Sustaining Material testing capacity in France: from OSIRIS to JHR

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Abstract – *Since 1966 the OSIRIS reactor located at Saclay centre, near Paris, is participating to French and international irradiation programs for Research and Development in the field of nuclear fuel and materials. CEA is operating OSIRIS to support industry and public bodies by strengthening knowledge for example in plant-life management (pressure vessel steel ageing) or high burn-up fuel qualification (pellet-clad interaction).*

However, OSIRIS, as most of existing MTRs in Europe, is over 40 years old. A safety and performance assessment has shown that even with a major refurbishment, OSIRIS would not allow guaranteeing the availability of the irradiation experimental capacity for the industry and the public bodies for few additional decades. A new high performance MTR, operated in a European and international framework, is necessary to meet the needs from industry and public bodies (Research centers, Safety Authorities…). This is the scope of the Jules Horowitz Reactor (JHR), a brand new MTR under construction at the CEA Cadarache center (star of operation in 2014).

The JHR design (reactor and experimental capacities) takes benefit of the large amount of experience from OSIRIS and others European MTR and will be for some decades a key International User Facility to the service of the nuclear community. The paper presents the status of the OSIRIS and JHR reactors and the actions that will insure a successful transition between them.

FROM OSIRIS…

I. - THE OSIRIS REACTOR

Detailed presentation of the reactor has been given in previous IGORR conference. The present one will give a more general overview of this MTR and the experimental devices used

OSIRIS is a research reactor with a thermal power of 70 MW. It is a light-water reactor, open-core pool type, the principal aim of which is to carry out tests and irradiate the fuel elements and structural materials of nuclear power stations under a high flux of neutrons, and to produce radioisotopes.

Located within the French Atomic Energy Commission (CEA) centre at Saclay, it is close to many research teams and inspection laboratories and has a large-scale technological infrastructure.

Fig. 1. The OSIRIS

I-A – Operation

OSIRIS operates around 200 days a year, in cycles of varying lengths from 3 to 5 weeks. A shutdown of about 10 days between two cycles allows reloading the core with fuel, to carry out light maintenance operations and to handle operations required for the experiments. Larger maintenance operations are carried out during dedicated shutdowns of longer duration in summer.

I-B – Flexibility in use

OSIRIS is a multi-purpose reactor, used for:

- technological irradiation for the purposes of the nuclear power industry or those of fundamental research,
- production of radioisotopes and doped silicon,
- Analysis by activation.

The basic principle of design of an open-core, pool-type of reactor enables direct access to the core.

Furthermore, the location of the rod mechanisms under the reactor pool ensures they are completely free of any irradiation.

I-C – Experimental services

The users have access to:

- large space around the reactor pool, five different levels in the reactor container and one level in the crown gallery, outside the container, to accommodate the land-based circuits for the experimental devices;
- a service during irradiation, provided 24 hours a day by specialists in installation, as well as an information processing system for the follow-up, storage and processing of data;
- a service after irradiation including:
    - 2 hot cells connected, by a channel, with the OSIRIS and ISIS reactor cavities
    - Equipment for non-destructive testing, before, during and after irradiation.

I-D – Reactor pool and Core unit

The reactor pool is 11 m deep, 7.5 m long and 6.5 m wide. On its southern face, it has a cavity 5 m high, to accommodate a gate, in order to isolate the reactor pool from the channel.

The OSIRIS fuel elements consist of 22 plates, each plate being made of alloy U3Si2 Al. The uranium is enriched to 19.75%. Each of the six control elements is followed by 17 plates identical to the ones of the standard elements.

Fig. 2. The OSIRIS reactor core.

II. - EXPERIMENTAL CONDITIONS

The core of the reactor can house up to 16 experimental devices in 4 positions where the fast neutron flux (E > 1 MeV) ranges from 1 to 2. 10^{14} n.cm^{-2} s^{-1}. Structures are also provided outside the core, making it possible to install up to 27 experimental devices on the first periphery, where the maximum fast neutron flux is 10 times weaker than in the core, and many others on the second and third peripheries.

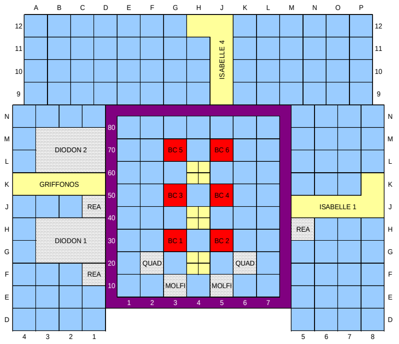


Fig. 3. The OSIRIS experimental locations.

II-A – Core position geometry

Each of the four experimental positions in the core contains a water box that can house and maintain the experimental devices in the core. Several types of water box are available. This means that various sizes of devices can be housed.

II-B – Neutron flux

Basic information about the neutron flux throughout the core is provided by the neutron calculations required for its operation and management. In order to qualify and supplement these calculations, measurements are made in the considered position using techniques suited to the type of flux measured (fast flux and heat flux).

Thermal flux

The maximum value recorded in the first periphery of the reactor is close to 3.10^{14} n.cm^{-2}.s^{-1}. (E<0,1 eV)
The maximum value recorded in the experimental locations inside the core of the reactor is approximately 2.10^{14} n.cm^{-2}.s^{-1}.

Fast flux

The highest fast flux in the core is $2.2.10^{14}$ $n.cm^{-2}.s^{-1}$. This is used to reach damage rates of about 7 displacements per atom (dpa) per year for certain materials.

II-C – Gamma heating

The maximum value of gamma heating reached in the core position is 13 $W.g^{-1}$ whereas it always remains lower than 2 $W.g^{-1}$ (of graphite) on the periphery of the core.

III. - EXPERIMENTAL DEVICES

Technological irradiations carried out in experimental reactors are used on one hand to meet the industrial needs of the present fleet of power reactors and on the other hand to meet the needs of new types of reactors satisfying the broad objectives of sustainable development. One of the main advantages of experimental reactors is to be able to carry out experiments up to limits that could not be achieved in a power reactor since instrumented irradiation can be produced by adjusting experimental parameters such as temperature and neutron flux.

The irradiation devices available in the OSIRIS reactor can be classified into 3 categories:

- Capsules designed to irradiate materials under conditions similar to those of water reactors. In these devices (CHOUCA and IRMA) the coolant is static. These capsules exist in various types:
    - Passive capsules in which only the temperature and neutron flux are measured. These capsules are used for the accumulation of fluence on materials.
    - Capsules in which, in addition to the capacities of the previous family, the samples are subjected to stress or strain under irradiation.
    - Metrology capsules, which are used to measure the dimensional changes of the samples in situ.
- The PHAETON capsules designed to irradiate materials and fuels under conditions similar to those in high temperature reactors for the new families of reactor.
- Loops reproducing the thermohydraulic, neutronic and chemical conditions encountered in LWR (loops GRIFFONOS and ISABELLE).

In addition of these 3 families of devices, there are 2 other more specific devices MERCI and IRIS (see III-F and G).

III-A – The CHOUCA device

The CHOUCA system is a device dedicated to the irradiation of materials in the core or on the periphery of the reactor. This device, when placed in the core of the reactor, cannot be introduced or withdrawn when the reactor is in operation.

Sample-holders are inserted inside the capsule to house the samples specific to each type of experiment, such as:

- irradiation of acquisition of fluence at controlled temperature,
- irradiation of samples placed under stress,
- Irradiation of samples under stress with dimensional follow-up during irradiation.

The experiments carried out in CHOUCA systems typically relate to:

- materials for the internal structures of various types of reactors,
- fuel cladding
- Neutron-absorbing materials.

The usual temperatures of the experimental load is from 250°C up to 400°C (± 5°C)

Fig. 4. Examples of CHOUCA loadings with various kinds of Candu or LWR samples.

III-B – The IRMA device

IRMA is a capsule designed for the irradiation, in an inert environment, of structural materials and more particularly, the steels used in pressurized water reactors.

In the field of vessel steels, this device is used for example:

- to characterize the effects of temperature and dose,
- to evaluate the toughness of areas affected by welding operations,
- to study the influence of the neutron spectrum on embrittlement,
- to study the influence of annealing on the ductile/brittle transition, temperature.

Situated on the periphery of the core, this device can be used for irradiation or withdrawn without stopping the reactor.

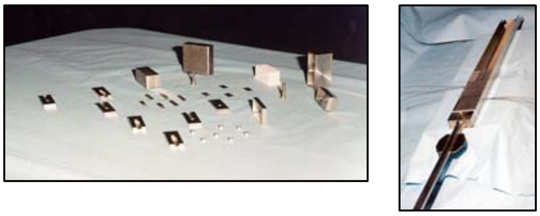


Fig. 5. IRMA sample holder and examples of loading.

The usual temperatures of the experimental load is from 250°C up to 320°C(± 6°C)

III-C – The PHAETON device

The PHAETON device is designed to irradiate materials at high temperature and in an inert environment. It can be installed: in the core or in the periphery of the reactor.

The temperatures of the experimental load is from 600°C upto 1100°C

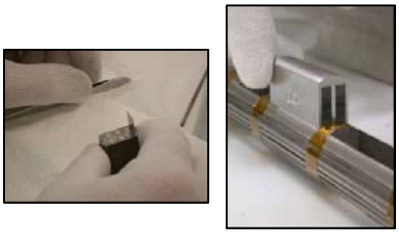


Fig. 6. Example of PHAETON device.

III-D – The GRIFFONOS loop

GRIFFONOS is designed to irradiate fuel rods under neutron flux conditions and fuel rod temperatures as close as possible to those met in pressurized water reactors. This device, placed in the periphery of the core, can be irradiated or withdrawn without shutting down the reactor. It can house various types of fuel rods: new or pre-irradiated, UO2, MOX, whether instrumented or not, produced by pressurised or boiling water reactors.

The experiments carried out with GRIFFONOS produce information required to understand the behaviour under flux of fuel rods, both current and future, in order to optimise their performance characteristics. The physical phenomena under study are varied: the central temperature of the fuel rod according to the power and burn-up rate, deformation of the clad during the pellet-clad interaction, generation of gas etc.

The fuel rod can house specific instrumentation:

- a core thermocouple,
- a clad thermocouple,
- a pressure pick-up to monitor the release of fission gases,
- a sensor for diametrical measurement under flux,
- Acoustic sensor to follow the composition of the released gaz.

The maximum linear on the fuel element is 600 W.cm^{-1} adjustable by displacing the device in relation to the core

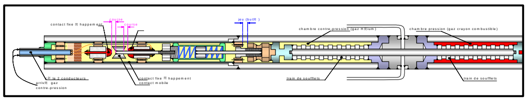


Fig. 7. Scheme of the pressure sensor used in GRIFFONOS for the Remora experiments [1].

III-E – The ISABELLE loop

ISABELLE loop is designed for the irradiation of fuel elements under thermohydraulic and chemical conditions representative of those of light water reactors. It is dedicated to the production of power ramps. The experimental load consists of a short fuel rod, either new or re-manufactured in hot laboratories by the FABRICE process using a fuel element irradiated in the power station. The power that can be evacuated by the loop is 60 kW and the maximum linear power on the fuel element is 620 W cm^{-1} with a maximum ramp speed of 700 $W.cm^{-1} min^{-1}$ [2].

The design of the loop and its positioning on the periphery of the core enable irradiation and withdrawal with the reactor in operation. The device is placed on mobile supports, the displacement of which in relation to the core of the reactor is used either to adjust the power of the fuel element, or to automatically control the power ramps or the cycles at variable speeds, slaved to the neutron power.

Fig. 8. The ISABELLE loop.

III-F - MERCI and MOSAÏC devices

MERCI and MOSAÏC are two devices dedicated to the accurate characterization of the residual power of a shortened LWR fuel rod immediately after its irradiation. This energy, produced after reactor shutdown, is mainly generated by the decay of unstable nuclei created during reactor operation. The knowledge of this physical quantity is of major importance for safety evaluation of a nuclear fuel after unloading including thermal aspects (residual heat) and radioprotection aspects (radiation spectra). A specific paper is presented during this conference [3].

III-G – The IRIS device

The IRIS device has been designed to irradiate fuel plates for experimental reactors. It has the same external geometry as a standard OSIRIS fuel element and is placed inside the core of the reactor. The device is cooled by the water of the primary circuit. Manufactured out of aluminium alloy, it is equipped with a latch in its upper section to avoid plate movement due to the effect of the ascending circulation of water. The latch can be removed to extract the plates during reactor shutdowns in order to carry out full dimensional measurements of the plate with a micrometer precision [4] and [5].

- The IRIS device can be loaded with 4 different fuel plates, separated by inert aluminium plates.

The plates irradiated in this way are subjected to a dimensional check on each cycle on a dedicated measurement bench.

Fig. 9. The IRIS

III-H – Instrumentation of the devices

Instrumentation is one of the key parameters for the performance of the experiments undertaken in the reactor. This is because during irradiation, various physical parameters must be measured on-line in a reliable and precise way. The experimental devices implemented at OSIRIS are equipped with various sensors and measurement systems, according to need.

The instrumentation usually used includes:

- measurements of the nuclear radiation for the characterization of irradiation (neutron flux, heating or gamma radiation) using SPND, activation dosimeters, calorimeters or sub miniature fission chambers,
- temperature measurements by thermocouples, placed on or near the samples, but also in the core of the irradiated nuclear fuels,
- measurements of the dimensions of samples: sensors of the LVDT type to measure the lengthening of fuel sheaths, or off-line strain gauges for on-line measurements of the diametrical strain of materials or fuels,
- measurements of the mechanical stress applied to samples when loading, the stress being created by systems of bellows using a pressure controlled outside the irradiation devices,
- Measurement of fission gas release in fuels under irradiation, using a backpressure sensor installed at the end of the fuel rods.

In the frame of a joint laboratory with the Belgium Research Centre (SCK-CEN), CEA is developing new instrumentation and is improving existing censors in order to have more accurate measurement for present experiment in OSIRIS and for the future JHR [6] to [9].

IV. – OTHER SERVICES

IV-A – Non destructive examinations

Two non-destructive examination facilities are implemented in the pool of the OSIRIS reactor. It includes an immersed neutron radiography facility and a gamma spectrometry bench.

IV-B – Associated hot labs

The OSIRIS reactor benefits from CEA R&D facilities both from the point of view of material studies with the LECI near the reactor in Saclay, and from the point of view of fuel studies with the LECA-STAR in Cadarache.

…TO JHR

Although OSIRIS is still providing experiments of very good quality, it is facing obsolescence and due to its ageing, it is planned to shut down OSIRIS during next decade. A safety and performance assessment has shown that even with a major refurbishment, OSIRIS would not allow guaranteeing the availability of the irradiation experimental capacity for the industry and the public bodies for few additional decades.

Consequently, it has been decided to launch the construction of the JHR in Cadarache.

The high technical skill of OSIRIS staff and its important know-how is important for the setting-up of the experimental capacity of the JHR and the two operating teams are working closely.

V. – CONTEXT: WHY JHR?

The development of a sustainable and safe nuclear energy requires R&D on fuel and material behaviour under irradiation with a high level of performance in order to meet the following needs and challenges for the benefit of industry, research and public bodies:

- A constant improvement of the performance and safety of present and future water cooled reactor technologies. Taking into account the lifetime extension and the progressive launch of generation III, NPPs using water coolants will be in operation through the entire century. They will require a continuous R&D support following a long-term trend driven by the plant life management, safety demonstration, flexibility and economic improvement. Lifespan extension of present Generation II reactors and demonstration of the lifespan of coming Generation III reactors is a major economical stake due to capital appreciation. Experimental irradiation of structure materials is necessary to anticipate and monitor structural material behaviour and, as a result, to contribute to the operation optimisation.

- Fuel technology in present and future nuclear power plants is continuously upgraded to achieve better performance and to optimise the fuel cycle, still keeping the best level of safety. Fuel evolution for generation II and III is and will stay a key stake requiring developments, qualification tests and safety experiments to ensure the economical competitiveness and safety. Indeed, experimental tests exploring the full range of fuel behaviour determine fuel stability limits and safety margins, as a major input for the fuel reliability analysis.

- To meet nuclear energy sustainable development objectives in the resources and waste management, generation IV reactors are mandatory and require innovative materials and fuels which resist to high temperatures and/or fast neutron flux in different environments. The selection, optimisation and qualification of these innovative materials and fuels raise critical issues concerning their in-service behaviour; utilisation of high performance Material Testing Reactors and other facilities will be necessary to fix these issues. For instance, future fission reactors as well as fusion reactors will require common innovative structural materials that could be grouped into three main categories to cover increasing operating temperature: a) 9Cr martensitic steels, including low activation versions, for applications up to 550°C; b) Oxide Dispersion Strengthened (ODS) ferritic alloys with improved thermal creep resistance to use at temperatures beyond 550°C, c) SiCf/SiC composites, constituted by stoechiometric fibres in a ceramic matrix for applications up to 1200°C. Large R&D and qualification programmes are needed in particular for the two last groups of materials.

- In addition, such a research infrastructure will contribute to build up technical skills in the nuclear industry and to train a new generation of research scientists, engineers and, ultimately, executives. Indeed, a high performance Material Testing Reactor, operated within international cooperation and complementary to other domestic research infrastructures, offers the appropriate framework to attract younger generations and to cross-fertilise international skill.

These above stakes require a sustainable and secured access to an up-to-date high performance Material Testing Reactor.

The question of the future and the availability of a state of the art reliable irradiation capacity was then set-up.

Following a broad survey within the European Framework Programs from the EC, the European community agreed that the need for Material Test Reactors in support of nuclear power plant safety and operation will continue in the context of sustainable nuclear energy.

At the same time, existing European MTRs, dedicated to the industry support, are ageing and face an increasing probability of shut down due to their obsolescence , both from the point of view of operational and safety performances. For example, R2 reactor in Sweden was shut down mid 2005.

The history of research reactors was mainly driven within national policy. As a major new trend, the implementation and access to international research infrastructures is an effective way to manage the rationalisation & optimisation of the research reactor fleet meeting requirements of safety, scientific and economic efficiency as well as training and competence management. As in fundamental physics for decades, the access to up-to-date high performance research reactors should be considered as an opportunity for several countries to obtain a top level expertise, as an alternative (to keep in operation) outdated domestic facilities.

The **Jules Horowitz Reactor** (**JHR**) copes with this context [10].

JHR is fully optimised for testing material and fuel under irradiation, in normal and non-normal conditions

- with irradiation loops producing the operational condition of the different power reactor technologies,
- with high flux capacity to address existing and future NPP needs.

JHR is designed, built and will be operated as an international user-facility because:

- Given the maturity and globalisation of the industry, domestic tools have no more the required level of economic and technical efficiency. Meanwhile, countries with nuclear energy need an access to high performance irradiation experimental capabilities to support technical skill and guarantee the competitiveness and safety of nuclear energy.
- Many research items related to safety or public policy (waste management, etc.) require international cooperation to share costs and benefits of resulting consensus.

This project is driven and funded by an international consortium gathering vendors, utilities and public stakeholders. This consortium was set up in March 2007 when the construction began. On site excavation is completed, the civil work has started in spring 2009 and the first concrete has been poured in August 2009 (see figure 10 below).The start of operation is scheduled for 2014.

At the present time, the partners of the consortium are

- Research laboratories: CIEMAT (Spain), CEA (France), NRJ/UJV (Czech Republic), European Commission, SCK/CEN (Belgium), VTT (Finland)
- Industrial organisation: AREVA, EDF, VATTENFALL

Two associated partners are also involved in the JHR: DAE (India), JAEA (Japan)

Discussions are on-going with research institutes and utilities to enlarge the JHR consortium.

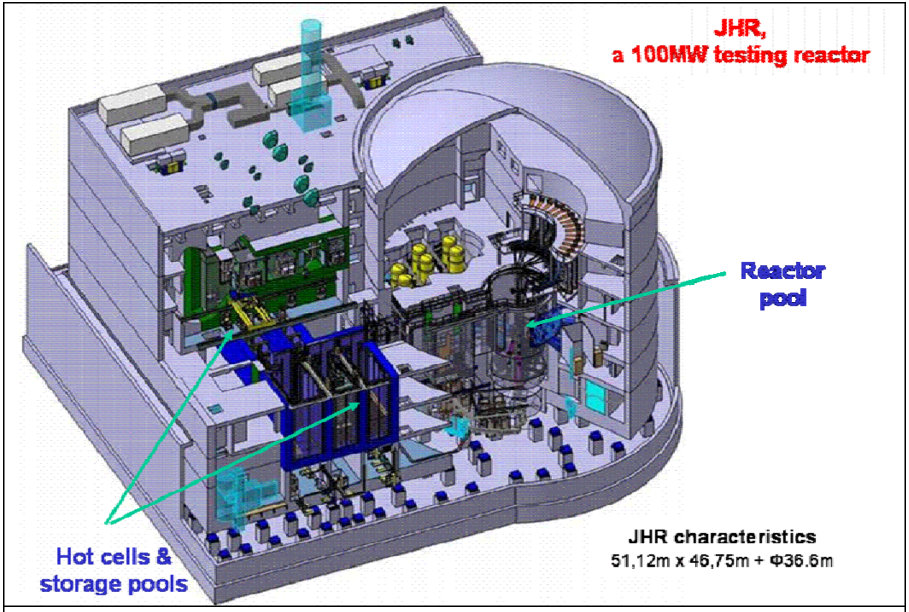
Figure 10: some view of JHR building site

First concrete of JHR (August 2009)

The JHR is a research infrastructure which performs screening, qualification and safety experiments on material and fuel behaviour under irradiation.

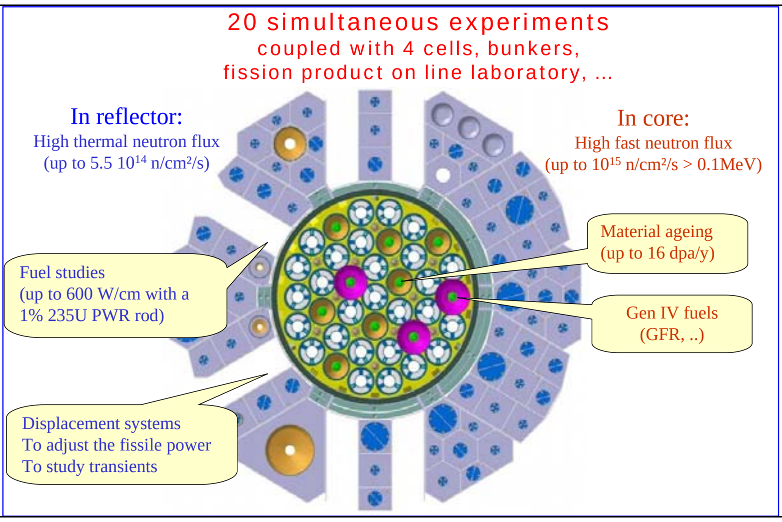
JHR is a water cooled reactor which provides the necessary flexibility and accessibility to manage several highly instrumented experiments, reproducing different reactor environments (water, gas or liquid metal loops), generating transient regimes (key for safety).

The JHR facility includes the reactor building, including core, cooling system and the experimental bunkers connected to the core through pool wall penetrations and the auxiliary building, including pools and hot cells necessary for the experimental irradiation process.



JHR layout showing the Reactor Building and the Auxiliary Building linked together by a water block connecting the core, the poles and the hot cells.

JHR core is optimised to produce high fast neutron flux to study structural material ageing and high thermal neutrons flux for fuel experiments.



The JHR core, in its core pool, is a high power density fuel rack in a vessel slightly pressurised and surrounded by a Beryllium reflector. Experiments can be implemented in the centre of fuel elements, in place of fuel elements, in the beryllium block or in water channels crossing the reflector. Experiments are connected to dedicated casemates in the reactor building through pool wall penetrations. The qualification of the JHR fuel is describes in reference [11] and [12].

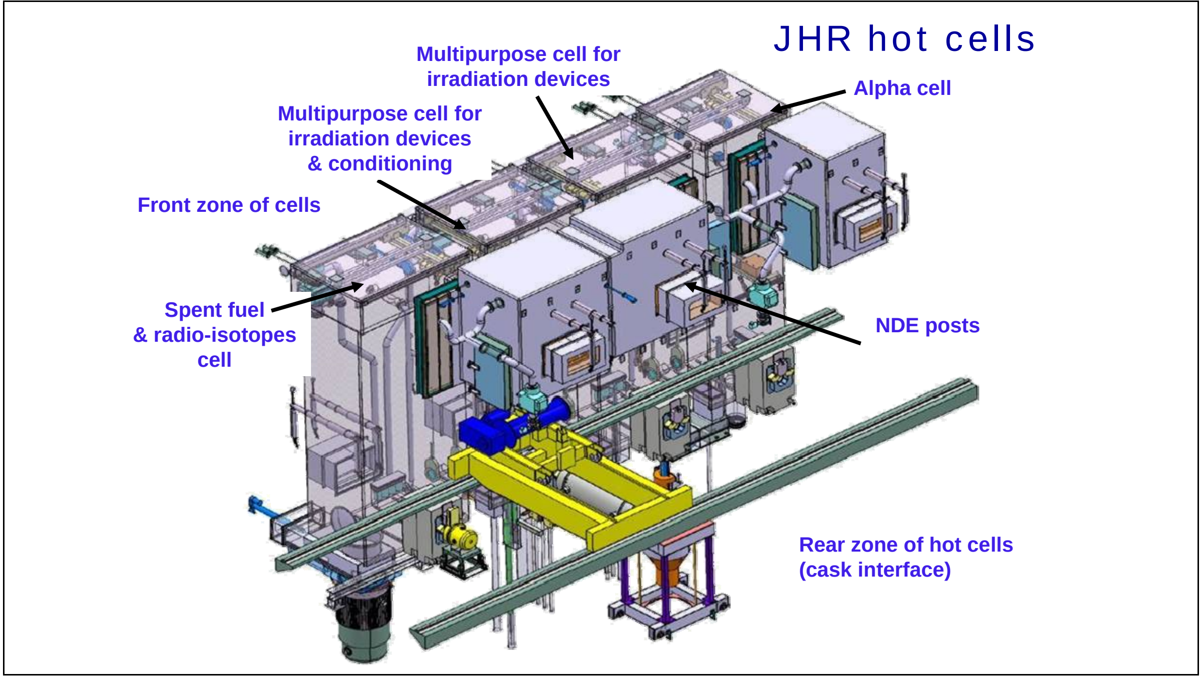
The JHR experimental capability is typically ~ 20 simultaneous experiments (in-core and in reflector) providing suited environments relevant for different reactor technologies and high neutron flux:

- Fast neutrons perturbed flux (taking into account a full experimental loading):
  - 10^{15} n/cm²/s >0.1MeV and 5.10^{14} n/cm²/s >1MeV
  - Damage per year : 16 dpa/year (8 times the PWR flux on internal material allowing to accelerate ageing)

- Thermal neutron flux: $5,5\ 10^{14}$ n/cm²/s, 600W/cm on 1% enriched fuel pin (to accelerate fuel BU and to simulate power transients)

The JHR experimental performance relies also on key out-of-core components:

- Loops for power reactors in normal or non-normal conditions
- Effective transient devices for safety studies, a major scientific challenge
- Hot cells for the current operation (preparing the experiment, non destructive exams) and alpha cell for Safety fuel experiments
- On line instrumentation and control (more data, better management, extrapolation capability with modelling)
- On line fission product measurement laboratory for gas and liquids



The reference [13] and [14] presents the development performed for the NDE benches.

VI. – JHR EXPERIMENTAL FLEET UNDER DEVELOPMENT

The design work of the JHR Experimental Device fleet is driven by identified and expected future experimental needs. Development of some devices has started. These first devices are important since they meet end-user expectation but also because they allow us to define most of the future JHR experimental standards and performances. Of course, as in any MTR, these experimental devices will evolve and additional devices will be designed according to the demand of end-users. The conception of this first fleet of devices integrates the operational experience accumulated by the existing MTR and specifically the OSIRIS one.

VI.A – Devices for material studies

Testing structural material requires high fast neutron flux while gradients generated by gamma heating are drastically minimised. Due to its high neutron flux capacity, an important gamma heating is expected in JHR when operated at its maximum power capacity.

In order to limit spurious heating from one sample to another (or from sensor to sample), aside from an **updated version of the CHOUCA device that will be called MICA in the JHR**, an in-core CALIPSO NaK integrated loop is under development (CALIPSO means In Core Advanced Loop for Irradiation in Potassium Sodium). Placed in the central hole of the fuel element, this device shall be autonomous for long-term irradiations and contains in a small volume all the components needed to ensure a forced convection in the test section.

For example, the sample–holder designed so far for the CALIPSO loop (sample carrier is currently re-designed following the demand), contains 3 experimentation bases holding 3 pre-pressurized tubular samples placed at 120° on each. The device allows us to gain quickly high fluencies thanks to a displacement per atom (dpa) rate up to 15 dpa/year.

The CALIPSO design phase is finished and some critical components (such as the electromagnetic pump or the embarked heat exchanger) are studied more in detail with the aim of launching very soon the manufacturing of prototypes.

For experiments requiring less neutron flux (and then, with less gamma power), a simpler loop operating with NaK under natural convection is developed. Material behaviour under high temperature conditions is a growing concern: the design of a gas loop in the JHR core, at high temperature (700-1200°C) and high fast neutron flux (from 1 to 5 10^{14} n/cm²/s), is considered.

VI.B – Devices for fuel studies

Different types of devices are currently being designed, driven by the type of experimental programme. As a first approach, one can classify the device design according to the solicitation applied to the fuel sample.

Water reactor fuel studies under nominal conditions

When the fuel rod failure is not an experimental objective or a risk, and when LWR conditions at the rod level are requested (temperature, pressure and coolant flow rate), the experiment will be set up preferably in a water loop called MADISON (for “Multirod Adaptable Device for Irradiations of LWR fuel Samples Operating in Normal conditions”). This loop will be put on a moving box in the JHR reflector, and will be capable of applying PWR or BWR conditions on the experimental load. This load will be constituted by a sample holder containing up to 4 instrumented PWR or BWR pre-irradiated fuel rods, with a fissile stack up of 600 mm and irradiated in a very homogeneous way. The target is to have less than 3% heterogeneity on the linear heat generation rate (LHGR) between any 2 rods.

For the current development, standard instrumentation of each rod will be a thermocouple (e.g. for fuel central temperature measurement) and a Linear Variable Differential Transformer type (LVDT) sensor connected to one end of the rod and measuring on-line a given parameter (e.g. clad diameter, fission gas release…).

The feasibility study of this loop is on-going in collaboration with the Institute for Energy Technology (IFE), operator of the Halden research reactor (HBWR, Norway).

The MADISON-type concept is likely to represent the standard attractive fuel irradiation service in JHR.

Reactor fuel studies up to limits and under non-normal situations

Research of LWR fuel product limits (e.g. ramps, internal over-pressurization, melting approach…), and post-failure behaviour studies under normal conditions (failed rod behaviour and fission product release studies), will be carried out in a loop called ADELINE (for “Advanced DEvice for testing up to LImits Nuclear fuel Elements”). The pre-design study of this LWR loop, also placed on a moving box in the JHR reflector, is completed –see reference [15]

The out-of-pile part comprises in particular the fission product and fissile material purification system. Fission product concentration in the coolant can be measured either on-line (by gamma spectrometry or delayed neutron detection) or by sampling in the fission product laboratory, thanks to a specific line working at low flow-rate.

The ADELINE design regarding neutron physics and thermo-hydraulics will offer high performance and a large flexibility. It is **largely inspired from the ISABELLE loop that is successfully used in the OSIRIS reactor**.

A dedicated loop to assess off-normal situations for sodium cooled fuel is under investigation.

Water reactor fuel studies under accidental situations

The safety experiments will represent a key service offer by the JHR. For LOCA-type experiments, the feasibility study of a dedicated capsule called LORELEI (for “Light water One-Rod Equipment for Loca Experimental Investigations”) has been started. The aim is to be able to reproduce the typical temperature time history and the quenching phase of a LOCA sequence on a single instrumented fuel rod, based on a single-effect approach.

The current LORELEI design will be able to fulfil a part of the LOCA needs of studies.

Other designs could be set up in the near future, depending on the physical mechanisms to explore and following the end-users demands. For example, it is foreseen to adapt it for tests on a small bundle, in order to assess some fuel bundle effects. For these tests, the non-destructive examination benches will be a crucial support to gain quickly a first detailed status of the tested sample.

VII.C - Preparing JHR success with OSIRIS experience

While the conception of the future experimental devices of JHR is under process, specific programs are carried out in the OSIRIS reactor to prepare the sample holders and the instrumentation that will be proposed to the users of the new reactor.

Specific papers in this conference present two experiment that are under irradiation for the CEDRIC one [16] and under conception for the MELODIE one [17]. Those experiments use innovative sample holder that allow to drive the stress that is applied to the sample, and to measure the experimental load deformation during the irradiation in a biaxial way.

In the up coming years a benchmarking program will be developed between the two reactors to insure the calibration of the JHR experimental fleet.

CONCLUSION

As indicated in this paper, the experimental capacity for testing material and fuel under irradiation stay an important topic and CEA is maintaining significant R&D programs to improve the performances of the experiments (especially putting innovation on the experimental devices such as on-line instrumentation…).

This continuous process leads to a strong feedback from the operation of OSIRIS and is of primary importance for the design of the hosting experimental systems of JHR and its NDE benches. This also means that, from technical skills point of view, the OSIRIS staff is closely linked to the JHR team –either for the definition of the operation procedures, the safety analysis or for the design of the experimental capacity.

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3. C. BLANDIN, S. LOUBIERE, S. BOURGANEL, JC. NIMAL, L. GROS D’AILLON, P. CLÉMENT "MERCI – MOSAIC: experimental tools for residual power measurement in the OSIRIS reactor" this conference

4. W. PETRY, A. ROHRMOSER, P. BOULCOURT, A. CHABRE, S. DUBOIS, P. LEMOINE, CH. JAROUSSE, J. FALGOUX, S. VAN DEN BERGHE, A. LEERNAERS, “UMo full size plate irradiation experiment IRIS-TUM – a progress report” *RRFM 2008 – Hamburg (GERMANY)*

5. M. RIPPERT, S. DUBOIS, J. NOIROT, P. BOULCOURT, P. LEMOINE, S. VAN DEN BERGHE, A. LEENAERS, W. PETRY, A. ROHRMOSER, C. JAROUSSE, "Overview on high density UMo Fuel in-pile experiments in OSIRIS" *RRFM 2008 – Hamburg (GERMANY)*

6. JF. VILLARD "Innovative Instrumentation for Research and Industrial Nuclear Facilities: in pile measurements" *IEEE Nuclear Science symposium, October 2008, Dresden (GERMANY),*

7. F. AUGEREAU, JY. FERRANDIS, JF. VILLARD, D. FOURMENTEL, M. DIERCKX, J. WAGEMANS "Piezo ceramic reliability for ultrasonic transducers in nuclear environments" *European Workshop on Piezoelectric Materials, July 2008, Montpellier (FRANCE),*

8. JF. VILLARD, D. FOURMENTEL, N. L'HULLIER, T. LAMBERT, E. MULLER "Improving High-Temperature and Fission gas Release Measurements in Irradiation Experiments" *IAEA Technical Meeting on "Rod Instrumentation and In-Pile Measurements Techniques", Sept. 2007, Halden (NORWAY),*

9. G. CHEYMOL, H. LONG, JF. VILLARD, B. BRICHARD "High level gamma and neutron irradiation of silica optical fibres in CEA OSIRIS nuclear reactor" *9th European Conference Radiation and Its Effects on Components and Systems (RADECS), Sept. 2007, Deauville (FRANCE),*

10 G. BIGNAN, D.IRACANE “The Jules Horowitz Reactor: a high performance Material Testing Reactor under construction” Nuclear Energy International (NEI-December 2008)

11 .M.C. ANSELMET ET AL "Jules Horowitz Reactor Project: status and fuel licensing process" RRFM 2009 Vienna (AUSTRIA)

12- JC. KLEIN et al "AMMON: an experimental program in the EOLE critical facility for the validation of the JHR neutron and photon HORUS3D calculation scheme" This Conference

13: D. PARRAT et al "Irradiation Facilities and examination Benches for implementing fuels programs in the future JHR Material Testing Reactor" This Conference

14: G. LE GUILLOU et al "Underwater NDE Systems in the JHR: Towards integration issues" This conference

15 S. GAILLOT et al: "The ADELINE irradiation loop in the JHR MTR: testing a LWR fuel rod up to the limits with a high quality level experimental process" This conference

16: M.AUCLAIR, L GOSMAIN, P. GUIMBAL, D. MOULIN, C. SAUDER, JF VILLARD "CEDRIC experiment: on line elongation measurement of a high temperature specimen under driven stress in the OSIRIS reactor" This conference

17 : PH. GUIMBAL, M. AUCLAIR, S. CARASSOU, P. MOILANEN, S. TÄHTINEN, JF VILLARD "MELODIE experiment: online follow-up of length and diameter evolution under controlled biaxial stress in the OSIRIS reactor" This conference

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