APPROACH IMPLEMENTED BY IRSN FOR THE ASSESSMENT OF PERIODIC SAFETY REVIEWS ON FRENCH RESEARCH REACTORS

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Abstract

As technical support of the French Nuclear Safety Authority (ASN), the Institute for Radiological Protection and Nuclear Safety (IRSN) has the responsibility to critically examine the periodic safety review performed by the operator of the French research reactors. The objective of the assessment is to evaluate the safety of an installation so that the ASN might make a decision for the continuation of the reactor operation towards the next periodic safety review. In this way, a presentation of the IRSN’s safety assessment of the installation and the related recommendations to a standing panel of experts (GPR) is realized. The purpose of this paper is to present the approach of the technical assessment carried out by IRSN of periodic safety reviews for the French research reactors. At the end, some outcomes of the latest technical assessment of the periodic safety reviews of the research reactors EOLE, MINERVE and ORPHEE, are given.

1. INTRODUCTION

In France, in accordance with the law of 13 June 2006, on transparency and security in the nuclear field, the operator of a research reactor shall perform a periodic safety review of his installation every ten years.

Once the safety review completed, the operator submits a final report to the French Nuclear Safety Authority (ASN).

For research reactors operated by the CEA (French Alternative Energies and Atomic Energy Commission), this report consists of three main parts in accordance with the guidelines of the ASN [1]:

— The conformity check of the installation with regard to its safety reference files, taking into account its modifications since the latest safety review;
— Experience feedback from the reactor operation and events occurred in the installation (or similar installations) since the latest safety review;
— The safety reassessment of risks presented by the installation in the light of safety rules changes (norms, fundamental safety rules, design and construction codes…) and of technical scientific advancements.

This report presents the conclusions of the review and, if necessary, the provisions the operator intends to make to correct the anomalies identified or to improve the safety of his installation.

As technical support of the ASN, the Institute for Radiological Protection and Nuclear Safety (IRSN) has the responsibility to critically examine the periodic safety review performed by the operators of French research reactors.

The main subject of this paper is to present the approach of the technical assessment carried out by IRSN, especially concerning the reactor operation safety assessment. Finally, some outcomes focused on this specific topic from the latest technical assessment of the periodic safety reviews of the research reactors EOLE, MINERVE and ORPHEE are presented. This paper is in line with a previous article [2] which focuses on specificities for research reactor safety reviews considered in IRSN’s safety assessment.

2. ORGANIZATION OF THE TECHNICAL ASSESSMENT OF PERIODIC SAFETY REVIEWS

The technical assessment of research reactors safety review is led by a generalist engineer who has to identify the main safety issues and who relies, if necessary, on experts in various fields to perform the related expertise. This analysis lasts in average 18 months.

The assessment of the report sent by the operator must be accompanied by a technical dialogue with him so as to ensure understanding of the submitted elements and provide, if necessary, additional information useful for the analysis. This technical dialogue is made of:

— Formal questionnaires submitted to the operator;
— Technical meeting based on the operator's answers to the questionnaires with, if necessary, a specific visit to the installation (fuel storage for criticality expertise, handling equipment for handling operations expertise…).

To have a global vision of the reactor safety, IRSN performs its evaluation around the main next items:

— The external and internal hazards for the installation;
— The radiological protection of workers;
— The reactor operation safety, focusing on the reactivity control, the core cooling, and the command control reliability;
— The safety of fuel storage for risks linked to criticality and cooling;
— The safety of handling operations, by hand and by overhead cranes;
— The confinement towards the environment, including the analysis of the ventilation network management during normal and accidental conditions.

This approach is in accordance to AIEA guidelines [3].

Moreover, as the organization and human activities can impact the reactor operation safety, human factors are taken into account for all topics considered in the IRSN's assessment. To do that, IRSN can notably observe some operation activities live (handling operations of fuel for core loading, safety thresholds control by workers for neutronic monitoring…) to examine how the implemented organization prevents operator error.

For each topic, the IRSN's safety assessment takes into account, in addition of the elements available in the report sent by the operator, the findings of the ASN's safety inspections, the operation annual reports established by the operator (annual activities, maintenance findings, nature and quantity of gas and liquid releases, workers' annual dose…) and the incident declarations.

At the end of the assessment, if some weaknesses are identified in the operator's safety demonstration, IRSN can make some propositions to improve the reactor safety or to consolidate the related safety demonstration, such as:

— Additional modifications or renovations of the installation (modification of ventilation network, additional safety devices…);
— Modification of operating rules (safety regulations for handling operations, safety criteria for control of criticality…);
— Additional studies (simulation of a new accident scenario…).

The operator can undertake to implement these proposals, besides the provisions already planned, but he can also refuse them if he considers that his safety analysis, for example for a specific operation, is adequate. However, if IRSN considers that a proposition is required to complete the safety analysis, the proposition is presented to the GPR and is called “recommendation”.

In this case, the GPR decides if the recommendation is required or not.

Finally, on the basis of this GPR’s judgment, the ASN makes a decision for the continuation of the reactor operation towards the next periodic safety review and for the actions (recommendations) to be performed by the operator.

3. PROCEDURE FOR THE REACTOR OPERATION SAFETY ASSESSMENT

The purpose of this paragraph is to describe the approach of the technical assessment carried out by IRSN of the operator’s reactor operation safety review.

For the reactor operation safety assessment, two types of risks are considered:

— Cooling accident;
— Reactivity accident.

The list of initiating events (classified into different categories) that must be considered for safety analysis is presented in AIEA guide [4].

3.1. Cooling accident

A cooling accident can be initiated by a:

— Loss of flow (dysfunctions of pump, fuel channel blockage);
— Loss of coolant (failure of primary circuit or damaged pool);
— Loss of heat sink.

3.2. Reactivity accident

A reactivity accident can be iniated by:

— Moderator changes;
— Inadvertent control rod ejections;
— Fuel insertion errors;
— Failure of experimental devices.

IRSN verifies that, for each category, the list of postulated initiating events considered by the operator is as complete as possible. Then, the IRSN’s approach, based on defence in-depth principle, consists in assessing the robustness of arrangements:

— To prevent the occurrence of postulated initiating events;
— To detect the occurrence of postulated initiating events;
— To prevent damage of the reactor core (safety actions).

To assess prevention aspects, IRSN examines the design and the periodic tests and maintenance related to equipments whose failure can lead to the event. These tests are realised to verify on one hand the operability of active systems and on the other hand the good condition of the equipments.

Concerning detection, IRSN’s performed almost the same analysis. Concerning the design, the assessment aims to evaluate the reliability the event detection (sufficiency and diversity of measured parameters, redundancy of the control and instrumentation system).

For safety actions robustness, IRSN verifies in addition that thresholds, defined at the design stage for the design basis accident, ensure a reactor safe state (i.e. without core damage).

In this way, computer codes can be used so as to simulate the bounding accident scenarios considered for each category of initiating events. To do that, IRSN verifies the bounding nature of the accident (input parameters, initial conditions and assumptions) to consider the consequences of the most penalizing accidents in the reactor operation safety assessment.

Moreover, it must be verified that the safety-related equipment, required to manage an event sequence, are operational with respect to bounding accident conditions.

In the next paragraph, some outcomes of the latest reactor operation assessments carried out by IRSN for the research reactors EOLE, MINERVE and ORPHEE, are given to illustrate the approach implemented by IRSN.

4. MAIN OUTCOMES OF RECENT REACTOR OPERATION ASSESSMENT PERFORMED FOR PERIODIC SAFETY REVIEWS: EOLE, MINERVE AND ORPHEE

Considering specific features of each research reactor (reactor operating requirements, experimental devices, site characteristics…) the main safety issues associated to these topics, differ from one reactor to another. In order to highlight that the safety assessment depends on specific features of reactors, two outcomes of the IRSN's safety review assessment are presented on:

- The EOLE and MINERVE reactors: zero power reactors (18 months for the IRSN's safety review assessment);
- The ORPHEE reactor: a providing thermal neutron beams reactor (15months for the IRSN's safety review assessment).

It is the case of the ORPHEE reactor whose power (14 MW) has to be evacuated contrary to the EOLE and MINERVE reactors (100 W) for which there is no core cooling system and so the only reactivity accident type has to be considered.

IRSN implemented the approach presented in paragraph 3 for all of the initiators of a reactivity accident considered for the EOLE and MINERVE reactors in different operation phases (preparatory operation phases, sub-critical approach and operation).

4.1 Outcomes of reactor operation assessment of the EOLE and MINERVE reactors

The EOLE and MINERVE[1] reactors are two critical mocks-up (see Fig.1) dedicated to the neutronic studies (essentially of moderated lattices). The EOLE reactor is an experimental reactor composed of a cylindrical vessel which can contain various types of experimental core emerged under water through a water circuit which controls the volume, the concentration and the temperature of this moderator. The MINERVE reactor is a pool type reactor (see Fig.1), essentially intended for reactor physics studies with measurements of effective cross-sections by the sample oscillation method. The oscillations are realized in a central accommodating experimental configurations situated in a square cavity (surrounded of platelets of highly enriched metallic uranium).

[1] The EOLE and MINERVE research reactors are located in Cadarache (south of France). They are in the same installation since 1977. The latest safety review of these reactors resulted in an examination by the GPR in March 1994. The second periodic safety review of the EOLE and MINERVE reactors was initiated in 2010 and gave rise to an examination by GPR in 2011.

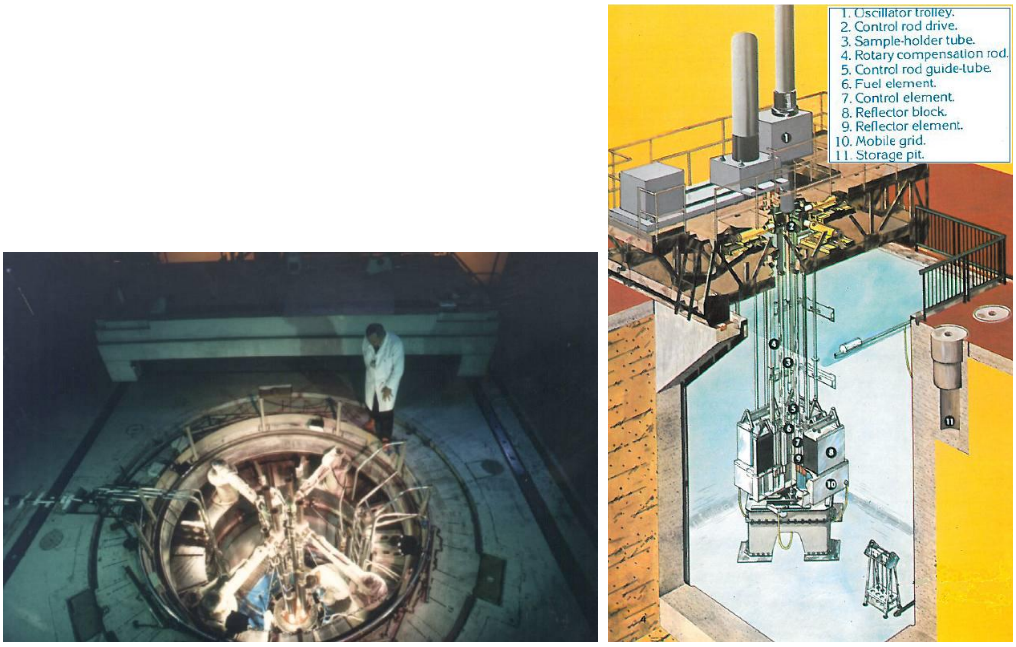

FIG. 1. Upside view of the core of the EOLE reactor (left) and cut-away view of the MINERVE reactor (right).

In its assessment, IRSN highlighted that the reactors safety is ensured mainly by the following dispositions:

- The reactor operation rules which impose notably a maximum super-criticality for each reactor (β/2 for the EOLE reactor) and other safety standard (such as a minimum anti-reactivity for the control rods…);
- Different checks performed by workers before initiating a sub-critical approach (checks on core loading with different fuel compositions, on safety standard…);
- The sub-critical approach which allows to detect (if the previous items fail) a core configuration error, by the extrapolation method of the sub-critical approach curves which reveals, in this case, a too or not enough reactive core before the end of the approach (whose the procedure is stopped in order to search and correct the related error before initiating again a new sub-critical approach).

Moreover to reinforce the safety reactors demonstration, the operator assessed the core consequences of each bounding accident scenario, in taking into account a total failure of the emergency scram. From the analysis findings, all of these reactivity accidents were without impact on the safety operation of each reactor. Indeed, in the case of a scram failure, the fuel temperature and the power of each reactor stabilized to very low values (maximum 80°C and 238 kW) what let the operator concluded that "in any event the integrity of rods is preserved".

Considering specific features of these reactors, there is no core consequence linked to an internal initiator event. This mainly relies on the low reactivity potential of each reactor. However, in conclusion to the safety assessment of these reactors, the main safety issues result from the large movements of quantities of fissile materials (nuclear fuels and nuclear samples), between notably the two reactors and four storage buildings where they are stored in, which can involve criticality risks and dispersion risks of radioactive materials.

4.2. Outcomes of reactor operation assessment of the ORPHEE reactors

The ORPHEE reactor[2] is a pool-type reactor which has been designed mainly to produce thermal neutron beams guided by neutron guides towards an experimental research station dedicated to the study of materials structure and energy states of condensed matter. The core is cooled with light water with a surrounding heavy water reflector tank. The core and the heavy water tank are immerged in a pool filled with demineralised light water (see Fig. 2).

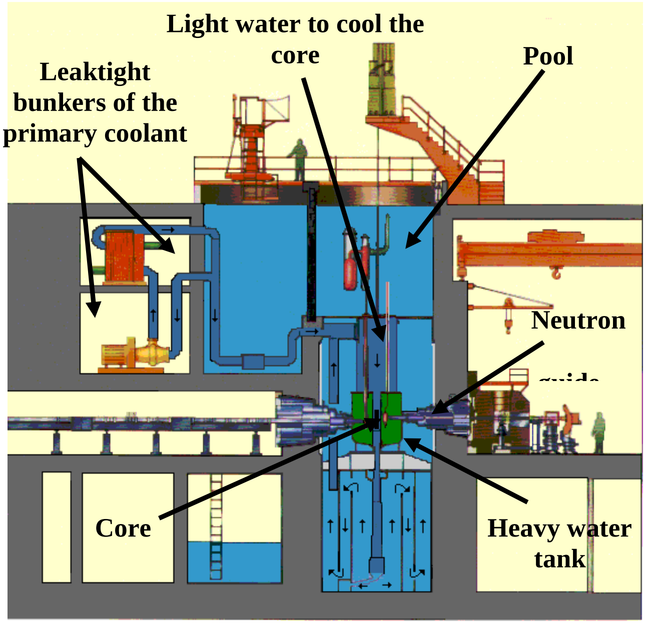

FIG. 2. Cut-away view of the ORPHEE reactor.

In order to avoid core uncovering and the related radiological consequences, the ORPHEE pool has to resist to an explosive BORAX-type accident (safety requirement: leaktightness). The IRSN's assessment consisted in verifying the pool behaviour under the pressure loading from this accident.

The first step of the IRSN approach consisted in verifying that the pressure loading considered by the operator is representative from a BORAX accident. In this way, IRSN performed calculations using up-to-date calculation tools to model the fuel-water interaction. These analysis findings led to question the conservatism of this loading. This highlighted the need to reinforce prevention of this kind of accident and the importance of means available to keep the core under water in case of loss of the pool integrity. In this regard, considering the uncertainties in modelling the BORAX-type accident and the fact that core uncovering is excluded, IRSN highlighted the importance of an available emergency booster water circuit, to avoid core uncovering.

Besides, the second step of the IRSN analysis was to identify the initiators of a reactivity accident (such as control rods lift, experimental devices destruction…). The related reactivity insertions are then characterized in order to determine the sequences which could lead to a BORAX accident. In this context, some calculations conducted by IRSN experts to evaluate the amplitude of reactivity insertions initiated by the destruction of some experimental devices, led to the conclusion that the simultaneous destructions of these devices could lead to a BORAX accident. This IRSN's result led the operator to reassess the reactivity insertion associated to the degradation of some experimental devices and to improve prevention of such accident by revising the planning of their replacement.

[2] The ORPHEE reactor is the most recent French research reactor since it first went critical in 1980. The reactor safety case was reassessed twice, in 1997 and 2010, since its building.

As mentioned before, for the ORPHEE reactor, cooling accidents have to be analysed. IRSN's assessment led to the conclusions that reactor's safety is ensured by the following dispositions:

— An emergency scram on various parameters (for example abnormal pressure or temperature in the core…);
— Flywheels on the pumps of the primary coolant circuit that ensure a sufficient flow in the core for a few time;
— A weak residual power so that the core can be cooled by natural convection, with the opening of natural convection dampers (without electrical power supplies, i.e. a passive operation) which allows core cooling with the pool water;
— The conception of the primary coolant circuit which is contained in several leaktight bunkers, situated mainly above the pool, so that core uncovering is impossible in case of a rupture on the primary coolant circuit.

The reactor robustness as regard to cooling accidents relies on passive equipments which are resistant to external hazards. IRSN concluded that no important core damages can occur and no improvements have to be realised.

6. CONCLUSION

The approach implemented by IRSN, for the assessment of periodic safety reviews on French research reactors, takes into account their specific features. In this way, the weaknesses and the main risks from these reactors can be identified and assessed. The objective is to verify and to improve the safety of installations with regard to their related risks so that the ASN might make a decision for the continuation of their operation towards the next periodic safety review. In this way, some IRSN's recommendations can be taken by the operator on the GPR request.

It was the case for the research reactors EOLE, MINERVE and ORPHEE, for which the continuation of their operation was authorized by the GPR, provided the operator takes some of the IRSN's recommendations. From this kind of technical assessment depends on enhancing safety.

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