THE JULES HOROWITZ REACTOR : A NEW HIGH PERFORMANCES EUROPEAN MTR (MATERIAL TESTING REACTOR) WITH MODERN EXPERIMENTAL CAPACITIES : TOWARD AN INTERNATIONAL USER FACILITY

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ABSTRACT

The Jules Horowitz Reactor (JHR) is a new Material Testing Reactor (MTR) currently under construction at CEA Cadarache research centre in the south of France. It will be a major Research facility in support to the development and the qualification of materials and fuels under irradiation with sizes and environment conditions relevant for nuclear power plants in order to optimise and demonstrate safe operations of existing power reactors as well as to support future reactor design. It will represent also an important Research Infrastructure for scientific studies dealing with material and fuel behaviour under irradiation.

The JHR will contribute also to secure the production of radioisotope for medical application. This is a key public health stake.

The construction of JHR which was started in 2007 is on-going. The first operation is planned before the end of this decade.The design of the reactor will provide an essential facility supporting the programs for the nuclear energy for the next 50 years.

JHR is designed to provide high neutron flux (enhancing the maximum available today in MTRs), to run highly instrumented experiments to support advanced modelling giving prediction beyond experimental points, and to operate experimental devices giving environment conditions (pressure, temperature, flux, coolant chemistry, …) relevant for water reactors, for gas cooled thermal or fast reactors, for sodium fast reactors, …So, the reactor will perform R&D programs for the optimization of the present generation of NPP, support the development of the next generation of NPP (mainly LWR) and also offer irradiation possibilities for future reactors.

In parallel to the construction of the reactor, the preparation of an international community around JHR is continuing; this is an important topic as building and gathering a strong international community in support to MTR experiments is a key-issue for the R&D in nuclear energy field. Consequently, CEA is welcoming scientists, Engineers (called Secondee) from various organisations/institutes who are integrated within the JHR team for a limited period of time (typically one year) for various topics such as physics studies for the development of the experimental devices (core physics, thermo-hydraulic…) and/or in support to the future Operator (Safety Analysis, I-C&C…).

This paper gives an up-to-date status of the construction and of the developments performed to build the future experimental capacity and latest actions to bring JHR toward an International User Facility.

1. Introduction

European Material Testing Reactors (MTR) has provided an essential support for nuclear power programs over the last 40 years within the European Community. However, these Material Test Reactors (MTRs) will be more than 50 years old in this decade and will face increasing probability of shut-down due to the obsolescence of their safety standards and of their experimental capability. Such a situation cannot be sustained long term since “nuclear energy is a competitive energy source meeting the dual requirements for energy security and the reduction of greenhouse gas emissions, and is also an essential component of the energy mix" [1].

Associated with hot laboratories for the post irradiation examinations, MTRs are structuring research facilities for the European Research Area in the field of nuclear fission energy.
MTRs address the development and the qualification of materials and fuels under irradiation with sizes and environment conditions relevant for nuclear power plants in order to optimise and demonstrate safe operations of existing power reactors as well as to support future reactor design :

- Nuclear plants will follow a long-term trend driven by the plant life extension and management, reinforcement of the safety, waste and resource management, flexibility and economic improvement.
- In parallel to extending performance and safety for existing and coming power plants, R&D programs are taking place in order to assess and develop new reactor concepts (Generation IV reactors) that meet sustainability purposes.
- In addition, for most European countries, keeping competences alive is a strategic cross-cutting issue; developing and operating a new and up-to-date research reactor appears to be an effective way to train a new generation of scientists and engineers.

The Jules Horowitz (JHR), Material Testing Reactor, is one of answers for the needs of future research infrastructure in Europe.

JHR will be operated as an international user's facility on the CEA Cadarache site. It will be dedicated to materials and fuel irradiations for the nuclear industry or research institutes and to radio-isotopes production for medical applications.

The design of this facility allows an important flexibility in order to comply with a large range of experimental needs, regarding the type of samples (fuel or materials), neutron flux and spectrum, type of coolants and thermal hydraulics conditions (LWR, Gen IV,…), in accordance with the scientific objectives of the programs. These experimental tools are under development and some of them will be available at JHR start up.

2. Organization arround JHR

2.1 JHR Consortium

The JHR, as a future international User Facility, is funded and steer by an international Consortium gathering today 10 partners from industry (utilities, fuel vendors…) and public bodies (R&D centres, Technical Safety Organizations TSO, regulators…) :

- SCK•CEN from Belgium,
- CIEMAT from Spain,
- VTT from Finland,
- UJV-NRI from Czech Republic,
- VATTENFALL from Sweden,
- DAE from India,
- CEA,
- AREVA and EDF from France,
- JRC from the European Commission,
- IAEC from Israel.

UK signed a bilateral agreement with CEA in March 2013 and will join the consortium as a future member second semester of 2013.

Till JHR start-up, this list may still be enlarged as discussions are in progress with several countries interested in joining the Consortium. CEA is in charge of the construction of the reactor and will be the Nuclear Operator.

2.2 In-Kind contribution

It is interesting to quote that some members of JHR Consortium have an in-kind contribution. As some examples :

- CIEMAT who represents a domestic Spanish Consortium is designing and launching, as its main in-kind contribution, the manufacturing of the three heat exchangers of the primary circuit,
- VTT who represents a domestic Finnish Consortium is designing and manufacturing, as its main in-kind contribution, an underwater non-destructive examination bench [8],
- SCK•CEN, as its main in-kind contribution, is performing JHR fuel element qualification under irradiation in the EVITA loop,
- NRI is designing and manufacturing JHR hot cells,
- IAEC is performing the preliminary design of the LORELEI safety loop able to implement LOCA-type tests on a single LWR experimental fuel rod,
- DAE is in discussion with CEA for designing a LWR corrosion loop in the reflector for clad corrosion materials and Stainless Steel IASCC (Irradiation Assisted Stress Corrosion Cracking).

3. The JHR irradiation capability within the international context

The JHR will be a major experimental infrastructure to meet industrial and public needs. As a modern irradiation capability, it aims at answering the above expressed needs and is designed to provide high neutron fluxes (enhancing the maximum available today in European MTRs), to run highly instrumented experiments on a separate effect strategy, to support advanced modelling for a broader prediction capability and to operate experimental devices giving environment conditions (pressure, temperature, flux, coolant chemistry…) relevant for the nuclear power systems being optimized or to be developed.

The development of relevant irradiation systems raises challenges concerning not only the irradiation devices and the associated on-line measurements, but also the non destructive examination benches, the examination and handling hot cells and the analysis laboratories (fission product laboratory, chemistry laboratory etc.). These support systems play a crucial role to gain quickly reliable data on the sample, sometimes no more accessible after a long delay or transportation, and to enhance strongly the MTR experimental process quality.

In parallel to the construction of the reactor, the preparation of an international community around JHR is continuing.

Moreover, as another important objective, the JHR will contribute to secure the European production of radioisotope for medical application (25% of the European demand on a nominal level, up to 50% in case of specific request). This point is considered as a key public health stake.

3.1 A modern facility with a large area dedicated to experiments

The Nuclear facility comprises a reactor building with all equipment dedicated to the reactor and experimental devices and an auxiliary building dedicated to tasks in support for reactor and experimental devices operation.

The reactor building (see Figure 1) is designed to provide the **largest experimental capacity** possible with the largest **flexibility**. One half of this building is dedicated to the implementation of equipment in support to in-pile irradiations (for example, water loops). This corresponds to 700 m2 over 3 floors for implementation of experimental cubicles and 490 m^2 over 3 floors for instrumentation and control equipment. A supplementary area is devoted to analysis laboratories.

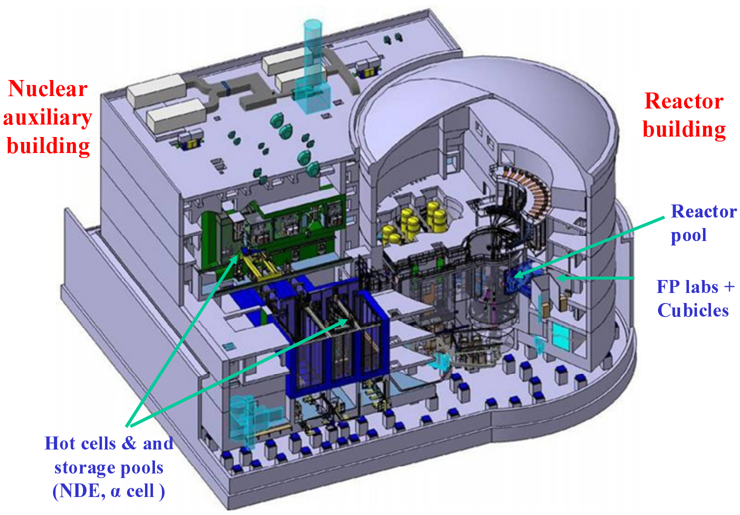

Fig 1. View of the JHR facility

3.2 A powerful reactor with numerous irradiation sites and irradiation conditions

The design of the reactor (see Figure 2) provides irradiation positions located either inside the reactor core with the highest ageing rate (up to 16 dpa/year for operation at 100 MW) or in the beryllium reflector area surrounding the core, with the highest thermal neutron flux. Numerous locations are implemented (up to **20 simultaneous experiments**) with a large range of irradiation conditions :

- 7 in-core locations of small diameter (32 mm) with a high fast flux (up to 5,5.10^{14} n.cm^{-2}.s^{-1} perturbed flux above 1 MeV),
- 3 in-core locations of large diameter (80 mm) with a high fast flux (up to 4.10^{14} n.cm^{-2}.s^{-1} perturbed flux above 1 MeV),
- 20 fixed positions (around 100 mm of diameter and one location with 200 mm) with a high thermal flux (up to 3,5 10^{14} n.cm^{-2}.s^{-1} perturbed flux),
- 6 positions located on displacement devices located in water channels through the Beryllium reflector.

A typical reactor cycle is expected to last 26 days, and operation schedule could consist of 10 reactor cycles per year.

3.3 JHR as an International User Facility

In parallel to the construction of the reactor, the preparation of an international community around JHR is continuing; this is an important topic as building and gathering a strong international community in support to MTR experiments is a key-issue for the R&D in nuclear energy field. Consequently, CEA is welcoming scientists, Engineers (called Secondee) from various organisations/institutes (not necessarily form the consortium members) who are integrated within the JHR team for a limited period of time (typically one year) for various topics such as physics studies for the development of the experimental devices (neutron physic, thermo-hydraulic…) and/or for support to the future Operator (Safety Analysis, I-C&C…).

As described in the IAEA paper on this present conference (A. Borio di Tigliole et al) the new initiative of the Agency to launch the ICERR (International CEntre on Research Reactor) concept is intended to help Member States willing to go on Nuclear Technology via the setting-up of a Research Reactor to create and sustain key-competences.

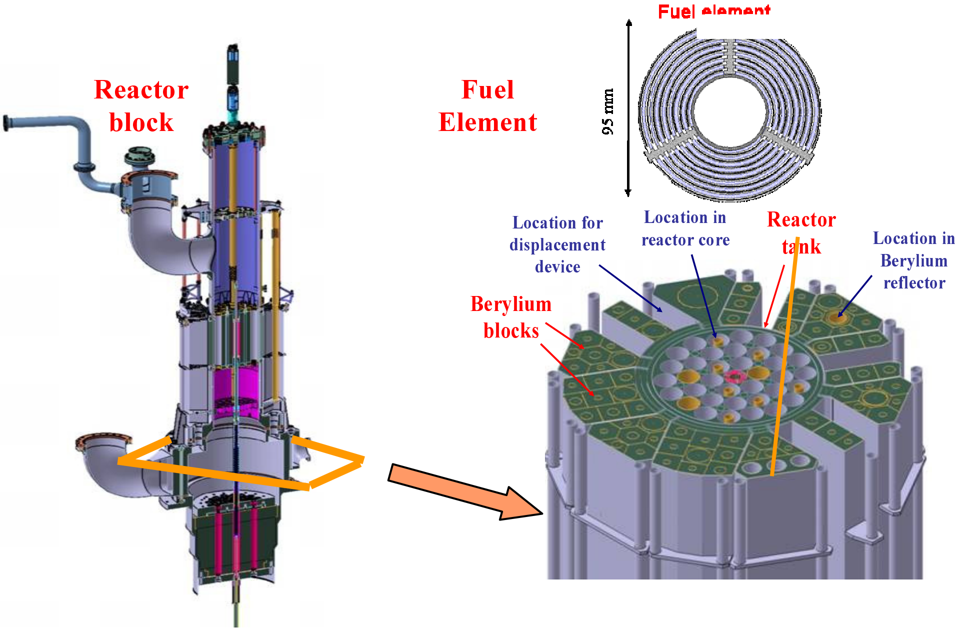

Fig 2. View of the reactor core with experimental locations

Actually, between the academic training and the “commercial training linked to a product” there is a need for setting-up a framework for Nuclear Education “in the field” using modern High-Performances Infrastructures dedicated to the training of future seniors scientists, Engineers…for the benefits of decision-makers in countries wishing to develop Nuclear Energy. These scientists invited to an ICERR for getting this Nuclear Education are called Secondee as described above.
The ICERR will provide Nuclear Education “in the field” that offer direct experience of working in nuclear facilities and provide training opportunities that fill the gap between academic education and commercial-product specific training. This will allow Secondee to learn about best practices in Material and Fuel Science, Nuclear Safety, Reactor Operation, Nuclear Technologies, Fuel management, Wastes Management, ancillary Hot Cells and Laboratories and so on. It also means that the hosting country has enough qualified staff to tutor in a good way the secondees.
JHR provides an informative model for potential ICERR as well as options for access to its own research facilities and training resources.

4. JHR update status

The construction of JHR which started in 2007 is on-going. Significant progresses on civil works were achieved in 2012 and in 2013.

5. JHR Safety

The JHR incorporates the safety analysis right from the design phase, based on a modern reference system and methodology; in particular similar to those used in present projects such as the EPR, GEN3 NPPs, under construction in Finland, China and France.
The JHR Safety approach has been presented in detail at the IAEA General Conference on Research Reactors in Rabat November 2011 and some examples of incorporating Safety from the design phase are described in this reference [7].
The methodological safety approach for the JHR described in [7], is highlighting various innovative aspects and the specific design features of the new experimental reactor. Moreover, some of the initial design choices and options are detailed, coming directly from this innovative approach and feedback from existing reactors.

Fig 3. View of the Building site June 2013

6. Conclusion

The JHR facility, currently under construction in the framework of an international consortium, is already open - regarding the experimental capacity - and will be more and more so to international collaboration. Its operation will provide a key infrastructure in the European and International Research Area for R&D in support to the use of nuclear energy.

7. References

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