Periodic Safety Review Management for French Research Reactors
Technical Support Organization Approach

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Abstract. Periodic Safety Review (PSR) is a key issue in the life of a Basic Nuclear Installation (BNI). Indeed, the safety review is an efficient means to improve the safety level of an installation and to take a decision for the continuation of the reactor operation towards the next decade. Based on the French practice and experience, the objective of this paper is to give an overview of the PSR management for French Research Reactors (RR). After a presentation of the new French regulatory context since the law on transparency and security in the nuclear field published in the Official Gazette on 13 June 2006, the expectations/requirements of the Nuclear Safety Authority (ASN) and the Institute for Radiological Protection and Nuclear Safety (IRSN) are given. The paper mainly focuses on the two basic parts of PSR, which are the conformity check and the safety reassessment. Anyway, if now in France the great safety principles applied for the safety evaluation of any research reactors are very similar to those used for Nuclear Power Plants (NPP), adaptations and graded approaches are used, due to specific features of research reactors.

1. Introduction

In accordance with article 5 of amended decree no 63-1228 of 11 December 1963, it was possible to ask operators to carry out a safety review of their installations. Now, the periodic safety review of basic nuclear installations is required by article 29, paragraph III, of the law of 13 June 2006 on transparency and security in the nuclear field which created the French Nuclear Safety Authority (ASN).

The previously mentioned paragraph stipulates that « *the operator of a basic nuclear installation shall perform a periodic safety review of his installation in the light of the best international practices. This review must enable the condition of the installation to be assessed with regard to the rules to be applied and allow updating of the assessment of risks or hazards presented by the installation* » for public health and safety as well as for the protection of nature and the environment, « *notably by taking into account the condition of the installation, the experience gained during operation, the evolution of knowledge and rules applicable to similar intallations.* » Upon completion of his review, the operator shall submit a report to the ASN presenting « *the conclusions of the review and when necessary the provisions he intends to make to correct the anomalies identified or to improve the safety of his installation. »*

It is also stated that « *safety reviews shall be conducted every ten years. However, the authorization decree may determine a different periodicity if justified by the installation's specific features.* »

The objective of this paper is to present the principles and procedures adopted for safety reviews of research reactors in operation in France, the specificities of such reviews and finally some key points of the latest safety reviews and more particularly the CABRI reactor, MASURCA critical mock-up and HFR reactor safety reviews.

2. Principles and procedures adopted to perform safety reviews

As regards the CABRI reactor safety review which is associated with the installation of a pressurized water loop and whose orientations gave rise to files and discussions between ASN, IRSN and the CEA between 1995 and 2001, it was decided to adopt the general principles implemented for safety reviews of power reactors. In a schematic way, these are structured as follows:

— check of installation conformity with the latest approved safety reference files,
— actual reassessment allowing for changes in regulations or in quasi-regulatory texts such as basic safety rules (RFS), standard practices, methods and knowledge since the previous safety review.

The safety review of basic nuclear installations operated by the CEA is the subject of DGSNR/SD3-CEA-05 guidelines of 2 December 2005, describing these general principles. These guidelines notably indicate that:

— the conformity check must take into account the modifications to the installation since the latest review (modifications to equipment or to their operating modes (periodic tests, etc.)) and those resulting from ageing. It must also be based on an in-depth inspection of active or passive equipment, if necessary with non destructive or even destructive testing ;
— the safety reassessment must encompass an examination - or even the redefinition - on the one hand of operating conditions and of degraded and accident conditions and, on the other hand, of internal and external hazards, notably in the light of experience feedback and further safety studies of the installation ;
— feedback must take account of the events which have occurred since the latest safety review at the installation as well as at similar installations in France and abroad ;
— this reassessment must be an opportunity to check the application of the in-depth principle with regard to the different conditions selected and to internal and external hazards. It must also consider the operating provisions relating to human and organizational factors.

Moreover, DGSNR/SD3-CEA-04 guidelines of 16 December 2003 relating to experimental devices specify that « *the overall safety review of the reactor shall systematically include a safety review of all experimental devices the operator intends to maintain in operation* ».

Besides, insofar as data important to the safety of research reactors operated by the CEA are defined in PGSEs (« overall site safety presentation ») relative to CEA sites, the above-mentioned guidelines also stipulate that PGSEs must be updated at least every five years.

The safety reviews of research reactors give rise to:

— files submitted by operators (orientation files specifying the future use of the installation and proposing issues to be addressed thoroughly with justification for their choice, safety options file(s) if for example significant modifications are planned (case of the CABRI reactor pressurized water loop), review file together with, if required, a safety report describing the installation as expected upon completion of the review),
— a technical assessment by IRSN which may be assisted if need by other French or foreign organizations (for example the Belgian organization AVN for the safety review of the CABRI reactor),

— a presentation to the Standing Advisory Group for nuclear reactors (GPR), on the basis of the report draft by IRSN,
— GPR opinion followed by ASN decision.

The technical assessment carried out by IRSN follows the same process as that adopted for the examination of issues relating to power reactors and for which GPR opinion is required by the Nuclear Safety Authority. Generally, the time required for this examination ranges between 12 and 16 months.

3. Important aspects and specificities for research reactors safety reviews

Important aspects and specific features are encountered during research reactors safety reviews:

— not all research reactors are constantly in operation: some of them are characterized by short-time operating phases at a significant power (case of CABRI and PHEBUS for example). This aspect is taken into consideration and may lead to avoid the study of a number of operating conditions and hazards (e.g. safe shutdown eaethquake) in power states ;
— the presence of operators or researchers in reactor buildings (e.g. at poolsides), not necessary in power reactors, requires an in-depth examination of risks in terms or workers' radiological protection and radiological consequences of degraded and accident conditions ;
— human and organisational factors may be very important in the prevention of degraded and accident conditions. In the case of the MASURCA critical mock-up, the « design basis accident » mainly involves a succession of operator errors during sub-assembly constitution and core loading ; thus, the robustness of the « lines of defense » with respect to degraded and accident conditions (for example « design basis accidents » or BORAX type severe accidents) may give rise to strong uncertainties ;
— within the framework of the conformity check, determining the state of safety-related equipment or at least of the equipment deemed absolutely necessary (e.g. the various containment barriers, absorbing control rod drive mechanisms, etc.) is essential. An assessment with appropriate inspections must then be carried out and, in the event of sampling inspections, extension rules must be provided if an anomaly is detected;
— within the framework of the safety reassessment, it is important that the operator should gather the operating requirements, technical criteria, files relating to the design basis and fabrication of safety-related equipment and reexamine them by considering how this equipment in view of its importance should be designed and built in view of the evolution of rules, methods, practices and knowledge. The deviations identified must be explained and measures must be proposed (more frequent periodic tests, change in equipment, etc.) ;
— the seismic reassessment of research reactors built for some of them in the 1960s is generally one of the great challenges encountered in safety reviews which may result in significant and costly modifications ; moreover, if the reassessment is carried out with a view to a long-term operation (« long-lasting »), the safe shutdown earthquake and paleoseisms must be taken into account.

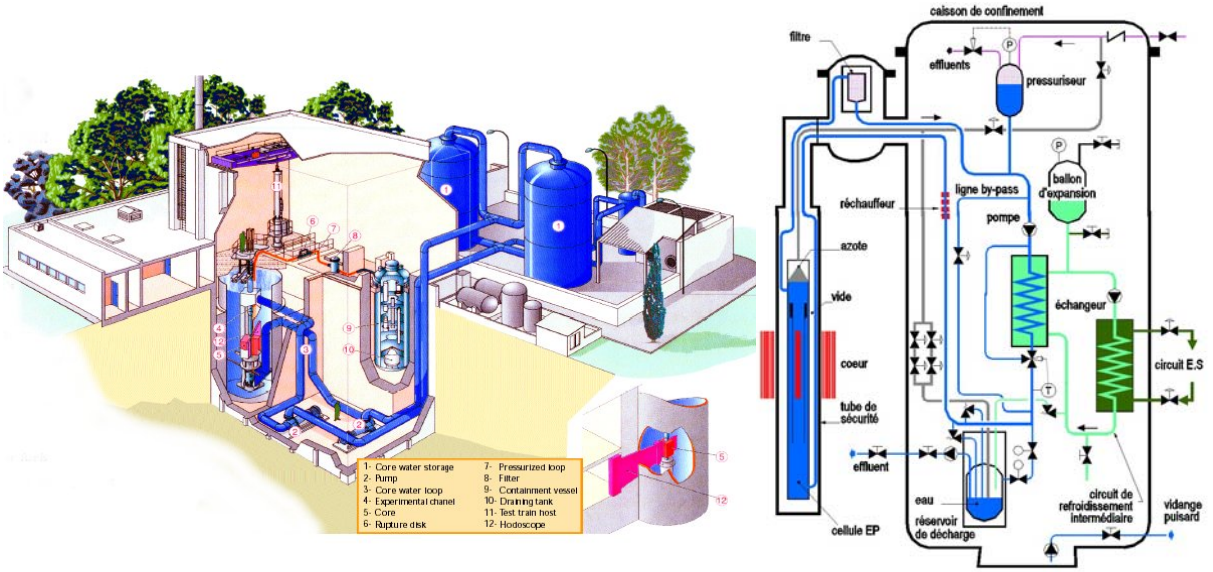
Upgrading or renovation of these reactors concerning fire hazard control (fire zooning, etc.), capability of core cooling systems to fulfill their function, confinement capacity of the containment (reduction in penetrations and direct leaks, etc.) and control of risks relating to handling are also major generic subjects. Besides, due to equipment obsolescence, operators have to consider the renovation of instrumentation and control systems.

4. Main issues of recent safety reviews : CABRI, MASURCA, HFR

The CABRI reactor safety review is associated with the project for the installation of a pressurized water loop in the reactor driver core (see Fig. 1). This review is carried out with a view to a « long-lasting » operation. Various safety options files concerning the loop as well as the reexamination of earthquake and fire risks were issued between 1995 and 2001. The review file was then submitted in early 2002 in the form of a « preliminary safety analysis report » and a GPR meeting was held at the beginning of 2004. The renovation of the installation, the construction and the installation of the loop are underway. The next step will be the examination of an « intermediate safety analysis report » which should be presented to the GPR between June and the end of 2008.

Figure 1

Cut-away view of the CABRI reactor and diagram of the experimental loop



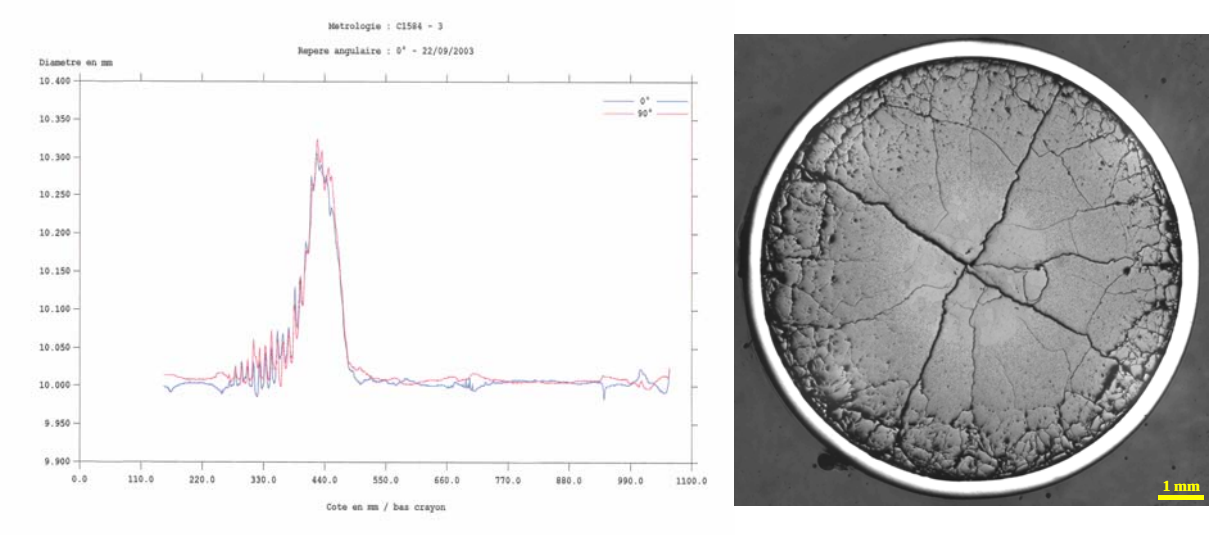
Two important issues were addressed during the first phase of the safety review. These concern the state of the driver core and the pressurized water loop.

Following discussions with IRSN and prior to preliminary safety analysis report submission, the operator was required to provide for a control of the state of the first fuel barrier by appraising about ten fuel rods. Profilometries were performed on all the fuel rods and one of them was subjected to axial and radial cuttings (see Fig. 2). They allowed to identify:

— axially regularly spaced folds over the cladding of a number of rods,
— notable radial deformation for two other rods. One of them was subjected to cuttings which revealed that it was not in conformity with expectations : more precisely, substantial core granulometry in the middle of fuel pellets (UO_2) which is a sign of meltdown, was observed.

Figure 2

Profilometry and radial cross section of a CABRI rod



Presently according to the operator, this meltdown results from the power « slow ramp » type tests which were carried out in the past. Such tests are not planned in the future test programme in the pressurized water loop. In addition, further to IRSN questions, more advanced neutronic calculations allowed the operator to detect that the distribution of powers in the driver core had been significantly underestimated, which partly explains the meltdown.

Nevertheless, the explanation is not yet entirely available ; it is based on a number of assumptions and some of them are not obvious. IRSN is assisted by the Belgian organisation AVN to assess the files submitted on this subject.

The operator is also required to submit a file on the ability of the driver core to continue the experimental programme in CABRI. In this respect, the operator must present its policy as regards the core currently in place (no replacement of rods (except the cut rod), only replacement of deformed rods, modification of the location of assemblies associated with the highest power factors, etc.), and demonstrate that the restarting core will be able to withstand future tests (« pulses »), in particular if folded rods, or posssibly core molten rods, are left in place.

Regarding the water pressurized loop, one of the objectives of the assessment, also conducted with the assistance of AVN, was to make sure that design, design basis and fabrication provisions concerning the equipment of the loop allowed to avoid events likely to be generated by the loop and not taken into consideration for the reactor design as degraded or accident situations. This « decoupling » principle led for example to check if the provisions provided for the pressurized water loop were consistent with a number of basic safety rules applicable to pressurized water reactors and suitable for the loop. In order to respect this « decoupling », the assessment notably led to formulate some requirements for the design and fabrication of zirconium alloy equipment, material less ductile than austenitic steels, but almost unavoidable for a reactor like CABRI, due to its neutronic transparency.

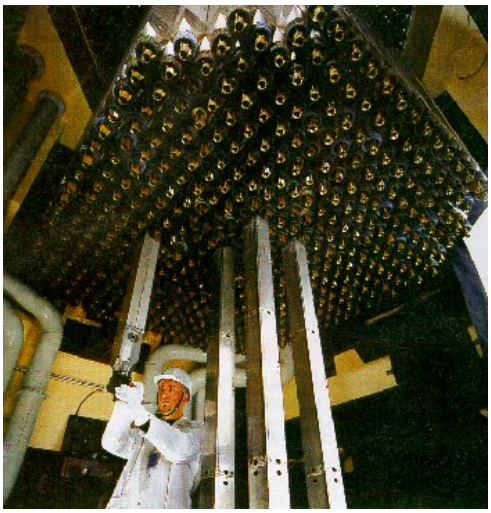
Nevertheless, GPR deemed that the operator should make sure that the consequences of the postulated total failure of the pressurized water loop would remain acceptable.

The safety review of the MASURCA critical mock-up (see Fig. 3), used to determine neutronic characteristics of various media and the qualification of neutronic calculations schemes was initiated in 2000 and gave rise to a first examination by GPR in 2006. This review is performed with a view to a « long-lasting » operation.

One of the operating features of this mock-up is the very low operating power (5 kW) and the fact that the core built « on a case-by-case basis » with items available in stock (fuel or solid sodium elements, etc.) is cooled by air convection. In addition, substantial quantities of fissile materials are stored in the « storage and handling building » of the installation, in the form of items of various compositions and geometries. The main risks involved are excessive reactivity in the mock up core, criticality in the « storage and handling building », dispersion of radioactive materials in the event of a fire. The control of such risks mainly depends on human errors prevention and on the control of potential hazards (earthquake, flooding, fire).

Figure 3

Underside view of the core at the MASURCA facility



The main issues upon completion of the examination of the « preliminary safety analysis report » by IRSN and GPR are as follows :

— the proposal by the operator to exclude the severe accident approved until then (« design basis accident ») corresponding to an inadvertent and unprotected introduction of reactivity in the core following reactor loading of a tube excessively loaded with fissile materials was not adopted, as this accident mainly involved human and organizational factors ;
— regarding criticality risks in the « storage and handling building », where experimental tubes are built manually, the operator, who had proposed to raise the allowable mass limits, was required to explore a spectrum encompassing as many configurations as possible in terms of kinds of items, geometries, etc. ;

— the « storage and handling building » design is not really suited to seismic hazard. Seismic reassessment leads to a project for a substantial reinforcement of the main structure and foundations ;
— lastly, concerning fire risk, in consideration of the state of the art in this field and in opposition to the operator's proposal, a fire zoning of the « storage and handling building » was deemed necessary.

In addition, in view of the variety of items in stock and faced with the difficulty in identifying all envelope configurations of items in the « storage and handling building » or in the core, the operator was required to draw up methodological guidelines for future safety analyses of experimental cores and for the study of operating transients, core seism behaviour, criticality risks, etc.

The High Flux Reactor (HFR) of the Laue Langevin Institute, located in Grenoble, was built between 1968 and 1971 to provide an intense neutron source dedicated to scientists who intend to do fundamental or applied research. The latest safety review, carried out with a view to « long-lasting » operation resulted in an examination by GPR in May 2002; This examination mainly concerned the seismic resistance of the installation in view of updated spectra (see Fig. 4).

Concerning seismic risk, the assessment of IRSN led to the conclusion that complementary safety requirements were needed and that it was necessary for the applicant :

— to identify safety important equipment, their functional requirements in case of earthquake and their associated technical requirements and to apply the "event approach" in order to identify exhaustively non seismic classified equipment the failure of which could induce failure to seismic designed equipment necessary for the fulfillment of important safety functions;
— to take provisions in order to maintain, in case of an earthquake, the confinement of radioactive materials in the building, by the concrete and metallic shells of the reactor ; so, the applicant has to define solutions in order to manage the risk of interaction between the reactor building and the neighbouring buildings;
— to carry out new seismic studies by using linear methods for the calculations ; the detailed analysis of weak points identified by these studies could be performed with realistic calculation methods (non linear methods) ;
— to reinforce the concrete pillar supporting the transfer canal and to reduce the number of spent fuel elements stored in this canal in order to reduce the potential source term, in case of an earthquake leading to their uncovering;
— to implement an emergency water make-up system.

The applicant has also taken commitments to the safety authority concerning the implementation of improvements of the fire protection system and the redundancy of the reactor protection system.

Figure 4

Reinforcement of the junction between reactor hall floor and reactor containment

5. Conclusion

Safety approach, safety requirements for research reactors have changed, evolved over time. Now in France, the great Safety Principles applied for the safety evaluation of any RRs are very similar to those used for Nuclear Power Plants (NPP) and are gradually applied. In a schematic way, safety reviews are based on two main parts, conformity check and safety reassessment. Nevertheless, some rules established for the design of NPPs are applied to RRs with adaptations due to specific features of certain reactors (short operating time).

The periodic safety review is a key issue in the life of a facility. It requires important means, ressources and can lead to very important work during and also after the PSR. Nevertheless, the safety review is an efficient means to improve the safety level of an installation and to take a decision for the continuation of the reactor operation towards the next decade.