Jules Horowitz Reactor - Towards the Future of the European and International Nuclear Research

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JULES HOROWITZ REACTOR - TOWARDS THE FUTURE OF THE EUROPEAN AND INTERNATIONAL NUCLEAR RESEARCH

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ABSTRACT

The Jules Horowitz Reactor (JHR) is a new material testing reactor under construction at CEA in Cadarache, France, to become one of the major infrastructures for scientific research on nuclear materials and fuels under irradiation as well as for medical isotope production. The reactor is designed to host various R&D programs dedicated to the optimization of operation of the existing nuclear power plants (NPPs), to assess the irradiation induced ageing of non-replaceable and safety related components in the operating NPPs, to support the improvement, development and deployment of the third generation of NPPs and small modular reactors (SMR) and to offer irradiation capabilities for GEN IV and fusion technologies. This paper will give the status of the construction of the experimental capacity and describe the works done by the International Consortium. Also, the on-going operation planning and the future schemes for co-operation will be described.

1. Introduction

1.1 JHR targets

The JHR is a 100 MWth pool-type reactor with a compact core cooled by a slightly pressurized primary circuit. The facility includes a reactor building and an auxiliary building to support both reactor and experimental devices operation, including hot cells, storage pools and laboratories. The construction of the JHR is carried out by an international consortium consisting of 15 partners currently and it will be operated as an international user's facility open to international collaboration. Having the capacity of performing in maximum 20 simultaneous experiments, the JHR will be the most versatile research reactor in Europe and its flexibility is an asset to address the needs expressed by the scientific community and the industry.

JHR is optimized for testing materials and fuels under irradiation in normal and off-normal conditions:

- with high thermal and fast neutron flux capacities to address existing and future NPP needs by providing operational conditions compatible with the various power reactor technologies,
- with innovative embarked in-pile and on-line instrumentation associated with out-of-pile analysis,
- with various non-destructive examination benches and analysis laboratories to perform state-of- the-art R&D experiments and to obtain reliable and quantitative results with high spatial resolution and precision.

In addition to these, production of the medical radioisotopes is of utmost importance to the whole Europe. The estimate is that the JHR will produce eventually at least 25% of the isotopes needed in Europe.

To achieve these objectives, the JHR Project has:

- set up an international consortium, for close partnership between the funding organizations,

• extended the collaboration to some international partners to help in the development of the first fleet of experimental devices,
• gathered an international scientific community for exchange of information and knowledge including scientific and technical seminars to identify and prioritize the topics of interest,
• organized and prepared within this International Consortium the first international programmes already for the pre-JHR era being open also to non-members of the JHR Consortium to start the co-operation aiming at fruitful use of the reactor in the future.

The general scheme of the JHR is presented in Fig 1.

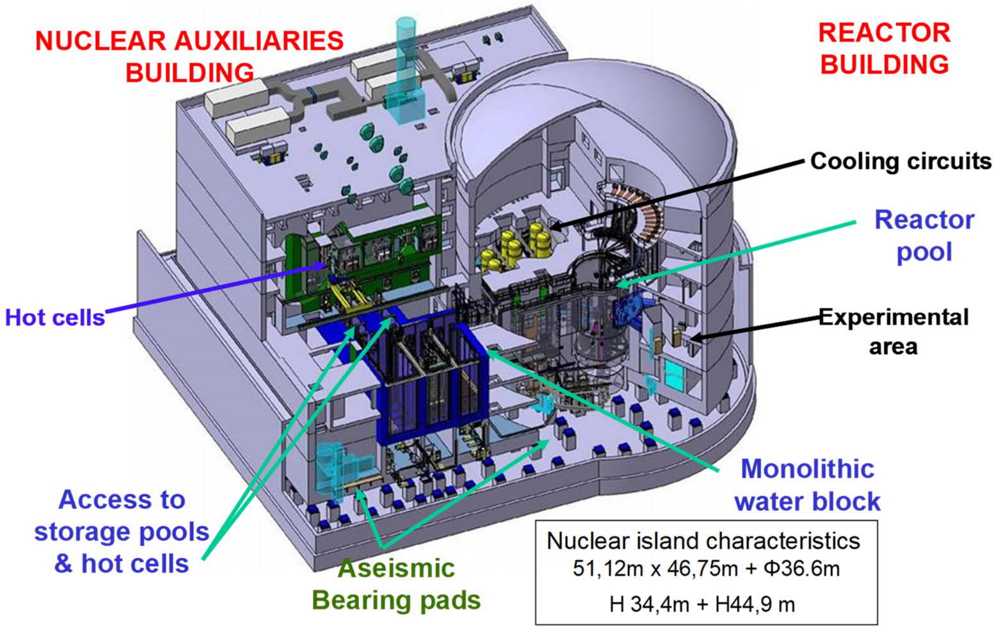

Fig 1. Jules Horowitz Reactor

2. JHR Consortium

The JHR project is an international operation. The consortium participating in the construction consists of 15 partners (Fig 1): CEA, Areva, Framatome, TechnicAtome and EDF (France), European Commission, Ciemat (Spain), SCK-CEN (Belgium) VTT Technical Research Centre of Finland (Finland), Studsvik (Sweden), National Nuclear Laboratory (UK), UJV (Czech Republic), DAE (India), IAEC (Israel) and CGN (China). Several partners, like VTT, represent a domestic consortium in their home countries. Also, several partners participate in the project by providing in kind contributions. The consortium is still open for new members.

Fig. 1 The JHR Consortium

The JHR consortium is led by the JHR Governing Board consisting of one member/partner. The JHR Project director is the leader of the construction project and reports to the Governing Board in annual meetings.

3. Construction status

3.1 Reactor construction

The construction of the JHR started in 2009. The JHR is an ambitious project, with very compact layout, aiming at research capabilities that have never been used before. This together with lots of external factors have had an impact on the construction schedule. E.g. the Fukushima accident led to new requirements also for the JHR. A control action plan has been set-up by the French Government in 2019 to lead the project in a more robust way. The general planning is under detailed reassessment and will be communicated by the end of 2023. More detailed description of the reactor construction is given in another paper by G. Bignan.

3.2 Status of the experimental devices

During the operation 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, i.e. the first fleet. The JHR project 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 (Fig.3):

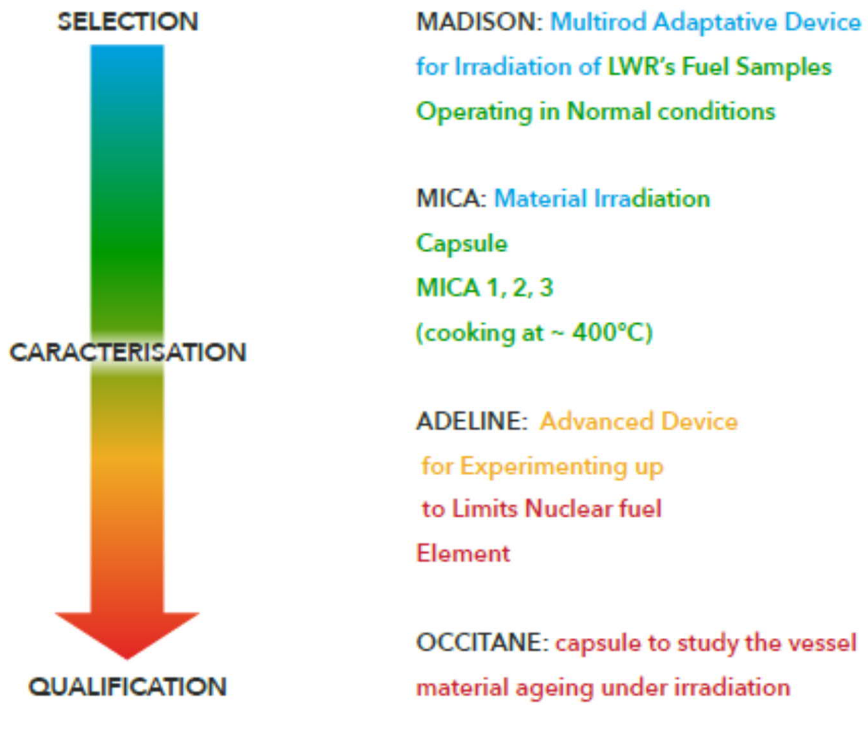

Fig. 3. First fleet of experimental devices for the JHR.

These devices have been considered to be the most needed based on the queries performed within the JHR community.

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.

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 *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.

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.

The *OCCITANE* device is a capsule type of device that is meant for investigating irradiation effects on pressure vessel steels.

The locations of the test devices in the reactor are shown in Fig.4

In addition to these irradiation devices, it is important to quote that at the start of operation phase also non-destructive examination devices will be available. The purpose of these devices is to examine the irradiated samples before, between and after the irradiation cycles using x-ray tomography, gamma measurements and neutron imaging.

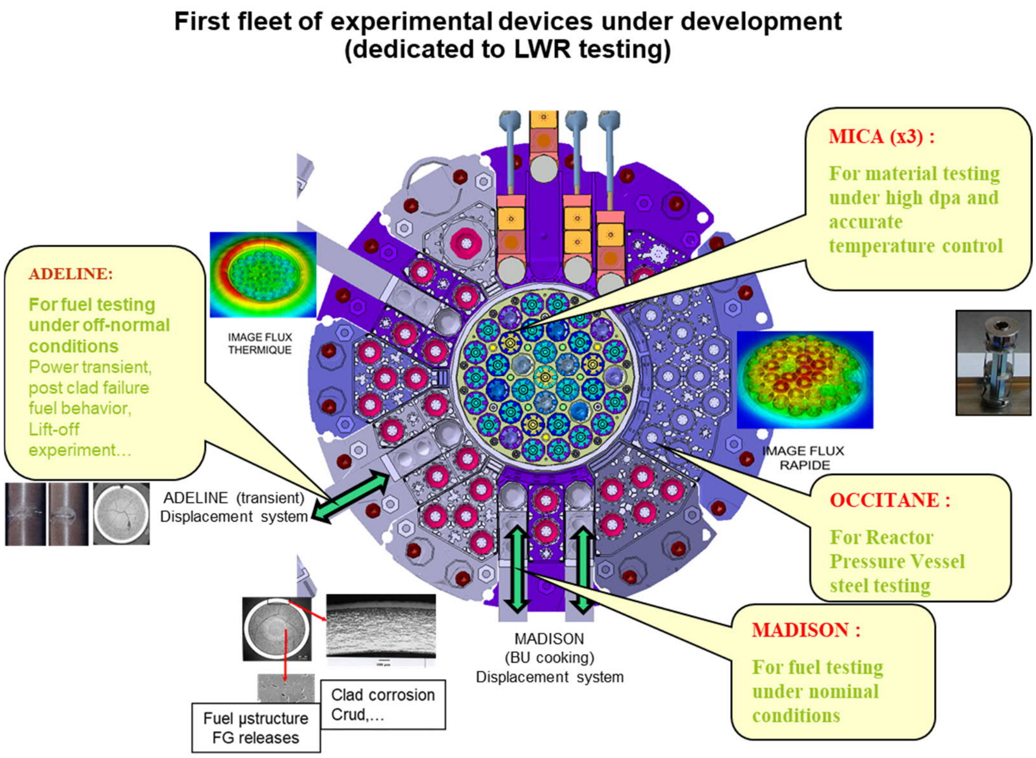

Fig. 4. Locations of the test devices in the reactor.

The second fleet of experimental devices will be taken in use after the first 4 years of operation. This fleet includes devices for e.g.

- material corrosion studies,
- loss-of-coolant-accidental situation simulations,
- JHR vessel aluminium sample irradiations,
- GEN IV material and fuel irradiations,
- material testing for fusion technology and
- residual power measurement after power shutdown.

Also, some other technologies are still to be planned based on the needs coming from partners or external actors.

4. International co-operation

The start-of-operation for the JHR is not currently scheduled for the coming years. Meanwhile, the JHR consortium has recognised several topics that need to be investigated even before the operation. Therefore, several co-operative actions/projects/programmes have been initiated.

4.1 JHR working groups and technical seminars

In 2012 the JHR Governing Board decided to establish three working groups (WGs) to plan the operation before and after the start-of-operation. Since then these three WGs have actively investigated and mapped different fuel, material and technological issues considered relevant to serve current and future needs in nuclear research. Even if the GEN II research topics are pretty much known, this is not the case with the future reactor technologies (small modular reactors, fusion, etc.). Therefore, the WGs are gathering together signals from different sources and mapping them together then targeting a solid experimental offer for the future needs. The working groups aim at helping the future JHR programme leader to initiate the research programmes.

The JHR consortium arranges annual technical seminars, which are open also to some non-members of the consortium. In the seminar, the progress of the reactor construction as well as the different test devices is given. In addition, discussion on the future needs and timely matters are taken. The WGs present their work and the international matters are discussed. Technical seminars are excellent opportunities also to invited non-members to come, have a look what is going on within the project, and see how the reactor itself looks like.

4.2 JHR International Advisory Group (IAG)

JHR Governing Board has also established an advisory group to provide advice and information to the JHR programme leader. Currently, the main task of the IAG is to develop a concept for evaluation the experimental costs for the reactor. The experimental costs vary a lot depending on the experiment type. In order to maximise the load for irradiation cycles and to get high utilisation of the capacity, the different experiments need to be thoroughly understood also from the financial point of view. After the cost evaluations, the role of the IAG will be (together with the WGs) to provide information and advices to the project leader in order to establish well balanced research programmes benefitting from the research capacity in maximum.

4.3 JHOP2040 project

European Commission (EC) is owning a noticeable amount of access rights to the JHR, 6%. Therefore, in its Euratom Research and Training programme in 2019, the EC made a call for a roadmap to use Euratom access rights to the JHR. The consortium responsible for construction of the reactor responded and the JHOP2040 (Jules Horowitz Operation plan 2040, https://www.jhop2040-h2020.eu) was established in September 2020 targeting at

producing strategic research roadmaps for the JHR operation during the first 4-year period and in a longer term to cover the first 15 years of operation.
The main objectives of the project are 1) to provide structure for the financial aspects related to the operation, 2) identify and review the current and future needs for fuel, materials and technologies both within and outside the current JHR consortium and 3) guarantee the extensive use of the JHR via Euratom access rights and fully exploit the planned JHR capacity by promoting and enhancing collaboration.
The duration of the project is 30 months and it involves not only the JHR consortium members but also external experts in the International Scientific Advisory Group and stakeholder and interest groups in the Support Group.
The first 4-year period of operation will be closely connected to the basic tests to be done with the experimental devices described above and will mainly focus on the issues with current GENII/III reactors. After the first 4-year period the available test matrix gets wider and the tests, that are focused more towards future technologies, are available. The important point for the EC is that the whole Euratom community can utilise the Euratom access rights. Therefore, in the JHOP2040 project the "JHR Euratom Stakeholders Network" (JHR-ESN), whose objective is to structure, compile and consolidate the EU Member State's needs for the future irradiation campaigns within the JHR in the frame of the available Euratom access rights, will be established.

4.4 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 (https://www.oecd-nea.org/jcms/pl_15313/framework-for-irradiation-experiments-fides).
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 have been actively working on the FIDES legal framework agreement, as well as preparing the first joint experimental programmes based on topics proposed by the JHR WGs. 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 was officially launched in April 2021, including four joint R&D projects gathering 27 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. The aim of the JHR consortium members in FIDES is to plan and test experiments and devices that can be used also in the JHR. So, the FIDES frame serves the pre-JHR era not only from the technological point of view but also in managing the co-operative processes between the consortium members.

In addition to this, the JHR consortium is seeking for additional ways to engage different nuclear groupings to ensure the proper utilisation of the JHR in the future and even co-operate during the pre-JHR era.

4.5 JHR School

One of the latest international actions related to the JHR and its operation is the JHR School, that was established by the JHR Governing Board in 2018 and the first school was held in 2019. The aim is to have the school every second year. The school is meant for training new experts on understanding all the possibilities where the JHR can be used and take advantage to get to know individual test types etc. and become trained as a future user of the reactor. The JHR School is led by the University of Bologna (Prof. Marco Sumini). The feedback from the first school was very positive and the JHR consortium is considering enlarging it outside the consortium, possibly via European Nuclear Education network (ENEN).

4.6 JHR Secondee programme

In parallel with the construction, there has been an active secondee programme running. The aim of this programme is that university students or colleagues from the JHR consortium members can work within the JHR Project and do some actual engineering work on some relevant topics. The secondee period requires a stay at CEA and offers in that way a close look to the organisation responsible for the construction and people working with different topics. During the construction period, tens of students or colleagues have worked at CEA for several months.

The activities related to the JHR can be summarised as shown in Fig. 5. The first criticality date is not official and will be confirmed by the end of 2023.

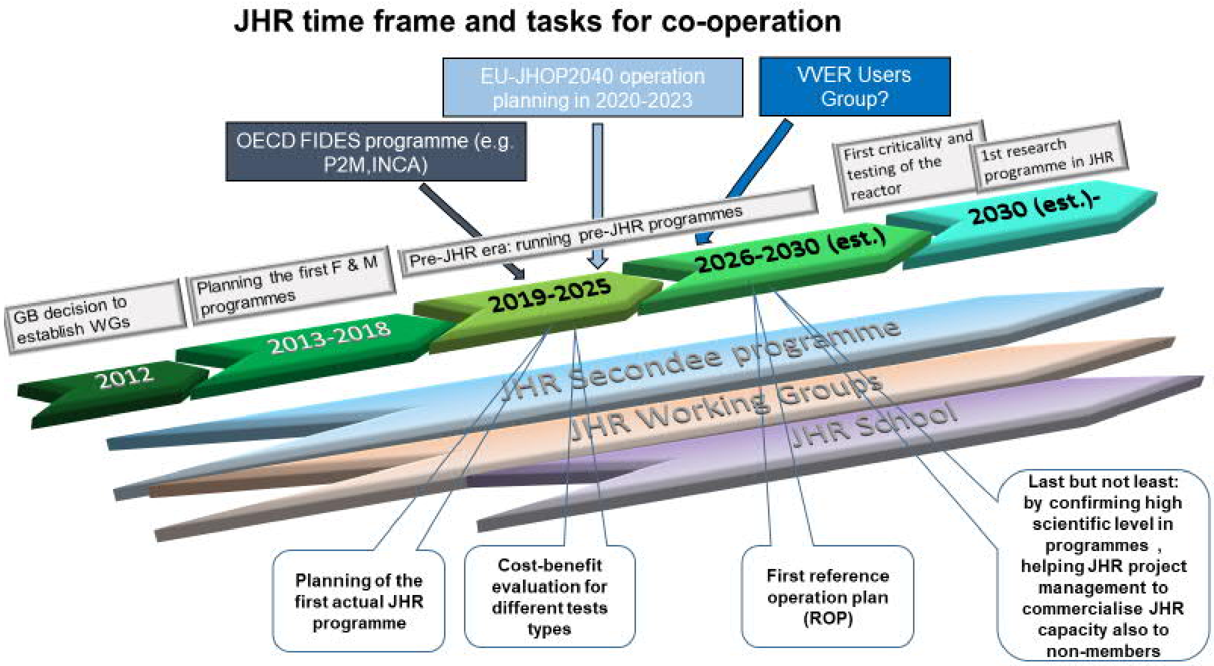

Fig. 5 The JHR time frame

5. Summary

The JHR is an extensive international effort to serve future needs in the nuclear research. It collects all major European nuclear research institutes, institutes also outside Europe and noticeable amount of nuclear industry to work together. Even if being a challenging project, the JHR will eventually be the next generation research reactor with the experimental capacity able to serve and adapt to the needs foreseen in the nuclear industry in the future.

The JHR Consortium has established many actions to take steps towards the operation. Lots of planning is currently done in all possible aspects to bring the Consortium to the operation of the reactor. And when in operation, the JHR will be the key infrastructure in determining the strategies and scales of the nuclear research in and even outside Europe.