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COMMISSIONING TEST PROGRAM IN CABRI AFTER THE REFURBISHMENT OF THE REACTOR AND THE IMPLEMENTATION OF A PRESSURIZED WATER LOOP

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ABSTRACT

The CABRI experimental reactor is located at the Cadarache nuclear research center, southern France. It is operated by CEA and devoted to IRSN safety programmes. It has been successfully operated ~~by CEA~~ during the last 30 years, enlightening the knowledge of FBR and LWR fuel behaviour during RIA and LOCA transients in the frame of IPSN and now IRSN programmes devoted to reactor safety. This operation was interrupted in 2003 to allow for a whole facility renewal programme. The main goal of this reconstruction project is to meet thermal hydraulics parameters identical to LWR standard and downgraded conditions, in particular for the need of the CABRI International Programme (CIP) carried out by IRSN under the OECD umbrella. For this, the sodium cooled experimental loop is now being replaced by a pressurized water loop. In addition, several key safety issues of the facility have been reanalysed in the framework of the safety re-assessment to take into account new functions, new requirements and upgrade ageing equipment.

The reconstruction project is funded by IRSN.

The aim of this paper is to present a general panorama of the operations for upgrading the facility and the commissioning test program.

Introduction

The CABRI facility is a pool type reactor. In the reactor, a dedicated loop controls phenomena relevant to the single experimental rod during a Reactivity Insertion Accident (RIA) type transient or a LOCA transient. It has been successfully operated by CEA for the last 30 years, enlightening the knowledge of FBR and PWR fuel behaviour under these accidental transients. This operation was interrupted in 2003 to allow a whole facility renewal program. The CABRI International Programme was decided in order to realize tests representative of PWR accidental conditions: initially designed for safety studies on fast reactor fuels in a sodium loop, the facility is thus being modified in order to have a water loop able to provide thermo hydraulical conditions representative of nominal PWR's. This new "Water loop program" will be devoted to study the behaviour of the advanced PWR fuel mainly under Reactivity Initiated Accident (RIA) but also during Loss Of Coolant type Accidents (LOCA). The main RD programs on fuel concern :

- the high burn-up fuels
- the new cladding materials,
- the mixed oxide fuels.

This international program is placed under the auspices of OECD and managed by IRSN.

Due to the French requirements by law, several key safety issues of the facility have been reanalysed in the framework of the safety re-assessment to take into consideration new functions, new requirements and upgrade ageing equipments.

Finally, the large modernisations of CABRI concern :

- the implementation of the new water loop,
- the upgrade of the facility which guidelines are issued from the safety review and the modernisation of equipments

CABRI reactor

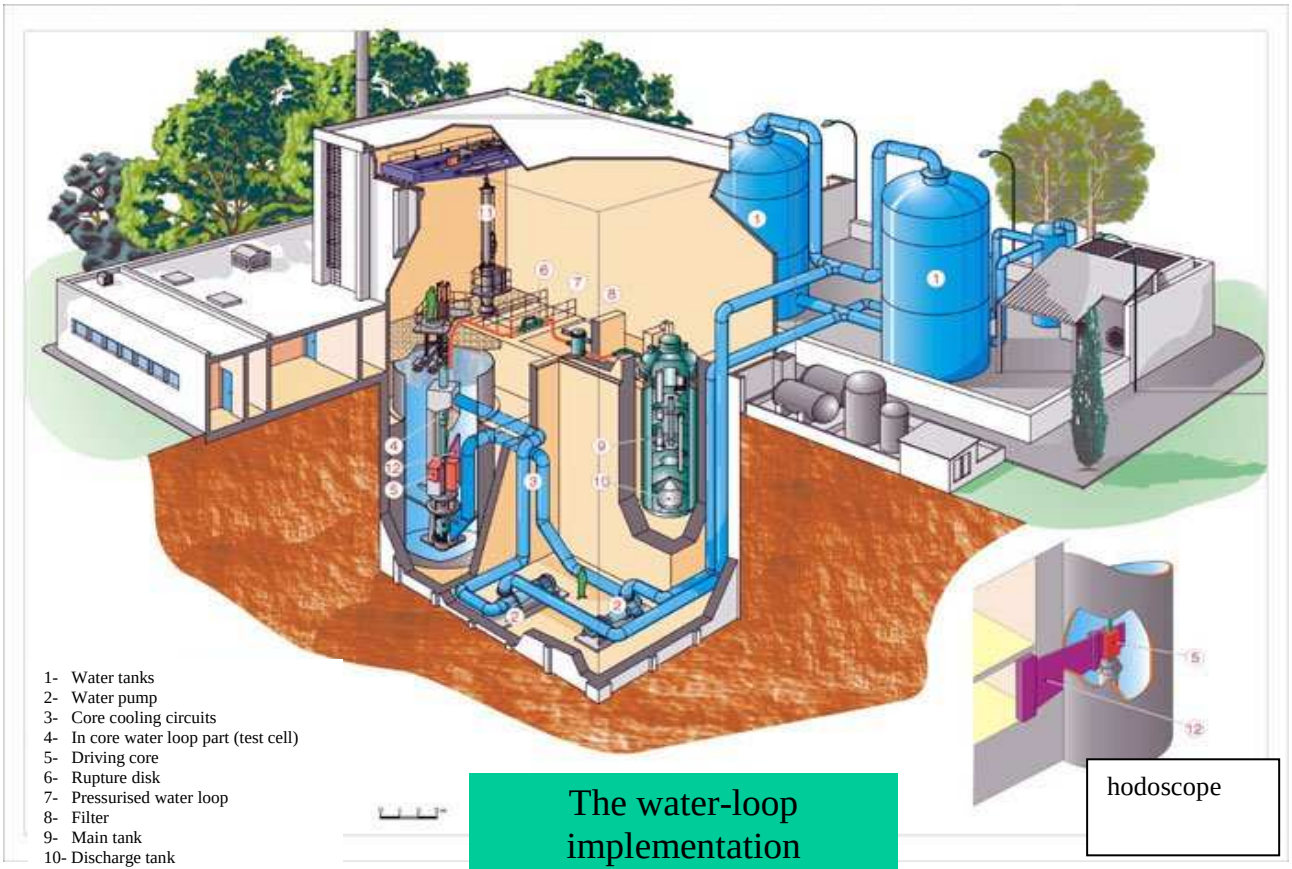
The pool type research CABRI reactor is located on the Atomic Energy Commission (CEA) site at Cadarache in Southern France. The reactor became critical for the first time in 1963. In 1975, a large program of modernization was established to perform RIA programs. Since this period, it was used for fast power transients and therefore to simulate a reactivity insertion accident (RIA). These tests, requested by the French Safety Authority, are in anticipation of increasing the fuel burn-up rates in electricity-generating reactors.

The reactor is made up of (see Figure 1):

- a driver core, with a maximum power of 25 MW in steady-state conditions, two tanks of 250 m3 are used as a thermal capacity (limited time at high power level)
- an experimental loop, with its own cooling system, one part of which is located at the centre of the block core and contains the instrumented test device with the experimental fuel pin to be tested.

The main characteristic of CABRI reactor is the reactivity injection system : four driver core assemblies, called "transient rods", are fitted with empty cylindrical tubes at their periphery; these tubes may be filled with pressurised helium 3 (gas absorbing neutrons) and depressurised by opening the motorised valves, to extremely quickly modify the reactivity and, therefore, the power of the driver core and consequently the test pin power by neutron coupling.

For the injection of reactivity, initiated from a power level of about 100 kW up to a maximum which could achieve about 20 GW, the reactor safety chain is inhibited for 1 s., Before the fall of control and safety rods , the power drops under the effect of the neutron feedback (Doppler effect).



1- Water tanks
2- Water pump
3- Core cooling circuits
4- In core water loop part (test cell)
5- Driving core
6- Rupture disk
7- Pressurised water loop
8- Filter
9- Main tank
10- Discharge tank
11- Transport cask for the test train
12- Hodoscope

The water-loop implementation

hodoscope

CABRI Reactor is also well equipped with experimental facilities :

- Hodoscope : this device allows to record the movements of the experimental fuel pellets of the test pin during the pulse. Many fission chambers equip the hodoscope to give the information about the behaviour of the experimental test pin
- IRIS : it is a non destructive scanning system for tomography and spectrometry

These two equipments perform on line non destructive examination (hodoscope) and post irradiation examinations (IRIS)

Implementation of a new pressurized water loop

The main goal of the CABRI International Programme project is the replacement of the sodium loop by a pressurized water loop in order to have the thermal hydraulics parameters identical to PWR standard and downgraded conditions. In order to deposit enough energy in the experimental test pin, the neutron coupling factor between the driver core and the experimental test pin must be as high as possible. This is particularly accurate for high burn-up fuels. The zircaloy for the in pile part of the water loop (two concentric shells) is the best candidate.

The Pressurized water loop include :

- one section installed in the centre of the block core of CABRI reactor, made of Zircaloy. This “in pile cell” is a nuclear pressure vessel of the PWR primary circuit. This cell is the pressurized water containment (PW containment) which houses the test device and contains the radioactive products (first barrier towards the test fuel). the safety tube, made also of zircaloy, takes place, around the cell. It provide thermal isolation between the Pressurize water loop containment and the reactor pool water (second barrier towards the test fuel),

The new block core and the in pile cell of the new loop

- one out-of-pile section in stainless steel, comprising :

- a “containment vessel” with all the systems required for the experiments (systems which are first barrier towards the test fuel) and which will act as the second barrier towards the test fuel,
- a double walling for the connecting piping between the PW containment and the loop coolant system in the containment vessel,
- a mechanic filter, catching “virtually” all the particles from any rupture of the test rod,
- a collecting tank for the loop gaseous effluents, located outside the “containment vessel”.

The containment vessel

The experimental loop and related systems are located in the reactor building, the third barrier.

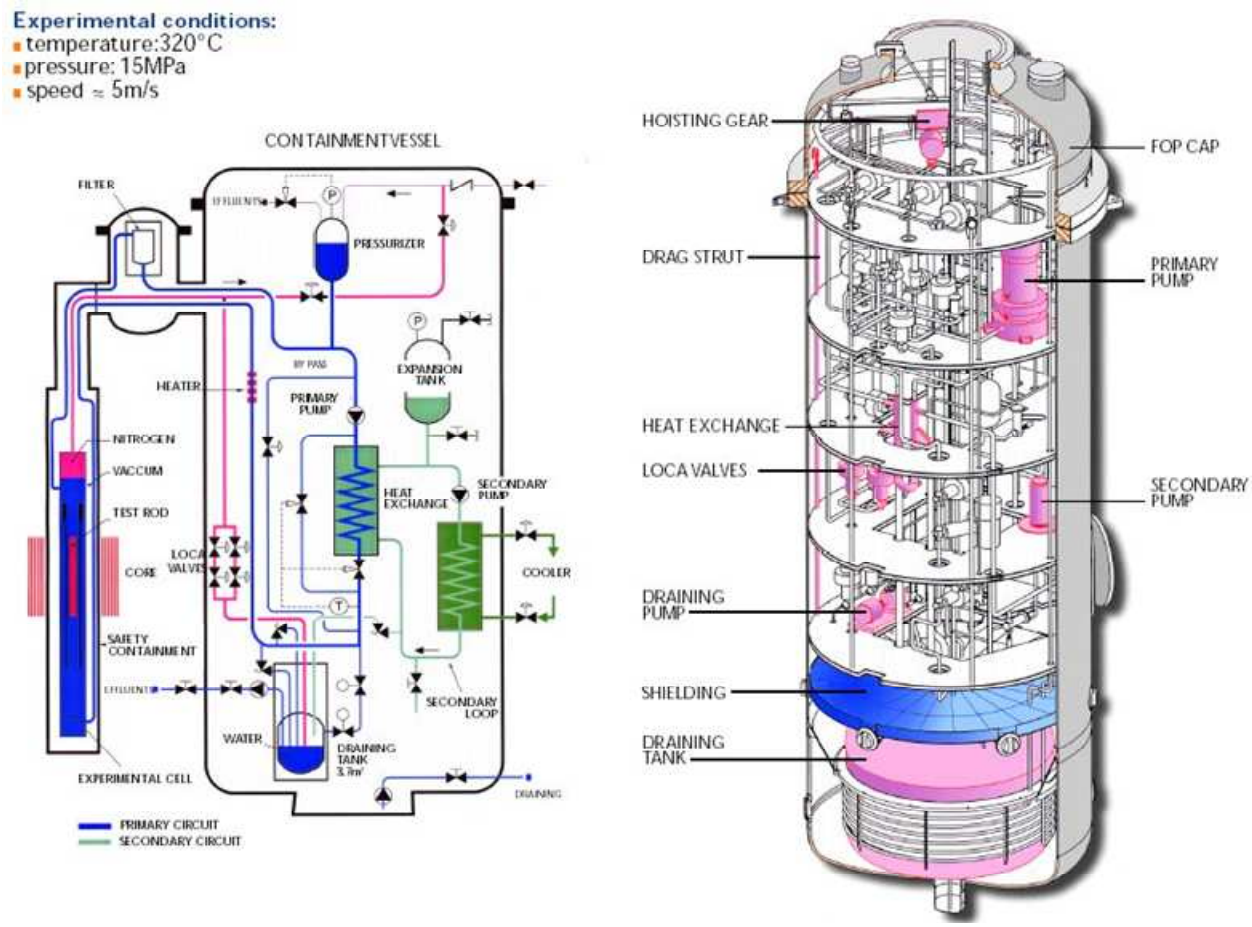
Concerning the conception of this “in pile cell” made of zircaloy, the validated design codes (ASME/RCCM) suggest the use of materials with a low anisotropy, a sufficient ductility and thoughness to prevent fast fracture, a good experience of fabrication and operation in equivalent conditions. The zirconium alloys (zircaloy) is not explicitly provided in design codes (ASME/RCCM). It was necessary to establish a specific RD program for using zircaloy. A program to demonstrate the zircaloy fracture toughness was set up :

- specific fabrication of a heat ingot,
- mechanical properties,
- fracture mechanics calculation,
- gathering of all experience and feedback on similar uses of the zircaloy

This program has been analysed by the safety authority and it considered to have an high quality production. Specific non destructive examination procedures and qualification have been done to answer to this requirement.

The impact of irradiation dose on the zircaloy is not taken into consideration due to the duration of each experiment.

Due to the different nature of materials, the pressurised water containment and the safety tube, l made of zircaloy, the other parts of the primary circuit and of their containment are made of stainless steel, it was necessary to develop and produce heterogeneous junctions to join the two parts



The new water pressurized loop

The facility upgrade : safety review and implementation of new equipments

The facility upgrade was due mainly by the implementation of this water pressurized loop but also by the results of the safety review.

The safety review

The safety review is an administrative process. As remind, similarly with the approaches for the French Nuclear power Plants, the basis of the global safety review are :

- a review of the facility in compliance with its last approved reference standards, including visit and control of equipments,
- a safety re-assessment (major part of the safety review), based on :
    - an analysis of the feed-back experience,
    - the identification and processing of discrepancies compared with current regulations (French regulation, IAEA, recommendations and guides…),
    - the updated safety studies taking into account the evolution of knowledge and of analysis methods (seismic re-assessment, fire attack..).

First of all, it could be necessary to define, the future of CABRI. CEA consider a use of this facility for long time (more than 20 years). With such hypothesis, the safety review started defining:

- the classification of equipment regarding their importance for the safety,
- the identification of 4 operating conditions (PWR methodology) associated to safety goals.

The methodology is also based on :

- the use of conception rules issued from standards of present conception codes or particular specifications (zircaloy for example). For existing components for which past conception codes were used an equivalence with recent codes is assessed,
- a systematic verification of the good level of safety standards of the overall facility,
- a verification of the good level of safety by the examination of design accidents,
- an examination of nuclear, and non nuclear internal risk along with external risk.

Regarding the systematic verification of the good level of safety of the equipments, some program have been done :

- a specific non-destructive program was established to control the primary circuit (radiography, US…)
- most of the “hot” fuel of the driver core were observed .

Non destructive examination of the primary circuit

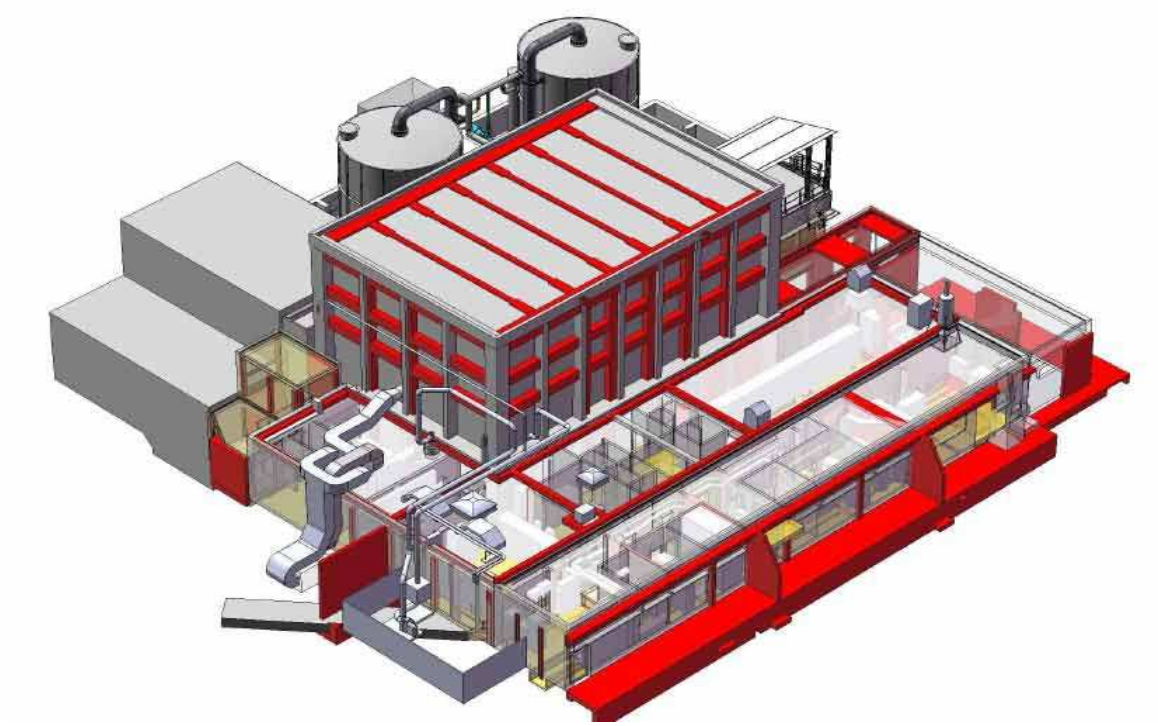
It is important to note the specificities of the CABRI operation :

- there is only short duration of the reactor operation : limitation of the presence of risk associated to control rods up, helium 3 in the core, power, water loop under high pressure. For example, the simultaneity of Safe Shutdown Earthquake (SSE) earthquake and reactor operation in considered as an out of design situation,
- the absence of staff in immediate proximity during reactor operation or loop pressurisation (control room located 300 m from the reactor),

Finally,, the facility had to be upgraded with the impact of the new regulation. For example, considering the earthquake, the revision of regulation in 2001 (Maximum Historically Probable Earthquake (MHPE) and a Safe Shutdown Earthquake (SSE) has been reviewed) had to be take into consideration : the reactor building, the auxiliary building, the core support, the reactor pool tank, the different equipments (the crane…) were modified.

To illustrate, the scheme below introduces the project of reinforcing the CABRI facility. These objectives are,

- reinforcing reactor building structures from outside,
- underpinning with carbon fibre fabric in the lower infrastructures,
- decoupling and reinforcing auxiliary buildings,
- partial demolition of the sodium compartment.



Seismic Building Reinforcement

The associated administrative process (safety review.) is ongoing.

The analysis of the preliminary safety report and the intermediate safety analysis report are completed. The French Safety Authority has responded favourably to the modification of the facility and its safety review. The analysis of response to the requests by the Safety Authority has been done and it is foreseen that the facility will re-enters in-service at the end of 2010.

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Description of the main new equipments

Equipments had to be installed in the facility to take into account the re-assessment of the safety review but also, considering the implementation of the new loop. The main new equipments are :

- the nuclear ventilation system,
- the liquid waste system,
- the reactivity control system
- the instrumentation and control system for taking into account these new equipments

The implementation or refurbishment of the following equipments has been necessary :

Nuclear ventilation system

Due to the implementation of a new loop, the new regulation for the nuclear venting system and the re-assessment of the emergency situation, the radiological consequences in and out of the building reactor would be reduced as low as possible. A new ventilation system was designed: the flow is increase (3000 to 13000 m3/h) and the system is now isolated.

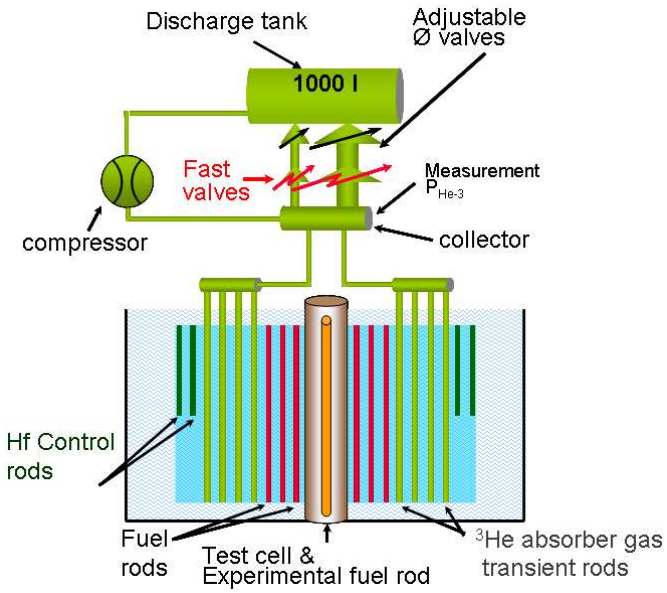
The new nuclear ventilation system

The liquid waste system

The implementation of a new liquid waste system was necessary due to the replacement of the sodium loop by the water pressurized loop. In the framework of reducing the activity of the liquid waste, resin facility and mechanic filter are employed. To facilitate the liquid waste management, it was decided to reduce the very highly liquid waste in normal or medium highly liquid waste by using specific resin facility. An R&D program was established to qualify this process. The mechanical filter is used to limit the aggregate parts, due to the experimental test, in the waste liquid. This system is also composed by glove boxes for sampling, circulating pump, and two specific tanks for liquid waste storage with biological protection.

The reactivity control system

The main device to perform the Reactivity Insertion Accident (RIA) transient is composed by a depressurisation of helium 3 gas system. In the framework of the re-assessment and the objective of reducing the probability of a severe accident (fast depressurisation of this system), a total modification of the reactivity control system was engaged to improve the level of safety by reducing the risks of default.



Depressurisation helium 3 gaz system

The instrumentation and control system for taking into account these new equipments

It has been necessary to substitute or adapt the old instrumentation and control system with new one for taking into consideration the new equipments but also the new regulation. Some new I&C systems are developed and installed.

Concerning the safety equipments, it is important to quote some of them:

- lastly, in accordance with IAEA recommendations for new facilities and given the planned additional operating time in case of earthquake, a seismic detection system to the CABRI reactor will automatically shut down the CABRI reactor . This new system is designed and its installation is ongoing To complete this system, some specific and independent measurement systems will be installed and connected to an Information/computing system located in an emergency control room. These information (temperature of water at the core inlet;sub-criticality of the core, water heating in the core,level of water in the reactor pool, radioactivity in the reactor building, position of the natural circulating valves, position of the isolating reactor building valves…) must be available after an earthquake.
- a specific device will be installed to shutdown the reactor by injection of boron liquid in the periphery of the core in case of earthquake event
- Implementation of new radiation measurement systems to take into account the evolution of the operation (new water pressurized loop and highly activity liquid waste).

Commissioning test program

One of the major challenging tasks of this project is to ensure the respect of the safety requirements and the experimental capabilities and reliabilities of this “new and unique facility” ; a large commissioning test program has been established.

The aim of this commissioning processus is to qualify the new equipments and re-qualify the equipment which were upgraded. In final, the demonstration of the all safety requirements but also the capabilities of the experimental facilities would be obtained. A specific organization was defined. The main issues of this processus are :
- the measurements of the core physics parameters at 0-power and on power : the aim is to verify the neutron parameters of the reactor ; by the implementation of the new loop (water replaces sodium) in the block core of the reactor, it is necessary to re-qualify the core after reloading.. It is also the opportunity to perform specific neutron and thermo-hydraulic measurements in the framework of a training program for news operators. Some dosimeters will be used to compare the experimental measurements and computed core calculations,
- ventilation test,
- start the water pressurized loop,
- re-qualify the experimental devices (hodoscope, IRIS),
- re-qualify the command control and the new IC system,
- re-qualify the handling device.

Conclusion

This paper presents the refurbishment of the CABRI Safety Test Reactor . It introduces the implementation of the new loop and the the safety re-assessment programme. In final, it describes the organization and the schedule of the Commissioning test programme to re-qualify this facility.