JULES HOROWITZ REACTOR – PRESENTATION of the PROJECT and PROGRESS REPORT

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ABSTRACT

The RJH project was launched by CEA some years ago, with the objective to replace, after 2010, the material testing reactors of the previous generation. The objectives are also:

- to realise a significant step in term of performances,
- to ensure a high flexibility of the design, in order to host in the future new experiments, which are not completely defined at the project stage,
- to reach a high level of safety, according to the best current practice.

After a summary of the main experimental objectives of the facility, the present paper deals with a detailed technical presentation of the project, resulting from preliminary design studies.

The following topics are covered successively :

- the main functionalities,
- the resulting design options and technical solutions,
- the layout of the nuclear facility.

A progress report of the project is given also, together with its key milestones, up to reactor operation.

1 OBJECTIVES AND PERFORMANCES

Nowadays the CEA has only one irradiation reactor, OSIRIS, in operation since 1966. This reactor is well suitable for the support of the present French PWR program, with a thermal neutron flux of approx. 2 10^{14} neutrons/cm²/s and a fast neutron flux (E> 0,9 MeV) of approx. 2 10^{14} neutrons/cm²/s at some irradiation places.

In the RJH reactor, the objective is to create a new irradiation tool, at CADARACHE, with improved performances, especially concerning the available thermal and fast neutron flux levels, the experiment instrumentation and duration. These performances answer, in a French context, to different aims:

- PWR material and fuel testing ; material testing requires an important fast flux,
- FBR fuel testing, for future reactors,
- experiments related to long-lived fission products transmutation.

The RJH is now scheduled for an industrial use in 2010.

RJH expected performances have been presented in previous papers (RERTR 2000 and IGORR 7). Refer to references <1> and <2>.

TABLE 1 : Main characteristics

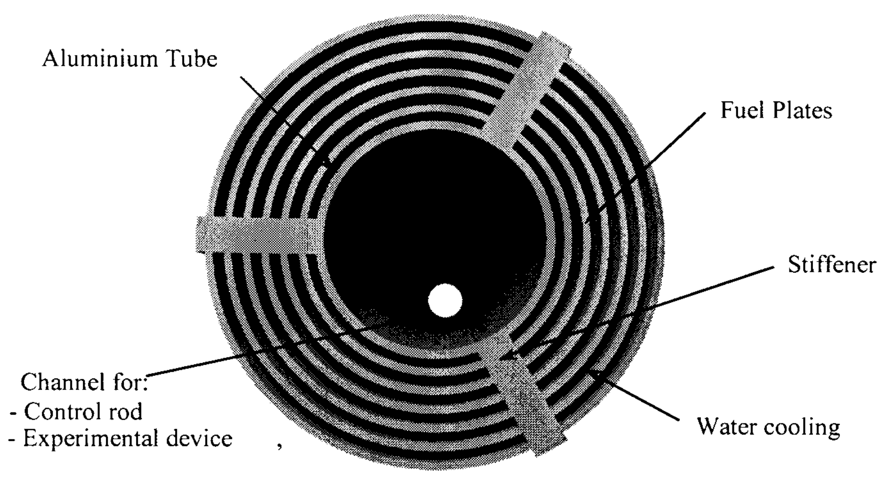
Characteristics or computed values	Values
Power (MW)	100
Fast neutron flux (E14 cm^{-2}s^{-1} > 0,907 MeV) at the centre of the core, unperturbed	6,4
Thermal neutron flux (E14 cm^{-2}s^{-1} < 0,625 eV) in the reflector, unperturbed	7,3
Max fuel enrichment (%)	19,75
Average surface heat flux (W/cm²)	190
^{235}U mass (U-Mo, 8g/cm^{3}) (kg) (Total core mass loading)	21

Table 1 gives the main characteristics of the preliminary design of the reactor, with a reference U-Mo core, having a specific power density of 600 kW/l.

The performance objectives of the RJH are not only given in terms of technical values such as flux levels, but also in terms of safety features, and in terms of evolutivity of the design for the future. As an example, one of the reactor design objectives is to allow a reactor tank change within 2 months, should it be necessary for new experiments.

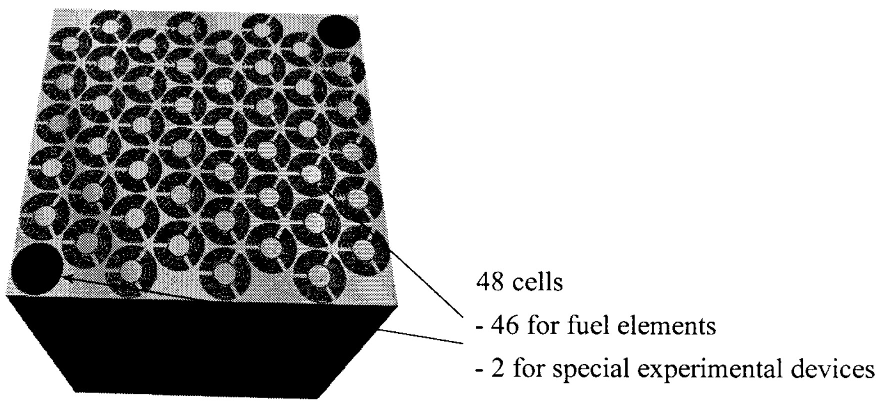
2 CORE AND MECHANICAL DESIGN

2.1 FUEL ELEMENT



The fuel element is made of curved fuel plates, arranged in a cylindrical pattern. In the preliminary design, the fuel element has a row of six U-Mo- Al fuel plates bonded to three stiffeners. An aluminium tube protects the inner plate.
Others designs are considered with silicide fuel, or with a larger fuel element.
The cylindrical shape of the element allows higher flow speed than a square assembly, and therefore a higher specific power. The central tube can receive either a control rod, or an experimental device.

2.2 CORE



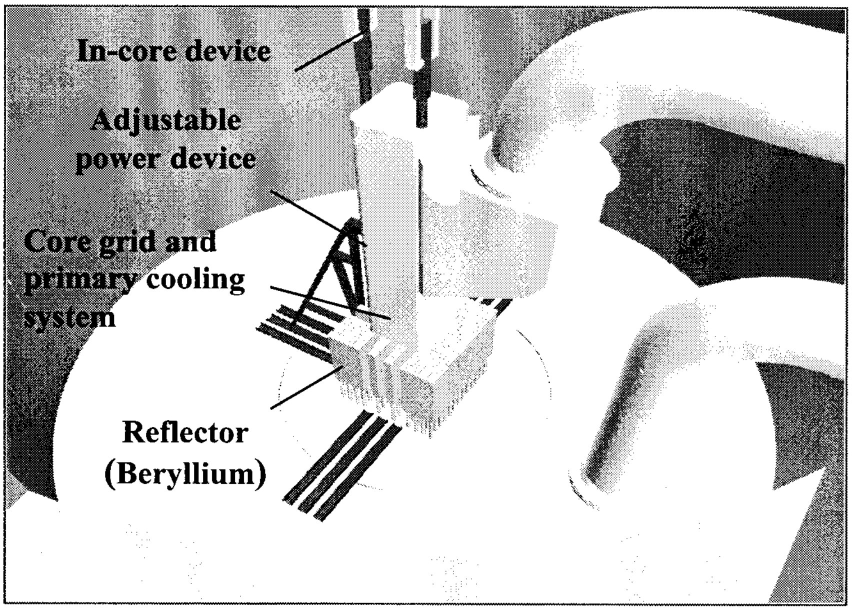
The core is arranged with a triangular lattice, in an aluminium rack, which is a part of the reactor tank.

The drawing gives a figure of the preliminary core, for which characteristics are given above.

2.3 REACTIVITY CONTROL

Control rods are located in the centre of fuel elements. The preliminary design takes two different systems into account, one for compensation of xenon and burn-up, and the other for safety shutdown. Hafnium rods have been chosen for the first system and other materials are considered for safety control rods.
Control rod mechanisms are located under the reactor pool, thus giving above the reactor an easy access to the core for the experiments. A second shutdown system is provided, by poisoning the primary water with a neutron absorbing material.
Standard fuel elements can receive an experiment or an inert aluminium tube; In the preliminary design, 16 fuel elements are standard ones with experiments hosting capabilities.

2.4 REACTOR TANK



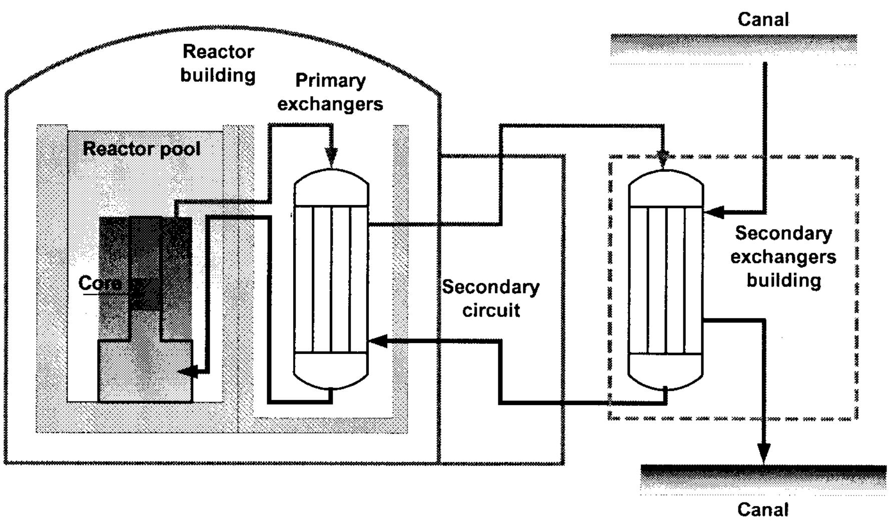
The primary circuit is closed to make it a real second barrier and to allow a pressurisation of approx. 5 bar at core outlet: the core has to be located in a pressurised tank.
In the preliminary design, the reactor tank has a rectangular section. A hexagonal section has also been considered.

Two aluminium alloys are under study for the tank, 6061 T6 and 5754 (AG3NET) alloys. A R&D program covering physical and industrial problems began in year 2001.
A zirconium shielding surrounds the reactor tank, to significantly reduce gamma heating in irradiation devices located outside of the tank.
A beryllium reflector surrounds partially the reactor tank, to increase core life time.

2.5 CORE COOLING

The whole primary circuit is located inside the reactor containment. The preliminary design was made with an objective of limiting the core inlet temperature at 25°C, from a heat sink at 18°C, with an intermediate circuit. To reach this inlet temperature, a rather large exchange surface has to be provided in the facility.
Other characteristics results from a preliminary accident evaluation:

- Fuel cooling is sustained even in the case of a pressure loss accident, with pool pressure at core outlet, the water flow being maintained,
- Pressurisation at 5 bars helps to prevent water boiling during loss of electricity supply,
- Water flows upward through the core, to help transient conditions with loss op pumping, down to natural convection.
- Primary pump redundancy was chosen in order to take into account a pump shaft rupture, with instantaneous decrease in water flow.



The tertiary circuit is a long pipe, coming from the Verdon river.

There is an intermediary circuit for safety reasons;

An alternative air-cooled tertiary circuit has also been considered, but performances are lowered by higher core inlet temperatures.

3 RJH EXPERIMENTAL CAPABILITIES

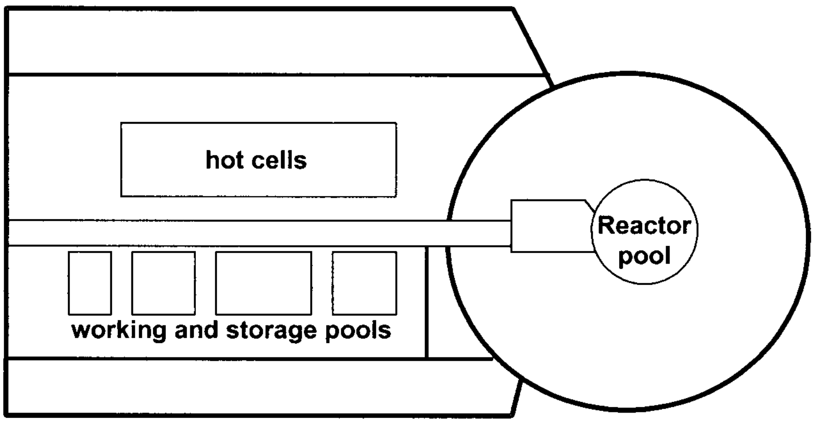
3.1 FUNCTIONAL DESCRIPTION

The facility will allow irradiation tests, in the core and in the reflector, depending on the required irradiation specification. It should be noticed that the reactor design allows the installation of eight irradiation displacement boxes, for the simulation of power variation effects and an accurate control of the irradiation conditions as well.

The facility will allow :

- The preparation and the sample loading of the irradiation loops and devices,
- The underwater loading and downloading of the experiments in the reactor,
- The intermediate measurements on the irradiated samples,
- The experiments dismounting and samples extraction,
- The non destructive PIE examinations of the samples (such as gamma & neutron scanning, ...),
- The conditioning of the samples in containers and transfer cask for their transportation to the PIE laboratory or to the waste storage facility.

3.2 REACTOR POOL ARRANGEMENT



The pools are distributed in two nuclear buildings: one for the reactor, and the others for nuclear and experimental auxiliaries. In the second building, experiments are prepared in a working pool, and dismantled or measured in hot cells.
The two sets of pools are connected by a lock designed to enable the transportation of experiments in a vertical position, while keeping the lower part in water and the upper part in air.

3.3 EXPERIMENTAL FACILITIES SUPPORT AREA

In-core irradiation devices are supported by auxiliaries in the experimental area of the reactor building, and, in the Nuclear auxiliaries building, by hot cells, laboratories and working pools. The objectives are to minimise examination time and to accept a large number of experiments and measurements.

3.4 HOT CELLS COMPLEX

Five main hot cells are located in the nuclear auxiliary building :
- Two hot cells are dedicated to work on reactor fuel experiments, one can accept an experimental device with failed fuels,
- one cell is dedicated to work on material testing experiments,
- one cell will be used for reactor operation,
- one cell will be dedicated to radioisotopes production.

Other small hot cells, located in the laboratories, are dedicated to gamma counting of small activated samples.

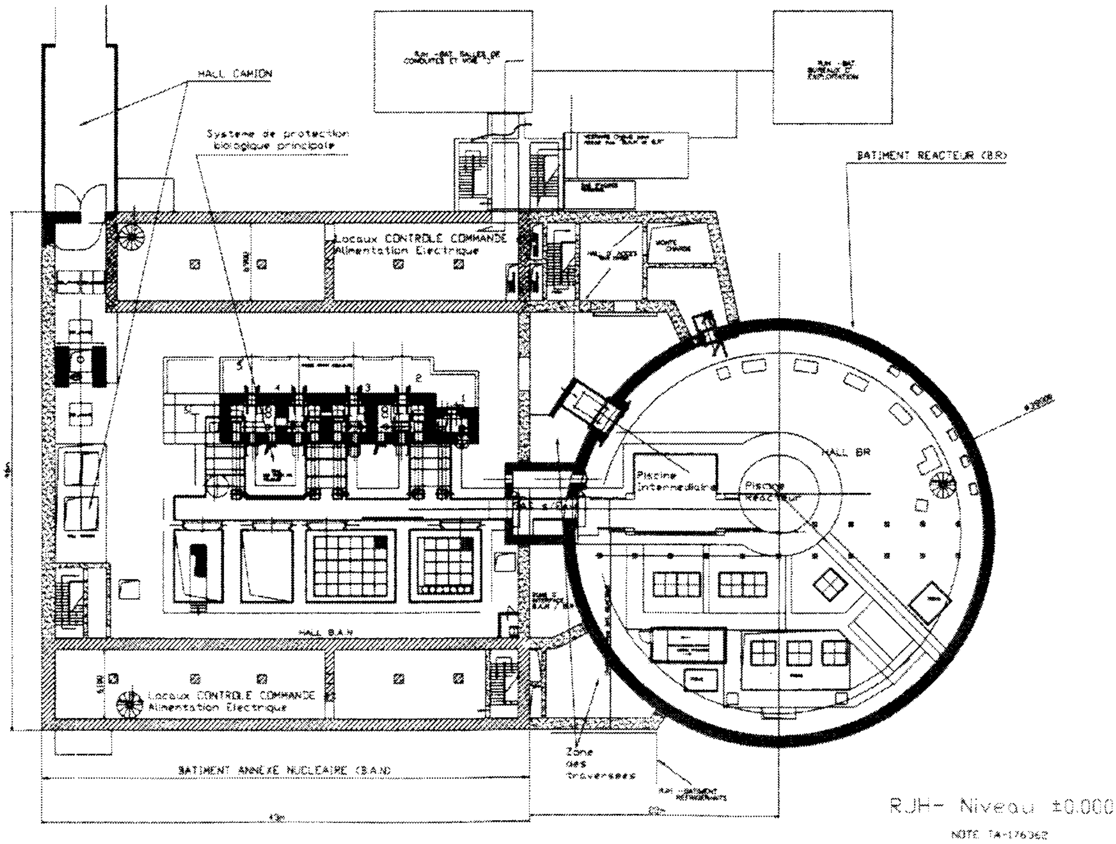
4 NUCLEAR BUILDINGS

The buildings were designed with the following objectives:

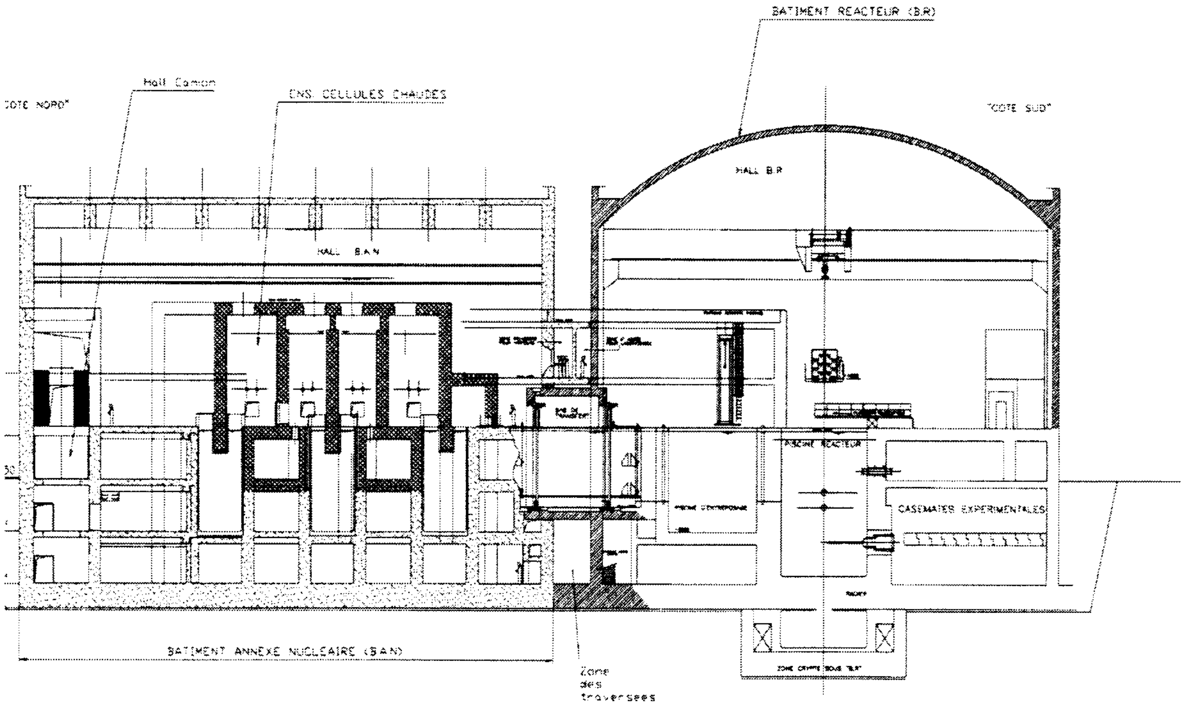
- to reduce the interaction between different activities (namely reactor operating teams and experimental activities). A design with two nuclear buildings was chosen, with the pools of the two buildings connected through an air/water lock at the third barrier level. Reactor and experimental areas are also separated, for confinement reasons, inside the reactor building.
- to take into account potential seismic hazards. this objective led to a height limitation of the buildings.
- to accommodate potential severe events (including ruptures of experimental loops, resulting in reactor building pressurisation). A cylindrical reactor building was chosen therefore.

The pools and their auxiliary circuits, including the whole main primary circuit, are located in a "water block" built on a single base slab. The volume of each casemate and of the water block are limited, to prevent any core decovering, even in case of a major leak in a circuit connected to a pool.

Horizontal cut view of the buildings



Vertical cut view



In the preliminary design, main characteristics of the buildings are:
Reactor building inside diameter: 36 m
Free height inside reactor and nuclear auxiliaries halls: 16m
Number of working levels: 4

5 RJH PROGRESS REPORT

The preliminary design of the reactor was achieved in 1999. Most of the studies were focused on key technical issues, especially on the core design and on the core tank.

In the year 2000, the reactor programme was re-evaluated to improve flexibility and versatility of the design. Some complementary studies are under way, focusing on ultimate performances of the core, and on the flexibility of the design with the highest level of safety, together with the launching of the next design phase. Detailed studies are going to start in January 2002, with an objective of first criticality in 2010.

6 CONCLUSION

RJH detailed studies are going to start in January 2002.
The very high performances of the RJH are supported by an extensive R&D effort on fuel and material behaviour, and on Neutronic and thermo-hydraulic codes.

References:

<1> Situation of the technological irradiation reactors – A progress report on the JULES HOROWITZ reactor project – presented at RERTR Las Vegas 2000

<2> The "Réacteur JULES HOROWITZ": The preliminary design – presented at IGORR 7 Bariloche 2000