

TRTR-2005/IGORR-10 Joint meeting

12-16 September 2005

Gaithersburg, Maryland, USA

Jules Horowitz Reactor

General layout, main design options resulting from safety options, technical performances and operating constraints

JP. Dupuy¹, G. Perotto², G. Ithurrealde³, C. Leydier¹,
X. Bravo⁴

¹ AREVA-Technicatome, JHR Project, 1100 Av. JR Guilibert Gauthier de la Lauzière – 13791 Aix-en-Provence

² AREVA-Framatome, JHR Project, 1100 Av. JR Guilibert de la Lauzière 13791 Aix-en-Provence

³ EDF, JHR Project, 1100 Av. JR Guilibert de la Lauzière 13791 Aix-en-Provence

⁴ COMMISSARIAT A L'ENERGIE ATOMIQUE, 13108 Saint-Paul-lez-Durance cedex, FRANCE

ABSTRACT

CEA is planning to set up a new Material Testing Reactor (MTR) named the Jules Horowitz Reactor (JHR) at Cadarache (France) by 2014, as a user-facility open to European and international collaboration. The design studies of the Jules Horowitz Reactor have been subcontracted to a group which includes Technicatome (Areva Group), Framatome (Areva Group) and EDF.

The JHR will be a tank pool type reactor using water as coolant and moderator. The reactor has been designed to allow irradiation with a large thermal and fast neutron fluxes required to support generation 2 and 3 reactors and to develop generation 4 technologies. It will offer large possibilities for technological irradiation needs (provisions to facilitate adaptability of reactor configuration to experimental programmes evolution, flexible experimental capacities, radio-isotopes production). A high level of safety, based on a defence-in-depth approach under best current practices, is implemented with special attention to experimental constraints.

This paper presents the JHR general layout and focuses on the main design options of reactor building and nuclear auxiliaries building, resulting from technical performances, safety options and operating constraints. Emphasis is placed on technical choices specific to JHR, for instance using aseismic bearing pads for nuclear building isolation, taking into account the experimental devices contribution in design, using pre-stressed concrete containment shell with metallic liner on the dome, closed reactor coolant system inside open reactor pool, dedicated pools, cells and laboratories.

CONTEXT

The JHR project objective is the construction of a new Material Testing Reactor (MTR) in Europe by CEA with European and international partners (utilities, vendors, public laboratories, European Commission and states) to study the behaviour of nuclear materials and fuels under irradiation.

This reactor will also contribute to European production of radioisotopes for medical use.

JHR will be settled in the CEA centre at Cadarache and will benefit from the infrastructures in this centre (hot laboratories, etc.). Start of operation is planned for 2014.

The JHR is targeting significant improvement in performances and service rendered, under cost constraints. The JHR project is thus characterised by special requirements for neutron flux performances, experimental capacity and flexibility. This new facility takes current safety requirements into account and the design incorporates an approach to controlling investment costs.

The engineering is carried out by an integrated team of about a hundred engineers and technicians from Technicatome – Framatome-ANP and EDF. This team provides a panel of specialists to implement techniques as diverse as those of reactors, experimental resources, laboratories, cells and civil engineering.

So-called definition studies between 2003 and 2005 are providing a consistent design fulfilling required technical performances.

THE JHR PROJECT SCOPE

The JHR copes with the context of the ageing of European research reactors. Designed in the 1960s, these reactors will be fifty years old in the next decade and will be gradually shut down due to their obsolescence.

Given firstly the lasting nature of needs and secondly the time required to design and create a new facility of this type, a new technological irradiation reactor (Material Testing Reactor – MTR) must be built in Europe by now.

This reactor with an intended service life extending to the major part of the 21st century should offer extended, high-performance experimental capacity to respond to the industry's short- and medium-term (support for existing reactors and renewal) and long-term (development of new reactor systems) needs.

In this framework, as a technological irradiation reactor, the JHR is designed to be flexible tool to perform experimental irradiation for the various power reactor technologies and generations.

The JHR platform will incorporate all the equipment required for experimental irradiation in its nuclear unit, in particular, reception and dispatch capacities for the various types of samples with capacity of interim control and non-destructive tests.

As a summary, this new facility includes the following:

- a high-performance, flexible reactor capable of providing damage of up to 16 dpa per year on materials and high-flux reflectors capable of a linear power of 600 W/cm on a PWR-type rod at 1% residual enrichment.
- hot cells with an alpha-specific cell for use on all operations on degraded samples,
- non-destructive testing capacity,
- chemical and dosimetry laboratories,
- hot and cold workshops.

This presentation focuses on the key points in the facility design.

PERFORMANCES

To cover needs of existing and future power plants, JHR will provide high neutronic performances for both the thermal flux and the fast flux:

Max. effective fast flux in core on sample ($E > 0.907$ MeV)	$5.5 \cdot 10^{14} \text{ cm}^{-2} \text{ s}^{-1}$
Max. effective thermal flux in reflector on sample ($E > 0.625$ eV)	$4 \cdot 10^{14} \text{ cm}^{-2} \text{ s}^{-1}$
Max. damage to material samples in core	16 dpa/year
Max. linear power on fuel sample in reflector (1% enriched irradiated fuel)	600 W/cm

(calculation results for operation at 100 MW power with UMo fuel)

The above neutron fluxes are given for a consistent computation of the core loaded with 28 experiments. The so-called effective fluxes are significantly higher than the one produced by currently existing MTRs.

The so-called effective neutron fluxes are significantly higher than the one produced by most existing MTRs.

EXPERIMENTAL CAPACITY

Experimental programmes impose a set of constraints relating to flux or spectrum control, temperature or power control, possible control of mechanical stresses and possible control of the chemistry of the coolant medium on the irradiated samples.

In this context, JHR is designed to accommodate a very wide spectrum of irradiation devices such as simple sample holders, pressurised and non-pressurised instrumented capsules, up to test loops with coolant recirculation, highly instrumented and able to reconstruct the environmental conditions of the various reactor systems tested: light or heavy water, gas, liquid metals.

The facility is sized to process 25 experiments simultaneously during a reactor cycle. This capacity may be increased to 40 in special configurations (large core geometry – see further on) ; possible swap between these two configurations meet the need of consistency between the JHR services and long term evolution of the market.

At reactor level, this capacity is spread between more than 10 experimental emplacements available simultaneously in the core and more than 12 experimental emplacements available simultaneously in the reflector, among which half on displacement devices. Special additional emplacements in the reactor are intended for the production of artificial radio-isotopes.

The JHR encompasses integrated experimental resources for improving the experimental capabilities :

- an on-line measurement laboratory for fission products,
- a dosimetry laboratory
- material and fuel non-destructive test stations linked directly to the facility's hot cells.

The facility includes a block of 4 hot cells: two multi-purpose beta-gamma cells to manage the experiments, one alpha cell and one cell for conditioning and evacuating the artificial radio-isotopes and irradiated fuel elements.

The alpha cell is dedicated to safety oriented experiments. It provides a capability to process samples and irradiation devices contaminated by alpha emitters.

This capacity will enable the JHR to meet European technological irradiation needs plus some international programs despite the progressive shutdown of the main European MTRs.

SAFETY

The safety of the JHR project is based on a defence-in-depth approach.

Inasmuch as the JHR is a new high performance material testing reactor , no specific safety reference standards exist at present in France for this type of reactor.

The safety approach for the design, operation and analysis therefore takes its inspiration from the reference safety standards for pressurised water reactors, particularly those introduced for the EPR project, and takes consideration of IAEA texts. Furthermore, the project may benefit from the recent safety instruction carried out in a new naval propulsion test reactor under construction at Cadarache.

JHR design approach finally takes benefit of valuable experience provided by several decades of experiments (in design, exploitation and safety analysis).

The different elements result in the following aspects for JHR safety methodology:

- analysis methodology of internal and external events derived from the current pressurised water reactors methodology; this provides a systematic, structuring framework for the design and safety analysis for facility protection and safeguard resources; this is complemented by analysis and implementation of design provisions against hazards;
- writing technical design and construction reference standards appropriate for a reactor of this type, particularly a collection of rules for the mechanical components (RCC-MX, including rules for design, procurement, manufacture, welding and process control; RCC-MX notably handles unused materials in the field of power reactors like aluminium alloys or Zircaloy (in addition to steel alloys), it also incorporates the processing of irradiation effect and temperature effect into design rules);
- developing an experimental devices guide which defines condition categories for irradiation devices based on device safety issues (radiological source term, energy content) and specifies predetermined safety provisions to be implemented given the risks and potential consequences of a system failure and the facility's ability to deal with this failure.

As a complement, as regards design aspects, two specific topics may be noted :

- it is implemented a systematic approach towards internal and external hazards, particularly with respect to external hazards (eg., earthquake and airplane crash), which results in a strategy to protect nuclear buildings and operations rooms at facility design level,
- JHR takes into account, as a beyond design basis accident, a severe core reactivity accident; this accident considers a fusion/destruction of the core of an explosive nature following a very large injection of reactivity. The design objective is to size the reactor containment so that, for surrounding populations, the potential radiological consequences of such an accident require no need for shelter, no need for evacuation, and no need to take iodine pellets.

OPERATION

The JHR is optimised to guarantee a high availability of 275 EFPD per year.

This requirement implies taking into account the operational aspects from design onwards, through notably an in-depth analysis of the life cycle of the experiments and an in-depth analysis of the shutdown operation sketch.

The service life adopted in the JHR design is a minimum of 50 years and therefore one of the basic characteristics is the ability to adapt to experimental needs likely to change radically during this service life.

These requirements are manifested in the design by:

- special care in sizing difficult-to-replace components, to make sure that they will be suitable for a variety of use configurations,
- constructive provisions to allow some parts of the facility to be replaced.

The cell block assembly located in the reactor pool has thus been designed to be removable and interchangeable.

COST CONSTRAINT

The JHR design is driven by objectives in terms of high performance irradiation capability and of reduced the unit cost per test.

These objectives are associated to an integration of the various operations required to carry out an experiment in a single facility:

- the JHR will incorporate the resources required to carry out an irradiation test from the final assembly of the experimental devices up to the recovery and dispatch of the irradiated samples for detailed analysis;
- the JHR facility will be directly capable of non-destructive interim and post irradiation tests as soon as the samples are loaded into the cell; instrumentation of fuel samples or destructive tests are implemented in other European or CEA hot laboratories.

This integration shortens the experimental process and minimises transports and ultimately favor improvement in quality and effectiveness of the service rendered for a large number of experiments.

The presence JHR design results from a severe and continuous cost management for :

- investment costs, by relying heavily on feedback from the RES naval propulsion test reactor currently being construction at Cadarache,
- operational costs by taking maintenance aspects and an analysis of feedback from existing reactor operations into account at the design phase,
- costs per experiment, by sizing the facility to conduct similar activities on several irradiated experimental devices simultaneously, even if the experiments in question are targeting different objectives.

As an illustration, as regards investment costs, one of the design strategies implemented during the definition studies phase has been to achieve a compact design of the nuclear buildings of the facility through an optimisation of equipment lay out in the so-called nuclear unit, while keeping connection with operation constraints.

PRESENTATION OF THE FACILITY

Site

The site chosen for the JHR nuclear facility is Bargette Est in the centre of Cadarache. This rocky site has been chosen for its rigidity and low fracturing of the limestone bedrock of the cretaceous period.

During the construction phase the site's location will isolate the JHR worksite from the centre of Cadarache.

Facility layout

The facility layout is based upon the following principles:

- all the experimental process and the main support functions are housed in the nuclear unit; this includes all the steps which deal with radioactive material,
- the nuclear unit protects the processes against external hazards and its design takes into account all the modern safety requirements in terms of internal hazard protection, common failure protection, and radiological risks management;
- others buildings are housing auxiliary functions without nuclear specifications.

For the nuclear unit, the protection against external hazard is ensured by a robust concrete design and an aseismic insulation. The internal layout fit the segregation of the different trains and access route conditions.

Inside the nuclear unit, the experiments require major resources for their preparation and operation, on-line data acquisition during irradiation and processing of samples outside irradiation (non-destructive tests, conditioning and dispatch of samples).

In order to manage irradiation and experiment processing activities, segregation by type and their potential risks has been chosen.

This design choice thereby limits the interactions between these various activities ensuring efficiency of the workers involved in the experimental process and the safety of these operations.

This principle has resulted in separating the activities of the nuclear unit into two nuclear buildings, thereby ensuring the isolation of:

- systems relating to the support activity for the preparation and pre- and post-irradiation processing of experiments in the Nuclear Auxiliaries Building (BAN), especially including storage and work pools, hot cells and laboratories.
- the systems specific to the reactor and experiments during irradiation within a Reactor Building (BR). Both types of systems are also separated within this building in a reactor operations zone and a core experiment operations zone, presented further on.

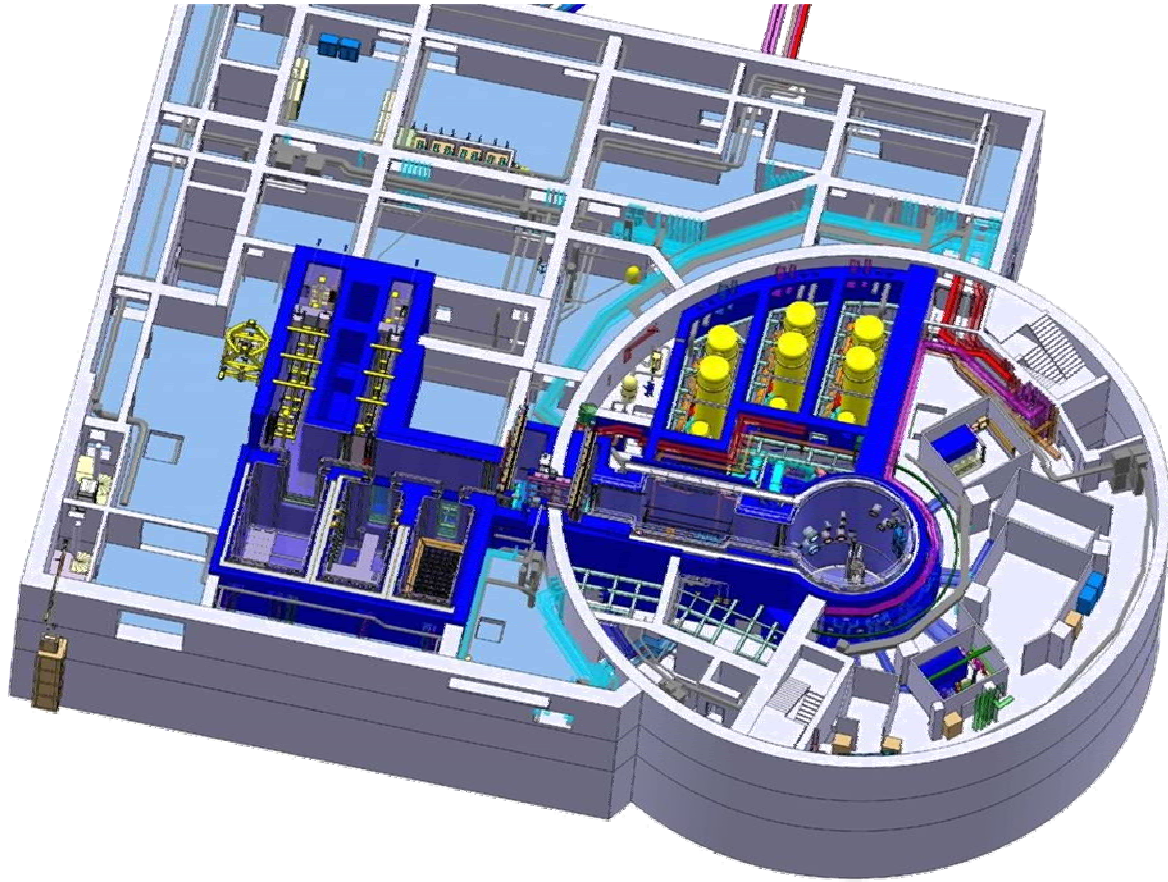
This segregation is manifested by physically separating systems, access, ventilation, electrical and instrumentation and control feeds.

Finally, it has been implemented a monolithic water block as a structuring link between Reactor Building and the Nuclear Auxiliaries Building. This water block ensures the process function of irradiated material underwater handling route and the safety function of avoiding any irradiated fuel dewatering.

The JHR water block is fitted with an underwater hatch that guarantees containment continuity at all times between the two buildings.

The water block notion has been used for various European research reactors. It involves defining a civil engineering monolithic structure, including all the pools and the bunkers containing the reactor coolant system.





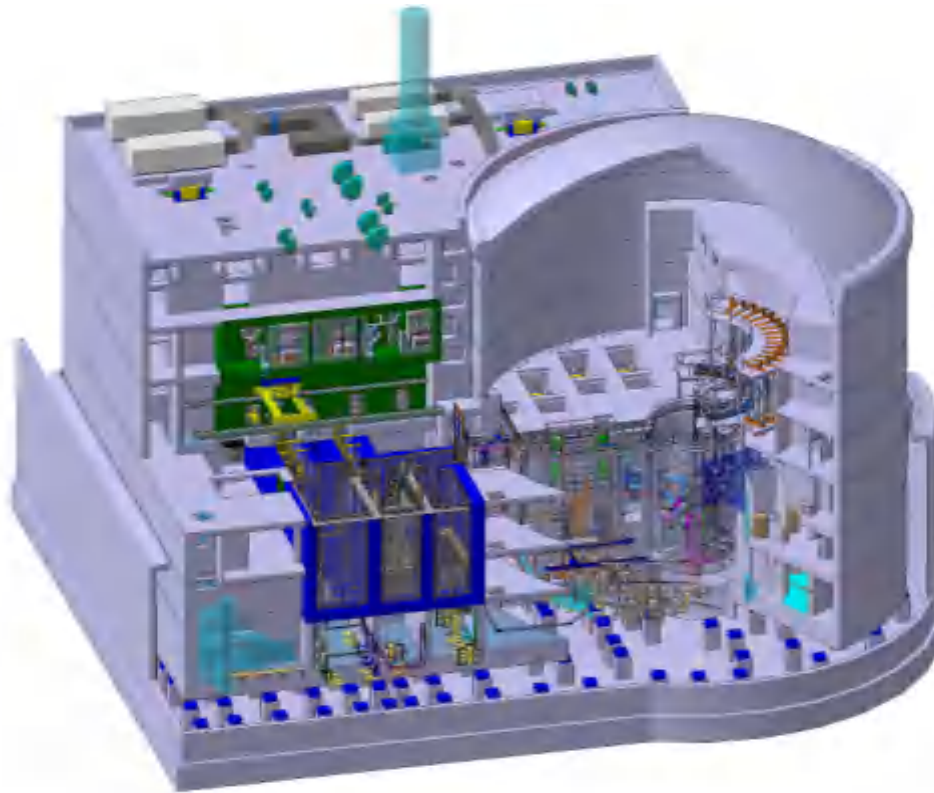
Aseismic insulation of the nuclear island

The seismic hazard on the JHR installation site at Cadarache is defined under the terms of French Fundamental Safety Rule 2001-01. It is characterised by:

- a Safe Shutdown Earthquake (SSE) of magnitude 5.8 and focal length 7.1 km,
- a represented paleo-earthquake of magnitude 7 and focal length 18.5 km.

The sizing spectrum for the facility is made up by the SSE and paleo-earthquake envelope.

The characteristics of the JHR facility and its experimental purpose have prompted the decision to place the JHR nuclear unit (common civil engineering structuring for the Reactor Building and the Nuclear Auxiliaries Building) on aseismic bearing pads.



The aseismic insulation is made up of around 160 hoop-reinforced elastomer support devices laid under the common nuclear unit raft and resting on concrete pads, themselves installed under a general raft.

The insulation is set at a frequency of 0.55 Hz, bringing the seismic acceleration over the entire height of the nuclear unit to about 0.12 g ("rigidification" of the nuclear unit behaviour).

It also controls the effects of low frequencies and induces significant reduction in requirements for the qualification of facility equipments and experimental devices. So the seismic event will not appear as design constraint for irradiation experiments.

This type of design is an off-shoot, in France, of the Cruas constructions (EDF, nuclear power plant with four units of 900 MWe), the storage pools at La Hague (Cogema, nuclear fuel reprocessing plant) and the STAR facility at Cadarache (CEA, hot laboratory).

Reactor building

The Reactor Building is built of partially pre-stressed concrete with a metallic dome. This guarantees a good level of leaktightness in a severe accident. In addition, passages through the Reactor Building are directed to a so-called leakoff recovery zone in the Nuclear Auxiliaries Building. In the bottom section (under the level of the free surface of the pools), the Reactor Building and Nuclear Auxiliaries Building structures consist in a single and unique structure to enable a transfer channel to be installed for underwater handling operations.

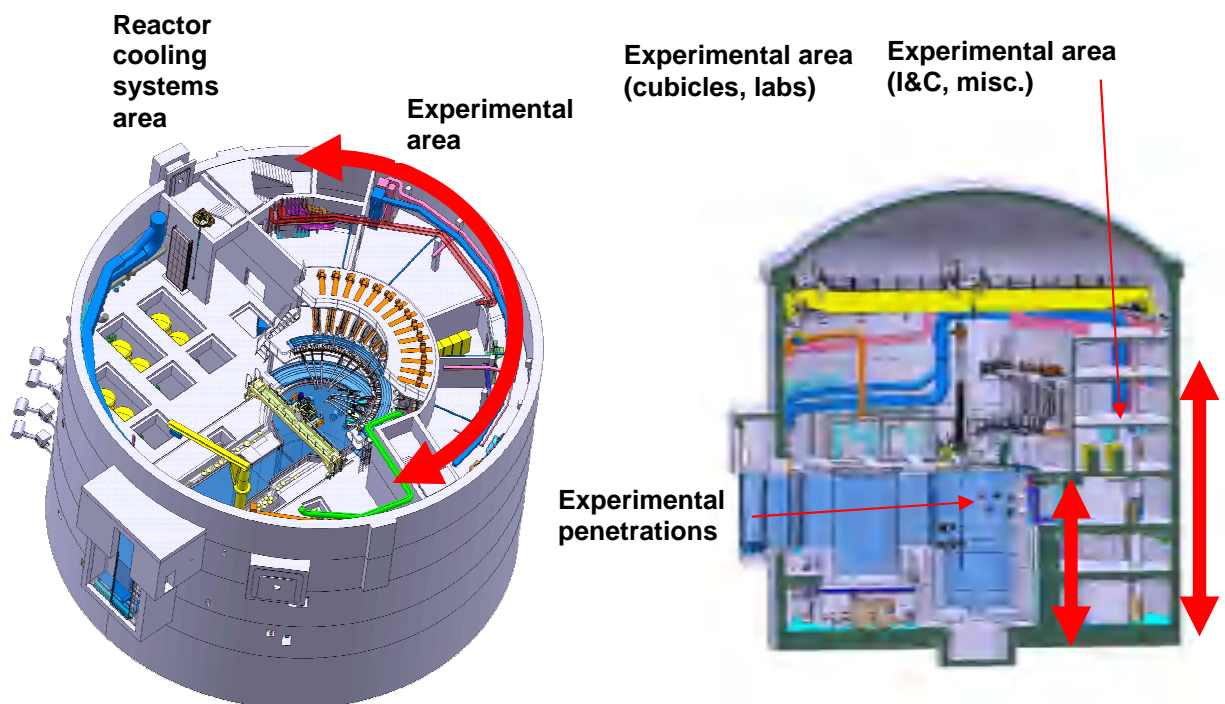
This approach is used to deal with certain overall requirements (seismic resistance, containment), by optimising the sizing of the containments with respect to the risks generated by the systems they are housing.

Major zones in the building are reserved for experimental cubicles and experiment support resources.

Under the Reactor Building hall, for example, three levels on top of each other have been left free for any future arrangement of experimental cubicles of the earthed sections of the experiments (surface area available on the three levels is 780 m²). The simultaneous presence of 12 experimental cubicles in service plus 2 experimental cubicles being prepared is taken into account in the design of this zone. The experimental zone also hosts the fission products analysis laboratory.

This experimental zone is adjacent to the reactor pool and receives the experimental penetrations from the reactor pool.

At reactor hall level, the experimental zone has two additional levels intended for the inactive earthed sections of the experiments, particularly the instrumentation and control and electricity.



Reactor block and reactor pool

The reactor block is located at the bottom of the reactor pool inside the Reactor Building.

The reactor pool consists of demineralised water and integrates a hot layer.

The core is situated approximately 9 metres below the water level and the direct vision of the reactor is an important feature for reconfiguring the irradiated experimental load and refuelling the reactor.

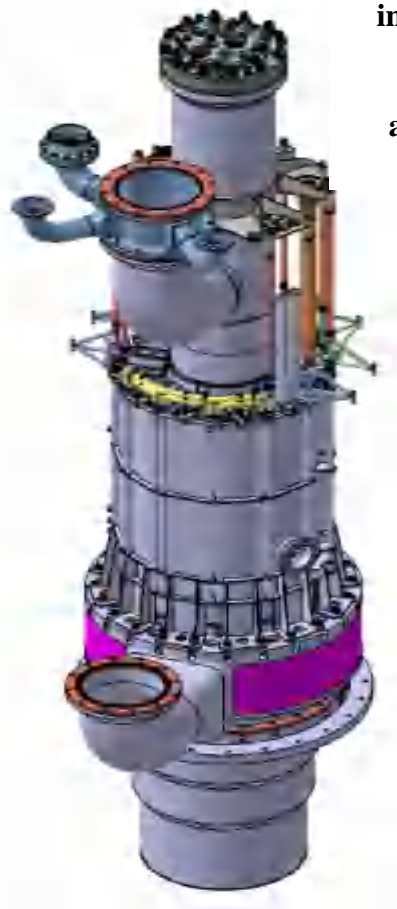
The reactor pool ensures an optimal radiological protection to the personal working in the reactor hall and above the reactor pool.

Inside the reactor pool, the reactor block is a housing that contains the fuel elements, installed in a cylindrical reactor vessel. This vessel surrounding as close as possible the compact fuel element net is placed on a water chamber and a pool penetration plug through which pass the absorber control mechanisms. The housing is closed by a cover holding the devices in the core. The main reactor coolant system is connected to the lower water chamber with a return via a lateral pipe at the top of the housing.

**Core housing
with its cover**



**The core housing in its
immediate environment:
placed on the water
chamber
and with the beryllium
reflector in place**



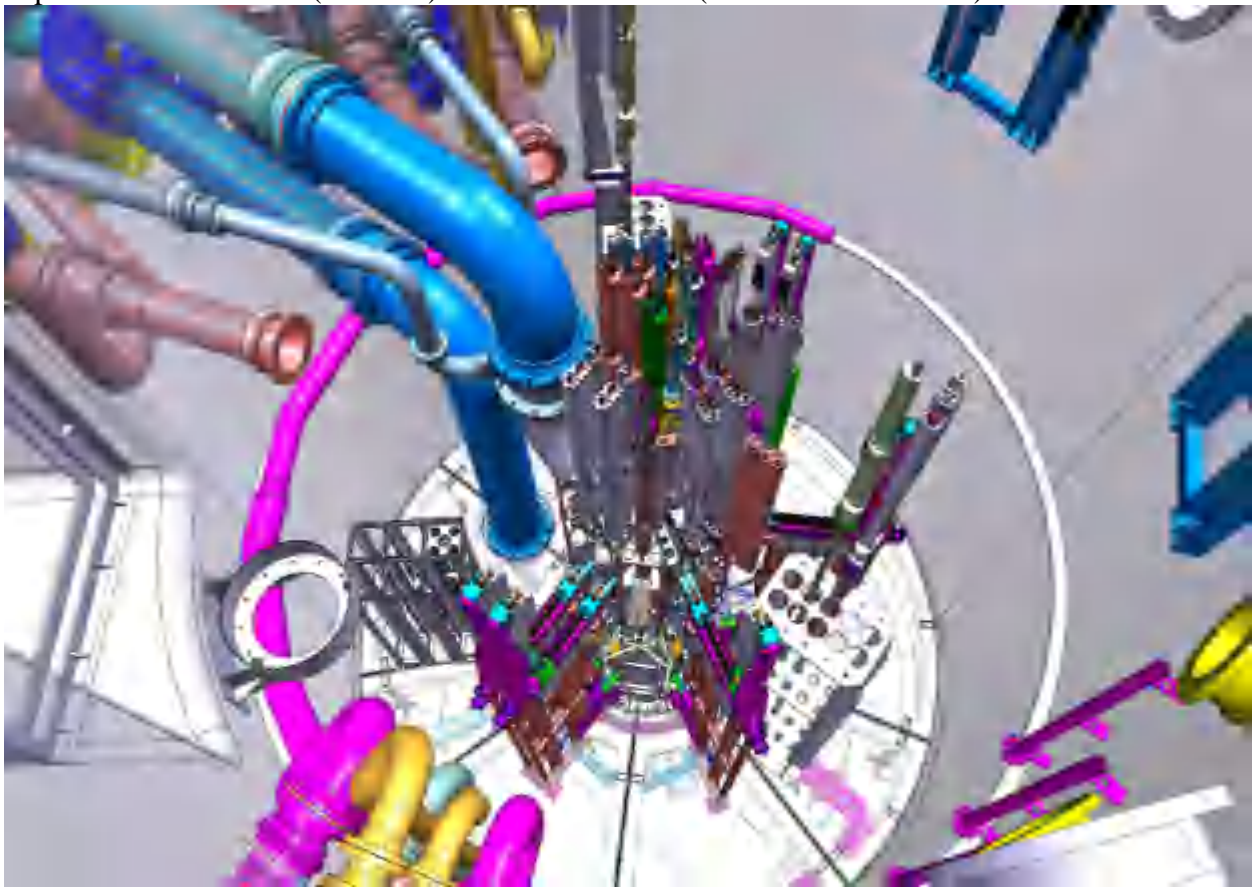
Around the reactor block, it is implemented a neutron reflector, made up of beryllium blocks. This reflector is directly accessible in the reactor pool is modular and may be easily reconfigured by rearranging the blocks in the reactor pool. The blocks are designed to receive devices of varying sizes and cool them with layers of water (fixed experimental emplacements). The reflector is also arranged to receive displacement devices; at constant core power, these may be used for controlled power variations on devices, by radial displacement with respect to the core. The recoil position of these displacement systems gives access to a low level of residual power on the devices, including when the core is at nominal power.

These provisions enable the reflector zone to be directly accessible in the reactor pool even when the reactor operates at full power.

The core and the reflector each have their own cooling systems. During power operation, the core is cooled by forced convection in the housing via a closed reactor coolant system. The pressurisation which is mandatory to meet the high level of flux performances is ensured passively (dynamic pressurisation) by the reactor coolant pumps.

The reflector zone is cooled by forced convection via the reactor pool cooling system that operates by sucking the pool water through the reflector structure. One dedicated leg of the pool cooling system is used to deal with the specific cooling constraints for the production of artificial radio-isotopes.

This design retains the qualities of the progressive nature and accessibility of the experiments in the reflector, whilst the slight pressurisation supplied by the housing (4 bar at core outlet) provides the thermo-hydraulic margins needed to push the reactor flux performances for the experiments in the core (fast flux) and in the reflector (thermal and fast flux).



The housing in the reactor pool
(largely hidden by the numerous experimental devices. Links between the devices and their earthed sections are not represented)

The core experiments are loaded during reloading shutdowns (inter-cycles), whereas the reflector experiments may be unloaded or loaded during the irradiation cycle. These operations are carried out under water using specialised handling equipment from the pool float.

Core

Core design is driven by the acquisition of high fast flux in the core and reflector and high thermal flux in the reflector.

One further objective is to design the core such that it can ultimately be operated with a 20% U5 enriched, new high density (8 gU/cm³) fuel meat

The fuel adopted for this purpose is UMo (uranium-molybdenum), currently under development within international collaboration. Should delays in developing this fuel mean that it is not available for starting operations, a back up U₃Si₂ fuel (silicide) at 4.8 gU/cm³ is also qualified to be used up to the UMo industrial availability. The typical enrichment level the back up fuel is 27% so as to guarantee an equivalent cycle length to the UMo fuel.

Given its high performances, the core design has focused on a highly heterogeneous assembly comprising the core, with a minimised volume of water to obtain high fast flux, and a beryllium reflector used to create appreciable savings in neutrons.

The maximum core power has been set at 100 MW. Given the high water velocity in the core, required to evacuate the power, a cylindrical fuel element design has been adopted for mechanical stability purposes. This cylindrical shape also provides an optimal geometry for neutron flux delivery on irradiation devices located at the centre of fuel elements.

Fuel element

Fuel plates are obtained by metallurgical bonding of the aluminium matrix containing the UMo or U₃Si₂ fuel grains and the aluminium cladding. Roll bending produces plates of the desired curve. These plates are then fixed onto three stiffeners that define the cylindrical element.

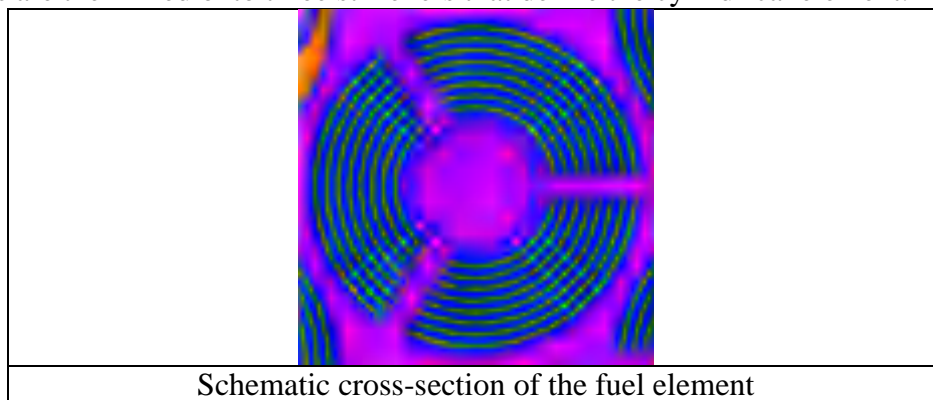


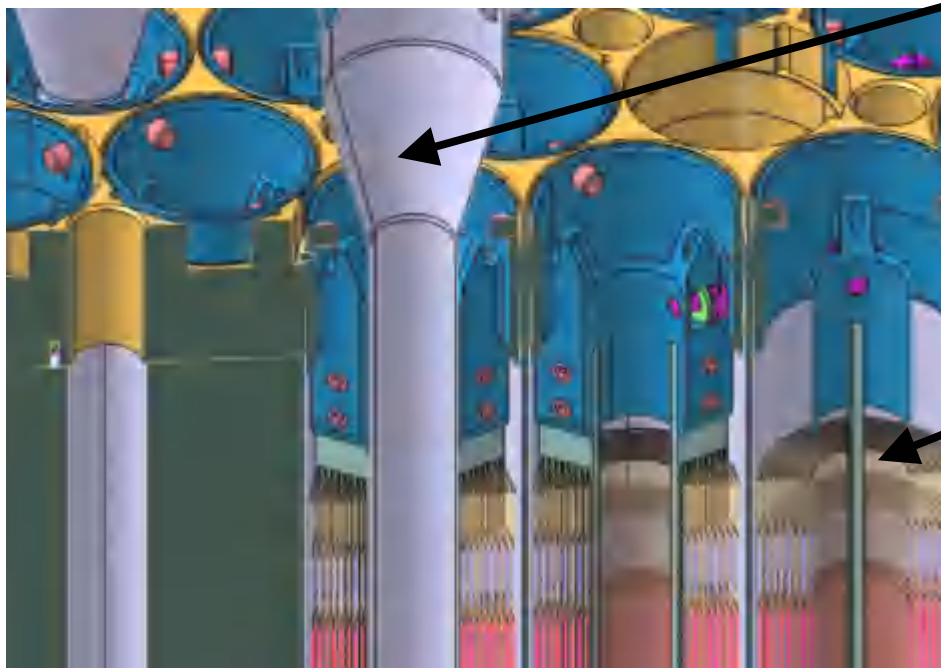
Table T1: Standard Element UMo-Al

Dimensions (radius x height)	47.5 mm x 1010 mm
Dimensions of the fuel section (thickness x length; width is variable)	0.61 x 600 mm
Thickness of water channels between plates	1.84 mm (2.2 mm for peripheral channels)
Chemical form of reference fuel	UMo8 dispersed in Al/U3 S12
Cladding	Al-Fe-Ni alloy, 0.38 mm thick

Each element may house in its centre an experimental device, a control absorber or an aluminium mandrel. In-fuel experimental devices will be surrounded by an aluminium tube for guiding purposes and for guarantying mechanical decoupling with the fuel element. Standard external diameter of such a in-fuel device is 32 mm.

It is also possible to remove a fuel element from a cell in the core to implement a large in-core experimental device. Standard external diameter of such a "large device" in the core is up to 70-90 mm.

View of the upper core section



Tube guiding the devices and protecting the core.

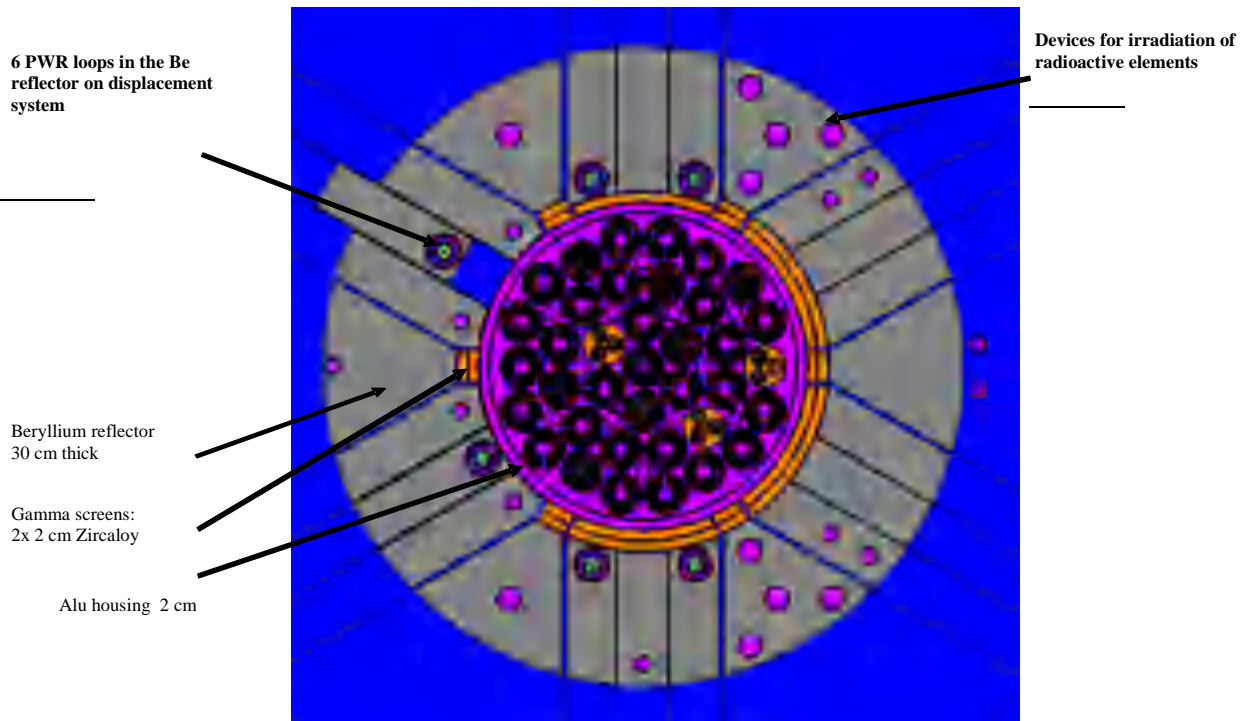
Fuel

Configuration and performances

Based on initial parametric studies, two core geometries have been adopted for studying in depth: a reference geometry with 37 cells producing nominal performances and a wide geometry with 49 cells capable of housing larger diameter loops in the core.

Reference core

This is based on a core housing with 37 cells, including at least 34 occupied by fuel elements. The following figure gives a simplified picture of this geometry :



The experimental load for calculating performances includes:

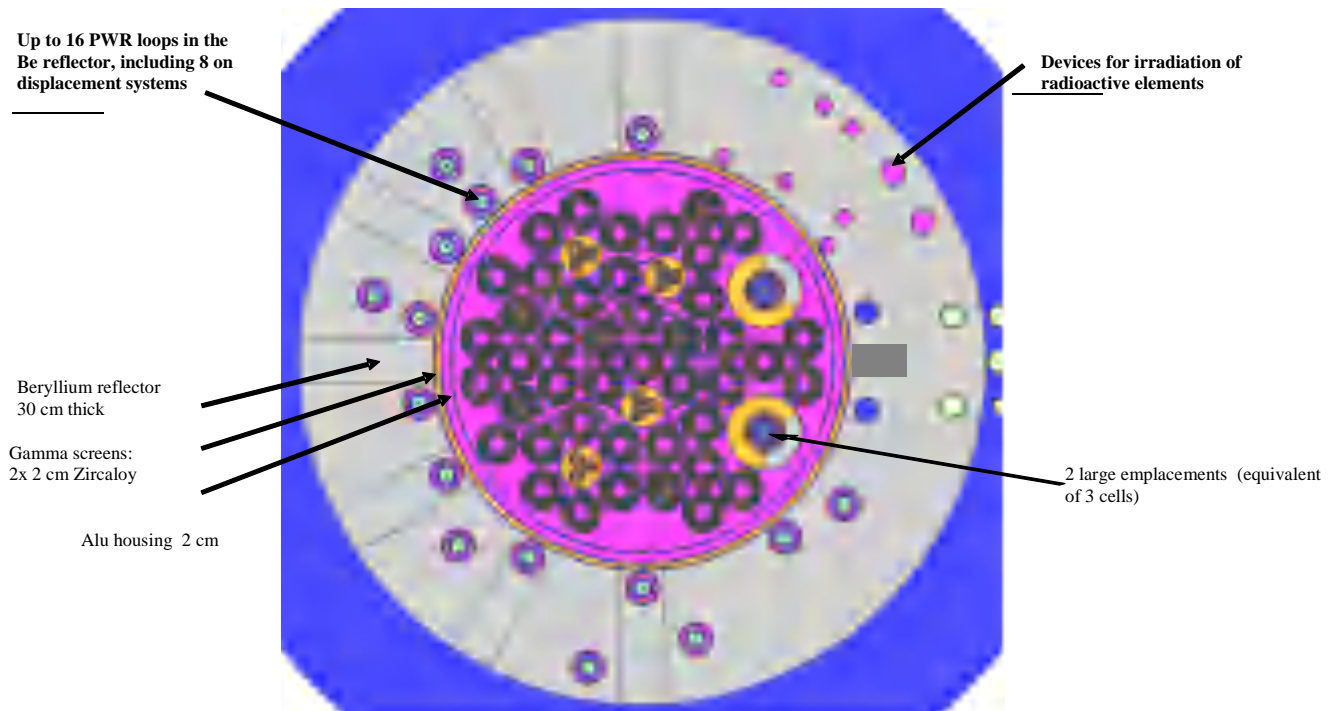
- 10 irradiation core emplacements comprising:
 - 7 isolated emplacements at the centre of a fuel element, carrying a standard materials device,
 - 3 groups of 3 standard materials devices in an aluminium housing occupying one cell in the core,
- 6 emplacements on displacement systems in the reflector,
- 6 fixed irradiation emplacements in the reflector,
- 9 emplacements in the reflector to produce artificial radionuclides.

The calculated performances for this configuration with its full charge are as follows for 100MW of nuclear power and a UMo fuel:

Max. effective fast flux (> 0.907 MeV on a standard materials sample at core mid-height	Between 1.8 and $5.5 \cdot 10^{14}$ n/cm ² /s depending on position
Max. effective fast flux (> 0.907 MeV) on a standard fuel device in the reflector (fuel at 1% U235)	$8.8 \cdot 10^{13}$ n/cm ² /s
Max. linear power on fuel sample in the reflector (calculated from fuel sample with 1% U235)	600 W/cm
Cycle length	30 days
Water velocity in the fuel	18 m/sec
Number of mobile absorber emplacements	27
Number of usable emplacements for fixed poisons	12

Large core

This core requires a replacement cell block with the installation of a more voluminous housing to incorporate a larger experimental capacity, including 2 large core emplacements (each taking the place of 3 standard fuel cells). So it will be possible to accommodate 2 larger devices (up to 125 mm external diameter). In addition, it is also possible to maintain these 2 irradiation devices in the reactor without any disconnection during the core refuelling.



The experimental load for calculation includes:

- 12 irradiation core emplacements comprising:
 - 6 isolated emplacements at the centre of a fuel element, carrying a standard materials device,
 - 4 groups of 3 standard materials devices in an aluminium housing occupying one cell in the core,
 - 2 large PWR-type devices with 9 fuel rods,
- 16 devices in the reflector loaded with PWR-type loops including 6 to 8 on displacement systems,
- 9 fixed emplacements loaded with devices for the production of radioactive elements.

The calculated performances for this configuration with its full charge are as follows for 100MW of nuclear power and a UMo fuel:

Max. effective fast flux (> 0.907 MeV) on a standard materials sample at core mid-height	Between 1.6 and $4.4 \cdot 10^{14}$ n/cm ² /s depending on position
Max. effective fast flux (> 0.907 MeV) on a standard device in the reflector (fuel at 2.25% U235)	$6.4 \cdot 10^{13}$ n/cm ² /s
Max. linear power on fuel sample in the reflector (calculated from fuel sample with 2.25% U235)	660 W/cm
Cycle length	30 days
Water velocity in the fuel	14.5 m/sec

Both core geometries studied keep the same position for the absorber mechanisms; there is no change, therefore, in the lower cell block structures in the reactor pool.

Control

The core has three control systems:

- a system operating the reactor power made up of 3 control rod mechanisms,
- an emergency shutdown system with 3 control rod mechanisms,
- a reactivity compensation system. This system is made up of 21 control rod mechanisms.
- Different technologies and commands are used for the different types of control rod mechanisms.

The operating system acts as a second reactivity shutdown system in addition to the emergency shutdown system.

The compensation system maintains the sub-criticality in the long term after reactor shutdown.

The number of compensation absorbers has been defined for maximum flexibility of the core loads.

The various types of absorber are installed in the core zone, at the centre of the fuel elements. Installing the absorbers at the centre of the fuel elements limits flux disturbances from the surrounding experimental emplacements in the core.



Reactor coolant system

The entire reactor coolant system is found in the containment vessel. It is made up of three loops each with a pump and two exchangers. The core housing is pressurised by head losses in the system (max. reactor coolant pressure in the order of 10-15 bar, depending on the required flow and the core head loss).

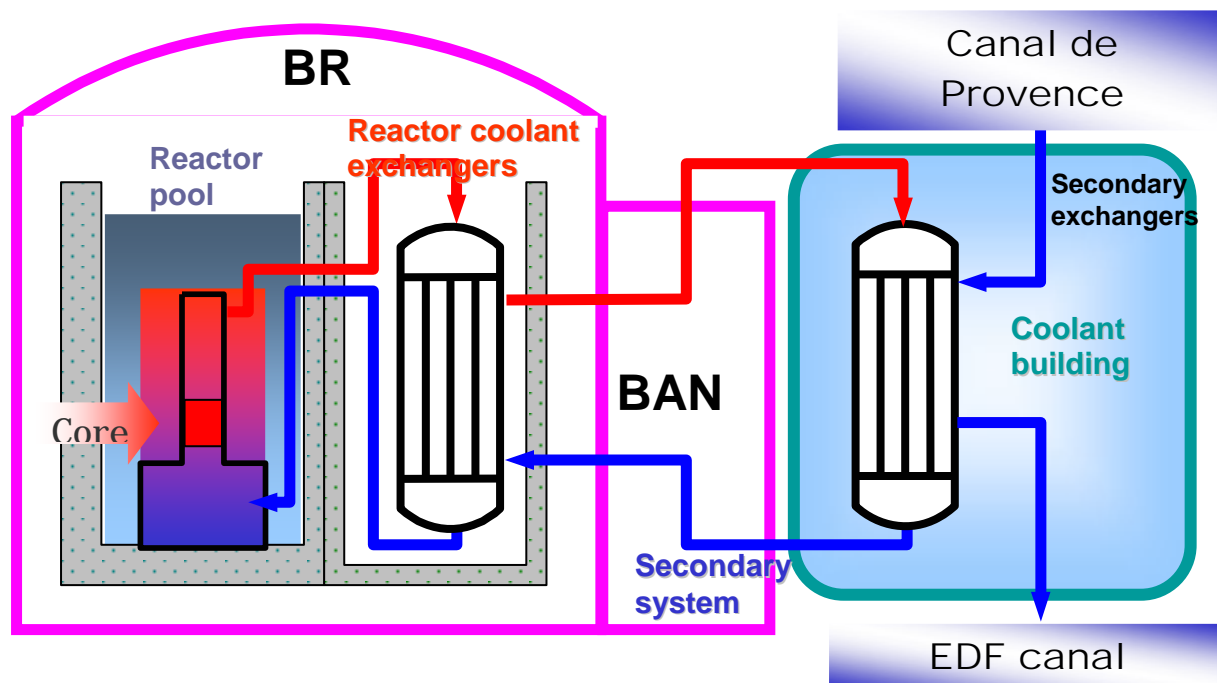
The reactor coolant system is designed without a decay tank. The design of the Reactor Building therefore includes special biological protection at the reactor coolant bunkering system which is inaccessible when the reactor is in service (impact, particularly, of nitrogen-16).

The reactor coolant flow is in the order of 8500 m³/h. The reactor coolant water circulation in the core is ascending.

The reactor coolant system is designed to maintain sufficient flow in the core for a large variety of postulated initiating events including piping breakages up to the rupture of one of the three primary circuit legs and the total rupture of irradiation device in the core..

An activated system evacuates the residual power after shutdown, before moving into natural convection mode a few hours after shutdown.

An intermediate closed system in overpressure transfers the heat from the reactor coolant system to the external cooling system. In this way the secondary system remains totally clean, even in the event of a minor leak in a reactor coolant/secondary exchanger. This scenario is normally implemented to cool the reactor pool.



NUCLEAR UNIT

The Nuclear Auxiliaries Building and experimental resources

The various irradiation experiments are carried out in experimental devices made up of a sample holder and, if appropriate, simple or double envelopes containing the sample inserted into the reactor, in either the core or the reflector. These devices may include an earthed section incorporating the instrumentation and control and electrical supply and, if appropriate, the fluid systems (earthed section of the loop coolant system) and special resources (glove boxes, experimental cubicles).

These devices require resources for preparing the experiments (hot and cold workshops, test benches), special measuring resources (dosimetry laboratory, fission products analysis laboratory, chemistry laboratory), resources for experiment preparation and post-processing, hot cells, particularly alpha cells, and finally storage resources (pools).

The Nuclear Auxiliaries Building also includes a work pool used to condition devices dismantled at the end of their useful life via one of two multi-purpose cells.

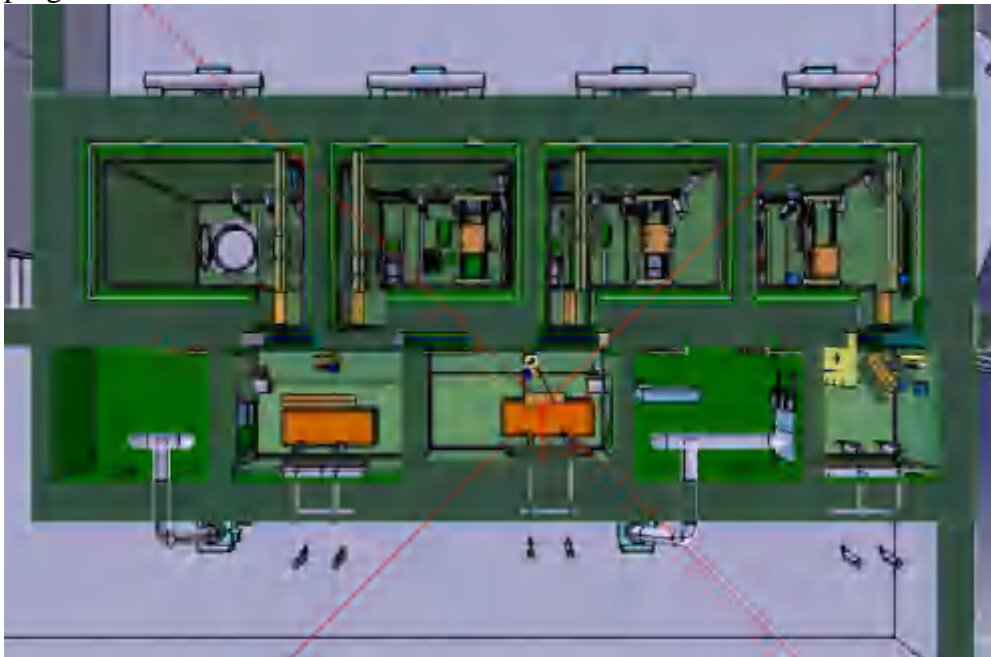
Hot cells

Hot cell operations incorporate in particular the handling of experimental radioactive samples, installing them in the experimental device, recovering them, non-destructive inter- and post-irradiation measurements and conditioning them for transport to other specialised installations for more advanced tests if necessary, operations on the irradiated reactor fuel (controls) and maintenance or assembly work on the irradiating structures (measurement benches, tooling, reactor components and experimental devices).

The JHR will have four hot cells, giving the facility sufficient capacity to prevent saturation of resources. Each one is designed to dominate in one function but without excluding the other uses to reconcile efficiency and flexibility :

- one cell (ECR) for conditioning the radioisotopes and the irradiated fuel elements (ECI) in transport casks,
- two multi-purpose beta-gamma cells (ECC and ECD) for fuel and material experiments; the ECD cell is also used as a conditioning cell; the ECC and ECD cells are linked directly to non-destructive exams (NDE) stations : an NDE fuel station (ECE) and an NDE material station (ECM).
- an alpha cell (ECA) for activities on experimental alpha emitter devices; this cell is intended to offer a capacity for repeated experiments on fuel samples ruptured, or even in extreme cases, pushed until fusion of small fuel samples; these experiments fit the facility containment and radiological protection conditions.

These cells are designed with the latest innovations from the La Hague reprocessing centre. They are therefore fitted with integrated maintenance and troubleshooting systems. The alpha cell is intended as a tool towards enlarging the ability of JHR to perform safety-oriented irradiation programs.



Laboratories

The JHR has several laboratories, mainly to ensure special measuring quality on experiments and to minimise lead times in obtaining experimental results. The most characteristic are the fission products analysis laboratory and the dosimetry laboratory.

Fission products analysis laboratory

This laboratory is a specific feature of JHR. It is used for on-line study of the emergence, composition and behaviour of fission products during experiments, particularly:

- the release of fission gases from sound fuels (generated within the matrix or in the cladding),
- the transfer of fission products through coolant circuits in the event of ruptured fuels (deliberately or otherwise).

These studies may be carried out for various reactor systems:

- REL, HTR or RNR type reactors requiring an analysis of fission products carried by a gaseous vector fluid ("Gas Experiment"),
- REL type reactor requiring analyses of the fission products contained in the coolant ("Water Experiment").

The fission products analysis laboratory has been sited in the experimental areas in the reactor building for minimizing sample lines length between irradiation area and measurements area (this minimize signal mixing). Two pool penetrations are dedicated to the fission lab sampling.

Dosimetry laboratory

This laboratory processes in real time, during the irradiation programmes, the doses integrated by the dosimeters extracted from the experimental devices during the inter-cycles.

The integrators are installed in the irradiation capsules, themselves placed in devices specific to core knowledge and arranged in the core or in the reflector.

Measurements using dosimeters must be performed very quickly after irradiation.

The devices are dismantled – to recover the integrators and their packaging for their transfer to the dosimetry laboratory – in the hot cells in the Nuclear Auxiliaries Building. The dosimetries are then transferred to the measurement laboratory via a pneumatic network.

Pools

Pools are distributed along the monolithic water block, both inside Reactor Building and inside the Nuclear Auxiliaries Building.

The irradiated fuel elements and the unloaded devices are stored in the pools in the Reactor Building before being transferred to a storage pool in the Nuclear Auxiliaries Building, in principle outside the inter-cycle period.

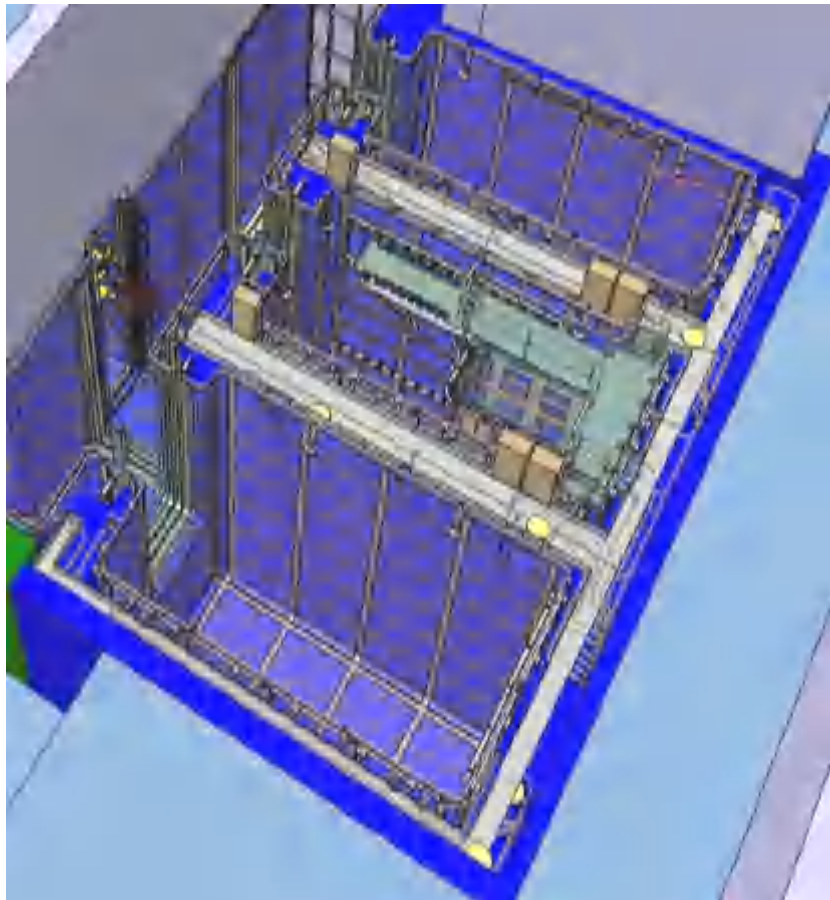
Very fast unloading of a priority device located in the core is still possible one hour after shutdown, with the rapid transfer of a device to the Nuclear Auxiliaries Building for tests in the cell during the inter-cycle.

The Nuclear Auxiliaries Building has three pools and a system of underwater transfer channels to the hot cells and the Reactor Building.

One of these pools is dedicated to the underwater storage of used core fuel elements.

The most irradiating of the experiment components are stored in a second pool. This pool may also be operated as a work pool. For example, it may receive irradiated components from a complete cell block whilst operating an underwater cutting machine.

The third pool is devoted to storing and monitoring irradiated devices. It is capable of storing 30 devices and encompasses a NDE station for irradiation devices.



CONCLUSION

The JHR will provide an integrated flexible material testing reactor securing the irradiation capacity for coming decades and complying with the most modern safety requirements. Taking benefit of the large experience from existing MTRs, JHR provides key improvements such as:

- expansion of levels and flux spectra accessible in conjunction with the short-/medium- and long-term needs of nuclear R&D,
- extensive integration of experimental resources,
- an alpha cell for safety experiments
- a laboratory for on-line measuring of fission products.

In terms of project sequence, the major options have now been decided, the overall design is available; performances, and investment cost and planning are confirmed.

At the end of the current study phase, the Preliminary Safety Report on the JHR facility will be submitted to the French Nuclear Safety Authority for the standard government construction approval process to take its course.

The detailed and manufacturing study phase will be launched early in 2006.

Particular points will be validated during this phase through qualifications, such as the aseismic bearing pads and the fuel element, and others will be committed, as for the control rod mechanisms.

The commitment of the Technicatome – Framatome-ANP and EDF engineering team to the CEA guarantees the coherence of the JHR project.