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IRRADIATION FACILITIES AND EXAMINATION BENCHES FOR IMPLEMENTING FUEL PROGRAMS IN THE FUTURE JULES HOROWITZ MATERIAL TEST REACTOR

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SUMMARY

Together with a Consortium gathering private and public, European and international, funding partners, CEA has launched the construction of the Jules Horowitz Reactor (JHR). This 100 MW new generation MTR will begin operation in 2014 in Cadarache, in the South of France. This MTR integrates the last safety requirements and will be a major European research infrastructure in the field of nuclear fuel and material characterization and qualification under irradiation during this century.
As the whole JHR irradiation device fleet has to be designed and manufactured, the basic design phase for a device shall be preceded by an essential work aiming to identify, and even to anticipate if necessary, the future experimental needs coming from the scientific community and the industrial companies (utilities, fuel vendors…). These needs come firstly from the mandatory steps of the nuclear fuel development process, but also and mainly from the associated planning for current fuel optimization and new fuel development, to be faced with the JHR operation.
After a first part describing a nuclear fuel development process and its implementation in the JHR, the paper will describe the results obtained in the design of irradiation devices for water reactor fuels and of examination benches, in relation with their application field driven by experimental programs. The expected main performances will be reviewed. The current status of the work and the collaboration set up around each study will be also underlined. The status of devices for irradiation of non-LWR fuel will be also presented.

1. INTRODUCTION

The current development of nuclear energy will face in the first half of this century to a specific situation characterized by:

- Operation of the standard water reactors up to their end of life, facing to aging process on irradiated materials and to maintenance of the staff expertise capability,
- Progressive commercial operation of new concepts of water reactors, using optimized fuels and plant cycle management,
- Development of innovative concepts, mainly based on fast neutron systems, either for energy production (electricity or heat) or for waste management (transmutation),
- Qualification of totally new components or materials for extreme conditions of use, such as under high neutronic flux of for fusion systems.

Moreover a continuous increasing demand exists for artificial radioisotopes production for medical use which has to be satisfied as a crucial problem of public health.

To reduce the experimental knowledge lack or to fulfill industrial needs coming from the large variety of materials and irradiation conditions to master, multipurpose research facilities such as Material Test Reactors (MTRs) are now key infrastructures, in complement of prediction capabilities gained thanks to progresses in the modeling. At the European level, several MTR facilities are under operation and able to fulfill the above demand. However this situation is not sustainable because all of European existing MTRs are aging and the running European MTR landscape could significantly change within the next decade [1].

In this context, together with a Consortium gathering private and public, European and international, funding partners[1], CEA has launched the construction of the Jules Horowitz Reactor (JHR). This 100 MW new generation MTR will begin operation in 2014 in Cadarache, in the South of France [2]. This MTR integrates the last safety requirements and will be a major European research infrastructure in the field of nuclear fuel and material characterization and qualification under irradiation during this century.

2. AN EXPERIMENTAL CAPABILITY DEFINED FROM EXPERIMENTAL PROGRAMS

As the whole JHR irradiation device fleet has to be designed and manufactured, the basic design phase for a device shall be preceded by an essential work aiming at identifying, and even at anticipating if necessary, the future experimental needs coming from the scientific community and the industrial companies (utilities, fuel vendors…). This step is not so easy because i) long term needs (comparable to the JHR construction time) are generally not expressed and ii) identified short term needs or issues shall be solved in the coming years.
With this objective a review of the future expected experimental needs has been started. This review will be based on a several step approach:

- Identification of the mandatory milestones in a nuclear fuel development process and for the product licensing acceptance, with highlighting of the common topics whatever the power reactor system. Issues caused by specific fuel design or reactor operating conditions shall be also identified,
- Evaluation of the future “nuclear fuel landscape” when the JHR will finish its calibration and test phase (2015). This first view set up by CEA experts is of course not a reference, but has to be considered as an input document for future discussions,
- Evaluation of the expected experimental R&D needs linked with the optimization, the development or the industrialization of fuel products and the associated time-frame, through test either in MTRs or in hot cell laboratories,
- Orientation of the fuel irradiation device design studies in accordance with the above needs.

This review is in progress and the highlights will be largely shared among JHR Consortium members. It will also give input for discussion among participants of the OECD-NEA Jules Horowitz International Joint Project (JHIP) which will be launched this autumn. The target is to gather research organizations and industrial companies on common interest programs, such as on i) fuel material properties basis data acquisition under neutron flux, ii) fuel product reliability and iii) fuel product safety. These programs have to focus on nuclear fuel behavior pending issues and shall be complementary of the work being carried out in other existing MTRs and hot cell laboratories within international projects. Moreover bilateral programs will cover specific issues related to e.g. the development of a new product, on-site problems pointed out by the operational experience etc.

3. DEVELOPMENT PROCESS OF A NUCLEAR FUEL PRODUCT

[1] The Consortium gathers currently (Spring 2009) several European research institutes (CIEMAT, NRI, SCK.CEN, VTT), Euratom, and three major European companies: two utilities (EDF and VATTENFALL) and a fuel vendor (AREVA). The Japanese Research Institute JAEA and the Department of Atomic Energy (DAE) from India also signed an agreement.

Four main successive steps can be identified in the development process of a nuclear fuel. Or course this order is not fixed and can slightly be adapted depending on program objectives and industrial milestones, with an overlap between the different steps.

3-1. Selection irradiations on fuel materials

The objective is to select one or a few fuel materials among a lot of candidates in order to reach targeted performances for the operating conditions of a given power reactor system. It is generally the first irradiation of the material because previous choice dealt with the experimental feedback on similar materials, theoretical approach or properties obtained on fresh material after manufacturing.

Irradiation results can be obtained on-line and in this case concern mainly temperature measurement or macroscopic properties (geometrical change…). However results are mainly obtained through post-irradiation examination (PIE) programs (microstructure evolutions, physical properties, thermal analyses…). It is worthwhile to insert in the batch a well-known reference material.

Main needs concern i) the possibility to embark a large number of samples and ii) the necessity to apply very homogeneous irradiation conditions among the samples, in particular for the temperature. For that aim the sample geometry and the enrichment can be adapted to the objective and the length of the experiment.

3-2. Characterization and understanding irradiations on fuel materials

This type of irradiation aims to gain data allowing identification and quantification of main physical phenomena occurring in the fuel material and governing its behavior under neutron flux. These allow setting up behavior laws and models and reduce parameter uncertainties. The experiment control shall be able to separate activated phenomena thanks to i) a specific irradiation protocol and ii) an instrumented sample for multiple on-line measurements: temperature, radioactive and stable fission gas and He releases, fuel creep, fuel-first barrier interaction etc…

Moreover intermediate non destructive examinations at some MTR intercycles permit to adjust some irradiation parameters (e.g. sample LHGR) or to gain results improving the experiment quality. For that aim, methods such as X and gamma tomography, neutronography or metrology are of great interest. After irradiation, data are completed by specific non destructive and destructive examinations in hot cells: metallographies and image analysis, SEM, SIMS, thermal conductivity etc…

A specific item concerns the gain of data on fuel material basic properties directly under neutron flux (diffusion coefficients, swelling, electrical conductivity…). These complex experiments lead to set up physical databases which can be usefully compared to values obtained on the material in out-of-pile conditions.

3-3. Irradiations in support to the qualification of the fuel product

This set of experiments occurred commonly after the two previous steps. It aims at verifying i) the behavior of the global fuel product (including the fuel material, the cladding and the fuel element design) and ii) that the results obtained under neutron flux separately on each component are still relevant after the industrial product manufacturing, in particular for all soliciting conditions expected in the normal life in a given reactor system.

A validation can be partially made directly in power reactors thanks to introduction of “test elements” accompanied by a close PIE surveillance program after each cycle. This test presents the advantage to respect all reactor environment parameters. However this strategy is not applicable if the qualification objective concerns irradiation conditions at the limits or not allowed in a power plant:

- Envelope operating conditions: very high burn-up, soliciting LHGR time histories and transients, power ramps,
- Plant management optimization: operation at intermediate power, cycling, innovative coolant chemistry, changes in neutronic spectrum,
- Risk of clad failure or seriousness increase of an existing failure: post-failure behavior in nominal conditions, heavy nuclei release, fuel centerline melting approach,
- Programs linked with margins and safety criteria: internal over-pressurization (or “lift-off”),

- Reactor system not existing or not operated at an industrial scale.

For these situations, MTRs are needed. However the whole fuel element behavior validation (thermal-hydraulics and thermal-mechanics issues, structure components ageing…) is not considered in this paper.

3-4. Safety tests

This set of experiments is essential for scientific stakes (fuel behavior modeling at the highest integration level) and for operational and industrial demands (fuel product licensing). It can be implemented either in dedicated reactors (such as NSRR and Cabri) for integral tests but also in parallel in MTRs for separate effect experiments aiming at covering a part of the issues (mainly database acquisition and phenomenology understanding). Parametric and understanding tests can also be implemented in hot cells if reactor conditions are not needed, or with out-of-pile facilities on fresh materials.

Three types of experiments can cope with strategy:

- Cooling lack simulation: LOCA-type tests, hydraulic quenching and post-quench material behavior, fission gas release thanks to thermal analyses,
- Power injection: RIA-type tests or more globally speaking fast transients, and core power oscillations,
- Fuel-coolant energetic interaction: fuel dispersion, steam shock wave, hydrogen production,
- Fuel severe degradation: fission product release, transport and deposit, fuel delocalization and melting.

These tests are very short and highly automated; and the test channel is heavily instrumented. The rest of the device can be space-consuming. More generally speaking these tests require a specific environment and are challenging and demanding regarding integration constraints, in particular if other experiments are present such as in a MTR.

3.-5. Fuel development process summary

The two next figures illustrate and summarize the fuel development process regarding the sample (fig. 1) and the type of experiments to implement in MTRs (fig. 2) in the case of a LWR fuel product.

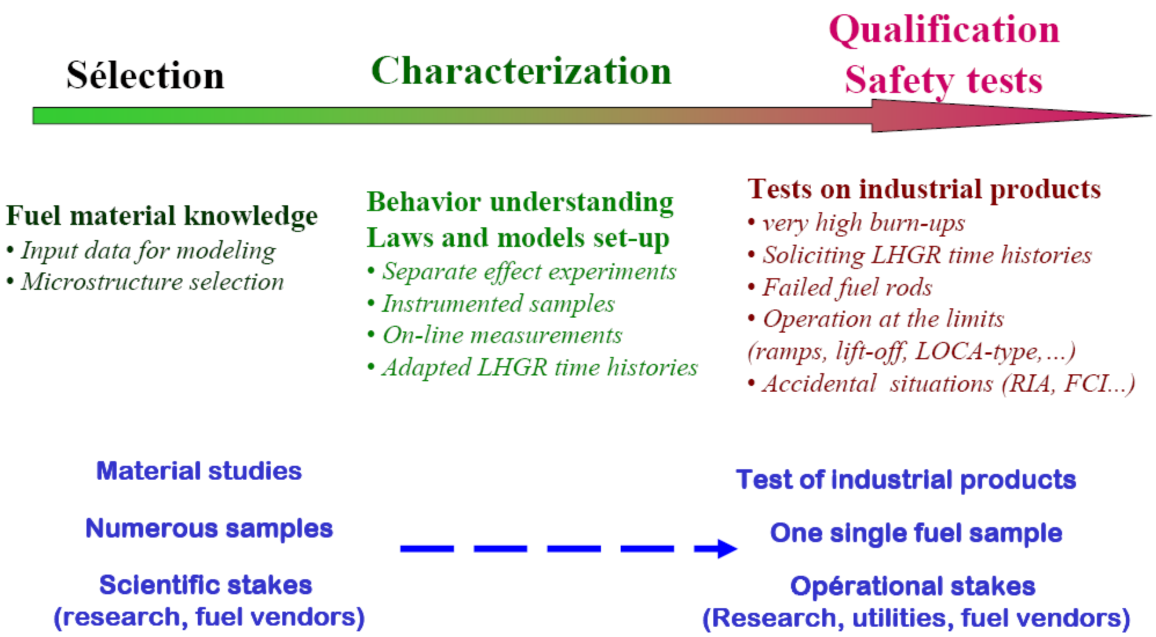

Figure 1 : Summary of a LWR fuel development process – Experimental sample issues

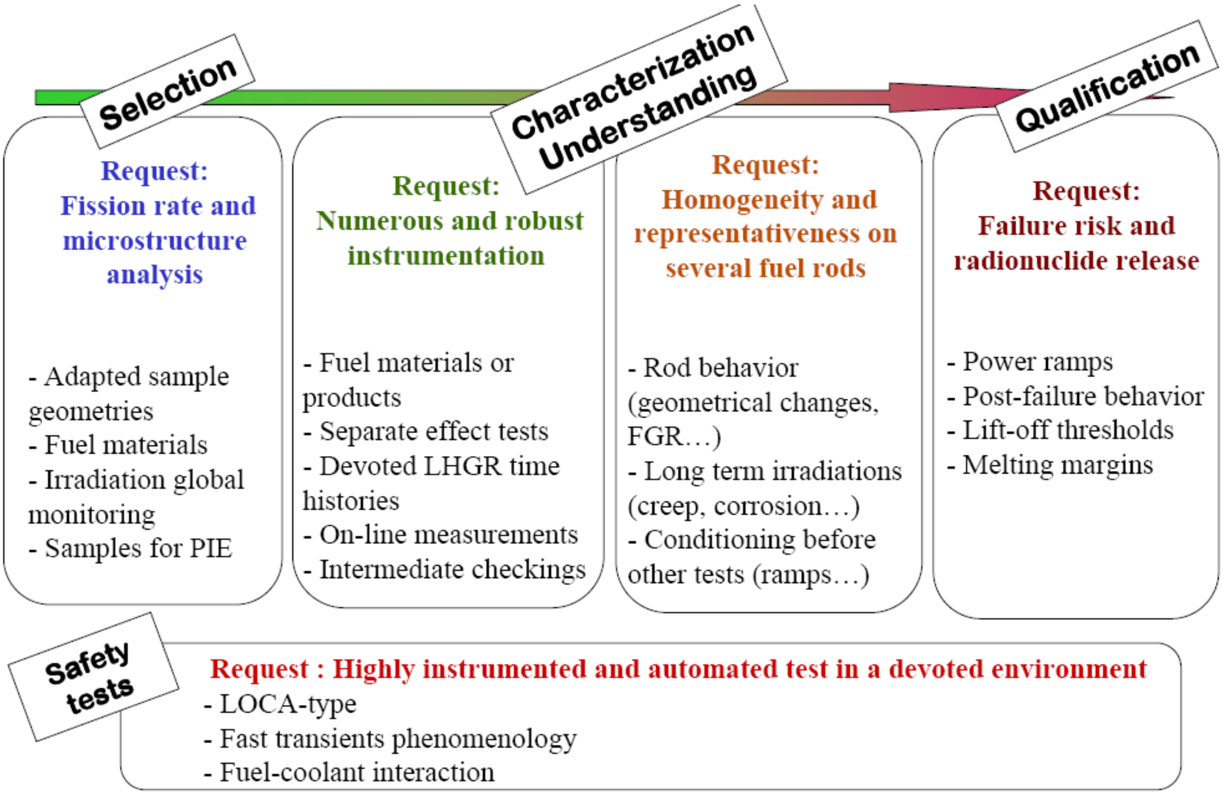

Figure 2: Summary of a LWR fuel development process – Experiment needs in MTRs

4. CONSEQUENCES ON THE FUEL IRRADIATION CAPABILITY DESIGN IN JHR

A first assessment of the expressed experimental needs has been made for the LWR fuel domain. It allows setting up a first global landscape of the expected fuel irradiation device park. This fleet global view is summarized in the table below.

Irradiation type	Suitable irradiation device type	Mandatory JHR support equipments (*)	Remarks
Selection	Capsule	• Gamma and X tomography benches	Design and cooling adapted to sample geometry
	Multi-rod loop	• Gamma and X tomography benches	Large embarking capacity Loop used in the cheapest mode
Characterization and understanding	Boiling capsule	• Gamma and X tomography benches • Neutronography bench • Fission Product Lab. (gas sweeping)	Simple and passive device Welcoming cumbersome instrumentation
	Multi-rod loop	• Gamma and X tomography benches • Neutronography bench	Long term irradiations

Support to qualification	Single rod loop with low failure risk	• Gamma and X tomography benches • Neutronography bench	• Soliciting LHGR time histories • Power ramps • Internal free volumes sweeping
	Single loop with failure or high failure risk	• Gamma and X tomography benches • Neutronography bench • Fission Product Lab. • Radiochemistry Lab. • Alpha hot cell	• Post-failure behavior in normal operation • Lift-off • Melting limits approach
	Multi-rod loop with low failure risk	• Gamma and X tomography benches • Neutronography bench	Long term irradiations (corrosion, crack propagation…)
Safety tests	Devoted capsule or single rod loop	• Gamma and X tomography benches • Neutronography bench • Fission Product Lab. • Radiochemistry Lab. • Alpha hot cell	LOCA-type tests
	Devoted capsule		Fast transient tests
	Devoted capsule		Fuel-coolant interaction tests

(*) These equipments are presented in paragraphs 6 and 7.

Table 1: First view of the expected JHR fuel irradiation devices in the LWR fuel field

Of course this list is evolutionary and will be improved by i) completing this assessment and ii) taking into account new emerging needs and new programs to implement at an international or bilateral level.
For non-LWR fuels, and mainly for Gen IV fuels, the scientific and operational needs specifications are progressively set up. The programs to be implemented in JHR shall be in accordance with the other material test reactors planned in Europe in this field (sodium or gas coolant technologies…). With that aim, and as a very first analysis result, the JHR experimental field will be probably significant and will take into account in priority tests at the limit conditions of the nominal operation and some safety tests.

5. STATUS ON THE JHR FUEL IRRADIATION DEVICE STUDIES

5-1. Overview of the fuel device design studies

The design work of the JHR irradiation device fleet is driven by identified and expected future experimental needs. Consequently, the starting of the basic design and/or the detailed design phases is related to the maturity of the demand, but also depends on the complexity of the device to set up. Consequently the device studies presented in this paper correspond to the current view of the long-term needs, which will be likely expressed during the coming decades.
This development is a first initiative towards the set-up of the whole JHR experimental device park. It will also depend on the future irradiation market, and on the strategy applied by the JHR Consortium members or by the International Joint Program Committee. In this context it is important to make the difference between the "housing device" (the in-pile containment of the device) associated with the external circuits (generally located inside a cubicle) and the sample-holder which is closely connected to the experimental objective of one given experiment.
Studies are based on an improvement strategy of the device performance and experiment quality compare to current programs implementation: precise knowledge and control of the local irradiation conditions on the sample (linear power, temperature field, coolant flow rate…) thanks to on-line measurements implemented as systematically as possible and with a mastered uncertainty.

The project currently focuses on a set of 3 fuel test device families. The objective is to have this set of devices operational at the reactor operation starting, at least on a first basis version.

5-2. The MADISON LWR irradiation loop

The first device family deals with LWR (PWR and BWR) fuel irradiation under nominal and representative conditions (thermal-hydraulical and chemical). When the fuel rod failure is not an experimental objective or a risk, and when normal LWR conditions at the rod level are requested (linear heat generation rate LHGR, coolant temperature and pressure, chemistry…), the experiment will be set up preferably in the MADISON water loop (Multi-rod Adaptable Device for Irradiations of experimental fuel Samples Operating in Normal conditions). The main objective is to allow comparison between several instrumented rods irradiated in the same conditions during (if necessary) a long-term irradiation. The variation in the fuel properties (microstructure, mechanical properties, fission gas release…) in relation to the burn-up or the Linear Heat Generation Rate (LHGR) will be investigated, along with slow power variations representative of slow transient phenomena in power reactors. Long-term irradiations (up to 3 years) are also targeted. They will investigate clad corrosion under irradiation or crack initiation. Moreover, irradiation of several samples for conditioning purpose before a ramp test is also of great interest.

The experimental load will be constituted by a sample holder embarking up to 4 instrumented PWR or BWR-type geometry pre-irradiated fuel rods, with a fissile stack up to 600 mm. Of course 2 half-rods can replace each rod, if comparative or statistical results are a stake. The standard instrumentation of each rod will be a thermocouple (e.g. for fuel central temperature measurement) and a Linear Variable Differential Transformer type (LVDT-type) sensor connected to one end of the rod and measuring on-line a given parameter (e.g. clad diameter, fission gas release…).

Requested performances in the test channel (sample and nearby environment) are the following:

- Homogeneous neutron flux (a less than 3% heterogeneity between any two identical fuel rods is targeted). A lot of neutronic calculations have been carried out at CEA in order to define the best rod array configuration (see figure 3 below),
- Large range of total (i.e. fissile + gamma) LHGR: e.g. up to 40 kW/m for very high burn-up fuels (equivalent 1% ^{5}U fresh PWR UO_2 fuels), with mastering of the gamma heating contribution,
- High precision measurements (a less than 5 % precision due to thermocouples and flow-meter is expected for the thermal balance),
- Production of standard chemistry of LWR power reactors as well as specific chemistry (e.g. Hydrogen Water Chemistry or Noble Metal Water Chemistry for BWR).

The in-pile part of the experiment will be installed in a reflector position of the JHR reactor on one of the displacement systems [2]. It will be made of a pressure flask and an irradiation rig which will carry the experimental fuel rods and the measurement sensors. This in-pile part will be connected to a loop system providing the adequate thermal- hydraulics (temperature, pressure, velocity) and chemical conditions that are representative of power reactors (PWR or BWR, depending on the experiment). Some components of the loop system will be installed out-of-pile in a dedicated experimental bunker of the reactor building.
The feasibility study of this loop is in progress in collaboration with the Institute for Energy Technology, operator of the Halden research reactor (HBWR, Norway). The MADISON-type concept will likely represent the standard performing and commercially attractive fuel irradiation service in JHR.

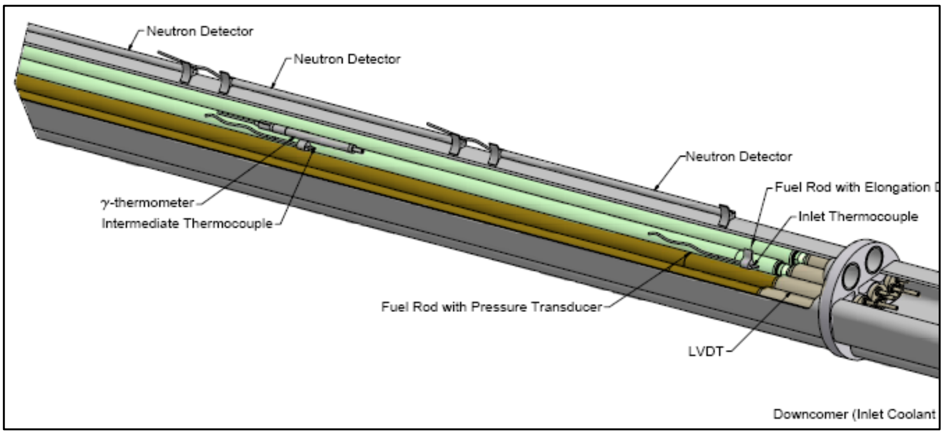

Figure 3: Schematic view of the MADISON test channel (IFE drawing)

5-3. The ADELINE LWR irradiation loop

The second family concerns also LWR fuel irradiation but the objective is to test the fuel beyond the dimensioning criteria in order to evaluate the failure thresholds or the fuel behavior under abnormal conditions (but not in accidental conditions). Research of fuel product limits (power ramps, internal over-pressurization or gas sweeping, fuel melting approach…) and post-failure behavior studies in normal conditions will be carried out in the ADELINE loop (Advanced Device for Experimenting up to Limits Nuclear fuel Elements). The loop design is an improved performances “mix” of the ISABELLE 1 loop (operating in the Osiris MTR) and of the JET POMPE loop (operated until 1999 in the Siloé MTR), which offered successful results and experimental feedback for power ramps [3] [4] and failed fuel behavior [5] programs. Two versions of this device (a simplified one and a full possibility) could be developed, depending on the demand and the failure risk, in order to optimize the implementation and the service offer for customers.
It will offer high performances for LHGR (target of 50 kW/m at the nominal JHR power with a 1% ^{235}U fresh UO_2 PWR fuel rod) and sample temperature control. It is designed for management of a degraded fuel rod (tight connection to the so-called “JHR alpha hot cell”) and for measurement of released activity (specific gas and coolant lines leading to the fission product laboratory). The basic design study of this LWR loop has been completed end of 2008 thanks to a contract with AREVA and now the detailed design phase has started.

This loop is described more in details in [6], other paper presented at this conference.

5-4. The LORELEI LWR capsule

The third and last family is devoted to the phenomenology of the thermal-mechanical behavior of a LWR rod under LOCA condition, thanks to the study of the LORELEI capsule (Light water, One Rod Equipment for LOCA Experimental Investigations). The experimental target is to be able to reproduce the temperature time history and the quenching phase of a LOCA sequence on a single instrumented fuel rod. The scientific target is mainly to understand the fuel thermal-mechanical behavior and to quantify the fission product source-term release. The design will be thought for welcoming tests on a small bundle. The device itself will be heavily instrumented and capable to manage the post clad burst and the post quenching phases [7].
This equipment will consist in a pressurized (up to 130 bars) in-pile thermo-siphon able to cool a unique fuel sample with thermal conditions representative of current LWR power reactors. It will be equipped with a gas injection able to rapidly dry-out the fuel rod and simulate LOCA transient. An electrical heater implemented in the sample holder will allow to get a homogeneous temperature distribution and a neutron screen can be used to flatten the neutron flux profile along the fuel sample. At last, water can be re-injected in the device to simulate the

quenching process. This design takes profit from the FLASH and FLASHMOX LOCA programs implemented or designed in the Siloé and Osiris MTRs respectively in the 80's and 90's, but has evolved to take into account current LOCA phenomenology issues.
A typical experimental process in this device will consist in a preliminary re-irradiation of the sample (several days with maximum linear power of 20 kW/m) in order to produce a representative Fission Product inventory. It will continue with a dry out of the fuel sample simulating the Loss of coolant, a heat up phase of the fuel and a quenching by water injection. This device will allow investigating ballooning and burst of the fuel cladding (the inner pressure of the fuel rod can be monitored to that purpose), clad corrosion phenomena (oxidation and hydriding), post quench behavior and fission gas release (to that purpose, the device will be connected to the Fission Product laboratory).
In 2008, the technical specifications were written, taking benefit of experiences of CEA teams involved in LOCA studies. In summer 2009, the design study of this device has been contracted with the French Nuclear Safety Research Institute IRSN. It starts with a preliminary design phase that will aim at proposing a first concept and demonstrating its ability to comply with specifications.

5-5 Other LWR fuel irradiation devices planned to be designed
The JHR reflector will also welcome standard boiling capsules for one instrumented LWR experimental fuel rod. Placed either in a fixed location or on a displacement system, it will be adapted to experiments, which don't necessitate representative LWR conditions outside the rod. The natural boiling conditions allow a large place around the rod, and this configuration is favourable for implementing fragile or cumbersome instrumentation (e.g. on-line axial and circumferential rod diameter measurement by metrology, as carried out by the DECOR sample-holder made by CEA). This type of device is also suitable for welcoming complex irradiation loads such as measurement of in-pile basic properties of the fuel.
Small irradiation capsules with static gas gap around the sample are also foreseen. This type of device will be suitable for irradiations on small fuel samples with adapted geometry, for microstructure selection or material basis data obtaining.
Finally, it is worthwhile to point out that the MADISON-type concept (see § 5.2), could evolve and be adapted to other environment conditions, such as for example a unit placed in a peripheral in-core position.
To be complete, one can mention that other devices are under development in support to experiments, such as fast and thermal neutron fluxes and gamma heating measurement devices.

5-6. Status of non-LWR fuel irradiation devices
Innovative development of a new generation of materials and fuels, which resist to high temperatures and fast neutron flux in different environments, is necessary for the development of future Gen IV reactors. New fuels for the different Gen IV systems need also to be characterized or qualified in research reactors. As the demand is less mature than for LWRs, the on-going fuel device studies address four topics [8]:

- Minor actinides burning: Parametric neutronic studies aiming at identifying the best locations in the JHR core or reflector for transmutation targets behavior studies. The objective is mainly to be able to obtain the representativeness of ratios such as {displacement per atom rate / fission rate}, and {He production rate / fission product rate},
- Sodium cooled reactors: A test device dedicated to fuel behavior and fission product releases under off-normal operating conditions,
- Gas thermal system fuels: This topic addresses high pressure and high temperature gas rig designed for the irradiation of compact stacks in the JHR reflector. The stack is swept by an inert gas at low flow rate to route the released fission gases to the fission product laboratory for quantitative measurements. A feasibility study has been performed in a European collaboration frame.
- Gas fast reactor fuels: The conceptual design of a gas rig or a gas loop in the JHR core has started. The chosen design has to cope with JHR constraints and will depend on the evolution of the demand. For this aim, the experimental feedback gained from the IRRDEMO experiment in BR2 will constitute a great added value.

6. NON DESTRUCTIVE EXAMINATION BENCHES IN THE JHR

The JHR experimental process includes also non-destructive examination (NDE) stands which aim is to increase the experiment quality through NDE on full devices or sample holders. To take profit from measurement means located inside the MTR facility is also of great interest in terms of result quality and time to result. Main objectives are:

- Initial checking of the experimental load state just before the beginning of irradiation (after transportation or insertion in the device),
- Adjustment of the experimental protocol after a first irradiation run (sample evolution, power tuning…),
- On the spot monitoring of the sample state after a test on the close-by stand located in the reactor pool and with limited handlings (e.g. geometrical changes after an off-normal transient, quantification of short half-life fission product distribution…),
- Completion of the post-irradiation examination (PIE) program.

6-1. Underwater NDE benches

The NDE means will involve two sets of benches. The first one concerns the examinations on the experimental sample still within the test device. These NDE benches will be therefore underwater and located in the pool of the reactor and in a storage pool. The non intrusive scanning systems developed on underwater NDE stands are:

- A neutron imaging system using the neutrons escaping from the core at the mid- plane level. A picture of the object is reconstructed from the attenuation of neutrons through the scanned object. This test stand is located on the reactor pool flooring,

- 2 photon imaging stands located in the reactor pool for the first one and in the component storage pool for the second one. These 2 stands are equipped with both gamma emission and X-Rays transmission imaging systems set on a same mechanical bench and using a dual penetration. The Gamma photons used are those self-emitted by the radioactive object (see figure 4) since X-Rays require a dedicated generator as a Linac (Linear Accelerator) for instance installed behind the pool wall (see figure 5).

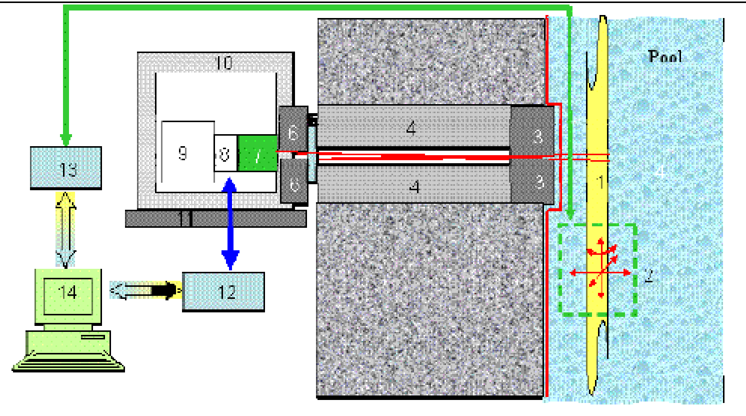

Figure 5: Schematic view of gamma emission system	
1 Object	8 Cooling system
2 Moving tables	9 Preamp.
3 First collimator	10 Shielding
4 Tubing	11 Support
5 Filter	12 Data acquisition
6 Second collimator	13 Position controller
7 Detector	14 Test supervision

Figure 4: Schematic view of the planned JHR gamma emission tomography system

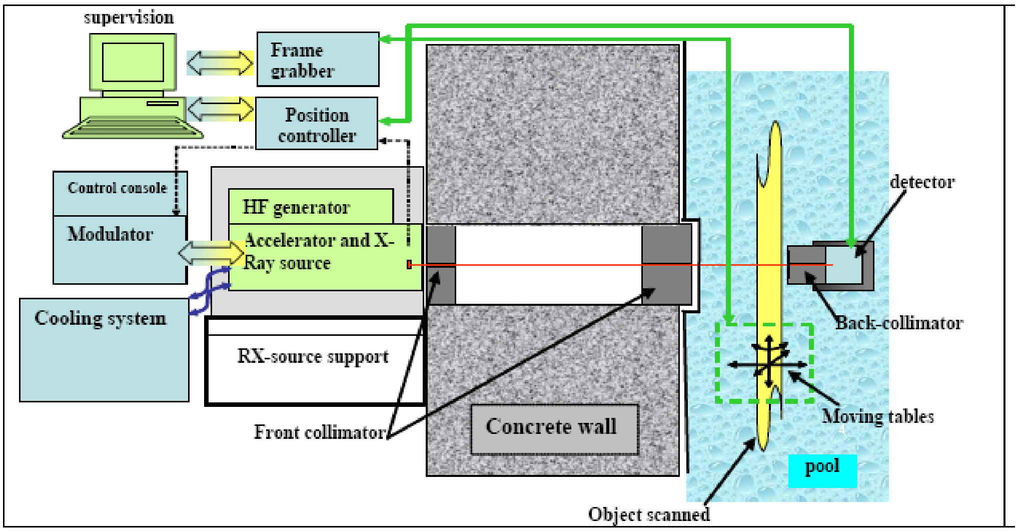

Figure 5: Schematic view of the planned JHR X-Ray transmission tomography system

The design phase of the two underwater photonic imaging stands started at the end of 2007 in collaboration with VTT (Finland). These systems will be respectively installed in the reactor pool (for experiments with short decay or for quick measurements) and in the storage pool of nuclear auxiliary building (for longer examinations such as tomography). They should be adaptable for all sorts of experimental devices, even still lead-connected to ground-based experimental cubicles for some of them.

6-2. NDE benches in JHR hot cells

The second set of benches concerns the examinations on the experimental sample itself after having been removed from the test device. These NDE benches will be placed into the two hot cells dedicated respectively to fuel and to material sample handlings. These hot cells are located in the auxiliary building, and their sizes are 3,4 x 2.5 x 4.2 m^3 and 4 x 2,2 x 4.2 m^3 for respectively material samples examinations and fuel samples examinations (see figure 6). The objective is to collect the standard set of data, such as photographic inspection, metrology, corrosion thickness measurement, crack identification, gamma scanning, X-ray tomography imaging,…

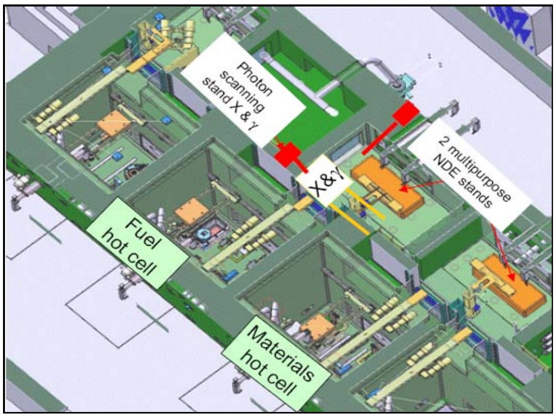

Figure 6: Multipurpose NDE benches for fuels and materials expected in JHR hot cells

Other uses associated with the experimentation are also foreseen in these hot cells such as instrumentation implementation (thermocouple, pressure gauge...) or instrumentation repairing on sample or sample holder. The accurate handling of small components and / or samples will be taken into account in the design of the equipments and in the characteristics of the remote manipulators.

Such first on-site PIE programs will be of course completed by destructive examinations programs in hot cell laboratory, which participate also strongly to the success of the experimental process.

7. LABORATORIES IN SUPPORT TO THE FUEL EXPERIMENTAL PROCESS IN JHR

The JHR facility will include several laboratories in support to the experimental process. Some of them have an operational objective because they will be devoted to:

- Reception, final assembling or checking of new components or devices, outside the controlled area,
- Interventions on already slightly irradiated materials (maintenance, calibration…) in controlled area. However, if the dose rate or the contamination risk in not negligible, the work will be done in the large material and fuel hot cells of the facility.

Two other laboratories will be closely associated to the scientific objectives of the fuel experiments:

- The fission product laboratory (see figure 7): This exceptional infrastructure will be solely devoted to the on-line and delayed measurement of radioactive and stable fission products, their temporary trapping for further measurements, and their purification and storage as a waste. So far the measurement capability will be based on the on-line gamma spectrometry technique and on Delayed Neutron Detection. Two experimental cells will be devoted to water coolant, and two others to gas as a coolant or as a sweeping fluid (at low and high activity level respectively).

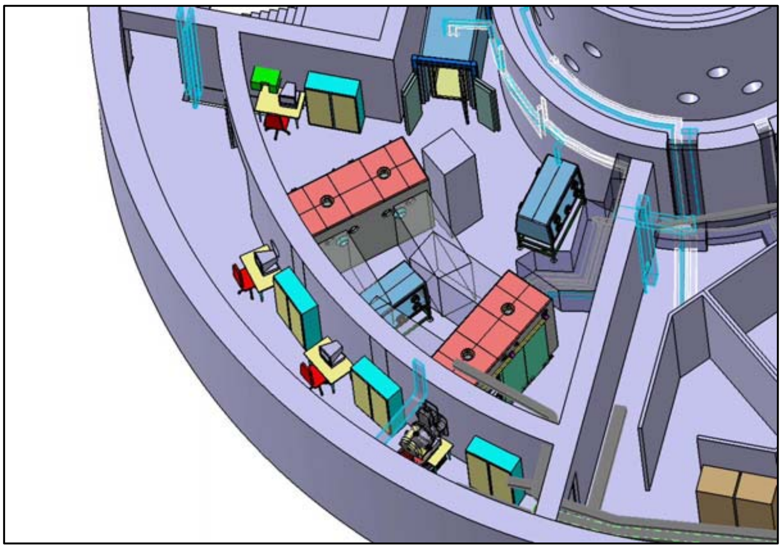

Figure 7: Schematic of the JHR fission product laboratory

- The radio-chemistry laboratory: this infrastructure will welcome all delayed physical-chemical or nuclear measurements on radioactive or inert fluids. Although the final equipment is under design, one can mention gamma spectrometry, mass spectrometry, atomic absorption spectrometry, tritium measurement… as standard techniques to install. In this laboratory will be also controlled the chemical characteristics of the used coolants.

8. CONCLUSION

The work carried out on the fuel JHR irradiation device design and presented in this paper is driven by identified and expected future experimental needs. The design priority is dependent from:

- The maturity of the demand, from the scientific community and from utilities and the industry,
- The needs and the time-frame expressed by the members of the JHR Consortium and the participants to the collaborative JHIP,
- The complexity of the device, this means the time needed by the design and the manufacturing phases.

As a consequence, the current work is the first step towards the final JHR experimental capability, and future evolutions or development of new devices will likely occur. Depending on the demand, these evolutions will concern either the housing device and the out-of pile circuits, or the sample holder and its integration in the housing device.

The first devices, which could be operated on the basis of a simplified version, will allow the implementation of a large set of programs that will be discussed in depth within the Members and the international community. These programs will require the developments of suited and dedicated sample-holders and associated instrumentation. These developments are generally not managed within the JHR project.

Importance of the international collaboration for designing the JHR devices and for driving possible evolutions on the first designs is essential. This collaboration has already taken place within the European Community thanks to the Integrated Infrastructure Initiative Program “MTR+ I3”, which end at the end of September 2009. It will progressively take a more important place by identification of future market evolutions, and by the strategy applied by the Consortium members and the JHIP. To participate to these organizations now is a relevant opportunity for a win-win approach, gathering needs and developing suitable devices fulfilling them, and before to fix the design.

REFERENCES

[1] C. Vitanza, D. Iracane, D. Parrat
"Future needs for material test reactors in Europe (Feunmarr findings)"
Proc. of 2003 Research Reactor Fuel Meeting (RRFM 2003), March, 9-12, 2003, Aix-en-Provence (FR)

[2] D. Iracane, G. Bignan, S. Loubière
"MTR in France; the transition from OSIRIS to JHR"
12th International Group On Research Reactors (IGORR 12), October, 28-30, Beijing (CN)

[3] A. Alberman, M. Roche, P. Couffin, S. Bendotti, D. Moulin, J.L. Boutfroy
"Technique for power ramp tests in the Isabelle 1 loop of the Osiris reactor"
Nuclear Engineering and Design, 168 (1997) 293-303

[4] C. Mougel, B. Verhaeghe, C. Verdeau, S. Lansiart, S. Béguin, B. Julien
"Power ramping in the Osiris reactor: database analysis for standard UO2 fuel with Zy-4 cladding
OECD Seminar on Pellet-clad interaction in water reactor fuels, March, 9-11, 2004, Aix en Provence (FR)

[5] D. Parrat, A. Harrer
"Failed high burn-up MOX fuel performance: The EDITHMOX 02 analytical irradiation"
Int. Conf. on Light Water Reactor Fuel Performance, April, 9-13, 2000, Park City (Utah-USA)

[6] S. Gaillot, D. Parrat, G. Laffont, C. Garnier, C. Gonnier
"The ADELINE irradiation loop in the Jules Horowitz MTR: Testing a LWR fuel rod up to the limits with a high quality level experimental process"
12th International Group On Research Reactors (IGORR 12), October, 28-30, Beijing (CN)

[7] S. Gaillot, D. Parrat, C. Gonnier, J.P. Chauvin
"Fuel safety experiments in the Jules Horowitz reactor: Dedicated loops for LOCA - type transients"
Int. Conf. on the Physics of Reactors: "Nuclear power: a sustainable resource" (Physor 2008), September, 14-19, 2008, Interlaken (CH)

[8] C. Gonnier, D. Parrat, S. Gaillot, J.P. Chauvin, F. Serre, G. Laffont, A. Guigon, P. Roux
"Development status of irradiation devices for the Jules Horowitz reactor"
2008 Research Reactor Fuel Meeting (RRFM 2008), March, 2-6, 2008, Hamburg (DE)