APPROACHING THE OPERATION PLANNING FOR THE JHR

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Abstract

The Jules Horowitz Reactor (JHR) is a new Material Testing Reactor (MTR) currently under construction at CEA Cadarache research center in southern France to become one of the major research infrastructures for scientific studies dealing with nuclear materials and fuels behavior under irradiation. The reactor is also being optimized for medical isotope production providing even up to 50% of the radioisotopes for medical applications for European needs.
The reactor is designed to host various R&D programs dedicated to the optimization of the operation of the existing Nuclear Power Plants (NPPs), to assess the irradiation induced ageing of the non-replaceable and safety related components of the operating NPPs, to support the improvement, development and deployment of the third generation of NPPs as well as small modular reactors (SMR). It will also offer irradiation capabilities for GEN IV and fusion technologies.
Its flexibility is an asset to address the needs expressed by the scientific community and the industry. Consequently, the JHR facility will become a major scientific hub for cutting edge research on fuel and material investigations.
The JHR consortium is gathering today 15 partners (one of them being the European Commission) and each consortium member has acquired Access Rights giving access to the JHR experimental capacity for the whole life of operation of the reactor. Such Access Rights could be used either for proprietary projects (bilateral contract) or for joint research and development projects.
In particular, these joint R&D projects will be open to non-members of the JHR consortium for the benefit of all European Member States and the international community.
The EU-JHOP2040 project is developing the first roadmaps for JHR's operations to cover the first 15 years of operation. The is to deliver procedures for Euratom how it can use its 6% Access Rights for the benefit of the member states. The work has included mapping of the experimental needs coming from the consortium partners or their domestic consortiums. These experiment matrixes include both short-term as well as long-term needs, which will be then reflected against the available experimental technologies in the reactor. The work will end up in presenting the possible programme model and its resourcing together with comprehensive listings of scientific topics to Euratom for them to adjust this outcome in their own future processes.

Jules Horowitz Operation Plan (JHOP2040)

Material Testing Reactors have been for many decades key research tools for fuel and material behavior studies under neutron flux supporting nuclear industries, research institutes and regulators. Whatever the progress in simulation, MTRs will remain a necessity for the qualification of new fuels and materials under irradiation notably in support to safety demonstration. Currently, in response to this need, the Jules Horowitz Reactor (JHR) is under construction. The JHOP2040 project presents a Coordination and Support Action aiming to 1) bring together with the JHR consortium of key actors, all relevant European nuclear research associations and member states that are not represented in the JHR consortium and 2) to produce strategic research roadmaps for the operation of the JHR. These roadmaps will cover both the first 4-year programme period and the following 11 years of operation. The outcome of JHOP2040 will be financial and programme model for Euratom taking into account also the governance and cost breakdown of the programmes. The JHOP2040 will strengthen and widen the JHR research network by bringing together relevant stakeholders and interest groups to identify and review their current and future needs for fuel, material and technology issues within and outside of the current JHR consortium. Extensive utilization of the JHR via Euratom access rights and full use of the planned JHR capacity by promoting and enhancing the collaboration between potential users is the ultimate goal.

The scope of the research and training needs considered by the JHOP2040 includes activities in support of:

- current generation NPP, including component optimisation, lifetime extension, enhanced surveillance, enhanced safety of operation and inspection and waste minimisation;
- material, fuel and design development for the next generation of fission nuclear plant including Small Modular Reactors (SMRs), Advanced Modular Reactors (AMRs), Liquid Metal-Cooled Fast Reactors (LMFRs), Gas-Cooled Fast Reactors (GFRs), Molten Salt Reactors (MSRs), High-Temperature and Very High Temperature Reactors (HTRs and VHTRs);
- materials irradiation and development for fusion reactors.

In this paper we focus on planning of the first four years of operation even if some references to the following 15 years will be also given.

JHR experimental capacity during operation

The start-of-operation for the JHR has not been announced yet but it is foreseen to happen during the next decade. The start of experimental programmes will be done in two steps. The first fleet of experimental set up will be limited to tests that are generally recognized to be the most needed. As the start-of-operation is known to be demanding in many ways it is considered unnecessary to include all possible devices at the same time. It is to be expected in any case that the first experimental programmes will be started in a stepwise manner.

JHR experimental capacity in the start-of operation phase

The first fleet of experimental devices covers equipment that is considered to be needed in the start-of-operation phase. That equipment will be Material devices MICA and OCCITANE and fuel devices MADISON and ADELINE as well as NDE benches and neutron imaging.

MADISON test device is designed to carry out irradiations of LWR fuel samples during which no clad failures are expected. Consequently, the experimental conditions correspond to normal operation of power reactors (steady states or slow transients that can take place in nuclear power plants). This experimental device is made of an in-pile part (holding the fuel samples) fixed on a displacement system. This system allows on-line regulation of fuel linear power on the samples.

ADELINE test device is able to hold a single experimental fuel rod from all LWR technologies to reproduce various experimental irradiation scenarios in which a clad failure is either a risk or an experimental objective. Similarly, to the MADISON test device, this experiment is made of an in-pile part located on a displacement system in the JHR reflector and an out-of-pile water loop.

MICA test device is designed to irradiate structural materials in the core of the JHR, within a fuel element. Its typical temperature range is between 280 and of 450°C for the samples. Seven different locations are available for MICA devices: two in the first ring, two in the second ring and three in the third ring of the JHR core

In the field of pressure vessel steels of NPPs, irradiations are carried out to justify the safety of this second containment barrier and to improve its lifetime and consequently the lifetime of the reactor itself. For this purpose, CEA is designing a hosting system named OCCITANE, which allows irradiations in an inert gas at least from 230 to 300°C.

Gamma Scanning and X-ray tomography systems for NDE investigations before, between and after irradiation fuel cycles will be available in the reactor pool, in the storage pool and in the hot cells (U/HGXR).

Neutron imaging system (NIS) will be installed in the reactor pool primarily intended to back the power ramp tests, but also to secure the JHR imaging capacity and to take advantage of the very different interaction of neutrons with matter.

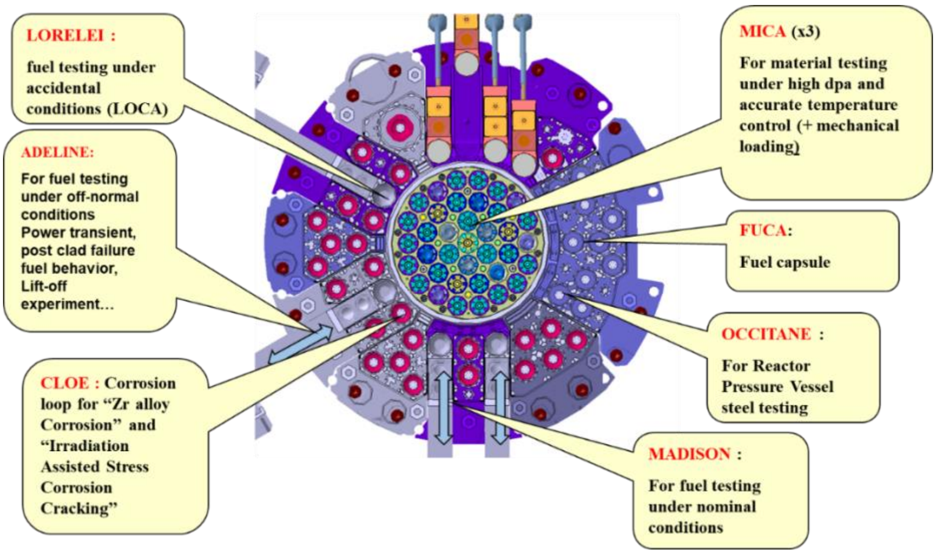

Figure 2: JHR core experimental positions

JHR experimental capacity after the start-of-operation phase

The second fleet of devices will expand the experimental capacity for e.g.:

- characterising new cladding materials, new fuel materials, new fuel assembly designs, new fuel management strategies (high burn-up, high duty) and the corresponding FP releases in LOCA situations (LORELEI device);
- a simplified fuel irradiation capsule (FUCA) in addition to the irradiation test devices;
- a mechanical loading device for irradiation experiments (MeLoDIE) to study biaxial creep online during irradiation;
- a corrosion loop to study the phenomena of irradiation-assisted stress corrosion cracking (IASCC) in the structural materials (CLOE);
- a test loop RISHI for irradiation studies in sodium at high temperatures dedicated to GEN IV structural material samples testing at different temperatures

These devices will be available in the JHR after the start-of-operation phase.

Start-of-operation strategy for the JHR

The planning of the experimental programmes is mainly done by three JHR Working Groups for fuel (FWG), materials (MWG) and technologies (TWG). These WGs have communicated and collected the interests of not only the JHR consortium members but also those of non-JHR members in different questionnaires and made the ranking lists based on those answers.

Based on the needs listed the main focus in the beginning of operation will be:

- For material studies: The experiments of greatest interest to the European nuclear community are mainly R&D actions related to LWRs, both those in current operation (i.e., Generation III reactors) and those in process of building and start-up (Generation III+ reactors). The main objectives of these actions are characterisation of material behavior in normal reactor or incidental operating situations, and performance improvement. In the short-to-medium term, the community is looking to perform R&D actions which will provide information making it possible to justify the integrity of the various structures, including in incidental situations (e.g., loss of the primary coolant for the vessel); to optimize their maintenance; and to validate their operation, including support for the evolution of the design margins and justifications for extensions to operational lifetimes.
- For fuel studies: Focus will be on testing of the irradiation devices and checking the capability of each device to produce experimental results under actual irradiation conditions that are consistent with the expected uncertainties and ensure that the results obtained match correctly with the existing experimental domain for qualification, constructed with inputs from other research reactors and used for the qualification of many scientific calculation tools. This point is crucial for the future experiments. In long-term planning the investigations of fuel rod behaviour in both normal operation (including transients) and during design basis accidents (loss of coolant accidents and prompt reactivity induced accidents) will be in focus. Current fuel designs, evolutionary advanced technology fuel designs and fuels for SMRs are all considered.
- For technologies: Focus will be in qualifying tests for the experimental devices. In practice, many of these activities need to be performed before the onset of JHR operation, in anticipation of the use of the JHR irradiation devices during the commercial period. For technological issues, it has been recognized a long list of new or improved existing technologies, which will require attention. Therefore, the technology development wngill not eventually be depending on the phase of operation as much as it is for the fuel and material studies but technologies will be developed on a constant basis or as needed.

How to utilize Access Rights in the JHR

JHR, as a future international User Facility, is funded and steered by an international consortium gathering industry (utilities, fuel vendors…) and public bodies (R&D centers, TSOs, regulators…). The generic model of JHR consortium is the following:

- CEA remains the owner and the nuclear operator of the nuclear facility with all liabilities,
- JHR Consortium Members are the owners of Guaranteed Access Rights to the experimental capacities in proportion to their financial commitment to the construction and with a proportional voting right in the Consortium Governing Board,
- A Member can use totally or partly his access rights for implementing proprietary programs with full property of results and/or for participating to the Joint International Programs open to non-members
- JHR consortium membership is open to new members until completion of the reactor.

CEA is encouraged by the consortium to enlarge JHR membership and, as of early 2023 the present members list of JHR consortium is the following:

CEA (France), EDF (France), FRAMATOME (France), TECHNICATOME (France), AREVA.SA (France), EUROPEAN COMMISSION , SCK-CEN (Belgium), CVR-UJV (Czech Republic), VTT(Finland), CIEMAT(Spain), STUDSVIK (Sweden), DAE(India), IAEC (Israel), NNL (UK), CGN(China).

Let's illustrate how e.g., the European Commission could us its Access Rights for the benefit of European Member States.

The EC (Euratom-JRC)- considering its contribution to the construction- gets:
- 6 % of guaranteed Access Rights to JHR experimental capability for the whole life of operation of the reactor- 6 % of voting rights in the JHR Consortium.

Regarding the utilisation of the Access Rights, they can be cumulated to some extend from one year to the following in order to implement greater research programs in one specific year (either proprietary program and/or Joint program (including shared with other Members).

The Operation Phase of the reactor will be partitioned in 4-year operation periods and shall be managed in consideration of the Reference Operation Plan (ROP) drawn up by the project leader for each four-year period and validated by the Governing Board.

To illustrate the Access Rights into comprehensive unit as quantity of experiments, let's converse Access Rights (AR) to Access Units (AU) regarding the experimental capacity of the JHR and the various factors associated to each experiment type. These Access Units have to be seen as some "units of account" for the use of neutron flux and experimental capacity.

Let us consider, as an example-see table below-, the following experiments distribution in JHR core and reflector representative of the present developments: each experiment represents a number of Access Units depending on different parameters as indicated later on.

The weight analysis of each experiment versus various factors as neutron flux, volume, complexity, impact factors, is presented in the table below. This weight is taken as a reference Access Unit of the experiment for one cycle. This assessment on the use of Access Rights to perform experiments in JHR is depending on various factors.

To translate these Access Rights to Access Units for each experiment, we need to take into account:

- the large variety and the specificities of these experiments,
- the number of experiments performed per year.
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To illustrate such approach, the following example of possible weighting per type of experiment is considered in Table 1:

Example of experimental possibilities for European Commission with 6 % Access rights

With the JHR configuration and operation described above, 6 % of Access Rights represents about 78 Access Units per year (6% of 1318).

So, the EC with its 6 % Access Rights can have access each year to:

- 7 to 8 Ramps type experiments using ADELINE device,
- or 6 Fuel loop irradiation type experiments using MADISON device,
- or 3 Material capsule type experiments.

Table 1: Preliminary weight factors of different experiment types in the JHR

Kind of experimentation	Fixed part			Variable part			Impact factor (Fuel consumption, performances,...)	"Weight" total
	Neutron flux factor	Equipment complexity factor	Utilities (water, electricity,...)	Volume factor	Operation complexity factor	Services (NDE, FP lab, hot cells,...)		
MADISON	1	3	2	1	3	2	---	12
ADELINE	1	3	1	1	2	2	---	10
MICA	1	2	1	1	2	0	1	8
specific MICA	3	2	1	1	2	1	2	12
LORELEI	2	3	2	1	3	3	---	14
OCCITANE	1	1	0	3	1	0	2	8
CALIPSO	3	2	2	2	3	3	1	16
CLOE	1	3	2	1	2	2	1	12
Fast reactor support	3	3	2	2	3	3	---	16
Boiling device	1	2	1	1	1	2	---	8

Table 2: Example of the JHR loading plan

Example of loading plan A.U. = Access Units			
Type of experiment	Associated Access Unit per experiment and per cycle	Number of JHR locations for the type of experiment considered	Cumulated number of Access Unit per year (on the basis of 7 cycles per year)
Fuel ramps studies (ADELINE)	10	3	210
Fuel loop steady-state studies (MADISON)	12	2	168
Fuel loop for LOCA studies (LORELEI)	14	0,3 (we consider only 3 LOCA tests per year)	30
Fuel capsule studies (FUCA)	10	4	280
Material capsule studies in core (MICA)	8	3	168
Advanced MICA in core	12	2	168
RPV studies in reflector (OCCITANE)	8	2	112
Corrosion studies (CLOE)	12	1	84
FR material studies	14	1	98
TOTAL	100		1318

Conclusions

4. Acknowledgements

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