UPSCALING CABRI CORE KNOWLEDGE FOR A NEW SAFETY CASE

G. RITTER, F. JEURY
CEA/Direction de l'Énergie Nucléaire/DER/SRES.
B[t] 721. Cadarache, 13108 St Paul Lez Durance, FRANCE

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 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 revisited in order to defend a comprehensive safety case before the safety authority. First item in the case is of course the core. The aim of this paper is to present the path leading to a new core operations domain through expertise, mechanical tests and numerical computations. The reconstruction project is funded by IRSN.

1. Introduction

The CABRI facility is made of a pool type reactor in which a dedicated pressurized water loop allows to control phenomena relevant to the single experimental rod during the transient. The core is basically a neutron oven, generating fissions in the experimental rod located in its centre. A vertical channel symmetrical across the core allows the hodoscope, a unique neutron digital camera, to monitor the course of fissions in the experimental rod along the experiment.

The core is made of 1488 stainless steel clad fuel rods with a 6% 235U enrichment. These rods are inserted in 5 types of sub-assemblies. The reactivity is controlled via 6 bundles of 23 Hf rods.

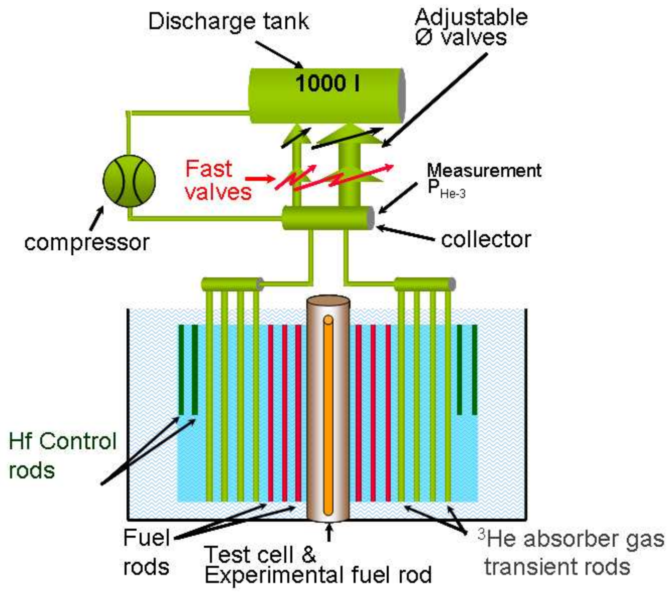

Fig 1. Principle of operation of the CABRI facility

Eventually, the key feature of the CABRI core is its reactivity injection system.
This device allows 96 tubes filled with 3He (major neutron absorber) up to a pressure of 15 bars and located among fuel rods to depressurize very fast in a discharge tank. The absorber ejection translates into an equivalent reactivity injection possibly reaching 4$ within a few 10ms. The power consequently bursts from 100 kW up to ~20GW in a few ms and decreases just as fast due to the Doppler effect and other delayed reactivity feed-backs. The experimental simulation of RIA the CABRI core provides to the experimental rod is of course also withstood by the driver core fuel rods.
This feed core fuel rods were designed in the early 1970's to operate in these very demanding conditions.
The facility renewal programme started in 2003 allowed for sharp examination of core fuel rods which revealed a local and partial fusion in one of the hot rods. A level 1 incident was declared to the safety authority. The up scaling of the CABRI core safety case had just started.

2. A new domain for operation

The allowed domain for operation was determined both by a maximum fuel temperature and a maximum heat flux to the coolant. These criteria were not coherent with actual core operating conditions and thus were replaced by a new set of limits. The features now describing the core fuel rod behaviour are the clad maximum temperature and strain as well as the fuel maximum temperature. The new domain for operation (cf. fig. 2) is now consistent with the confinement function allocated to the core fuel rod cladding.

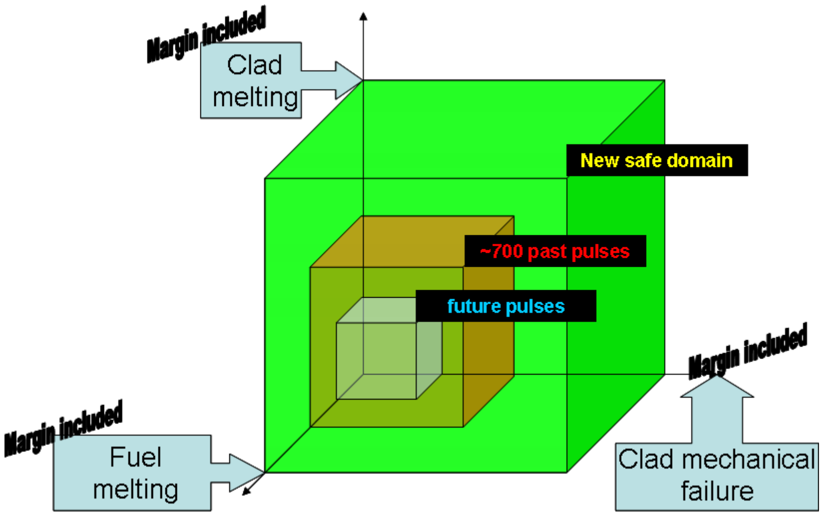

Fig 2. New domain for operation

3. Validation of core behaviour through expertise, dedicated experiments and numerical computations

Understanding past CABRI experimental programmes

After that the evidence of a local fusion was uncovered, a comprehensive analysis was started to analyse the cause of this event. The investigation included destructive rod examinations, a full characterization of fuel pellets and a very large programme of computational simulations of past experiments according to three key viewpoints. The study was based on cutting edge thermal hydraulics, reactor physics and mechanics. According to this enquiry the fusion event seems to have occurred during a ramp type of test. This type of test will not be performed anymore in the future.

Safety assessment for future experimental programmes

The ability to meet past experimental conditions by numerical simulation was a first step towards proving the control of future programmes. An additional mechanical tests campaign was conducted onto the clad of used and fresh rods. The goal of this operation was to determine maximum stress conditions for the clad. It thus allowed defining the maximum tolerable strain and temperature in the clad. The numerical simulation action launched to understand the past was also extended to demonstrate the capacity to meet experimental objectives while remaining within a safe perimeter. The thermal hydraulics models were validated in that perspective on a set of experiments typical of CABRI conditions. Eventually, the hot rod behaviour during future CABRI like tests was computed according to best estimate and conservative hypotheses. It showed future experiments would not take the rods beyond the safety domain.

4. Commissioning the facility for the upcoming CIP series

Re-starting CABRI after 6 years without experiments will come up through a dedicated procedure. All core physics features will be tested step by step, bottom up, until full confidence is acquired on the safety of the facility. The main characteristics will be validated during two key phases, i.e. neutron commissioning and power commissioning, described hereafter.

Neutron commissioning

During these tests the reactivity will be monitored in a static mode either by control rods level difference or by ^{3}He pressure difference. The integral and differential rods and ^{3}He reactivity worth will be measured. An attempt to monitor slow dynamics reactivity feedbacks like moderator or coolant effect should be initiated. But also during the power bursts an effort will be dedicated to retrieve an assessment of the Doppler effect. Eventually, the main parameters to be measured in CABRI are of course the weight of delayed neutrons and the neutron lifetime β and l.

Power commissioning

The absolute power module will be measured at medium power by a usual heat balance. This will allow the calibration of experimentalists and facility operators ion chambers. During the power burst and as there can be no heat balance at such a power level, it will be necessary to rely also on an integration methodology corresponding to a dosimetry experiment. This power integration will be compared to the energy integrated by the ion chambers during the peak of power. The coupling between core and experimental rod should be determined through a set of dosimetry measurements. The nature and location of dosimeters should be optimized in order to assure the best measurement.

The last phase of power commissioning will proceed through a progressive pattern in order to remain conservatively within the new safe operations domain. This so-called start-ups phase will consist in power bursts initiated by the reactivity insertion system. The key parameters of this device are the ^{3}He pressure and the ^{3}He valves aperture, respectively determining the maximum injected reactivity and the maximum injection rate. In that perspective, these crucial factors will be increased stepwise from ❶ to ❾ as in figure 3.

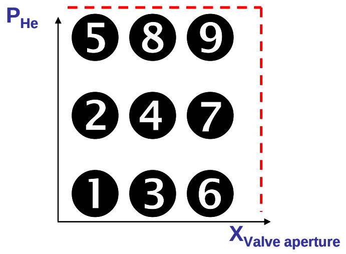

Fig 3. Experimental start-ups commissioning pattern

5. Conclusion

This paper presents how the CABRI core safety case was upgraded. It introduces past and future operation domains. It also reminds how the understanding of the past presented the conditions leading to a partial and local fusion event. Eventually, the assessment of the core fuel rods behaviour during the future experimental programme through numerical simulations showed it would remain well within a safe perimeter.

When the core is ready to start commissioning under standard conditions, all possible parameters will be progressively checked while in operation to make sure that pre-test safety assessments were correct.