The "Réacteur Jules Horowitz" :
The preliminary design

A. BALLAGNY - S. FRACHET
CEA
Direction des Réacteurs Nucléaires
31, 33 Rue de la Fédération
75752 PARIS Cédex 15

J.L. MINGUET - C. LEYDIER
TECHNICATOME
1100, Avenue Jean-René Guillibert Gautier de la Lauzière
13791 - Aix en Provence Cédex 3

ABSTRACT

The "REACTEUR JULES HOROWITZ" is a new research reactor project dedicated to materials and nuclear fuels testing, the location of which is foreseen at the CEA-CADARACHE site, and the start-up in 2008.

The launching of this project arises from a double finding :

⇨ the development of nuclear power plants aimed at satisfying the energy needs of the next century cannot be envisaged without the disposal of experimental reactors which are unrivalled for the validation of new concepts of nuclear fuels, materials, and components as well as for their qualification under irradiation.

⇨ the present park of experimental reactors is 30 to 40 years old and it is advisable to examine henceforth the necessity and the nature of a new reactor to take over and replace, at the beginning of next century, the reactors shut-down in the mean time or at the very end of their lives.

Within this framework, the CEA has undertaken, in the last years, a reflection on the mid and long term irradiations needs, to determine the main features and performances of this new reactor.

The concept of the reactor will have to fulfil the thermal neutron irradiation requirements as well as the fast neutron experimental needs, with a great potential versatility for any new irradiation programs.

The selected reactor project, among several different concepts, is finally a light water open pool concept, with 100 MW thermal power. It could reach neutronic fluxes twice those of present French reactors, and allows many irradiations in the core and around the core, under high neutron fluxes.

The reactor will satisfy the highest level of safety in full accordance with international safety recommendations and French safety approach for this kind of nuclear facility, thus giving an added safety margin keeping in mind the versatility of research reactors.

The feasibility studies have been focused on the main items, and have permit to determine :

- the core and fuel designs, with added pressurisation,
- the different core surrounding structures in connection with the core studies,
- overall layout of the reactor/auxiliary pools and reactor building.

PROCESS

The Jules Horowitz reactor (JHR) feasibility study, initialised in 1996, was completed in June 1999. This study enabled defining the principal reference options that will be explored in greater details in future studies.

Although most of the options were taken independently of each other, it was necessary to follow a certain logic in order to guarantee a global consistency of the technical solutions.

Although it is possible today to plan irradiation requirements for the beginning of the next century up to the start-up of the JHR with a reasonable accuracy, it is much more difficult to make plans for 2020 or 2030 and to estimate what could be the loading plan for that type of reactor in a re-configured European energy system. Consequently, from the start of the study, the accent has been placed on the capacity to adapt core configuration to an evolving experimental load, whether for volumes or for performances.

CORE AND FUEL ASSEMBLIES

The fuel adopted is one known as «low enriched Uranium Fuel» (or LEU) for which the U5 content is limited to 19.75% for non-proliferation reasons.

In order to obtain a longer cycle, fuel with the highest density possible must be used; to qualify such a fuel an extensive development program has been started on the Uranium-Molybdenum (UMo) fuel enabling to reach densities up to 8, and even 10 g of U/cm^3. However, all the core elements, and in particular the reactivity control, will be designed to be compatible with either this new fuel or the silicide fuel (U_3Si_2 containing 4.8 g of U/cm^3) used extensively today world-wide and more specifically in OSIRIS. The latter would be used in case the UMo is not completely qualified for the JHR start-up.

The fuel assembly is composed of concentric cylindrical plates, enabling higher flow speed than that obtained with a square assembly of similar size, and therefore the extraction of more energy. Furthermore, each assembly includes a central hole which can receive, indifferently, a control rod, a safety rod or an experimental device of medium size, without disturbing the network. The assembly could include 6 or 8 plates according to the size of the experimental device.

The core thus composed is secured in a machined mono-block aluminum rack, this is also used as a reactor tank. The tank is rectangular to facilitate the fitting of a Beryllium reflector around it.

The maximum core power is 100 MW and its specific average power can vary between 300 kW/l and 750 kW/l, the «reference» value around which most of the core studies are performed being 600 kW/l. This enables the definition of 3 cores of 100 MW:

- A medium core, known as «reference core», with a volume of 166 litres and a specific power almost twice that of OSIRIS, enabling to achieve almost all the objectives set at the start of the feasibility study, with the exception of tests requiring the accumulation of a very high damage rate (in the range of 200 dpa).

- A large core, of 330 litres and specific power similar to that of OSIRIS, enabling the performance of a very large number of experiments not needing a very high flux level.
- A small core of 133 litres, enabling to meet 750 kW/l, and therefore higher performances (particularly in fast flux), allowing, however, only a reduced number of experiences.

By reducing total core power the two smaller versions allow to run the reactor in a cheap way in case it would be required to reduce the number of experiments and/or levels of performance.

In order to limit neutron leakage and to improve fuel life duration, a Beryllium reflector is designed for installation around the tank.

INTERNAL ELEMENTS AND PRIMARY CIRCUIT

The primary circuit will be totally closed, in order to build an effective 2nd barrier. This configuration is limiting the access to the experiments located in the core. However, all the experiments located in the reflector are outside of the primary circuit and therefore accessible at all times. this is an essential advantage for experimentation.

The benefit of pressurising the primary circuit has been debated at length. In nominal operation mode, constraints imposed by cladding temperature does not allow to take advantage from pressurisation (which is increasing boiling temperature). However, in transitory modes with reduction of flow it provides important margins against boiling. A core outlet pressure (i.e. 5 bars) slightly higher than the minimum necessary to avoid boiling in nominal functioning has therefore been adopted.

In order to improve natural convection during transient conditions with loss of pumping, ascending circulation of the primary fluid in the core has been adopted. To avoid communication between the primary circuit and the pool during transients and to keep the benefit of the closed primary circuit, the residual core power is evacuated towards the pool water by a specific device (likely an exchanger immersed in the pool) ensuring that the primary circuit remains tight.

The internal structure is composed of a mono-block aluminium frame that constitutes both a rack and a tight tank covered with a thin plate, made of aluminium. The tank is rectangular and is closed by a plug containing several openings to enable the passage of the experimental devices located in the core. On the external faces, γ protections are placed to limit heating of the experimental devices situated in the reflector by irradiation coming from the core.

All these elements can be easily disassembled under water, to enable rapid modification of the core configuration.

EXPERIMENTAL CAPACITY

One of the main objectives searched for in this primary phase was to provide an experimental capacity:

- maximum,
- as diversified as possible,

- adaptable to evolving requirements.

This has resulted in the core configuration described previously (cf. sketch hereafter), and, for the version called «reference core», enabled the accommodation of 16 devices in the core and more than 20 in the reflector.

The solution adopted allows satisfaction of almost all the requirements expressed, with the exception of those needing the acquisition of very high fast flux levels (dose in the range of 200 dpa) within a reasonable time delay.

ASSOCIATED EXPERIMENTAL RESOURCES

It covers the facilities aiming at fulfilling the requirements of the experimental programs, and should enable the supply of «turnkey» irradiation from samples reception up to the release of results to the customer after irradiation. For that, it is essential to ensure adequate support to minimise examination time and to accept a flow of experiments corresponding to the reactor's experimental potential. The number and characteristics of the hot cells, the examination process, the path of experiences. The number and characteristics of the work areas and experiment preparation areas have thus been defined for that purpose.

This led to design several laboratories, to analyse fission products, chemistry, dosimetry, or perform analysis by activation and 5 hot cells devoted to different activities (on standard fuels, minor actinides, structural material, radio-elements, or for device dismantling). Are also foreseen non-destructive examination processes such as an immersed neutronography, gammametry, an examination work station associated to the hot cells and specialised underwater work areas.

ORGANIZATION OF BUILDINGS

The studies on this subject have been driven by two major concerns:

- to limit exposure of personnel to radiation,
- to reduce, as far as possible, interaction between the different activities in order to limit the number of accidents and diminish their consequences,

They are leading to the separation and confining of the different activities to 2 separate and adjacent buildings: a **reactor building (BR)** housing the reactor operational area and the experimental bunkers, and a supplementary **nuclear activity building (BAN)** housing activities on radioactive components and, specifically, all the experiment-related activities.

In addition, the following principles have been adopted:

- underwater transfers between the 2 buildings in continuous mode,
- inspectability of the 2nd and 3rd barriers,
- impossibility to dewater fuel assemblies stored in the pool by using passive features whenever possible,
- optimisation of the number of holes through the reactor building directed to the BAN and grouped in a leak collection area.

CIVIL ENGINEERING

The **water system,** composed of all the pools, transfer channels and the underwater lock is continuous and is built on a single base slab.

All the pools and channels have a stainless steel cladding and are equipped with a leak detection system.

The BR and BAN walls have been designed to resist the impact of falling aircraft, earthquakes and external flooding; however, only the BR walls can resist the internal pressure resulting from a dimensioning accident of BORAX type.

Consequently, a cylindrical shape is recommended for the BR, this being more appropriate for resistance to internal pressure. On the other hand, the BAN has a parallelepipedic shape, which enables optimization of its internal fitting.

SCHEDULE

The design study phase must be completed by 2002, The building starting is foreseen in 2003, which should lead to reactor criticality by 2008.