JHR
Jules Horowitz Reactor
SAFETY HONESTY GET RESULTS TEAM MINDSET

Status Report 2020

cea

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1. Foreword

Despite the challenges faced due to the Covid-19 pandemic, the year 2020 turned out to be productive for JHR construction and operations. Construction work was temporarily halted a few times during the first half of the year to deal with issues raised by the new health and safety restrictions, but work was able to continue onsite once the measures were in place. In 2020, the CEA also rolled out its new project organisation making the CEA both the owner and the vendor, while TechnicAtome and Framatome remain responsible for their own supplies. Actions to finalise the construction phase also had to be rescheduled.

Different in-kind contributions steamed ahead in spite of the pandemic. The Spanish in-kind contribution (heat exchangers) was installed in the JHR, installation of the Czech in-kind contribution (hot cells) was continued, and the Finnish in-kind contribution (NDE benches) achieved several major milestones when the hot cell devices and part of the underwater devices were successfully delivered to Cadarache. In addition, in-kind contributions related to the development of other experimental devices were continued according to the strategy defined for these devices.

Yet 2020 did not only involve construction. It also marked the beginning of operational schedule. The JHR International Advisory Group (JHR IAG), set up by the Governing Board, started defining its methodology to assess the experimental costs. Secondly, the Euratom-funded initiative called the Jules Horowitz Operation Plan 2040 (JHOP2040) was kicked off. It aims at providing roadmaps for the Commission on how Euratom access rights can be used for the benefit of all Euratom members. At the OECD-NEA, the 'Framework for Irradiation Experiments' (FIDES) was launched and will include reference tests and testing capabilities for the JHR. Finally, scheduling for the JHR specific archive material (JAM) project was continued with the objective of purchasing the reference material to cover the entire service life of the JHR.

As the reactor nears completion, the number of related construction and installation activities increases every day. The JHR consortium has reiterated its willingness to actively participate in the programme and work together to reach our common goals. The JHR consortium members must now get ready for the start of operations. We are also looking to welcome new members into the consortium, which, thanks to the CEA's efforts, looks like a very promising possibility in the near future.

I look forward to greater success for the project in 2021.

Petri Kinnunen
JHR Governing Board Chairman

1. Foreword

On 3 October 2021, Jules Horowitz (1921-1995) would have celebrated his 100th birthday. When he was a child, his family left Poland and settled in France where he studied engineering. After World War II, he became director at the Atomic Piles department at the newly created *Commissariat à l'énergie atomique* (CEA) where he contributed to the successful start-up of Zoe, the first pile reactor in France.

During his long and rich career devoted to the development of atomic energy, he created the *Institut de recherche fondamentale* (now known as the Fundamental Research Division at the CEA), and helped found the Institut Laue-Langevin.

In due recognition to his tremendous contribution to experimental nuclear facilities, the future reference material testing reactor in Europe was named after him.

Despite the disruptions brought about by the Covid-19 pandemic, 2020 has paved the way to the completion of the JHR construction phase. The installation of the reactor block vessel and the start of electromechanical work in the nuclear unit are clear signs that the project has transitioned from the design phase to the site erection phase, while keeping occupational safety its top priority, the level of which has strongly improved.

Thanks to a newly simplified organisation, the CEA was able to define a detailed roadmap up to start-up with all stakeholders. This roadmap, which is under final assessment by the CEA's governance bodies, will steer JHR activities from 2021 onwards.

The whole JHR project team is therefore looking forward to paying a warm tribute to Jules Horowitz by achieving its major milestones and continuing its steady progress towards completion!

David Emond
JHR Project director

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 work throughout construction and commissioning has and will continue to be carried out in the safest possible conditions. Indeed all the contractors of the project, including CEA, have signed the security policy document and are engaged to place the safety as their main concern.

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

Nous, les parties prenantes du projet RJH, plaçons la sécurité par-dessus tout et la considérons comme la priorité dans toutes nos activités que ce soit dans les bureaux, sur le chantier ou ailleurs.

Nous nous engageons à contribuer au déploiement de la culture de sécurité par le CEA et nous ambitionnons d'atteindre le « zéro accident ».

Nous nous **engageons** à faire connaître et respecter les standards de sécurité pour préserver la vie et la santé de tous les intervenants sur le chantier RJH, qu'il s'agisse de nos salariés ou de nos sous-traitants.

Nous mettons **tout en œuvre pour permettre le respect des standards de sécurité** dans nos domaines d'activité, et en cas de danger, nous nous engageons à **interrompre** notre activité.

Nous **informons** nos partenaires de la Charte pour la Sécurité et leur demandons de la respecter. Nous **privilégions** les partenaires qui partagent nos valeurs en matière de santé et sécurité et qui contribuent au déploiement de la culture de sécurité.

Nous formons et sensibilisons nos managers afin qu'ils assument leur responsabilité permanente dans le déploiement de la culture de sécurité.

Nous développons la **compétence** et améliorons le **comportement** du personnel sur les risques liés à leurs activités, par **l'information et la formation** des travailleurs aux postes de travail en leur expliquant les standards de sécurité.

Nous adoptons une **attitude d'ouverture et de dialogue** vis-à-vis des acteurs de la sécurité. Nous **analysons** les incidents et accidents afin d'en tirer les leçons et d'éviter leur répétition par une amélioration continue. Nous **fixons des objectifs** et mesurons régulièrement l'**efficacité** de nos actions.

Nous traitons les écarts aux standards de sécurité de manière proportionnée, du rappel pédagogique jusqu'à la sanction.

David EMOND

Directeur du Projet RJH

Cadarache le 24 janvier 2020

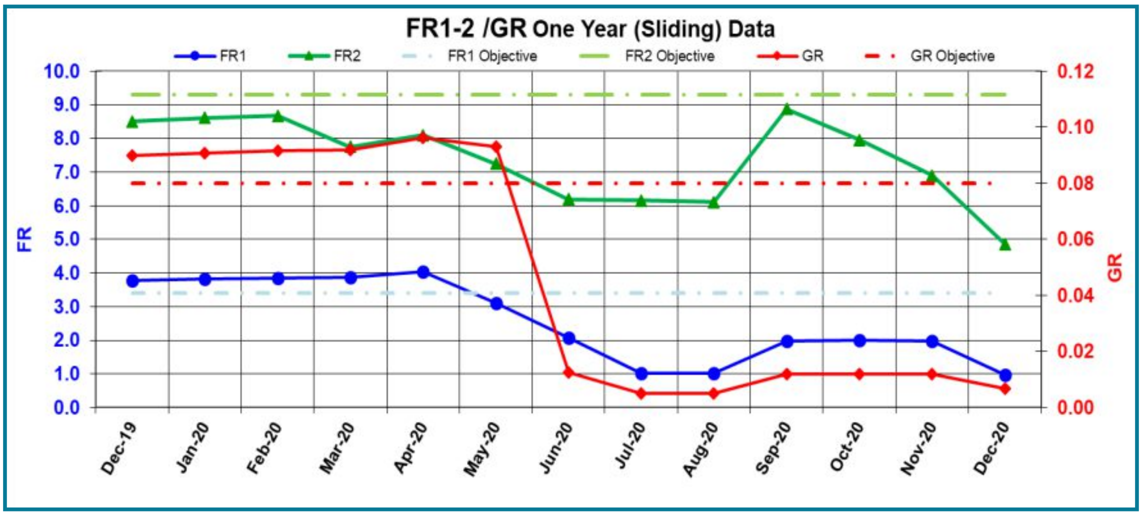
2. Safety

The JHR Project strives to provide a safe and healthy work 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 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 safety standards when going about their daily activities.

2.1. Occupational safety indicators

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

Fr1 : 1.0
FR2 : 4.9
TG : 0.01



- FR1 (Frequency Rate 1): this safety performance indicator defines the number of occupational accidents with lost time over a 12-month period per million hours worked.
- FR2 (Frequency Rate 2): this 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 safety performance indicator defines the ratio between the number of workdays lost multiplied by 1000 and divided by the working hours.

The main accidents in 2020 were:
- 1 injury with lost time: 7 days off
- 4 accidents without lost time
- 22 events requiring first-aid care

Average number of contractor staff on the construction site per month in 2020:

560	589	614	366	506	739	662	612	689	715	708	527
Jan	Feb	Mar	Apr	May	Jun	Jul	Aug	Sep	Oct	Nov	Dec

2.2 Covid-19

The staff working on the JHR project went into lockdown on 17 March 2020 following the measures announced by the French government. The construction site was placed in safe standby conditions and work was halted until 25 May 2020 when authorisation to resume work was granted.

As work was progressively resumed on the centre, strict compliance with the health and safety measures made it possible to avoid any outbreaks on the JHR construction site.

The main health and safety measures are:

- At the entrance to the construction site: compulsory hand washing
- Travel on the construction site: on foot where possible (number of people in a group kept to a minimum)
- Social distancing: keeping 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 156 cases reported for the JHR Project (project team and contractors):
- 21 people tested positive for Covid-19
- 89 people were contact cases
- 40people were showing symptoms
- 6 people suspected and not included under the other three categories

2.3. Occupational safety actions

2.3.1. Safety behaviour visits (SBV)

The JHR project has implemented 'safety behaviour visits'. This involves observing employees (JHR project staff and contractors) going about their work and then discussing what was observed in order to find solutions to improve the working conditions.

Employees are asked to think about the situation themselves so they can solve their own safety issues and improve their workplace conditions.
This approach actively engages employees to implement actions decided together.
A total of 52 visits were carried out in 2020, with 162 good practices observed and 91 hazardous behaviours corrected.

2.3.2. Safety day

Safety Day was celebrated on 13 October 2020 at the JHR Project. This is a special day where people focus on wellbeing at work, safety training and meeting with the manager to discuss health and safety matters.

2.4. Awards

2.4.1. Company safety award

In 2020, three company safety awards were presented at the general safety assembly for:

- Implementation of good practices
- New safety initiatives
- Ownership of safety issues

2.4.2. Worker of the month

In 2020, twelve employees were presented with a "worker of the month" award for the following reasons:

- Zero safety non-conformity observed over a period of 3 months (compliance with the JHR safety fundamentals)
- Model behaviour with respect to the 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

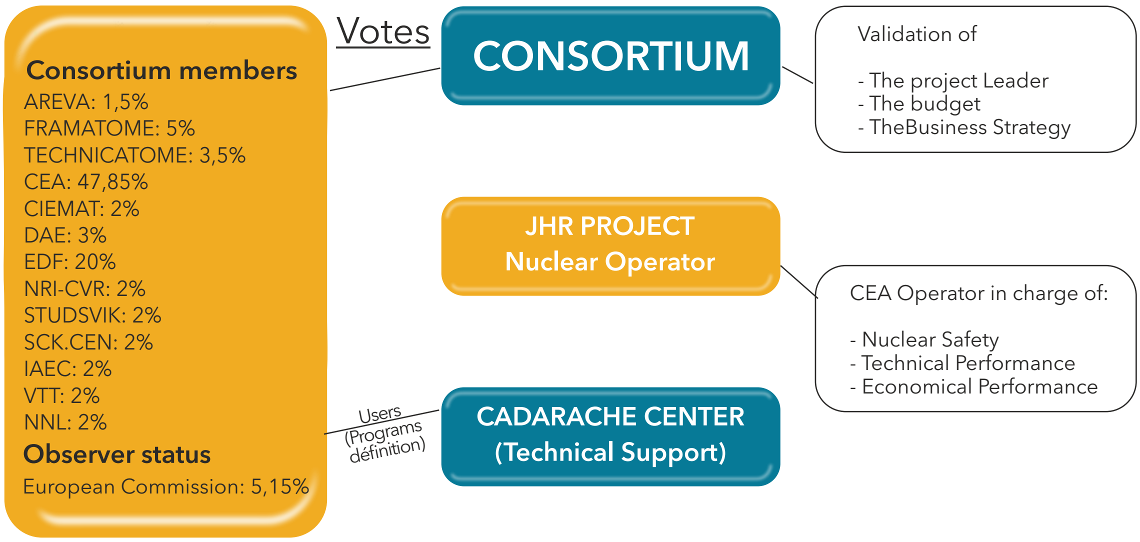
2.5. Emergency drills

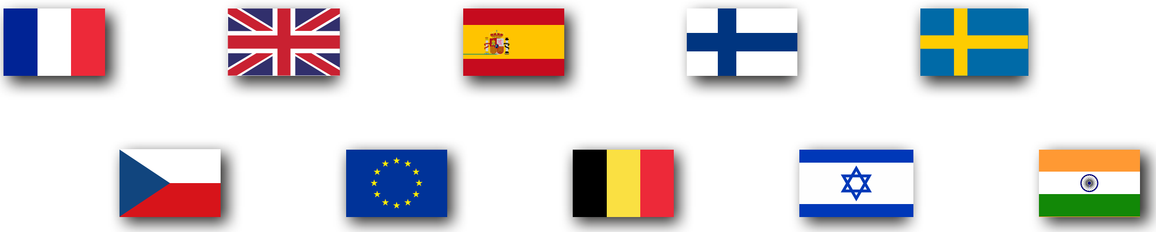
About 10 emergency drills are organised every year to train workers in how to react in case of an accident and to benefit from lessons learned.
Hazardous situations are analysed and the evacuation of victims in areas difficult to access is tested.
In 2020, one of the most spectacular emergency drills involved evacuating a victim after an anoxia beacon was triggered in the auxiliary building pool.

3. Organisation

Consortium organisation

The JHR Project is steered and financed by 14 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.

3. Organisation

Petri Kinnunen
VTT

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
CEA

JHR Project Director

A project director, 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.

Peter Baeten
SCK CEN

Philippe Braidy
AREVA SA

Bucalossi Andrea
JRC

Enrique Gonzalez Romero
CIEMAT

Sujay Bhatttacharya
DAE

Daniel Jardenas
STUDSVIK

Benoit Desforges
TA

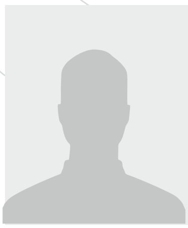
Jonathan Hyde
NNL

Philippe Stohr
CEA

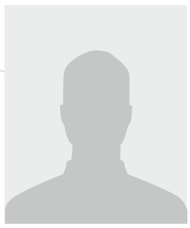
Manuel Carrasco
EDF

Petr Berezina
CVR

François Billot
Framatome



IAEC



Dzubinsky Mykola
CE

Jean-Pierre Coulon
Clients and
Consortium Directorate

4.1. Governing board an consortium activities

The goal of JHOP2040 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.

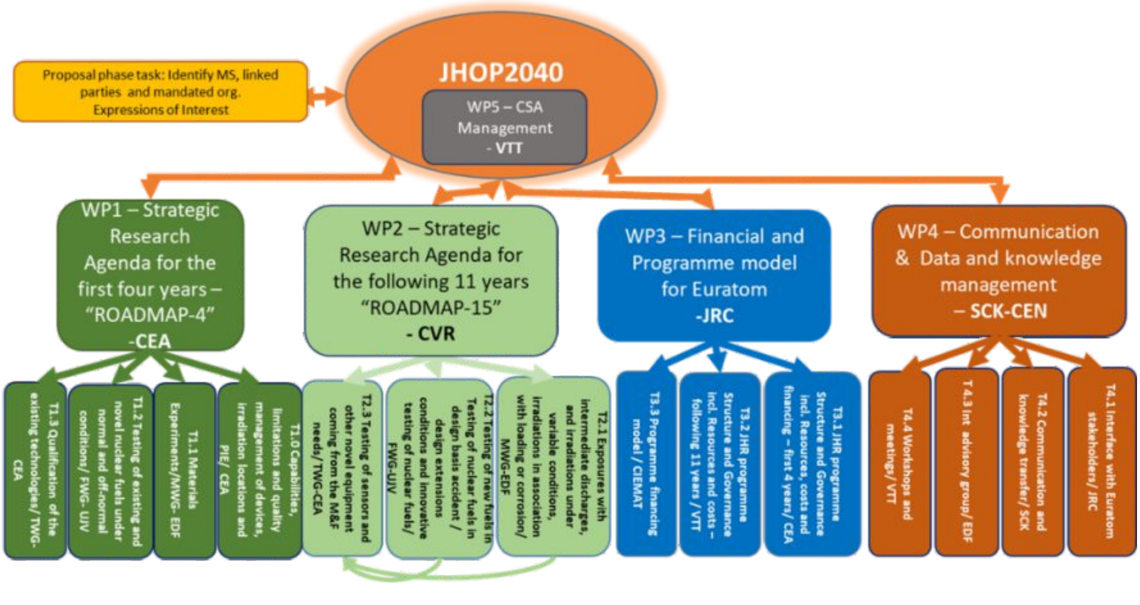
JHOP 2040 comprises the following members/ countries:

- 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 JHOP20240 through its Work Packages:

The project started this year, with the kick-off meeting held on 8-9 September 2020 and followed by two steering committee meetings.



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 rescheduled for September 2020 but eventually had to be postponed once again because of the ongoing disruptions.

It has been rescheduled for late April 2021 in the Cadarache castle. To accommodate for the special circumstances, it will be possible to participate either onsite or remotely via a webinar.

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 international community of the OECD-NEA will have the possibility to perform important research programmes on innovative fuel and structural materials.

The FIDES legal framework will be officially launched in March-April 2021, including four joint R&D projects gathering 25 organisations (nuclear operators, fuel manufacturers, R&D organisations, TSO, etc.) 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 (Accident Tolerant Fuel) cladding.

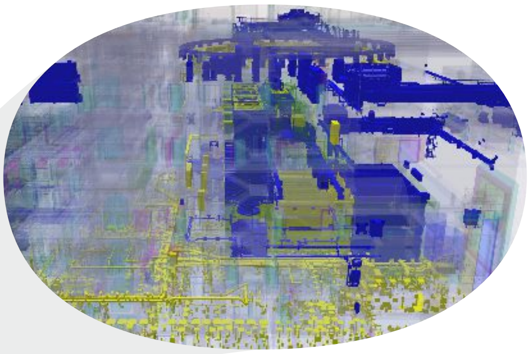
4.2.3. IAEA ICERR

The CEA was designated as an International Centre based on Research Reactors (ICERR) by the IAEA in 2015 for 5 years. Such international recognition led to successful collaborative actions with several IAEA Member States. The CEA directorate decided in late 2019 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 evaluation 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.

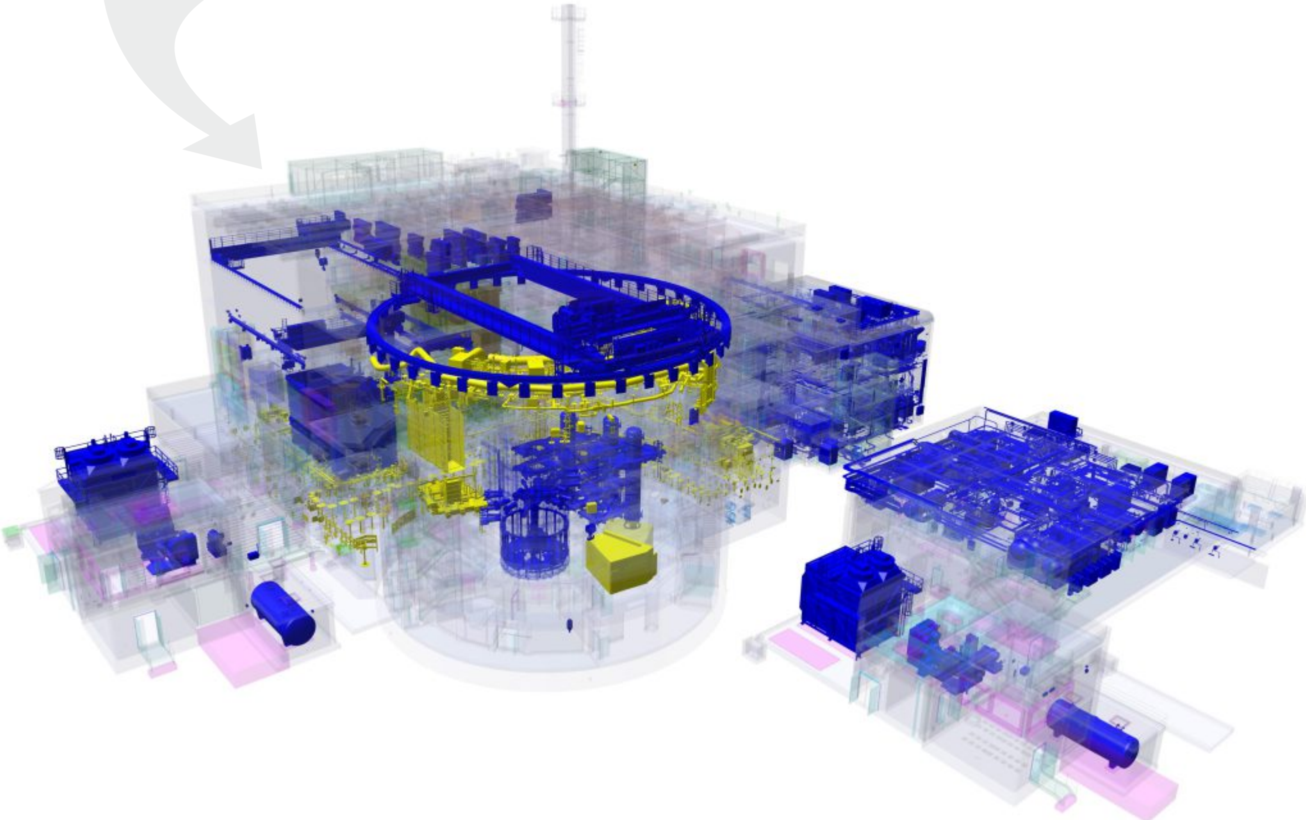
Global overview

Alexandre Lagarrigue
Site Safety and Security Manager

In 2020, site activities were marked by a number of challenging milestones, such as: the start of electro-mechanical installation in the nuclear unit, continuation of reactor building activities for the reactor block, steel structure erection in the primary bunkers, and installation of the pool slot gates.

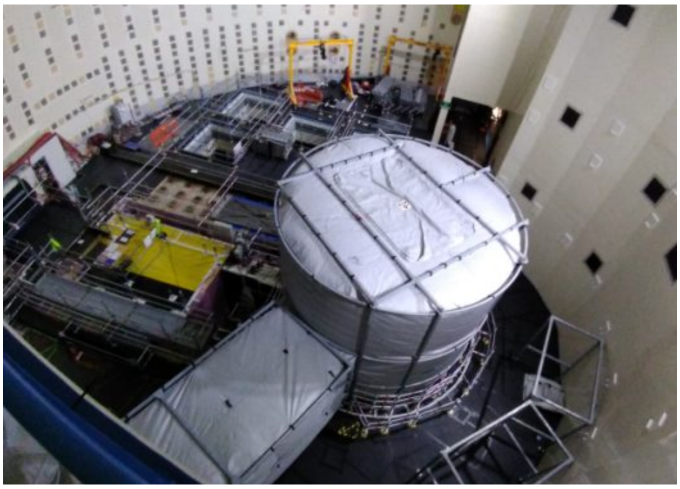


In blue, the components assembled until end of 2020
In yellow, the components plan to be assembled in2021

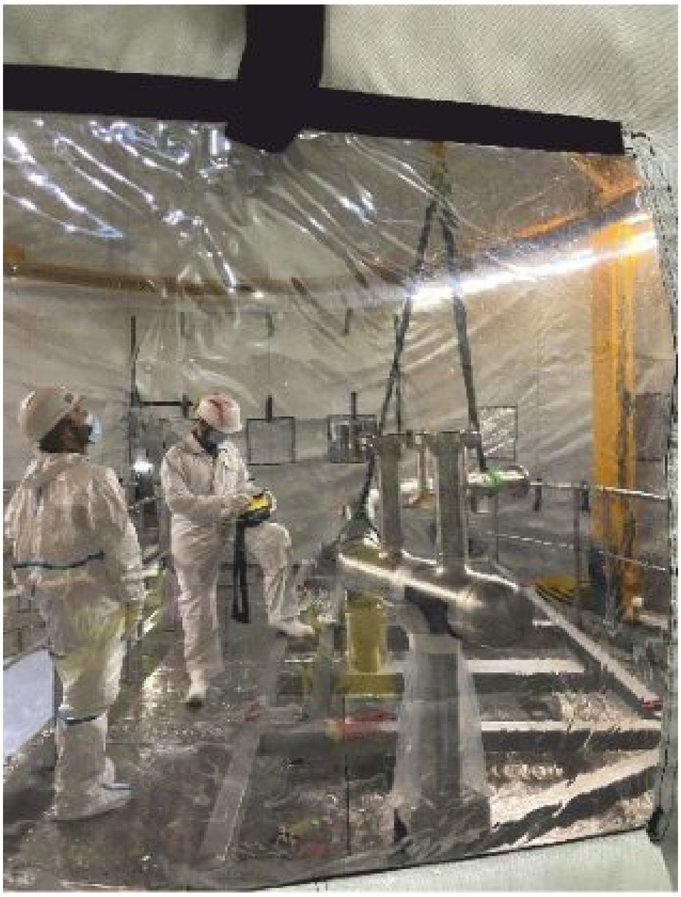


The main issues at hand were managing safety, technical coordination and nuclear cleanliness. These issues were addressed successfully by meticulous preparation of the activities, which was possible thanks to the strong involvement of the CEA and contractor site teams. Specific management tools were also put to good use.
Nuclear cleanliness for reactor block installation was monitored throughout the site work. In order to comply with the cleanliness specifications, a specific cover had to be positioned over the reactor pool. This cover is equipped with an independent access hatch and a crane used specifically for these activities (picture right side).

In 2020, the JHR site was also impacted by the global pandemic. For the two months during which construction activities were suspended, this time was used to prepare upcoming site activities with contractors and to roll out safety awareness campaigns with them (e.g. safety during mechanical handling operations). During this phase, already installed equipment had to be monitored, which was ensured through contractor feedback and periodic rounds on site.



Reactor pool cover and crane



6. Construction progress

6.1. Buildings, pools and cells

This year has been marked by the following successes:

- Commissioning of the Cold Mounting Workshop
- Contract amendments signed to implement building design changes
- Reinforcement of anchors in shielded cubicles
- Factory acceptance of cofferdam frame for the pools and canal
- Factory acceptance of the frame supporting the devices for the aerial electrical cables (DLC).

6.1.1 Engineering

6.1.1.1 Civil works and buildings

In 2020, the engineering work focused on writing the specifications for tenders to contract work in painting, finishing, the steel structure for polar crane (RMP) access, and construction of the technical gallery between the buildings.

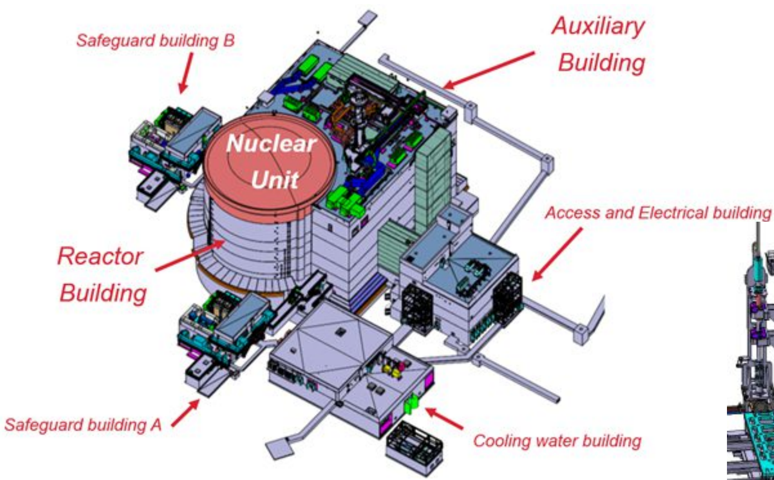
Philippe Daubrive
Construction Manager

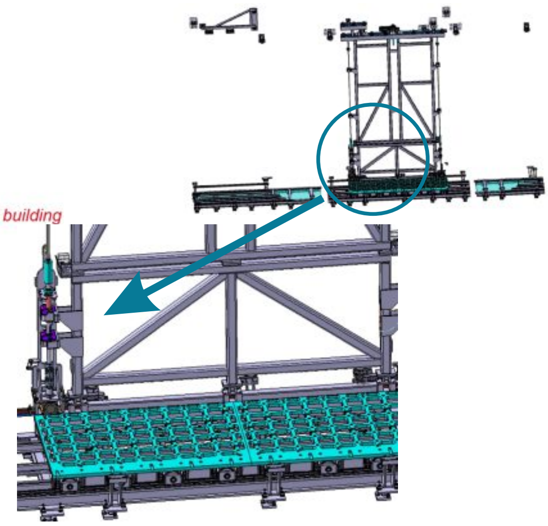
Guillaume Talhouarn
Building,Pools
& Cells Manager

6.1.1.2 Pool liners

The detailed design has progressed this year with the completion of:

- Airlock doors: detail drawings and design report - approved for construction
- Conveyor design - completed
- Post-Fukushima stress tests on the anchor system and reactor pool feedthroughs - completed.





Progress has been made in:

- Detailed design of the Electrical Instruction and Control (EI&C)
- Preliminary design of tools used for assembling and removing feedthrough plugs under water.
- The preliminary design of the tilting system for the airlock doors and cofferdams.

6.1.1.3 Secondary handling

Work continued on the detailed design of the conveyor system in 2020.

6.1.2. Factory activities

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

Factory acceptance test successfully completed for the first three lifting devices to be used inside hot cells (3D manipulator).

6.1.2.2 Heavy remote manipulator arms

The year 2020 was marked by the factory acceptance of the heavy remote manipulator arms.

6.1.2.3 Lightweight remote manipulator arms

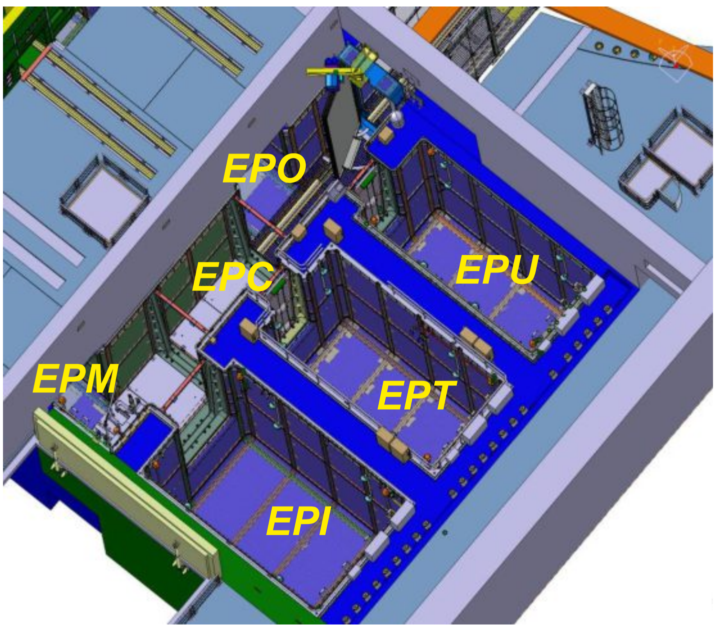
In 2020, the manufacturing of the lightweight remote manipulator systems started, leading to the assembly of the subset components.

6.1.2.4 Pool liners

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

- Two into reactor building:
  - RER (reactor pool)
  - REE (intermediate pool)
- Three into auxiliary building:
  - EPI (irradiated component storage)
  - EPT (storage for irradiate experimental devices)
  - EPU (irradiated fuel element storage)

The year was also marked by procurement activities and completion of the welding test for the airlock doors, together with the factory acceptance of the cofferdam frame for the RER, EPM and EPI pools and canal.



6. Construction progress

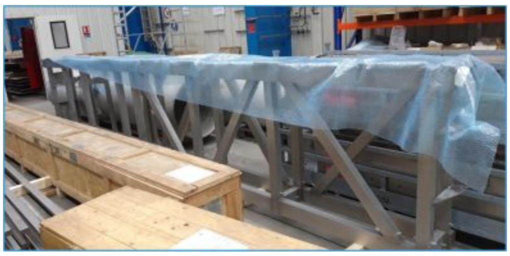
Progress was made with the following items:

- Manufacturing of the liner sheets for the EPO and EPM canals
- Manufacturing of the EPI gamma feedthrough

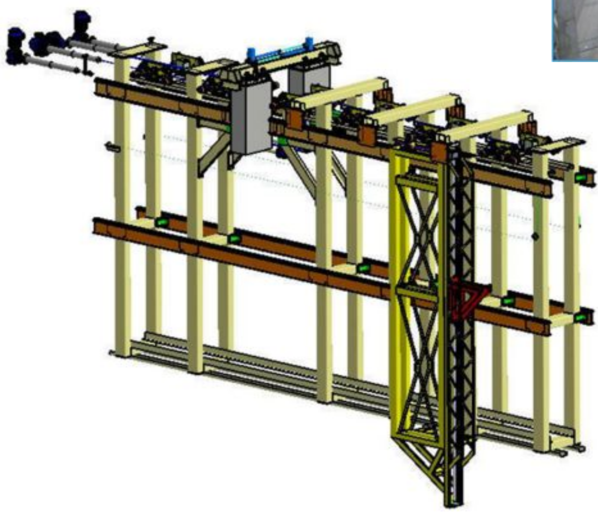

6.1.2.5 Secondary handling

In 2020, two more components reached factory acceptance status:
- EMD docking table

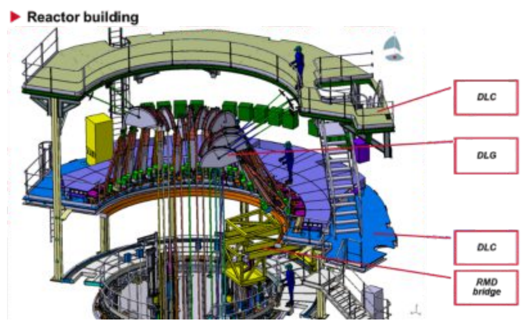




- Frame supporting the devices for the aerial electrical cables (DLC).



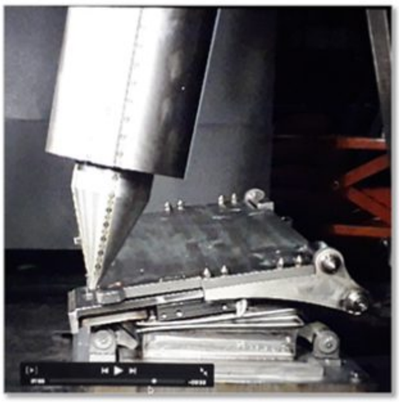
- Another significant development was achieved with the first conveyor (procurement completed and manufacturing), which is now undergoing factory assembly. Difficulties were encountered during manufacturing and welding, especially when it cames to comply with geometric requirements because of the slender shape of the components (6*5 m).
  The first assembly and factory tests in 2021 will allow us to measure the real performance levels.
- Manufacturing of the reactor pool polar crane bridge (RMD), the cable winding system (DLG, see picture) and the EMC docking table, have all progressed this year.



6.1.2.6 Hot cell equipment (UJV-CVR in-kind contribution)

In 2020, manufacturing of the hot cell equipment progressed:

- Procurement and factory manufacturing of equipment
- Partial factory acceptance (excluding the neutronic shielding) of the drawers for the ECR hot cell
- Impact test of an experimental device on a hot cell hatch

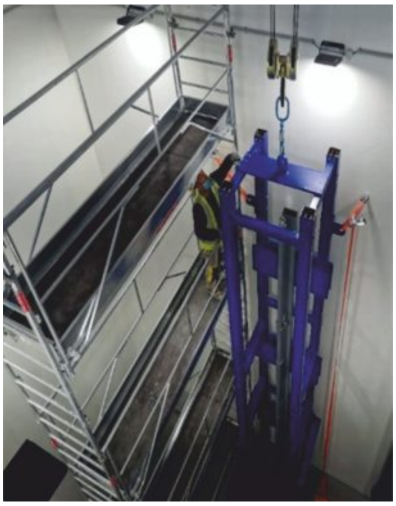


6.1.3. Onsite building and acceptance

6.1.3.1 Civil works and buildings

- Construction of the access control building (PGZ) and erection of fences around the JHR site
- Construction of the BMM Cold Mounting Workshop, including handover for operation

- Modifications to concrete basemat to accommodate for equipment in the cooling system building (BMR)
- Preparation of openings and hoppers in the nuclear building before mechanical and electrical balance of plant (MBOP/EBOP)
- Reinforcement or additional anchorage in cubicles



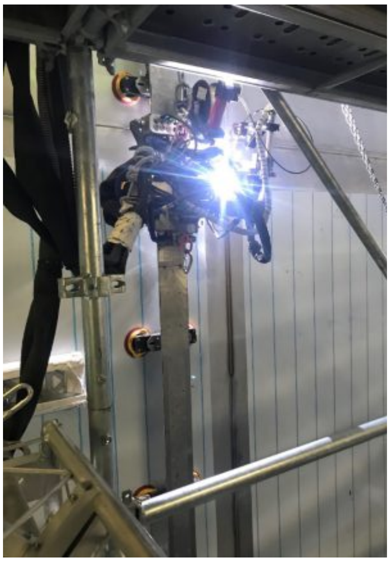
6.1.3.2 Experimental utilities and pools

- Hot cells (UJV-CVR in-kind contribution)
    - Assembly of shielded sliding doors between small and large hot cells
    - 17.5 tonne monorail and small service crane installed and tested, including load tests

6. Construction progress

- Pool liners
  - Auxiliary building (BUA) pool lining operations: concrete was poured over the anchors in the EPM pool, the EPT pool is ready for installation of its liner, the second phase of concrete pouring in the EPO pool was completed, the liner is being installed in the EPU pool, and the EPI liner has been fully installed.


- Insertion and assembly of the cofferdam frame for the RER, EMP and EPI pools





- Main handling operations
  - Commissioning completed for the EML, EMP and EMZ

- Secondary handling
  - The EMT transfer table (19 T) was assembled onsite the supplier tests (T0 and T1) were successfully completed.

6.2. Reactor block

Despite the disruptions caused by the pandemic in 2020, the reactor block team managed to meet its key milestones for the JHR project. It is worth highlighting the assembly of the reactor block vessel, which is a major achievement of the project as a whole.

In addition to activities completed onsite, factory manufacturing operations were able to continue, confirming the solid progress made throughout the year. Highlights: tests were performed under water on the vessel cover lifting beam (highly complex system), and manufacturing of the last reflector sectors were resumed.

Georges Thomine
Reactor Block Manager

6.2.1. Manufacturing

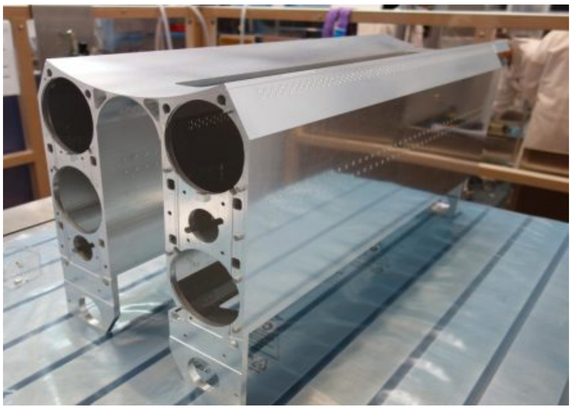
In 2020, the reactor block made progress in the following fields:

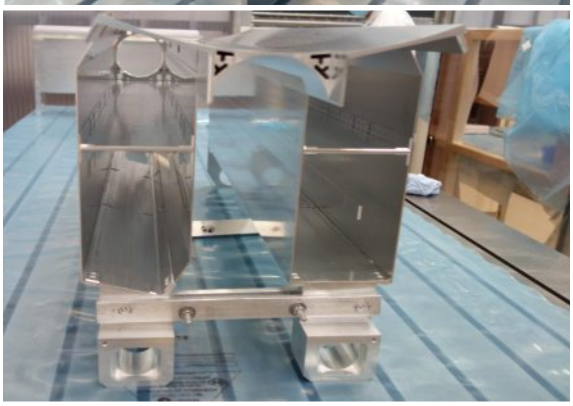
- The nuclear pressure equipment certificate of conformity was issued for the reactor block
- Components of various mechanisms were manufactured and qualified
- 31 dummy fuel elements were manufactured and calibrated
- Floor of the RER pool and the REP primary system pipes were manufactured and installed
- Numerous systems continued to be manufactured and tested:
    - Vessel cover system
    - Upper internal systems
    - Core compartment systems
- Manufacturing of displacement systems
- Reflector manufacturing operations were continued:
    - Rivetting of the C3, C4 and C5 sectors

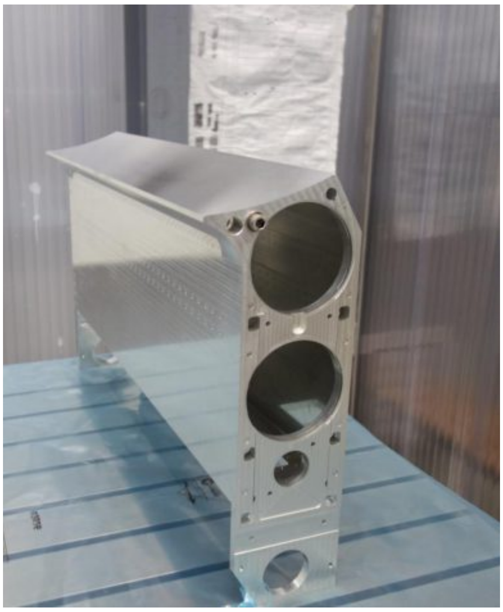
Tests performed on the vessel cover lifting beam under water

Assembly of the bottom mobile part

Assembly of the top mobile part





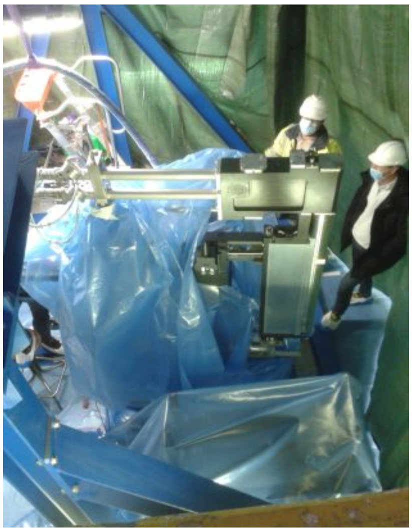


- Manufacturing of hoop plates




In 2020, the MOLY Project made the following progress:

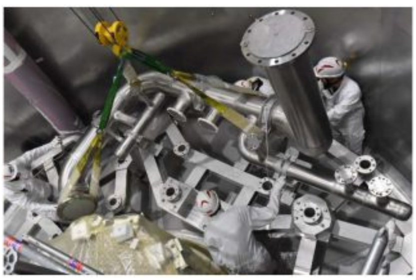
- In-pile part: manufacturing of practically all the parts and the start of factory tests

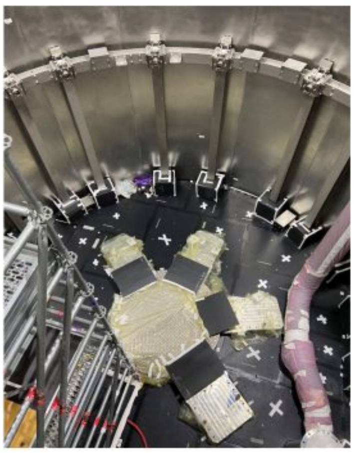
6.2.2. Assembly

The year 2020 was marked by the following progress illustrated below:

Assembly of the floor structure for the RER reactor pool

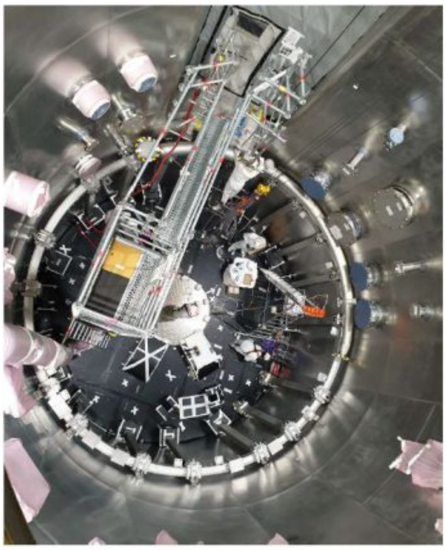


Assembly of the suction line for the reactor pool cooling system (REP)



Assembly of the displacement system and the mounting structure supporting the reactor pool floor

Assembly of the REP discharge line



Assembly of the seal support plate between the water box and the vessel

Installation of the vessel at the bottom of the reactor pool

Lowering of the reactor vessel (also called reactor block) into the RER pool

6.3. Fluid and HVAC systems
6.3.1. Engineering
6.3.1.1 Fluid systems

Rémy Pommier
Fluids and HVAC Manager

The main achievements for the fluid systems were:

- Drafting of the functional files for each system that needed to be updated with the main configuration (V3.2)
- Completion of the design for the auxiliary and non-safety-related buildings to define the construction sequence
- Execution of the detail design for the lower floors (level -1, -2 and -3) of the nuclear auxiliary building (BUA).

6.3.1.2 HVAC (except the emergency diesel generator building, BAS)

This year, the main studies finalised for HVAC were:

- Update of the functional files for each system to take into account the main configuration status (V3.2)
- Completion of the design phase for the auxiliary building to define the complete construction sequence
- Execution of the detailed design for the lower floors (level -2 and -3) of the BUA building and the mezzanine floor of the BUR reactor hall.

6.3.1.3 HVAC back-up building (BAS)

Regarding the progress made in engineering for the HVAC back-up building (BAS), the 3D model establishing the work programme for each party was finalised.

6.3.2 Assembly
6.3.2.1 Fluid systems

In terms of construction, this year saw the beginning or the completion of:

- Installation of fluid systems in the auxiliary buildings (BAV, BMR), which is still ongoing
- Installation of the fluid systems started in the nuclear unit building (level -2)

Installation of piping systems in the nuclear unit building (Level -2)

Installation of the demineralised water pump skid in the auxiliary building

The main 2021 objective will be to complete the installation of the main equipment in all the non-safety-related auxiliary buildings.

6.3.2.2 HVAC (except the BAS buildings)

Regarding the HVAC manufacturing progress, this year focused on:

- Installation of auxiliary building equipment, with work still ongoing
- Start of installation work in the nuclear unit (level -2)

Auxiliary building (BMR) roof: ongoing installation phase

6.4. Electrical and I&C systems
6.4.1. Engineering

Philippe Guillemot
Electrical and I&C
systems Manager

In 2020, the key progress made in electrical and I&C system engineering was:

- Creation of configuration 3.2 modification sheets (more than 400 for the E3C project)
- Start of studies using configuration 3.2: electrical, I&C, radiation monitoring system

In terms of the experimental devices, the main engineering highlights in in 2020 were:

- Changes to the scope of work, which required changing the team in charge. This situation was managed through the creation of a dedicated 'task force' for 4 months that delivered more than 80 spreadsheets and drawings for all the experimental objects
- Proof of concept achieved for real-time calculations
- Integration of CEA equipment into the 3D model and clash resolutions (picture below)

6.4.2. Construction

The main construction achievements of the year was the installation of the back-up diesel generator in the nuclear auxiliaries building A and B.

Raphaël Palhier
Experimental
Devices Manager

6.5 First-phase experimental devices and associated utilities

During the operational phase, 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.

For the first fleet, the JHR project is expected to offer the following range of experimental devices with their related utilities:

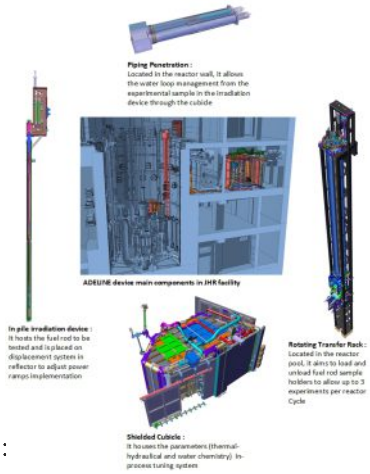
MADISON: Multirod Adaptative Device for Irradiation of LWR's Fuel Samples Operating in Normal conditions

MICA: Material Irradiation Capsule
MICA 1, 2, 3
(cooking at ~ 400°C)

ADELINE: Advanced Device for Experimenting up to Limits Nuclear fuel Element

OCCITANE: capsule to study the vessel material ageing under irradiation

6.5.1 ADELINE



The Adeline experimental device is dedicated to single fuel rod studies in light water reactor (LWR) process 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 apply power ramps to the samples. The main components of the device are given on the right side.

The main activities for ADELINE have been linked to the topics:

- Zircaloy-4 supply

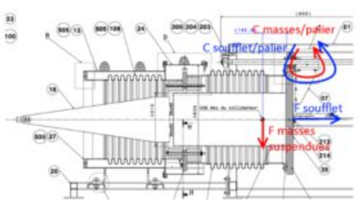
- V-Cone fabrication (2020)

- Jet pump system manufacturing

6.5.2 Neutron imaging system (SIN).

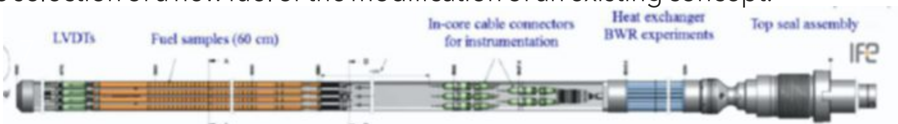
The neutron imaging system is a non-destructive examination bench installed in the reactor pool. It is designed to characterise the experimental load from ADELINE before and after power ramps.

The year 2020 was dedicated to the detailed design studies and to the test and qualification campaign on a full-scale mock-up. Tests were done in the CEA TOTEM pool and aimed at checking the effectiveness of metallic seals, robustness of the metallic bellows during cycles, and the efficiency of the bellows driving system design.



6.5.3 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 power reactor operating conditions. The Madison device will be specifically dedicated to studies involving the selection of a new fuel or the modification of an existing concept.



Madison design inspired from the IFE's.

The Madison device is a complex loop composed of two parts:

- An in-pile 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's linear power and transient scenarios will be representative of conditions that do not lead to cladding failure
- A water loop (out of pile part) implemented in JHR reactor building will supply the in-pile part with the thermohydraulics and chemical conditions required by customers.

The CEA plans to have this device available for JHR start-up.

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

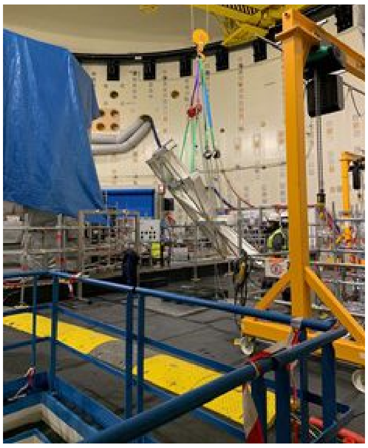
This experimental device will ensure the continuity of most experimental devices existing in these experimental reactors: OSIRIS experiments performed in the GRIFFONOS and ISABELLE4 test devices, Halden experiments performed in the IFE irradiation device with a single or multi-rod irradiation rig.

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

▶ Main achivement in 2020

The main objectives stated in the last status report have been met, though with some delay due to the Covid-19 pandemic.
Cubicle manufacturing is complete and its installation in the JHR facility was started in late 2020. The purpose of this heavy structure (weighing about 40 tonnes, with a stainless steel liner, reinforced with steel beams, able to withstand 1 bar of internal overpressure, and equipped with biological shielding) is to mitigate consequences of a hypothetical break in the high-pressure primary cooling system.

General view of the cubicle (fluid feedthroughs for the loop not shown)



Installation of the floor frame in the JHR building

IFE Halden has completed the fabrication and assembly of a full-scale mock-up loop (fully representative, including I&C), but without actual fuel rods (nuclear power simulated by electric heaters). The dual objective is to validate the design (thermohydraulic performance, chemistry, control systems and fine adjustments) and the maintenance operations using a full-scale mock-up cubicle, in inactive conditions, before manufacturing the final loop.

The unit/component testing, integration and loop cold tests are all complete. IFE started the hot steady-state tests of the loop in late 2020.

Overall view (purification filters in white)

High-pressure system (with thermal insulation in place)

The fabrication of the primary pump for the mock-up loop by a manufacturer specialized in canned motor models for the nuclear industry is underway. The main components of the primary pump are now ready, with some delay due to the impact of the Covid-19 pandemic on the supply chain (e.g. forged parts). For the moment, IFE is testing the loop with an existing pump available in Halden.

6.5.4 MICA
6.5.4.1 Engineering

MICA is an experimental capsule whose objective is to study the behaviour of structural materials under irradiation for LWR reactors (maximum temperature: 300-450°C). Although mainly inspired by the CHOUCA device used for decades in the OSIRIS reactor, the MICA device has been fully redesigned to fulfil the requirements and specificities of the JHR project.

Manufacturing of the head mock-up
Before the call for tender process is launched for three MICA capsules, a mock-up of the device head (and other elementary sub-systems) is being built (fig.1).

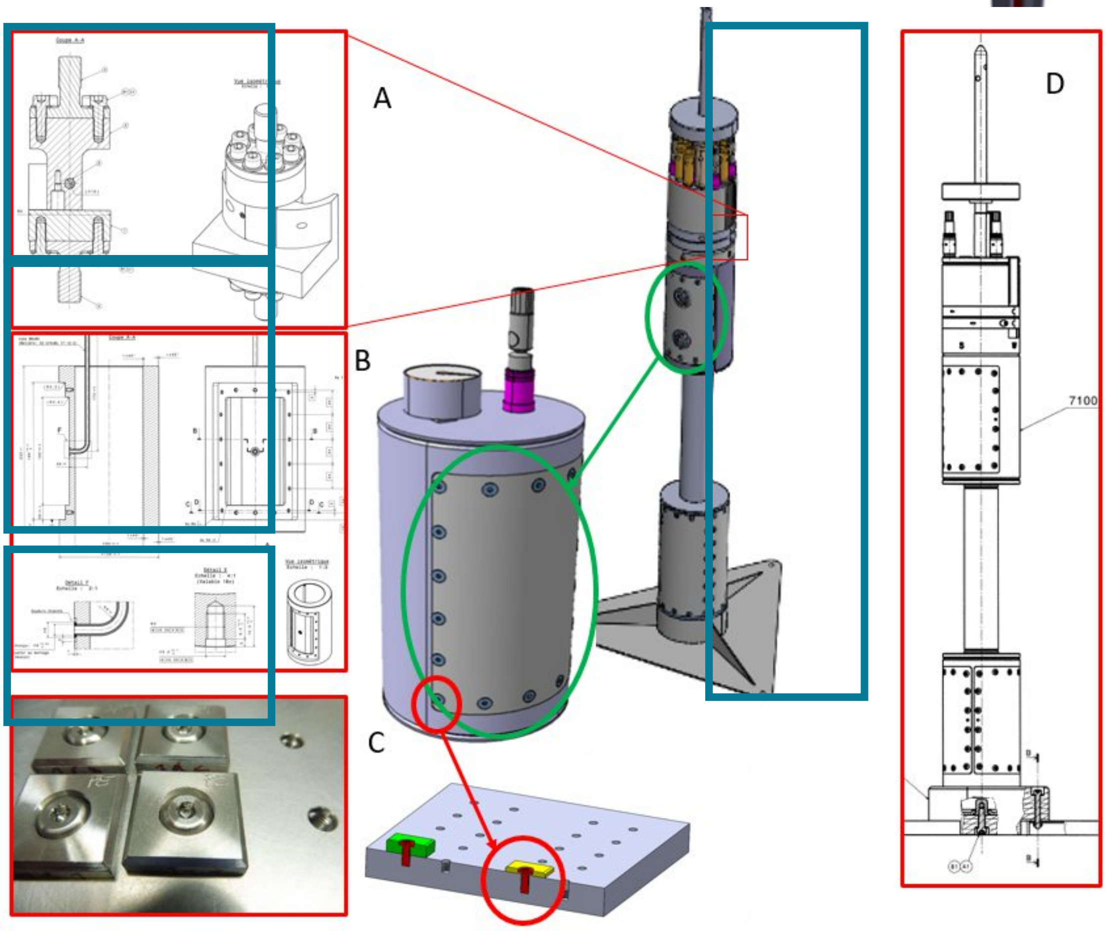


Figure 1 : Mock-up of the bolted joints, cover and head of the MICA device

An industrial company has been selected to manufacture this mock-up system, including a tightening test bench (A), a unitary sealing system (B), a tensile test mock-up (C), and the overall head mock-up (D).

6.5.5 Non-destructive examination devices (VTT in-kind contribution)

Within the framework of JHR construction, non-destructive examination (NDE) systems have been required for:

- Underwater examinations on integral devices (in-pool):
  - o Neutron imaging system (reactor pool)
  - o 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):
  - o Gamma and X-ray scanning system (HGXR system).

6.5.5.1 Status of the UGXR benches

The project focused on testing in 2020. After testing the first bench at the workshop in 2019, a decision was made to transfer the benches to VTT's subcontractor (Idom) laboratory where the testing was continued. The tests revealed that some modifications needed to be made to the bench frames; these changes were carried out over summer in 2020. VTT and the CEA also considered that the original accuracy requirements for the benches were too demanding and some concessions were made. During the second half of the year, Idom focused on finalising the UGXR out-of-pile part (see next) and the bench testing was put on hold.

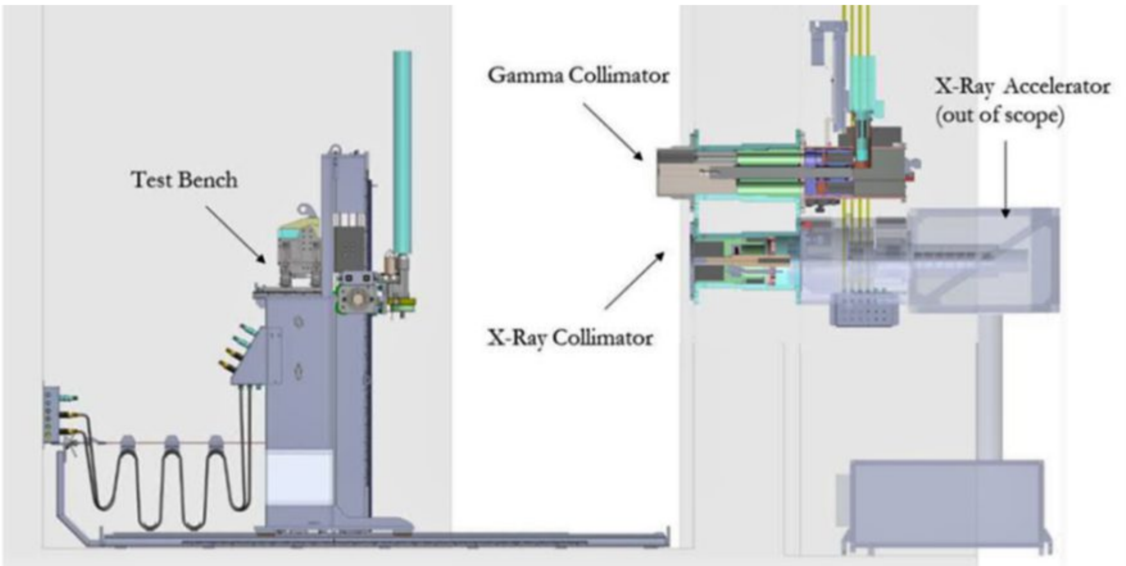
6.5.5.2 Status of the UGXR out-of-pile part (collimators and biological shielding)

The underwater collimators and biological shielding were manufactured at the same time as the UGXR benches. The year 2020 focused on assembly and testing. Factory acceptance tests were carried out in Bilbao in July and VTT inspected the tests remotely. After these tests were declared successful, the devices were transported from Bilbao to Cadarache where the site acceptance tests were performed in October. The testing period for the collimators was quite tight as the testing followed that of the HGXR devices (see next). The end of 2020 focused on finalising the documentation.

Assembly of the collimator system onto the test nozzle

Packing of the electrical cabinets for transportation

6.5.5.3 Status of the 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. After a testing and assembly period in 2019, VTT's subcontractor arranged a training session for CEA staff at the beginning of 2020. The equipment was then successfully transported from Bilbao to Cadarache where the CEA issued final acceptance, finalising the end of the project.

HGXR devices assembled at Cadarache (Totem hall)The hot cell bench on rails (left), the gamma collimator system with detector shield (middle), and the electrical cabinets (right).

6.5.5.4 Implementation of the benches in the building site

Nuclear non-destructive examination systems (NDE) will be implemented in the future Jules Horowitz Reactor (JHR) to perform examinations on experimental samples by high-resolution X-ray imaging and by quantitative measurement of the spatial distribution of gamma emitters. These systems will be implemented in the reactor (RER), the irradiated component storage (EPI) pools, and in a shielded hot cell for measuring either the entire immersed test device still containing the experimental sample, or a separate experimental sample before transferring it to the hot cell.

6.5.6 CLOE DAE in-Kind Contribution

Following the successful achievement of the preliminary design for the CLOE loop in 2019, 2020 focused on the detailed design studies performed by BARC (India) and the drafting of several documents that are currently being reviewed by the CEA.

6.5.7 LORELEI IAEC in-kind Contribution

A significant portion of the year was devoted to the detailed design of the LORELEI loop (tasked assumed by IAEC/ROTEM in Israel) and the production of several documents that will be reviewed mid-2021. This should lead to final acceptance of the detailed design phase by the CEA.

ASN	French Nuclear Safety Authority
ATF	Accident Tolerant Fuel
BAS	Emergency diesel building
BAV	Auxiliary cloakroom building
BMM	Cold Mounting Workshop
BMR	Auxiliary refrigeration and utility building
BUA	Nuclear auxiliary building
BUR	Nuclear unit reactor building
BWR	Boiling Water Reactor
CGN	China General Nuclear Power Group
DES	CEA Energy Division
DEXP	EXPerimental Devices
DLC	Support structure for the aerial electrical cables
DLG	Winding system
DMES	Start-up Files
EBOP	Electrical Balance Of Plant
EI&C	Electrical, Instrumentation & Control
EMD	Docking table
EML, EMP, EMZ	Cranes
EMT	Transfer table
EPC, EPO, EPM	Canals
E3C	Centralised Electricity and Control Command
EPI, EPT, EPU	Pools (BUA)
FIDES	Framework for IrraDiation ExperimentS
GB	Governing Board
HFDS	High level Defence and Security
HGXR	Hot cell Gamma and X-Ray benches
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 cladings
IRSN	French Institute for Radiation protection and Nuclear Safety
JAM	JHR Archive Material
JHOP2040	Jules Horowitz Operation Plan 2040
JHR	Jules Horowitz Reactor
LAQ	Development and qualifications work package
LWR	Light Water Reactor
MBOP	Mechanical Balance Of Plant
NDE	Non-Destructive Examination
OECD-NEA	Organisation for Economic Co-operation and Development / Nuclear Energy Agency
OPC	Scheduling, coordination & control
PGZ	Access control building
PL	Project Leader
PPI	Integrated Project Platform
PTI	Integrated Technical Platform
PWR	Pressurised Water Reactor (BUR)
REE	Intermediate pool (BUR)
RER	Reactor pool
RMD	Reactor pool polar crane bridge
RMP	Polar crane
ROP	Reference Operating Plan
RPP	Main Cooling Primary System
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
ZOE	Zero Energy, uranium Oxyde, heavy water

April 2021

JHR Project
Bv2 - Chantier RJH - BP9
13115 St Paul Lez Durance - France