

CABRI REACTOR SAFETY REASSESSMENT

*Joint Meeting of
The National Organization of Test, Research and
Training Reactors
and
The International Group on Research Reactors
September 12-16, 2005*



CABRI reactor safety reassessment (1)

- OVERVIEW

- 1. CABRI reactor in the context of future experimental needs*
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- 3. Experimental program*
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- 5. Pressurized water loop*
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- 7. Safety assessment of the reactor fitted with the loop*
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- 9. Conclusion*

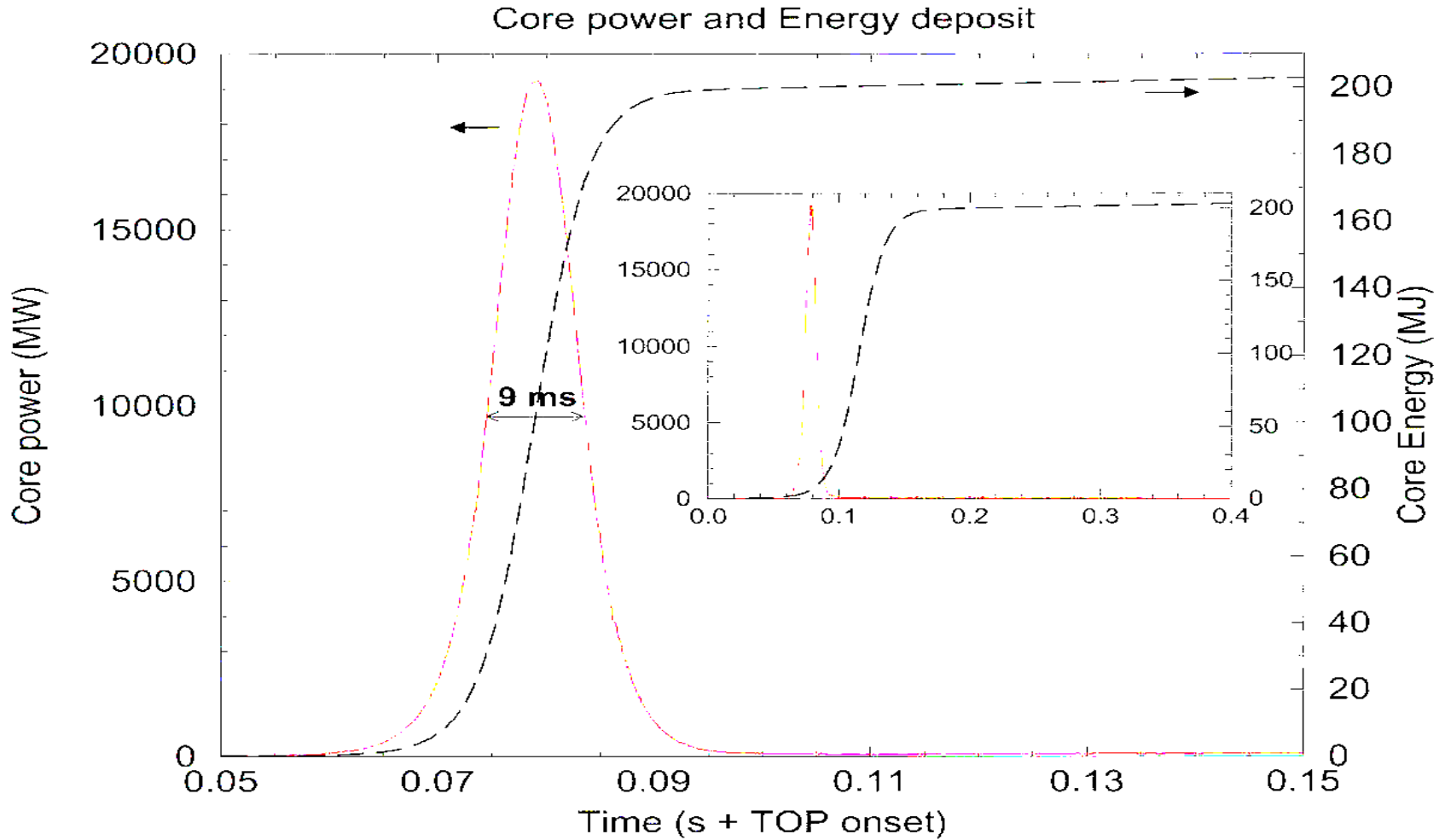
CABRI reactor safety reassessment (2)

1) CABRI reactor in the context of the experimental needs

- **Reactor operated by the CEA**
- **Site : Cadarache (south of France)**
- **Buildings constructed in 1962**
- **Pool type water reactor, with driver core and experimental loop containing a test pin**
- **Driver core : UO₂ fuel pins (enriched with 6% of ²³⁵U)**
- **Neutrons pulses by « transients rods » (3 \$, with 50 \$/s)**

CABRI reactor safety reassessment (3)

REPNa5



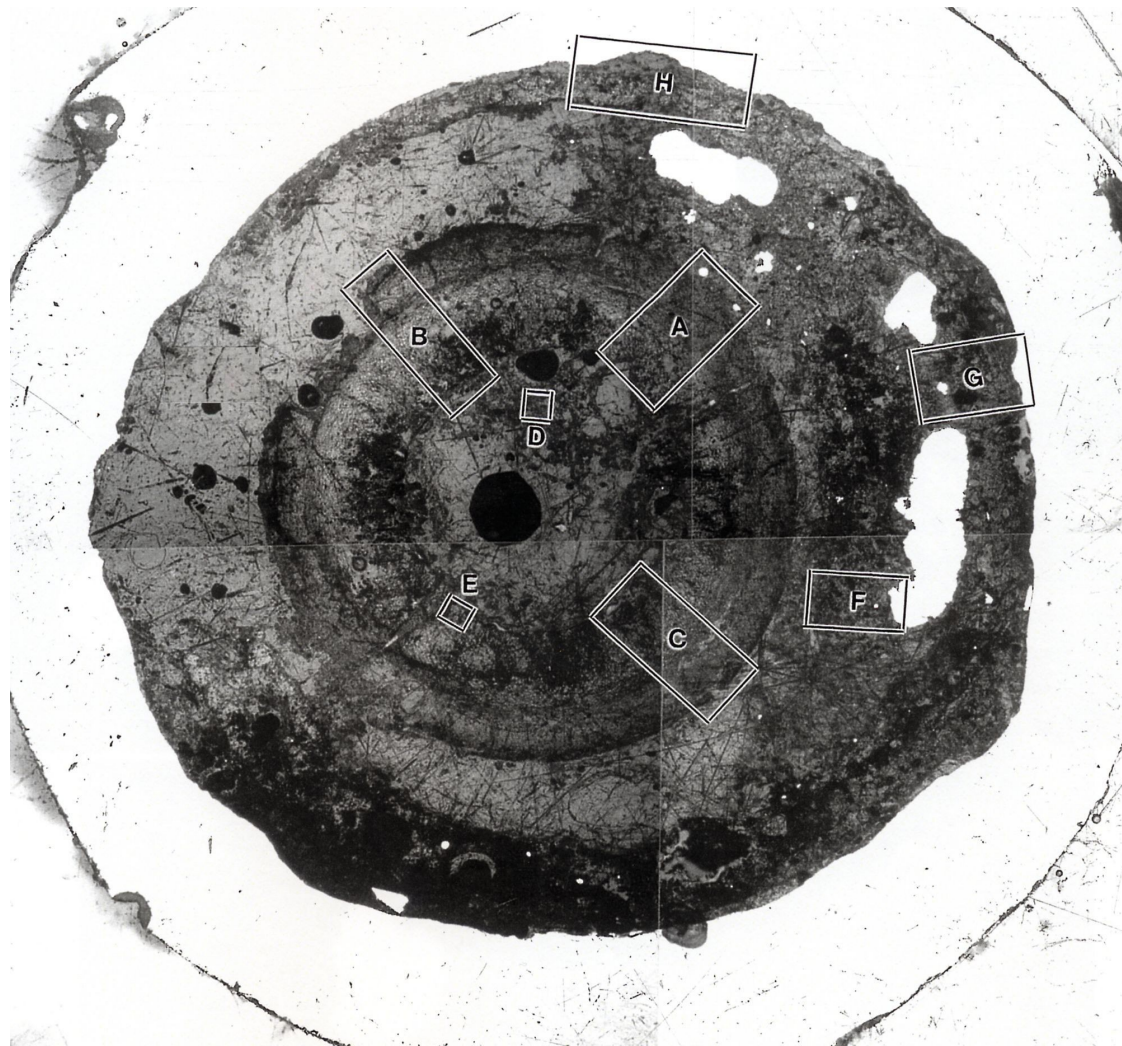
CABRI reactor safety reassessment (4)

2) *Experimental program*

- **Until now, experiments carried out on FBR and PWR with the loop in sodium**
- **Energy depositions with clad failure, fuel melting, ejection in the test channel with thermodynamical interaction**
- **About 70 tests since 1978:**
 - ***for FBR (59 tests) : CABRI 1, CABRI 2, CABRI Fast, CABRI Raft***
 - ***for PWR (14 tests) : CABRI REP Na, CIP***

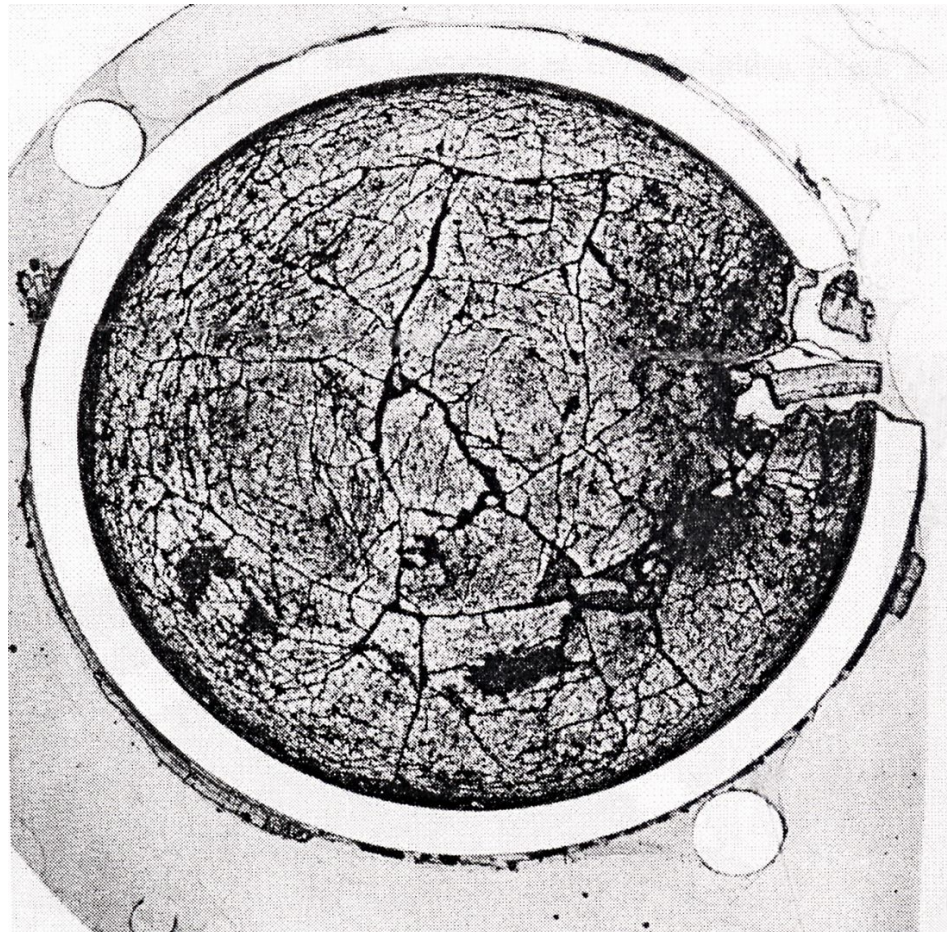
CABRI reactor safety reassessment (5)

(example of experiment)



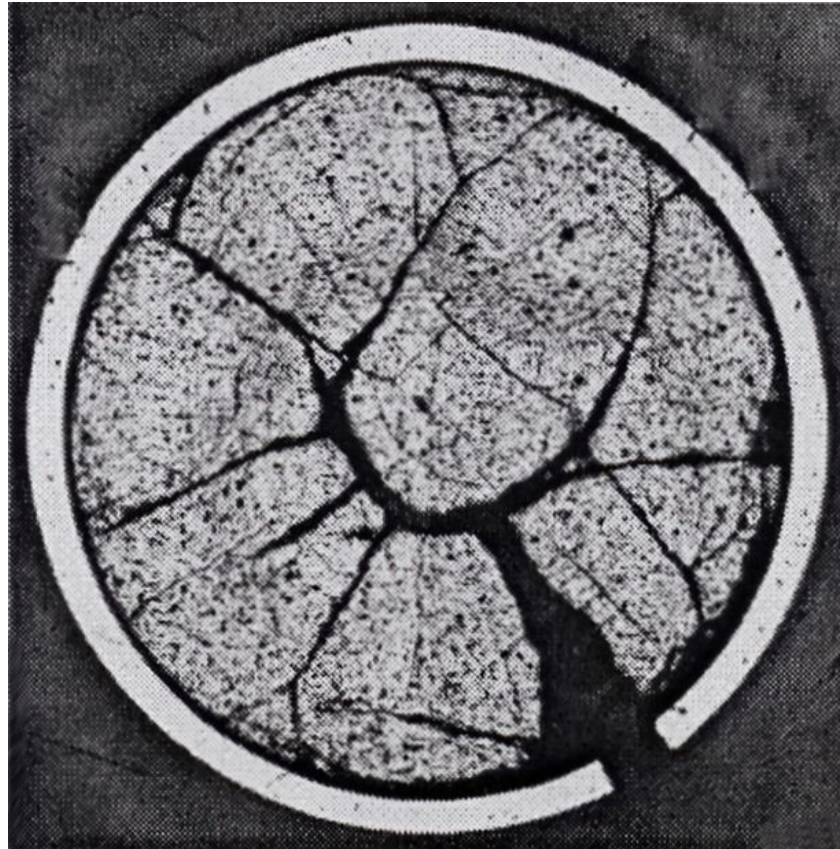
CABRI reactor safety reassessment (6)

(example of experiment)



CABRI reactor safety reassessment (7)

(example of experiment)



CABRI reactor safety reassessment (8)

Future experimental program

- **About 60 tests scheduled for 2008, over 20 years, involving UO₂ and MOX pins with high burn-up (100 GWd/t for UO₂ and 90 GWd/t for MOX)**
- **Testings in real PWR conditions, for RIA transients**
- **Energy depositions with clad failure, possibly fuel ejection in the test channel with thermodynamical interaction**

CABRI reactor safety reassessment (9)

- **Main goals:**
 - ***improve knowledge of the interactions between fuel, cladding and coolant***
 - ***estimate safety criteria margins (thresholds for cladding failure and fuel dispersion)***
 - ***study fuel relocation, zirconium oxidation by steam reflooding, damage mechanisms of the cladding***

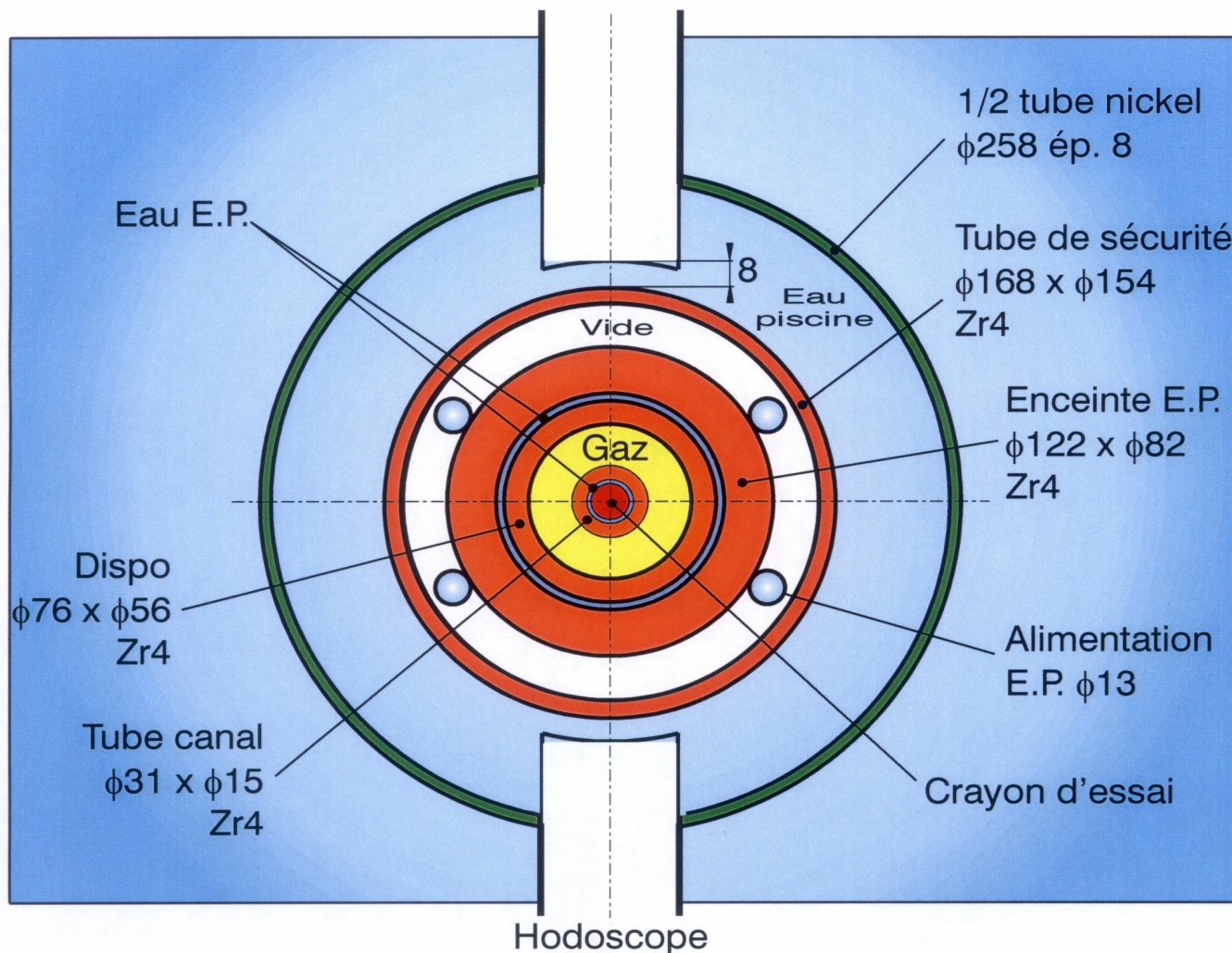
CABRI reactor safety reassessment (10)

3) *The pressurized water loop*

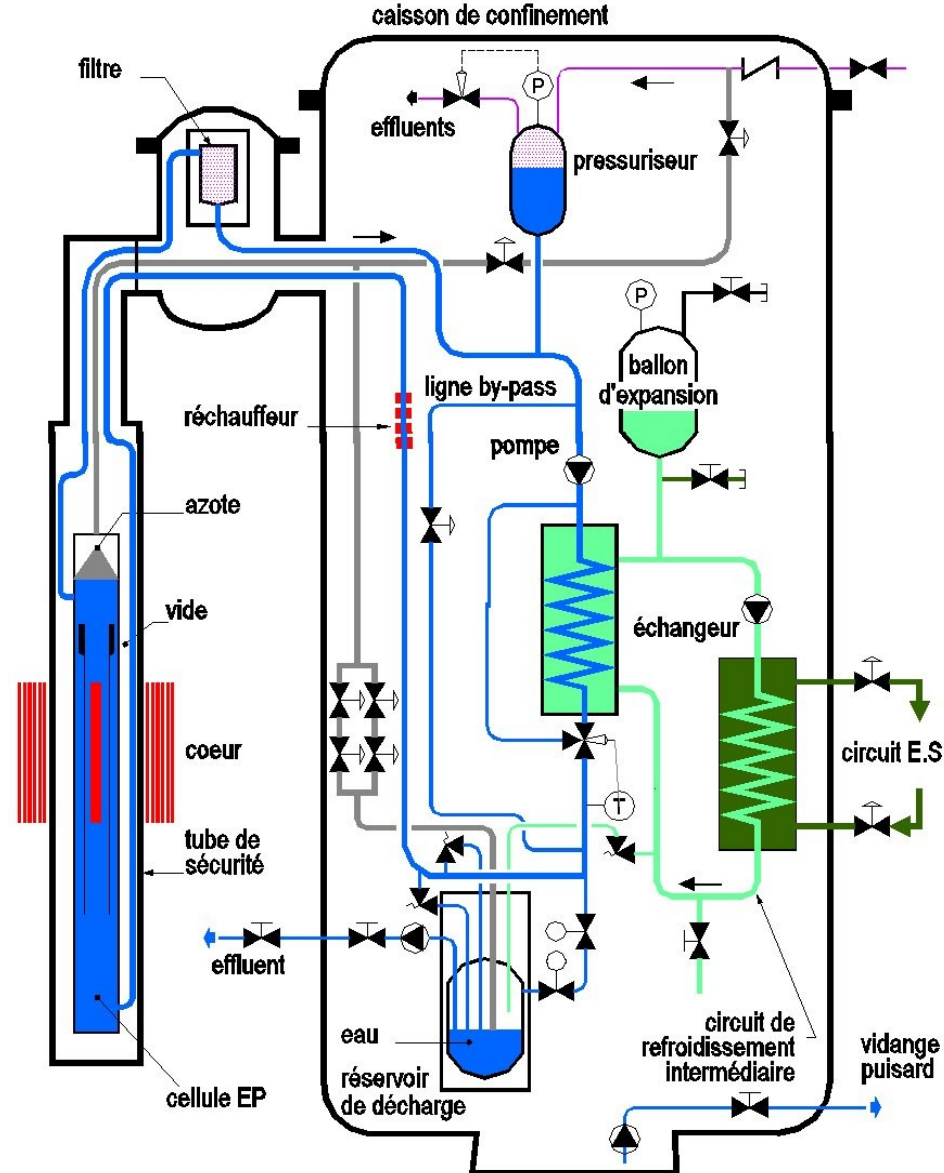
- A « test section » in the center of the driver core
- Two barriers in zirconium (neutronic transparency), surrounding the « test device »:
 - *the « pressurized water containment » (155 bars, 350°C)*
 - *the « safety tube »*
- An out-of-pile part, with a pressurizer, a « discharge tank », a « collecting tank » for the gaseous effluents, filters, and a « containment vessel »
- Loop fully implemented inside the reactor building (third barrier)

CABRI reactor safety reassessment (11)

Cross-section of the in-pile section of the experimental loop



CABRI reactor safety reassessment (12)



CABRI reactor safety reassessment (13)

4) Safety assessment of the reactor fitted with the experimental loop

- **Challenges and organization**
- **Safety specificities**
- **Main IRSN conclusions**

CABRI reactor safety reassessment (14)

Challenges and organization (1)

- In February 2002, the objective of the modification of the installation induced the CEA to submit a PSAR, in order to obtain an authorization by an administrative decree
- Two scope were addressed :
 - *the safety analysis of the pressurized water loop*
 - *the global safety review of the installation*

CABRI reactor safety reassessment (15)

Challenges and organization (2)

- Similarly to the approaches for French power reactors, the basis of the global safety review were:
 - A review of **installation compliance** with its last approved reference standards, including visit and control of equipment
 - A **safety reassessment** (major part of the safety review), based on:
 - ❖ a feed-back analysis (events review)
 - ❖ the identification and processing of discrepancies compared with current regulations (French regulation, IAEA recommendations and guides, etc.)
 - ❖ the updated safety studies taking into account the evolution of knowledge and of analysis methods (seismic reassessment, etc.)

CABRI reactor safety reassessment (16)

Challenges and organization (3)

- **Organization:**
 - *leading of the analysis by the Department of the IRSN, in charge of gas cooled, fast breeder and experimental reactors*
 - *involving of ten specialists Departments of the IRSN (seismic behavior, mechanic, metallurgy, radioprotection, etc.)*
 - *involving of the BCCN*
 - *involving of the Belgian society AVN*
- **The assessments were presented to the Standing Group for the reactors (January and May 2004)**

CABRI reactor safety reassessment (17)

Safety specificities (1)

- No constant operation of the reactor (a few days/year)
- Weak radiological inventory in the driver core
- No staff in the vicinity during reactor operation or loop pressurization
- Power trips in the driver core with inhibition of the reactor protection system
- Part of the reactor cooling system outside the building
- First barrier of the experimental loop also a barrier against the pressure

CABRI reactor safety reassessment (18)

Safety specificities (2)

- Clad failure (test pin), ejection of the fuel and fuel/water interaction (dynamic character) are normal « operating conditions » for the loop
- Use of Zircaloy, a fragile material, for the first barrier inside the core (« *pressurized water containment* »)
- Important radiological inventory of test pins (fission products)
- Management of liquid effluents with high activity

CABRI reactor safety reassessment (19)

Main IRSN conclusions

- Use of the Zircaloy for the two barriers of the loop
- Assessment of the overpressure induced by fuel/water interaction
- Design basis for the first loop barrier
- Design basis for the second loop barrier
- Operating conditions for the reactor, for the loop and for the effluents facility, interactions between reactor and loop, reference accident
- Seismic hazard analysis

CABRI reactor safety reassessment (20)

Use of the Zircaloy for the two barriers of the loop

- Though the Zirconium alloys are not provided for in design codes ASME or RCC-M, IRSN considered that the use of Zircaloy (as fabricated for the loop) is acceptable, on conditions below:
 - *use the ferritic steel rules of the design codes (rules for bolts)*
 - *obtain a high quality production, especially absence of nicks*
 - *avoid incursions in the plastic domain by appropriate design rules*

CABRI reactor safety reassessment (21)

Assessment of the overpressure induced by fuel/water interaction and design basis for the first loop barrier (1/2)

- By the very fact that tests can induce cladding failure and that the test device is open, the overpressure produced by fuel/water interaction is an important data for the design of the first loop barrier (« pressurized water containment » and primary circuit)
- IRSN considered acceptable the value of 480 bars (pre-design) for the case of UO₂ experimental pins (internal overpressure inside of the test device, in the interaction area)
- For the special case of MOX experimental pins, further developments and analysis are to be made and approved before tests

CABRI reactor safety reassessment (22)

Assessment of the overpressure induced by fuel/water interaction and design basis for the first loop barrier (2/2)

- The overpressure loading (dynamic loading) on the primary circuit, including the « pressurized water containment », will not be taken into account to set the « leak test pressure »
- In accordance with regulation, it is required that the protection valves on the loop not open during the overpressure wave

CABRI reactor safety reassessment (23)

Design basis for the second loop barrier

- **The second barrier of the loop (« safety tube », « containment vessel ») has to be designed to withstand the effects of the first barrier rupture, with the most severe criteria, in order to remain leaktight and not injure the driver core**
- **Nevertheless, for local dynamic loadings on the second barrier (jet effects, shocks, etc.), smaller margins would be acceptable, insuring leaktightness**
- **In addition, in the frame of a « defence in depth » approach, the operator has to demonstrate that the consequences of the simultaneous ruptures of the two barriers would remain acceptable**

CABRI reactor safety reassessment (24)

Operating conditions for the reactor and for the loop, interactions between these two parts, reference accident (1/3)

- For the global safety demonstration and in addition to the analysis of internal and external hazards, the operator drawn up lists of operating conditions for the core, the loop (and also for the facility effluents): they include normal and accidental conditions, due to equipment failure or human error
- They are classified into categories depending on estimated frequencies of occurrences, with associated « general safety objectives » in terms of radiological doses
- The operating conditions for the loop include (few) relevant global operating conditions of the reactor

CABRI reactor safety reassessment (25)

Operating conditions for the reactor and for the loop, interactions between these two parts, reference accident (2/3)

- **Vice versa, the requirements assigned to the loop equipments (barriers and systems) are defined with the aim of not create new operating conditions for the reactor and not jeopardize it; nevertheless, the consequences of the two barriers failure, particularly for the driver core, have to be assessed**
- **Some technical implications were emphasized by IRSN in order to comfort prevention, detection or limitation of the consequences of the operating conditions**

CABRI reactor safety reassessment (26)

Operating conditions for the reactor and for the loop, interactions between these two parts, reference accident (3/3)

- In a frame of BDBA for the reactor, a « reference accident » is studied, in order to check that the consequences would remain acceptable for the public: it is a positive reactivity insertion in case of multiple failures on the « transient rods » command system or programming error
- IRSN emphasized that this classification implies a very high fiability level for the command system

CABRI reactor safety reassessment (27)

Seismic hazard analysis (1/2)

- The seismic movements spectra for MHPE and SSE spectra have been approved
- The seismic behavior requirements have also been approved for:
 - *equipment (leaktightness, non-conversion into missile, functionality, etc.),*
 - *concrete structures (lack of crumbling, control of overall deformations, etc.)*

CABRI reactor safety reassessment (28)

Seismic hazard analysis (2/2)

- **MHPE is combined in particular with normal operating configurations of the reactor and the loop**
- **Due to the short operating times of the CABRI reactor, SSE is only considered in the state of pressurization of the loop and with reactor shutdown**
- **IRSN has not identified an element that would preclude the seismic reinforcement of the buildings**
- **A reinforcement process using carbon fibres has yet to be validated and alternative classic process has to be studied**

CABRI reactor safety reassessment (29)

5) *Conclusion (1/2)*

- The new operating life of CABRI with a pressurized water loop is an important challenge in terms of R&D programs, technology (using of Zircaloy), exhaustive safety review (compliance review, safety reassessment)
- The reassessment is supported by a structured and systematic safety demonstration, with the use of classical operating conditions and hazards analysis, as for power reactor
- Nevertheless, operating specificities of the CABRI facility implies specific analysis, with the help of fundamental considerations using « defence in depth » or « lines of defence » approaches — As generally for research reactors, safety standards and recommendations for PWR are, for some topics, not relevant

CABRI reactor safety reassessment (30)

Conclusion (2/2)

- **After the Safety Options analysis, the second step of the reassessment, with the PSAR analysis, has been crossed without major objection**
- **The use of the Zircaloy needs distinctive attention in terms of design and manufacturing: IRSN and BCCN keep up with the progress on these topics**
- **Seismic reinforcements process has also to be keep up with**
- **The Intermediate Safety Report will be forwarded early in 2006, with the aim of an authorization for the facility restart, scheduled for 2008**