates have many bores, holes and threads.

Closure head installed in January 28th 2021

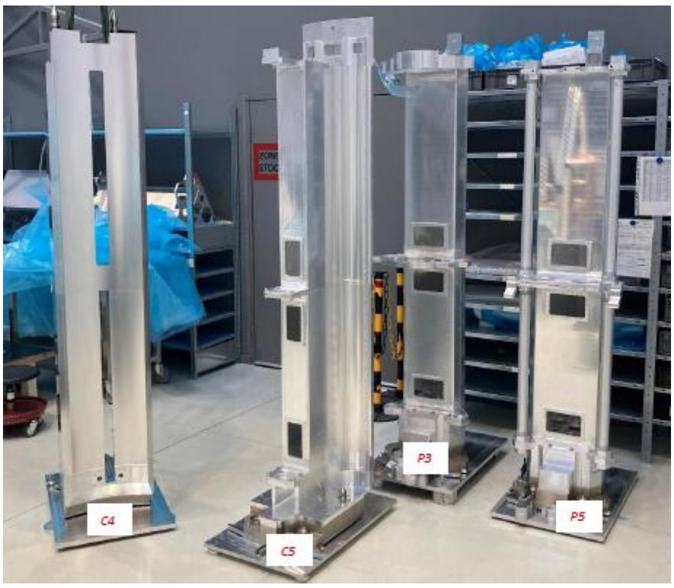
7.2.2.2 In factory activities

Reflector

The month of February 2021 marked the end of riveting operations on the reflector sectors. It took approximately 12,000 rivets to manufacture all 9 sectors of the reflector.



View of reflector sectors

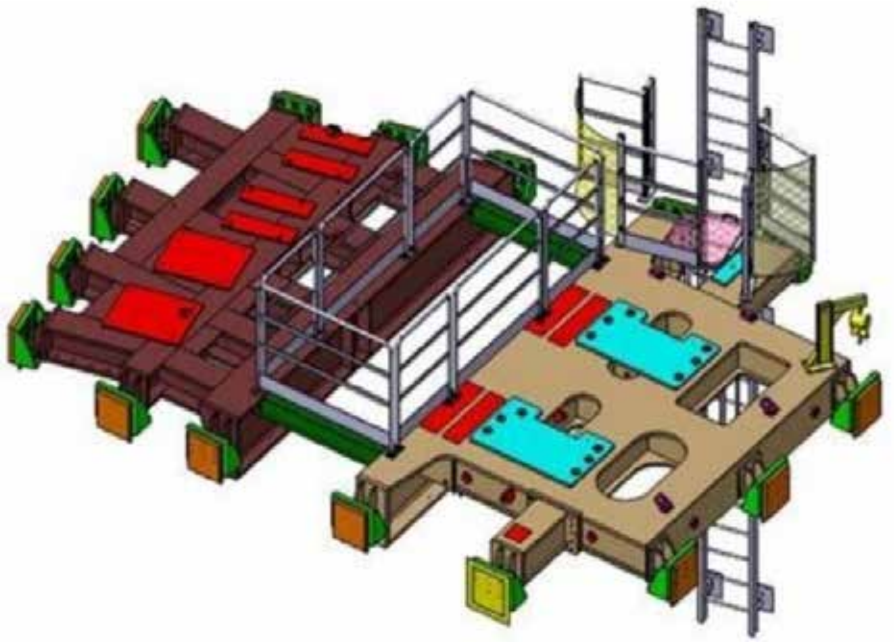


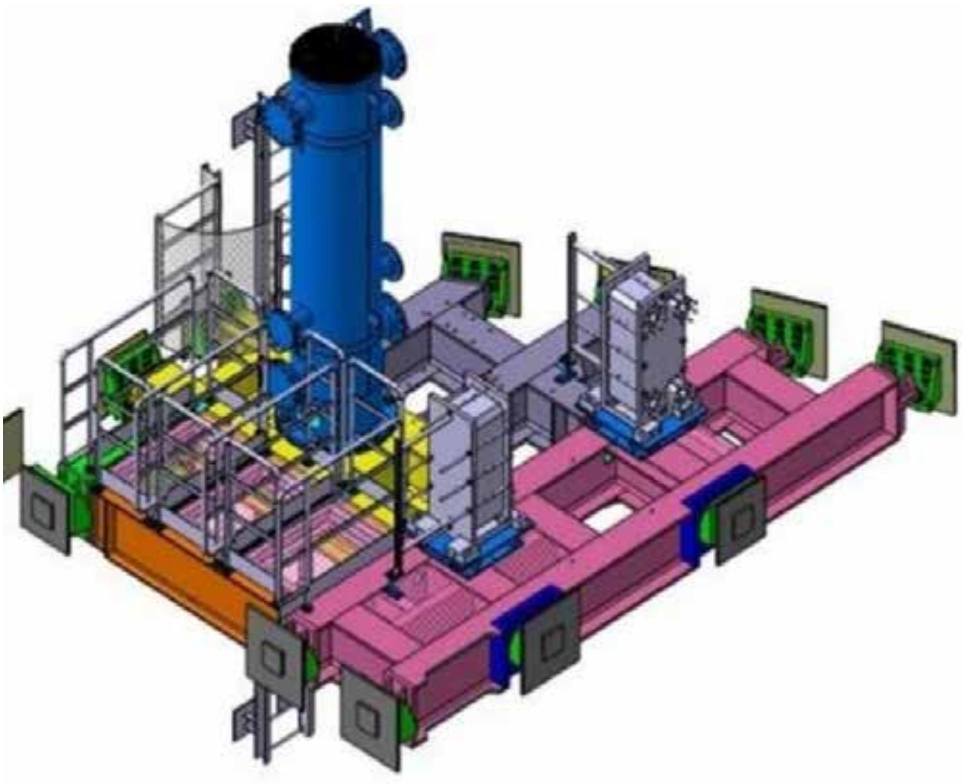
Sectors C4, C5, P3 and P5 complete with rivets

MAIN ACHIEVEMENTS IN 2021

The year 2021 for the floor structure was marked by:

- Three floor structures designed to support the primary cooling water circuit, the reflector, the reactor pool, the core emergency cooling water system and the BUR pool lines and heat exchangers.
- The assembly of the floor structure for the shielded cubicles in the reactor block unit.
- The assembly operation was completed according to the schedule on 23rd September 2021.

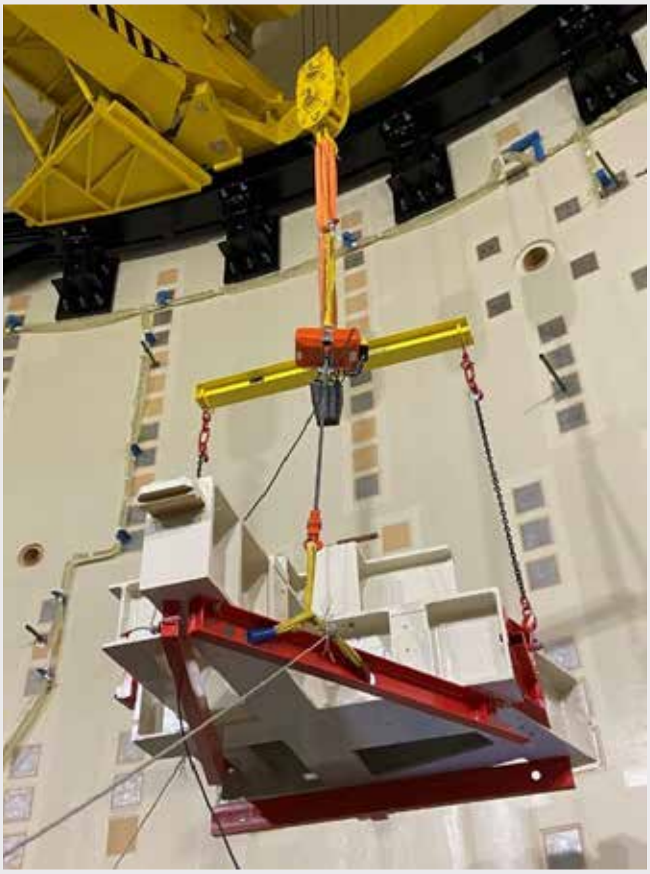




- Manufacturing, painting and load test completed in the factory

- Delivery of the floor structure sections

- Handling and installation of the floor structure sections through the cubicles.



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 2021

The main achievements for the fluid systems were:

- Launch of the design closing reviews (configuration V3.2)
- Execution of the detailed design for the lower floors (level -1, -2 and -3) in the nuclear auxiliary building (BUA) and for the bunkers in the nuclear reactor building (BUR) to secure the estimated erection timeline.

KEY MILESTONES IN 2022

The following main milestones have been identified for the coming year:

- Further progress in the design closing reviews (configuration V3.2)
- Launch of detailed design documentation (isometrics), excepting for the CEDE (experimental bunkers rooms) erection areas in the nuclear building.

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

MAIN ACHIEVEMENTS IN 2021

This year, the main HVAC studies finalised were:

- Update of the functional files for each system to take into account the main configuration status (V3.2)
- Execution of the detailed design for the lower floors (level -2 and -3) in the BUA building and the mezzanine floor in the BUR reactor hall.
- Completion of the most important safety concerned equipment reviews

KEY MILESTONES IN 2022

The main tasks planned for the coming year are:

- Update the functional system files to take into account major topics of the sub-configuration status (V3.2f) and 3D model validation
- Update and confirm the achieved milestone for the most important safety concerned equipment reviews in order to launch qualification and manufacturing processes.

7.3.1.3 HVAC back-up building (BAS)

MAIN ACHIEVEMENTS IN 2021

Regarding the progress made in engineering for the HVAC back-up building (BAS), the functional system files taking into account the main configuration status (V3.2) and 3D model validationwere updated.

KEY MILESTONES IN 2022

The main tasks planned for the coming year are:

- Completion of the design closing reviews (configuration V3.2)
- Update and confirm the achieved milestone for the most important safety concerned equipment reviews in order to launch qualification and manufacturing processes.

7.3.2 Manufacturing

7.3.2.1 Fluid systems

MAIN ACHIEVEMENTS IN 2021

The main achievements in fluid system manufacturing were:

- Manufacturing completed of all major components for the auxiliary building components and equipment
- Manufacturing of pipe spools launched on a large scale.

KEY MILESTONES IN 2022

The key milestone for 2022 will be the delivery of key components and equipment for the conventional auxiliary buildings, as well as components for the nuclear auxiliary building.

7.3.2.2 HVAC (excepting the emergency diesel generator building, BAS)

MAIN ACHIEVEMENTS IN 2021

The main manufacturing achievements of this year were:
Manufacturing of components and equipment to be installed on the lower floors (level -2 and -3) of the BUA building and the mezzanine floor of the BUR reactor hall (support structures are still being delivered).

KEY MILESTONES IN 2022

The key milestone for 2022 will be to continue the delivery of 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 2021

The main manufacturing achievements of this year were: Manufacturing of tests components

Qualification of ventilation damper used in the safeguard buildings

KEY MILESTONES IN 2022

The key milestone for 2022 will be the supply of the test components.

7.3.3 Assembly

7.3.3.1 Fluid systems

MAIN ACHIEVEMENTS IN 2021

In terms of construction, this year saw:

- Major progress on all utility production levels in the BMR building

Piping systems installed in the BMR pumping room

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

KEY MILESTONES IN 2022

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

7.3.3.2 HVAC (excepting the BAS *buildings)*

MAIN ACHIEVEMENTS IN 2021

Progress made in the field of HVAC concerned:

- Completion of HVAC support structures and preparation of ducts on the reactor hall concrete platform (BUR)
- Installation work in the nuclear auxiliary building (level -2 and -3)

KEY MILESTONES IN 2022

In 2021, the team will focus on:

- Completing the installation of all equipment in the Auxiliary refrigeration and utility building (BMR, level 0)
- Installing ducts for the mezzanine in the reactor building hall (BUR)
- Installing the ventilation and air-conditioning systems on levels -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

MAIN ACHIEVEMENTS IN 2021

In 2021, the key progress made in electrical and I&C system engineering was:

- Design revues in configuration 3.2 for:
  - Electrical equipment (50 % of reviews completed). Some examples include:
    - Electrical penetration
    - Safety electrical panel
    - Sound, video and telephone systems
    - Access control system
  - Radiation monitoring system
- Update of I&C system studies in configuration 3.2 (65% of studies completed)

KEY MILESTONES IN 2022

The main milestones for the year will be:

- Continued design reviews in configuration 3.2 for:
  - Electrical equipment (100% of electrical distribution equipment reviews completed)
- Completion of the update of I&C system studies in configuration 3.2
- Start of qualification for electrical equipment:
  - Electrical penetration with two solutions
  - Thermal testing of safety electrical panels
  - Earthquake testing of high voltage circuit breaker

7.4.2 Construction

MAIN ACHIEVEMENTS IN 2021

The main construction achievements for the year were:

- Manufacturing of radiation sensors. Some examples include:
  - Alpha and beta particle monitor (Figure No. 1)
  - Mobile atmospheric area monitor (Figure No. 2)
  - Mobile gamma area monitor (Figure No. 3)
  - Mobile neutron area monitor (Figure No. 4)

Figure 1

Figure 2

Figure 3

Figure 4

- Manufacturing the automation platform for safety-class 3 I&C (see Figures 5 and 6).
  - Modifications to the I&C (reactor protection) cabinets to take into account configuration 3.2
  - Cabinet reactor protection (Figure No. 7)
  - Safety control panel (Figure No. 8)

- Continued manufacturing and installation of cable tray supports on the lower levels of the nuclear unit.

540 manufactured and 250 mounted

Figure 9

Figure 10

- Manufacturing of safety radiation sensors
- Continued manufacturing of cable tray support structures
- Continued installation of cable tray supports on the lower levels of the nuclear unit
- Creation of the object libraries for HMI and automation software development
- Factory test of safety-class 2 I&C system software.

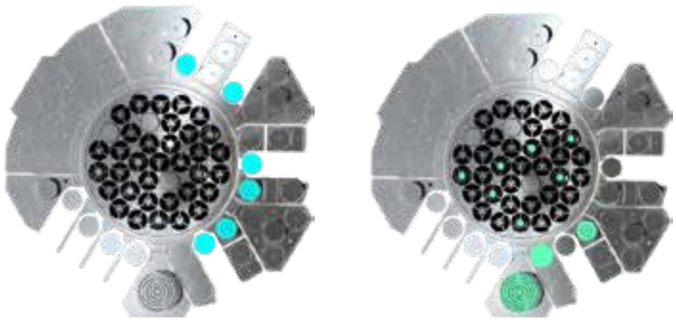
Raphaël PALHIER
Experimental Devices Manager

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.

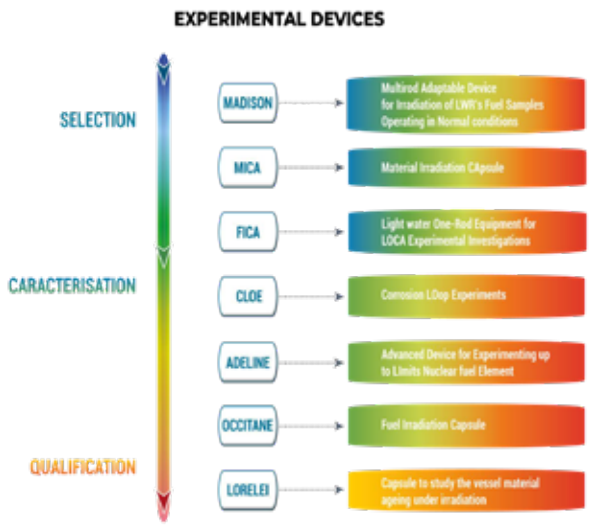
One of the JHR objectives is to carry out material and fuel experimental irradiations. To do so, the project is developing experimental devices that can be used as either simple capsules or complete loops.

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



Fuel (in blue) and material (in green)

TYPE OF EXPERIMENT		FUEL	MATERIAL
Reliable cooking	CAPSULE	1 FICA	6 MICA
			1 OCCITANE
	LOOP	1 MADISON	1 CLOE
Cooking in incidental situation	CAPSULE	–	–
	LOOP	2 ADELINE	–
Cooking in acccidental situation	LOOP	1 LORELEI	–



The first fleet of Experimental device concerns 1 Adeline, 1Madison, 3 Mica, 1 Occitane

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 ^{99}Mo required in nuclear medicine for a wide variety of tests (e.g. bone cancer diagnosis).

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

The production system and its associated equipment and tools are managed by the reactor block project whose progress is detailed elsewhere (see 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 for 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. Some of them entail 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 devoted to the production of radioisotopes.

7.5.1 Development of devices and tools for radioisotope production

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

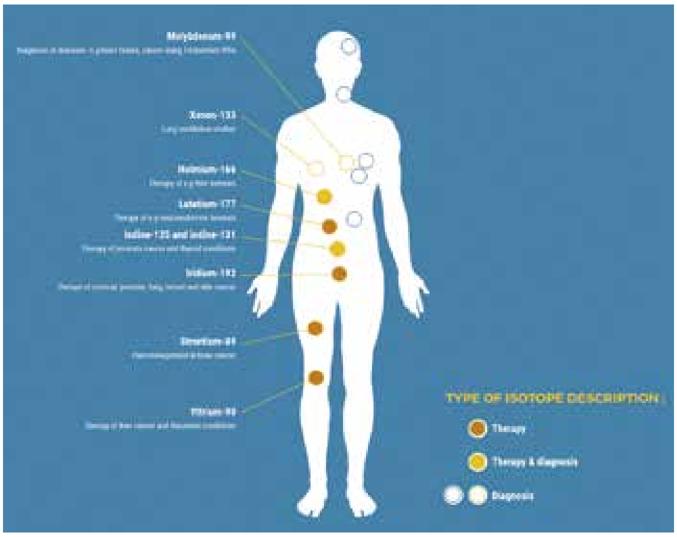
The JHR has the following objectives:

- Produce radioisotopes for the medical sector, as well as for applications.
- The JHR will be able to produce numerous radioisotopes for medical purposes (e.g. ^{90}Y, ^{153}Sm, ^{166}Ho, ^{169}Er, ^{177}Lu, ^{186}Re, ^{192}Ir, ^{103}Pd, ^{125}I, etc.), but also for industrial and R&D purposes (e.g. ^{192}Ir, ^{60}Co, ^{75}Se and ^{169}Yb used for non-destructive testing, sterilisation of equipment, etc.).
- Secure the production of medical radioisotopes:
    - Production between 25% (about two billion of patients diagnosed) and 50% of yearly European requirements for ^{99}Mo
    - Production from start-up of therapeutic radioisotopes to sustain developments

(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.



Example of medical radioisotopes that the JHR could produce.

This supply chain can be succinctly illustrated as such:

MAIN ACHIEVEMENTS IN 2021

Preliminary design studies for the multiple artificial radioelement (multi-REA) devices began in 2021. One of the challenges is to limit the production of nuclear waste (especially aluminium waste for the future customers). For this reason, different concepts are being investigated and will be tested using mock-ups in 2022.

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

A radioisotope target life-cycle study in the JHR facility was conducted. This study helped define the optimal path to manage relatively short half-life radioisotopes that will be produced in short basket-type or Moly devices, by reducing the duration of post-irradiation operations.

KEY MILESTONES IN 2022

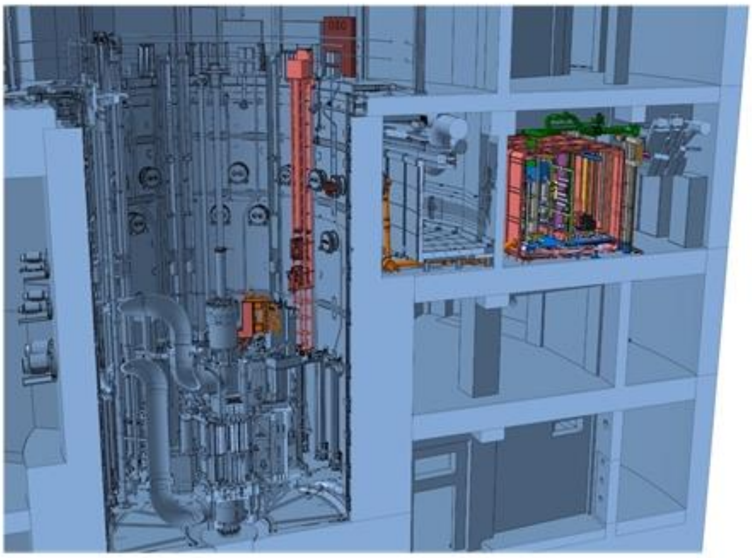
- First half of 2022: Construction of a mock-up of irradiation containers to test their leak tightness after several opening/closing cycles
- Continuation of irradiation device design studies
- First half of 2022: Preliminary safety study
- Last quarter of 2022: Preliminary design project review to validate the technical studies carried out during the year and to give the green light to continue the engineering design studies.

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 is placed on a displacement system 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.

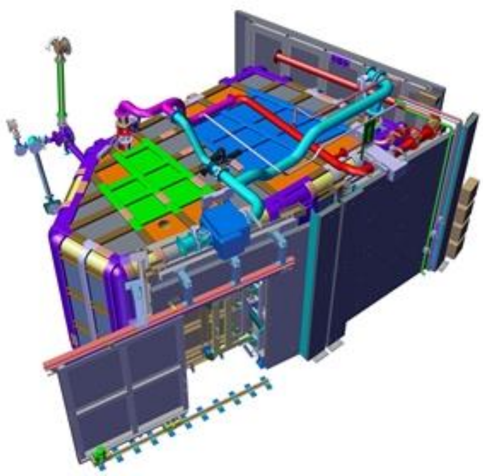
Piping Penetration :
Located in the reactor wall, it allows the water loop management from the experimental sample in the irradiation device through the cubicle

In pile irradiation device :
It hosts the fuel rod to be tested and is placed on displacement system in reflector to adjust power ramps implementation



ADELINE device main components in JHR facility

Rotating Transfer Rack :
Located in the reactor pool, it aims to load and unload fuel rod sample holders to allow up to 3 experiments per reactor Cycle



Shielded Cubicle :
It houses the parameters (thermal-hydraulical and water chemistry) in-process tuning system

MAIN ACHIEVEMENTS IN 2021 AND FOCUS ON RISKS MITIGATION IN 2022

Zircaloy4 final acceptance (2021) and storage in the JHR warehouse (January 2022)

High fluxes can be reached on the sample thanks to the use of zirconium alloy as the material for the in-core irradiation device.

Underwater line development and design (2021) and full-scale prototype line fabrication for endurance tests on a dedicated bench (2022)

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

Optimisation of the shielded cubicle layout

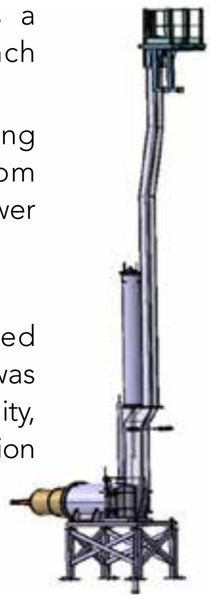
Organisation and shielding of the process components have been improved to limit the occupational radiation doses, and both the local and overall weight of the shielded cubicle.

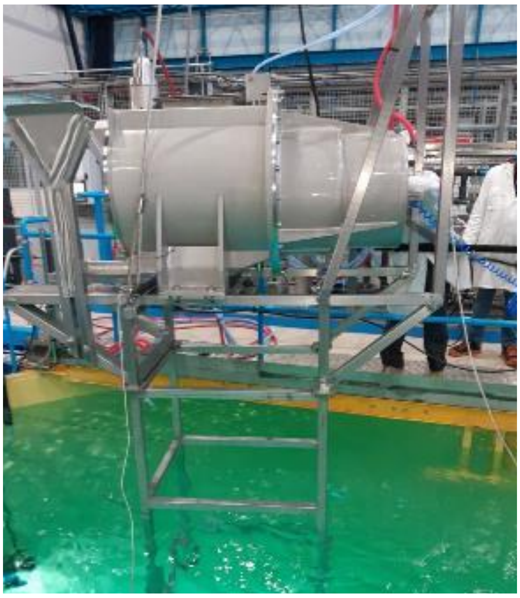
Neutron imaging system (SIN)

The neutron imaging system is a non-destructive examination bench installed in the reactor pool.

It is designed to characterise, among others, the experimental load from ADELINE before and after the power ramps.

The year 2021 has been dedicated to the full-scale mock-up, which was tested in the TOTEM pool CEA's facility, and to the expertise and implementation of its results in the bench design.

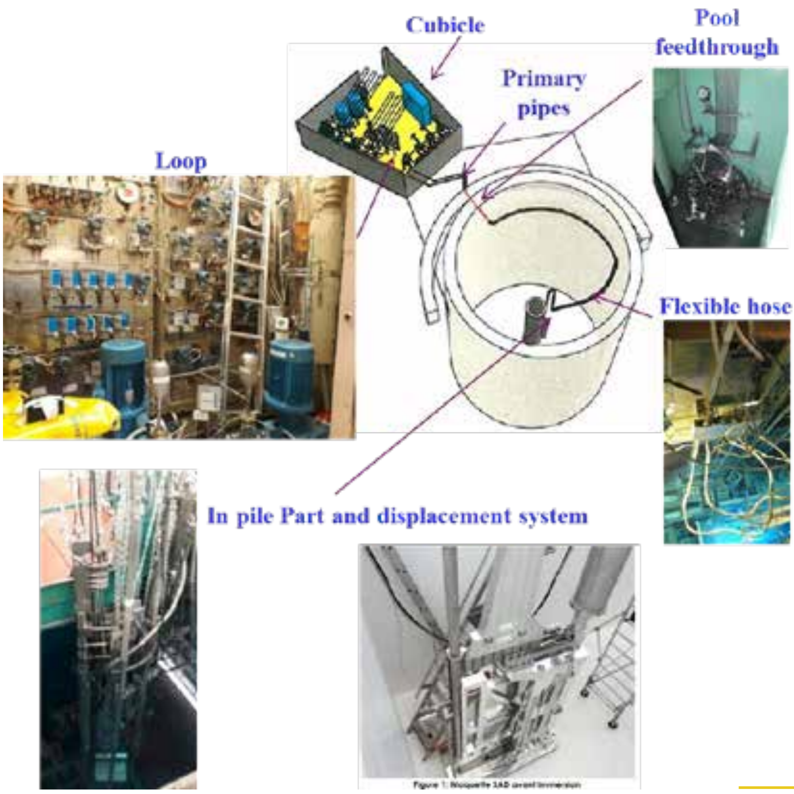




7.5.3 MADISON

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 have this device available for JHR start-up.

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 that purpose, CEA has subcontracted to IFE/Halden the detailed design of the first irradiation rig (including instrumentation), the water loop and I&C system.

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.

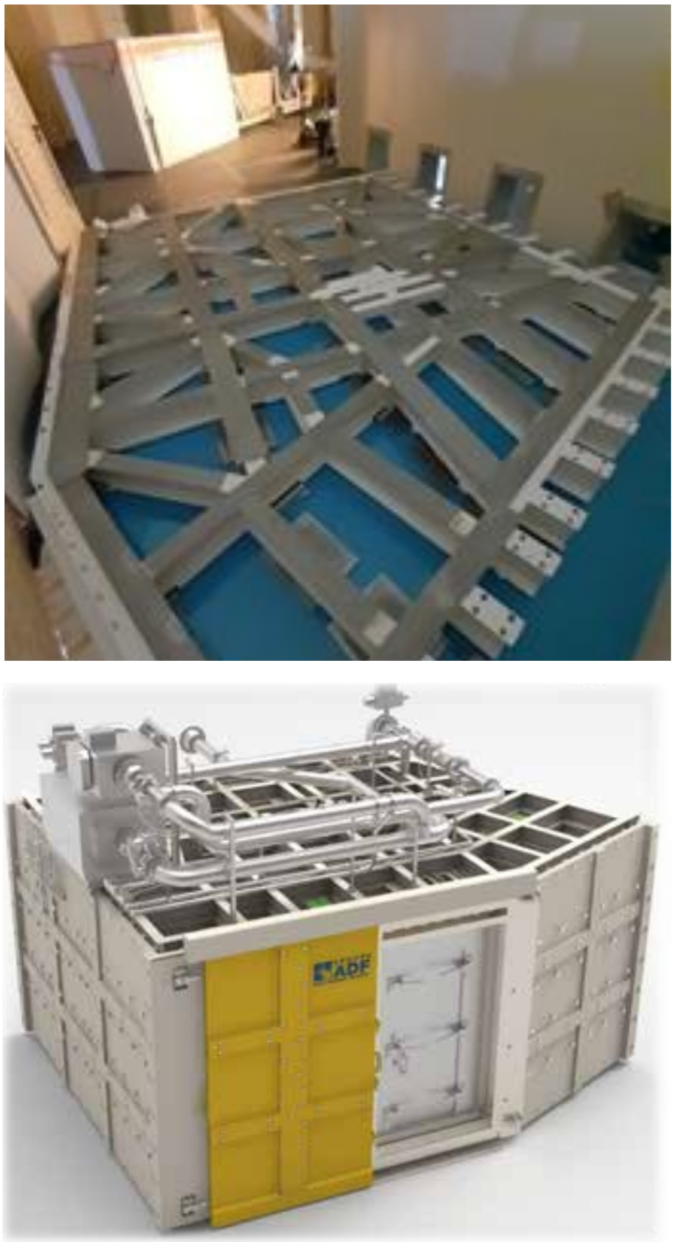
The first MADISON device will use most instruments currently employed in these two reactors, and specific changes to the MADISON irradiation rig will make it possible to use all of them (counter-pressure sensors, diameter gauge, etc.).

MAIN ACHIEVEMENTS IN 2021

The project encountered some delay due to postponements but the main roadmap is still progressing well and is consistent with new milestones.

Installation of the cubicle in the JHR facility was expected to end in 2021, but encountered difficulties 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 case of a hypothetical accidental breach in the high-pressure primary system.



General view of the cubicle (fluid feedthroughs for the loop not shown) and floor frame installed in the JHR building

As planned, IFE Halden has completed the assembly and started 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 goal is to validate the design (thermohydraulic performance, chemistry, control systems and adjustments), but also maintenance operations in a full-scale mock-up of the cubicle without the irradiation conditions (cold conditions), before manufacturing the final loop.

The mock-up loop successfully reached PWR conditions in March 2021, at about half the nominal flow, using an existing pump available in Halden instead of using the actual primary pump due to delays in delivery. The next step is to integrate the primary pump to reach full operating conditions.

Overall view (purification filters in white)

The primary pump has been fabricated and the pump has been pressure-tested. The shaft bushings are made of a carbon-based ceramic and some other parts require a special surface treatment to improve hardness.

KEY MILESTONES IN 2022

Installation of the cubicle in the JHR facility is scheduled to end this year.

After delivery to IFE in Norway, the main circulation pump should be tested with the other components in the mock-up loop at IFE, at nominal flow, for final testing and training of JHR experimental staff on the mock-up loop, international travel restrictions permitting.

A full-scale test bench to run the first qualification test of the flexible hoses has also been made. The goal is to be able to experimentally demonstrate that the fatigue life of these components largely exceeds the number of cycles expected during their lifetime.

Finally, the CEA has contracted an engineering company to assist in the detailed design of the loop (piping and seismic calculations, calculation and design of the heat exchangers according to the RCC-MRX code) in view of preparing for the final loop manufacturing. With this support now exceeding 10 man-years, a first version of the Safety Report has been submitted, as have the design studies of the pool feedthroughs and the double-wall piping between the cubicle and the pool.

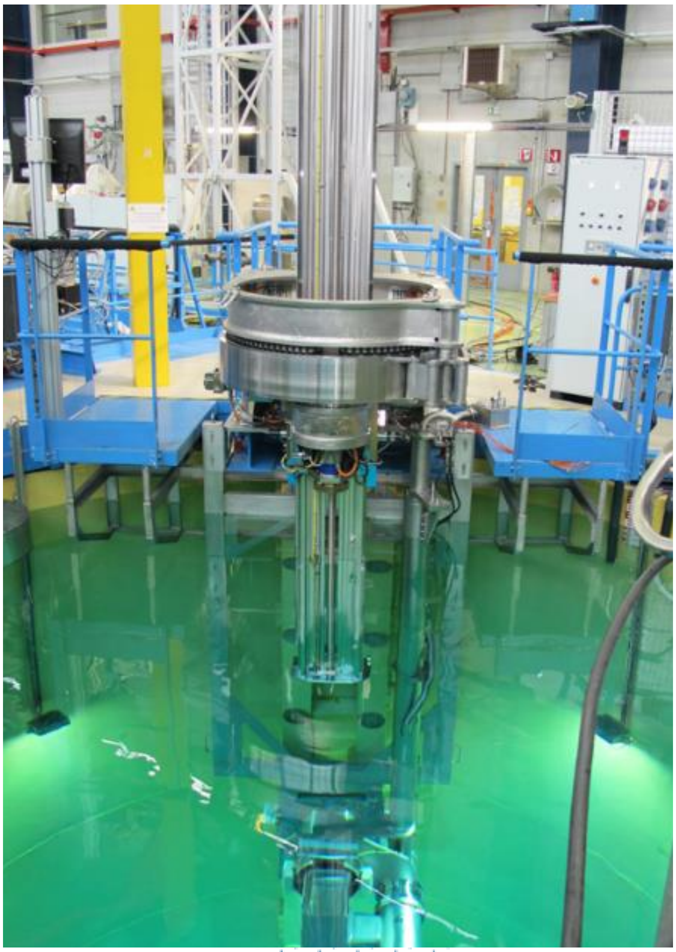
7.5.4 Non-destructive examination devices (VTT contribution)

Within the framework 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 the reactor and one for the storage pools.
- In-air examinations on samples (hot cells)
  - Gamma and X-ray scanning system (HGXR system).

7.5.4.1 Status of the UGXR benches

The underwater benches were transported to Cadarache in early 2021. The first bench (A) had already been tested at VTT's subcontractor's (Idom) laboratory. The second bench (B) was fully tested at Cadarache. Unfortunately, during the bench B site acceptance tests (SAT), some structural support components were damaged in the bench, which caused noticeable delay in the bench acceptance and delivery process. The lead time for manufacturing the spare parts turned out to be more than 30 weeks, which means that the bench can only be re-assembled and re-tested in autumn 2022. Bench A is operating correctly and was installed to the Cesarine pool in the Totem facility for training in underwater operations. This delivery is expected to be fully finalised by the end 2022. In 2020, VTT and the CEA considered that the original accuracy requirements for the benches were too demanding and some changes were made. Even if the highest accuracies cannot be achieved with the benches (based on the test results), their performance seems to have reached a very good level and the benches will eventually provide the high-quality information expected.



Bench B on the testing tower and bench A in the Cesarine pool of the TOTEM facility

7.5.4.2 Status of the UGXR ex-core part (collimators and biological shielding)

In parallel with the UGXR benches, the underwater collimators and biological shielding were also being manufactured. The year 2021 focused on the final assembly of the collimator structures in their final positions in the JHR. For the other collimators, only the crane for installing the collimators was introduced but not the collimators themselves as the CEA needs them for training purposes in the Totem facility. The installation work was started in summer 2021 and will be finalised in February 2022. Access to the JHR site requires very thorough planning and the time windows for completing the installation work are quite tight.

Installation of support structures and handling crane in the JHR

7.5.4.3 Hot cell bench and collimators

The delivery of the hot cell gamma measurement and X-ray radiography bench and the collimators (HGXR) was finalised in early 2020. The equipment is now in the TOTEM facility at Cadarache where the CEA trains with them and is defining the experimental protocols needed for future operations in the JHR.

Hot cell bench and collimators in the TOTEM facility

7.5.5 CLOE DAE in-kind contribution

Following the successful completion of the preliminary design for the CLOE loop in 2019, the follow-up in 2020 and 2021 focused on the detailed design studies performed by BARC (India) and the drafting of several engineering documents. These documents have been reviewed and approved by the CEA who acknowledged the very good quality of the latter.

Due to the Covid-19 pandemic, the arrival of the BARC secondee at Cadarache had to be postponed in 2021 and has been rescheduled for the second semester of 2022. This secondee is tasked with drafting the equipment's component specifications for procurement.

CLOE loop component qualification building

7.5.6 LORELEI

Significant work has been done by the IAEC/ROTEM to finalise all the documentation to complete the detailed design studies for the LORELEI loop dedicated to accident scenario studies such as loss-of-coolant accident (LOCA) tests in the JHR.

An expert review process was set up in 2021 by the CEA on several topics (mechanic, thermohydraulics, etc.) acknowledging the very good quality of the documents.

A final detailed design review was held in October 2021, involving formal delivery of the documentation (technical drawings, documents, etc.) by the IAEC and acceptance by the CEA, thus closing this important phase of the LORELEI project.

Delivery of the hard drive by the IAEC to the CEA. This hard drive contains a few thousand documents for the completion of the LORELEI loop detailed design.

7.5.7 CARMEN measurement device in the JHR

CARMEN is a measurement device that will be used to improve the overall knowledge of the reactor and these experimental conditions for better modelling and better experimental results by measuring the gamma and flux heating and the neutron flux.

MAIN ACHIEVEMENTS IN 2021

Engineering design studies began in 2021 with the following objectives:

- Finalisation of the optimisation process on the calorimetric cell (type CALMOS-2) used on the OSIRIS reactor for use in CARMEN through a mock-up
- Mock-up of cable spirals with strong dimensional constraints
- Optimisation of the design for the device developed for core locations with the aim of ensuring compatibility with reflector locations
- Safety study
- Beginning of thermohydraulic studies in the core and the reflector.

KEY MILESTONES IN 2022

- Signature of the contract with the SCK-CEN for the irradiation of the CARMEN calorimetric cell in the BR2 reactor. Documentation preparation for the commissioning phases.

- First semester 2022: construction of the CARMEN full-scale mock-up for fatigue tests on the vertical displacement system
- First quarter of 2022: Finalisation of thermohydraulic studies in the core and the reflector
- Mechanical engineering design studies
- Study of organisational and human factors during CARMEN operation in the JHR

Mock-up of the CARMEN calorimetric cell before assembly

Mock-up of the cable spiral

7.5.8 MECADEX

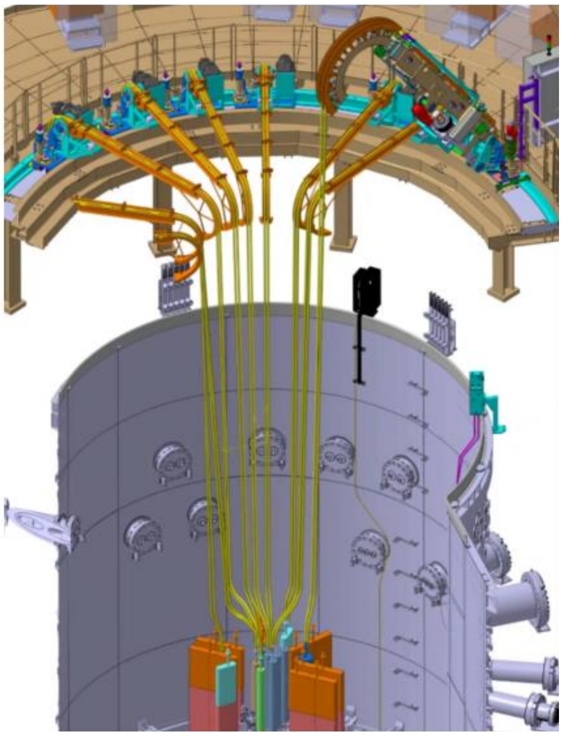
In order to operate the JHR experimental devices, the MECADEX project is in charge of studying and manufacturing all the common mechanical equipment required in the JHR facility, from the preparation of the device up to its dismantling after irradiation. This mechanical equipment is required all along the operational cycle, from the reactor building up to the hot cells.

A metallic structure, that supports the biological shielding, is being studied to protect operators from radiation when circulating in the corridors between the reactor pool and the experimental cubicles.

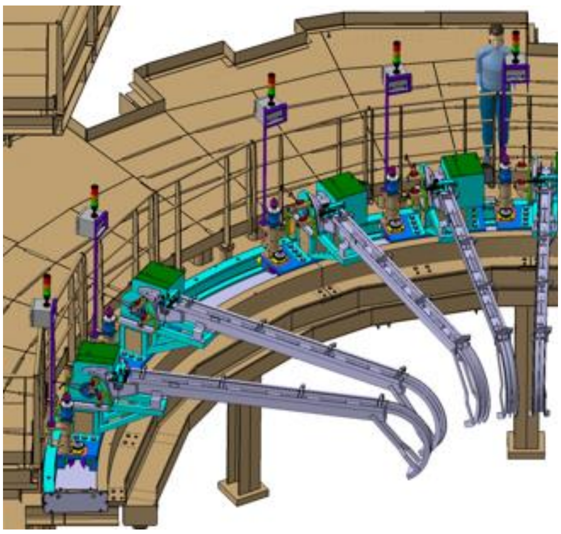
Radiation comes from experimental loops and other fluid systems, so this biological shielding is installed in the three lower levels of the reactor building. Such protection will also allow the operators work in the penetration of the reactor pool.

DLG bracket

Some experimental devices will have fluid and electrical lines connected during its irradiation cycle. These so-called "aerial lines" connect the experimental device to control units in the reactor building. The DLG brackets will be used to support these aerial lines of the experimental devices during their operation in the reactor.



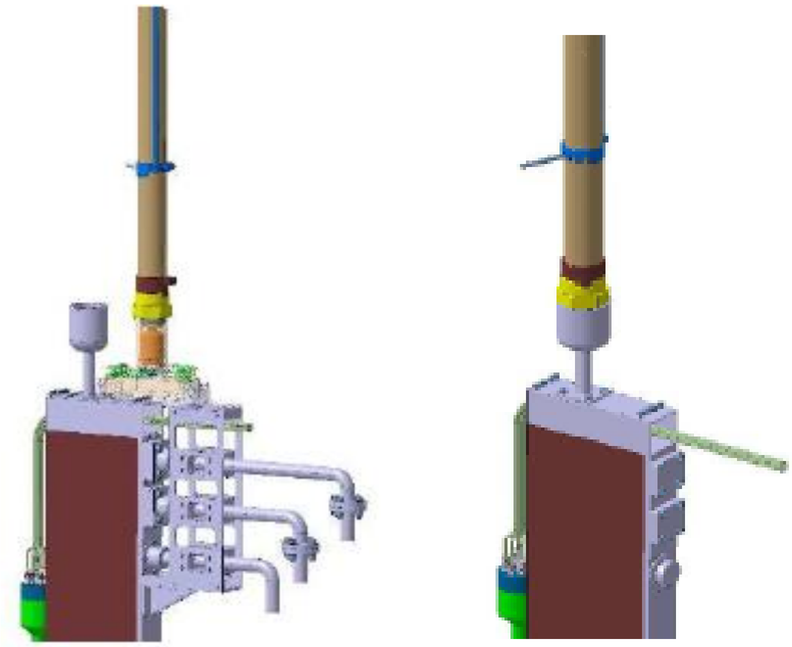
View of the DLG brackets supporting the aerial lines



Detail of the DLG brackets

Handling tool for experimental devices

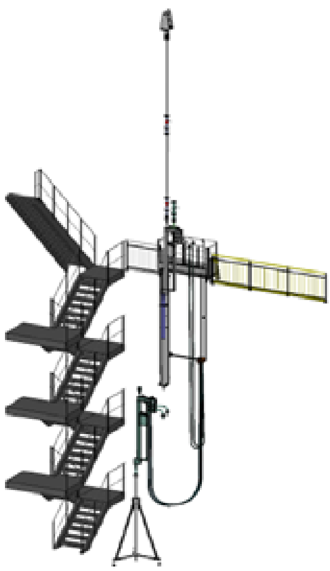
The MECADEX project is also studying the handling tools needed to transport the experimental devices from their preparation station to the processing cells, thus passing through all the different workstations during the irradiation stages in the reactor. Several handling tools will be available depending on the type of the experimental device to be handled. Here above is a representation of the handling tool for the reflector experimental devices with its two gripping ends.



Reflector handling tool with its two gripping ends

Nowadays, a handling test bench is being manufactured to be installed in an annexe building next to JHR in order to validate the initial design of the handling tool. This test bench will also be used to test the handling of an experimental device between its workstation and its irradiation location in the reflector.

Handling test bench



Others handling tools will also be needed to operate the experimental devices in the JHR (camera tools, tool-handling poles, etc.): these will be studied and manufactured by MECADEX.

Tools for experimental devices

Finally, MECADEX is also studying others common tools that will be necessary to operate experimental devices, in particular for operation carried out in the JHR hot cells. These tools are, for example, handling grapples, tool supports, transfer tools between cells, dummy experimental devices for tests, etc.

MAIN ACHIEVEMENTS IN 2021

In 2021, the MECADEX project finished the detailed design for the biological shielding in the CEDE corridors and started preparing the tender process expected for 2022. The goal is to contract manufacturing for the beginning of 2023.

Regarding the DLG brackets, the detailed design was prepared in 2021 and it will be finished in mid- 2022. Again, the goal is to contract its construction in 2023.

Concerning the handling tools, the handling test bench is now being manufactured. It will be installed in the BMM building at the beginning of 2022 and the future JHR operator's team will start tests in order to start detailed design for the handling tools in mid-2022.

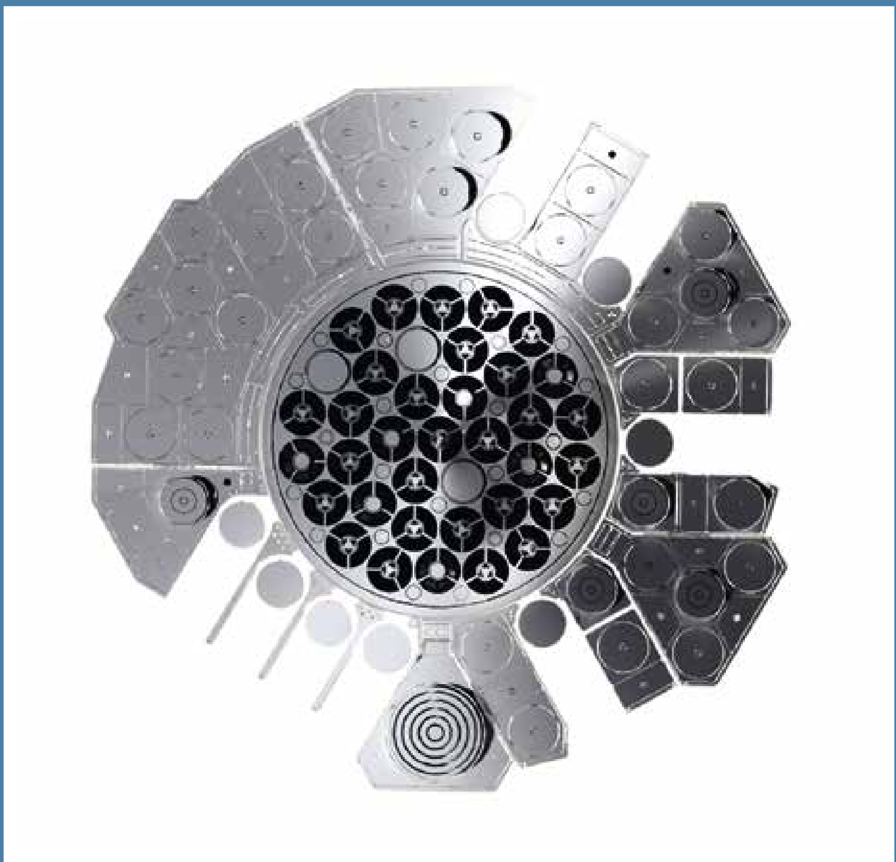
KEY MILESTONES IN 2022

The MECADEX project expects to finish its "to do list" for all the experimental device tools in 2022; the goal is to start all the detailed design for those tools before the end of 2022.

Handling tools currently in manufacturing

7.6 Working Group on Internals Stabilisation Analysis

Following the detection early 2020 of abnormal vibrations on some components inside the reactor block, a dedicated Working Group called « Internals Stabilisation Analysis » has been created to solve this problem. A combined approach of modeling and experimental tests has been set-up in order to find an acceptable situation. First milestones of this roadmap have been successfully achieved in 2021 with promising design enhancement and the implementation of a modeling tool allowing the orientation and validation of several options to solve this issue.



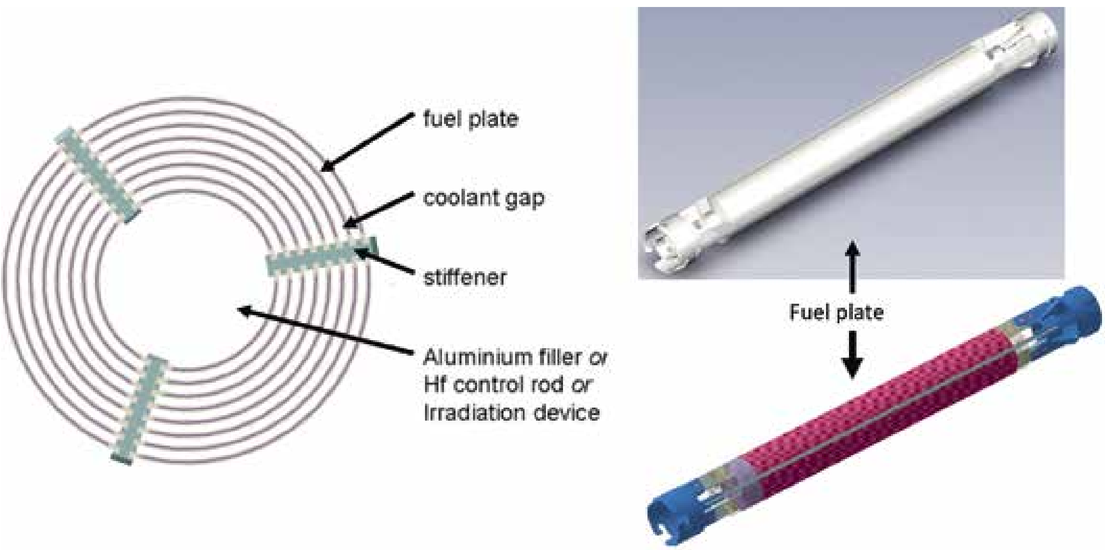
Olivier MARCILLE
Operation Preparation Manager

8.1 Fuel manufacturing

On 8 July 2021, the CEA took part in the acceptance procedure for the fuel plates manufactured by Framatome-Cerca in Romans-sur-Isère. This is the first step in the manufacturing of the second JHR core (start-up core).

A long-term partnership based on dialogue and openness made it possible for this milestone to be reached in a particularly difficult context due to the pandemic.

One of the second JHR core fuel plates with BUREAU VERITAS, FRAMATOME/CERCA and CEA representatives



JHR fuel element

8.2 Training process

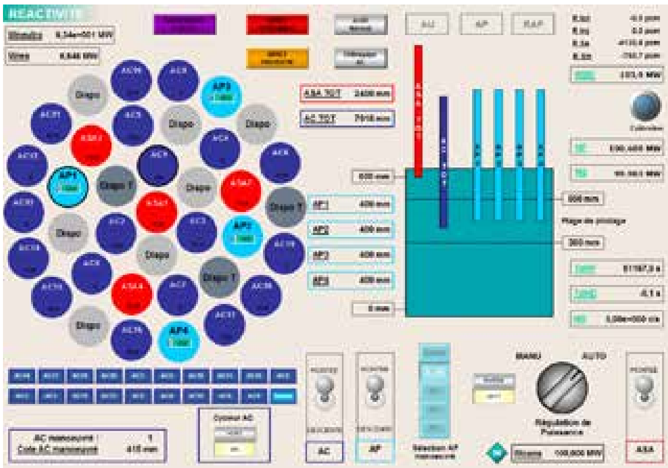
The future JHR operator is responsible for developing and implementing the training programme ensuring that operating team will be correctly trained and qualified to carry out their functions, from commissioning through to nominal operation.

This involved:

- Identifying the required skills by providing an exhaustive list of all activities that operators have to perform, taking into account the nuclear safety, occupational safety, quality and environmental requirements
- Developing the training programmes
- Writing the training material.

The training courses include, for example:

- Professional certifications to operate an experimental reactor (based on nuclear and reactor physics and thermohydraulics skills)
- Training on occupational safety and nuclear safety culture: occupational health and safety, radiation protection, nuclear safety culture, waste management, nuclear material management, etc.
- Training developed by the operating team. The JHR operators created about ten "basic technical training modules" representing the knowledge and skills needed for any sort of operator position. They also created approximately seventy "professional technical training modules" to explain the operation of systems (core operation, ventilation, handling means, primary cooling, tertiary and secondary cooling, water purification, reflector, pools, instrumentation and control, etc.) using design and manufacturer documents
- Participation in the commissioning phase will allow the future operator to take ownership of the facility and its operation
- Writing the documentation is a significant component of training
- The JHR simulator allows the future operator to understand the behaviour of the reactor in all conditions (normal, incident and accident), and to test the related procedures. It is a key tool for the future operator, both for initial training and refresher training.



Screen shot of a reactivity diagram

View of the training room

8.3 Operation documentation

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

Up to the end of 2021, the future JHR operator had been writing 60% of the documents required for pool filling, 40% of the documents required for global tests and for the first nuclear material acceptance, and 15% of the documents required for fuel loading. This task will continue in the next few years.

Safety drill in the tertiary cooling system: evacuating a victim from the stilling basin
Polar crane during regulatory load testing

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 2021, the future JHR operator temporarily took charge of operating the polar crane in the nuclear unit. It also took charge of a new building for the storage of spare parts.

The future operator is also in charge of the tertiary cooling system, which has been in operation for a few years now.

8.5 Operation preparation

In 2021, a working group studied the organisation of the annual shutdown. This task made it possible to estimate JHR availability at about 190 irradiation days per year. This result complies with the observed range of international Material Testing Reactors (MTR).

Another working group defined the periodic inspection and testing programme within the framework of the safety report.

Loading tests of the polar crane

9 ACRONYMS

ASN	French Nuclear Safety Authority
ATF	Accident Tolerant Fuel
BAS	Emergency diesel building
BMM	Cold Mounting Workshop
BMR	Auxiliary refrigeration and utility building
BND	Emergency safeguards building
BUA	Nuclear auxiliary building
BUR	Nuclear unit reactor building
CGN	China General Nuclear Power Group
DAI	Fire detection probe in hot cells
DLG	Winding system
DMES	Start-up Files
EI&C	Electrical, Instrumentation and Control
EIS2	Electronic Instrument System 2
EMI	Convoyer in transfer channel
EMT	Transfer table
EPC, EPO, EPM	Canals
EPI, EPT, EPU	Pools (BUA)
ESPN	Nuclear Pressure Equipment
FIDES	Framework for IrraDiation ExperimentS
HFDS	High Level Defence and Security
HGXR	Hot cell Gamma and X-Ray benches
HMI	Human Machine Interface
I&C	Instrumentation & Control
IAG	International Advisory Group
ICERR	International Centre based on Research Reactors
IFE	Institute For Energy technology of Halden
IJP	International Joint Programme

INB	Licensed nuclear facility
INCA	In Pile Creep studies of ATF cladding
IRSN	French Institute for Radiation Protection and Nuclear Safety
JAM	JHR Archive Material
JHOP 2040	Jules Horowitz Operation Plan 2040
JHR	Jules Horowitz Reactor
LWR	Light Water Reactor
NDE	Non-Destructive Examination
NEA	Nuclear Energy Agency
OECD	Organisation for Economic Co-operation and Development
PGZ	Access control building
PPI	Integrated Project Platform
PTI	Integrated Technical Platform
PWR	Pressurized Water Reactor
REE	Intermediate pool
RER	Reactor pool
RMD	Reactor pool polar crane bridge
ROP	Reference Operating Plan
RSS	Reactor cooling secondary system
SAT	Site Acceptance Test
SBV	Safety Behaviour Visit
TSO	Technical Support Organisation
UGXR	Underwater Gamma and X-Ray benches
VTT	Technical Research Centre of Finland
WP	Work Package

JHR
Jules Horowitz Reactor
SAFETY HONESTY GET RESULTS TEAM MINDSET

April 2022

Jules Horowitz Reactor

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