
Safety Reassessment of the Old Installations Involved in Fuel Cycle

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Approach of the Institute for Radiological Protection and Nuclear Safety (IRSN)¹

Application to an Older French Nuclear Laboratory

1. IRSN 'S GENERAL APPROACH

1.1 Safety must not be definitely taken for granted

Nuclear plants are the subjects of authorization procedures, involving a technical examination of safety and radioprotection measures proposed by the operator at different plant-life stages:

- prior to the construction (creation authorization),
- prior to start-up (operating authorization),
- after a certain number of years in operation, in order to profit from a first operating feedback (industrial commissioning authorization).

Thereafter, a periodical plant safety reassessment must be carried out, usually every ten years. Obviously, safety must not be definitely taken for granted. It must be checked regularly and its required level must take into account evolutions of the techniques and of the safety approaches and practices. Remember the sociological context demands continuous safety improvements. This means ever-stricter regulatory limitations. Finally, the many modifications realized during the operating time and the ageing of equipment may potentially mean a decrease in the plant safety level.

¹ The Institute for Radiological Protection and Nuclear Safety (IRSN), created by the French Agency for Environmental Health and Safety law, then by the decree n°2002-254 of February 22, 2002, is a public establishment of an industrial and commercial nature (EPIC), under the joint authority of the Ministers of Defense, Environment, Industry, Research and Health. It groups together more than 1 500 experts and researchers from the "*Institut de protection et de sûreté nucléaire*" (IPSN) (Institute for Nuclear Protection and Safety) and the "*Office de protection contre les rayonnements ionisants*" (OPRI) (Office for Protection against Ionising Rays), with expertise in nuclear safety and radioprotection as well as in the field of the control of nuclear and sensitive materials. It provides a technical support to the French nuclear safety and radioprotection authority (DGSNR).

1.2 Plant safety review

Safety reassessment is the opportunity to review plant safety in the light of new safety and radioprotection regulations and practices, taking into account all the operating feedback (dosimetry, effluents, waste, anomalies and incidents, etc). Moreover, it can be the opportunity for the operator to check that the plant is in conformity with its design and operating documents.

The objective of such a reassessment is to assess the safety level of the plant by identifying any non-conformity with the current regulations and practices, in order to examine their acceptability, given the compensatory actions proposed by the operator. This leads to a heavy operation, which can last several years. It includes safety document updating by the operator and the IRSN's safety assessment required by the Nuclear Safety and Radioprotection Authority.

1.3 A lot at stake for the operator

Such a reassessment means that there is a lot at stake for the operator. The older the plant, the higher the stakes, which may even mean modifications to the plant or to its operating field. For example, questions related to seismic behaviour are frequently a subject requiring the reinforcement of buildings. The feasibility of this may lead the operator to decide to shut down the plant more or less in the short term.

1.4 Safety reassessment generic approach

Firstly, the operator has to reassess plant safety and its justifications. Given the future operating context (life time, evolution of activity and materials implemented), he has to make a decision about any drift from his safety documents (regulatory operating field) and from state-of-the-art practices. If need be, he must propose adequate compensatory measures.

Answering the Nuclear Safety and Radioprotection Authority's request, the IRSN carries out a global plant safety assessment, and more particularly assesses the acceptability of the operator's proposed measures. The objective is not necessarily to eliminate the existing non-conformities, but to check that the plant's safety and radioprotection arrangements are adequate for the future operating context, respecting the regulations in force.

Therefore, the approach involves the systematic examination firstly of the operating situations, taking into account the feedback, and secondly of deteriorated and accidental situations, based on updated plant safety studies.

The practice of this periodic safety reassessment enables the avoidance of any serious discrepancies between the plant's operation and the new regulations and practices, and encourages an on-going upgrading of plant safety and operating practices.

1.5 An increasing part of safety assessment activities

Most nuclear plants and laboratories were commissioned more than ten years ago (frequently twenty or even more than thirty years ago). Consequently, safety reassessment of such plants represents a growing part of technical assessment activities. Examples include the latest safety reassessments carried out by the IRSN for the uranium isotopic enrichment plant on the Tricastin site, as well as for

some of the CEA irradiated nuclear fuel laboratories, and storage and radioactive waste plants on different sites.

Such safety reassessments need to involve the IRSN specialists from all the technical fields of nuclear laboratories and plants safety, such as radioactive material containment, non-criticality control, workers and public protection against ionising ray exposure, fire and explosion protection, earthquake protection, electricity supply and control-command failures, human factors, waste and effluent management, etc. Thus, an older plant reassessment means a heavy workload, usually involving time spent by more than ten specialists.

One of the main difficulties is the assessment of the arrangements proposed by the operator to deal with the identified unsatisfactory points. Indeed, the implementation of state-of-the-art safety practices may sometimes be impossible in an existing plant (for example: adequacy with fire sectoring regulations). Consequently, the operator proposes measures that would give an equivalent safety level.

This difficulty particularly concerns earthquake protection, as no general rules allow an assessment of the seismic behaviour of existing buildings. This can lead to long, often complex assessments. Firstly, the building's behaviour is examined, taking into account the possible interactions with neighbouring buildings. Secondly, the adequacy of the reinforcements proposed is checked, remembering the residual plant's lifetime and the decrease of the radioactivity in the plant as given in the operator's proposals.

2. A CASE STUDY: ACTIVE NUCLEAR FUEL EXPERIMENT LABORATORY

2.1 General points

This laboratory, operated by the CEA since 1964, is located in the nuclear centre of Cadarache. It is dedicated to the study of irradiated materials and fuels, including:

- contaminating activities (irradiated experimental device dismantling, short experimental rod processes, drilling and cutting into sections of irradiated fuel rods, rod sample cutting and preparation, rupture experiments on rod sections, nuclear waste characterization and conditioning, etc),
- potentially contaminating activities (non-destructive control of irradiated rods and samples, experimental device preparation, experimental rod pressurization and welding, irradiated sample conditioning and temporary storage, nuclear transport container loading and unloading, etc).

In chronological order, this laboratory experimented first on materials and fuels from the French natural uranium-graphite-gas reactors (GCR), then from fast breeder reactors (FBR) and more recently from pressurized water reactors (PWR). It can also receive test devices coming from experimental reactors. An extension of the laboratory was built in the early 1990's for the stabilization and the re-conditioning of old GCR reactor fuels stored in the nuclear CEA centre of Cadarache. This modern additional building was designed according to the current safety approach, particularly in its dimensioning against seismic risks.

2.2 Description of the buildings

The old part of the laboratory is around 80 m long, 40 m wide and 15 m high, on three levels (basement, first floor and second floor). It is mainly composed of two joined buildings, with the first floor housing radiologically-protected reinforced cells where irradiated materials and fuels are handled. The biggest one contains ten large cells made of very thick reinforced concrete walls (around a meter). The second building contains five smaller cells made of less thick lead walls (around 15 cm).

A front zone and a back zone surround each group of cells. The front zone groups together the different work stations for the operation of cells. The back zone, composed of separated premises, is especially used to connect containers to cells, in order to allow the input and output of nuclear materials and fuels.

The peripheral part of the plant involves the non-nuclear activities. On the front zone side, it is composed of office premises and on the back zone side, of technical premises and workshops.

The basement mainly houses under-cell galleries, the air-extraction ventilation network (including ventilators and last-level filtration), the liquid effluent tanks, an area for a temporary storage of waste containers and the plant's electricity transformer.

In the central part of the main building, a second floor mainly houses a large nave covering the upper part of cells and their back zones. In its peripheral part, there are technical premises for the air-admission ventilation network, and office premises.

2.3 The history of the renovation approach

Since the early 1990's, the CEA has been preparing a plan for the renovation of this nuclear laboratory. The objectives are:

- to obtain a global upgrading of the safety and operating homogeneity between the older and the newer parts of the plant,
- to take into account medium term activity evolution planned for the CEA's other nuclear laboratories.

One of the main objectives of the plant's renovation is the improvement of its seismic behaviour, as it was not built according to the parasismic rules now in force. Firstly, the CEA followed an approach involving an examination of the plant's potential behaviour, its possible upgrading and the limitation of the consequences in case of earthquake (especially by a modification of the operating conditions). The reinforcement studies began in 1992, involving recognized seismic-risk experts. Different reinforcement options for the plant were studied up to 1996. Finally, given the complexity of the solutions studied, the provisional unavailability of the plant and the related costs, the CEA took its decision. The major civil engineering modifications, which would have allowed the consideration of long-term operation continuity without any restriction, could not reasonably be engaged.

Consequently, the CEA proposed a partial reinforcement of the buildings in association with a limited plant life time, involving a progressive transfer of both contaminating and high-mass nuclear material activities currently carried out in the older part of the plant to its newer part (which will also have to be modified to receive these activities). This strategy led to a broad four-year renovating program, in order to allow a further ten-year experimental period in the older part of the plant, under improved safety conditions. Beyond this period, the operator should reduce the amount of nuclear materials there by a factor of ten. The residual activity could be limited to low-contamination work involving small quantities of irradiated fuels, and to radioactive waste work.

Furthermore, the IRSN's safety assessment of the present plant has led the Nuclear Safety and Radioprotection Authority to authorize the CEA to continue the operation of the old part of the plant for a five year period, provided that some compensatory arrangements (basic upgrading concerning the control of containment, fire protection, electricity supply, handling, etc) are undertaken while awaiting the renovation completion.

Apart from the renovated plant safety assessment, the conditions to realize the renovation works are the object of specific safety files. Each step of renovation has first to be authorized by the Nuclear Safety and Radioprotection Authority, based on the IRSN's assessment, which especially takes into account the renovation works' disturbance of operation and the specific exposure risks for workers during the renovation.

2.4 Main improvements during the renovation

The safety evaluation of this older-concept part of the laboratory, as carried out by the CEA, has led to the identification of improvements which have to be made to the plant. The main fields concerned are described below.

Radioactive material containment

Radioactive material containment is based on two static barriers (cell walls, premises walls), completed by a dynamic containment (ventilation). Because of the older principles of the design, ventilation is particularly important, as cells have no real leakproofing. Consequently, containment is mainly ensured by the air-flow circulation, and not by static equipment. The air extracted from cells is purified through a pre-filter (in the cell), then through a single level of very high efficiency filtration before its release into the environment.

In the renovated plant, the CEA has planned the following main improvements:

- upgrading the first static barrier (reinforcement of the cell leakproofing, with a set leak rate objective),
- leakproofing reinforcement during transfer between cells and nuclear containers,
- installation of a second level of very high efficiency filtration at the cell outputs,
- separation of cell and general building ventilation networks.

Fire protection

Considering the weaknesses of the plant concerning fire risks, the operator has taken a number of compensatory measures since 1998 in order to improve the existing situation, while awaiting the renovation. The arrangements are related not only to prevention (calorific load reduction, inflammable and explosive product limitation), but also to sectoring (ventilation network protection, fire wall resistance), surveillance (additional automatic detectors), and intervention (dry extinguishing agent).

The main improvements in the renovated plant are:

- fire sectoring in the buildings with isolation of premises involving safety-important equipment and premises having a non negligible fire risk,
 - definition of fire sectors and of fire and containment sectors, with a fire-resistance in accordance with the length of the possible fire,
 - backup of the sectoring automatic systems with on-the-spot manual commands,
 - replacement of the previous automatic fire detection system by a modern and well-proven system,
 - definition of a new piloting of ventilation in case of fire (air-input closing, air-output maintenance as long as the first level of filtration is not threatened, fire-cut valves and filtration surveillance, etc).

2.4.1 Power cut risks

The ageing of electrical equipment, most of which was installed at the beginning of the plant's life, was at the origin of several incidents on safety-important equipment over the last few years. Moreover, weaknesses were demonstrated concerning the separation of the different electricity supply networks (normal, ensured, back-up), preventive maintenance and common modes on the ventilation power supply.

The renovation plan has scheduled a general replacement of the electricity supply networks, in order to minimize the impact of electrical defects or of failures on safety functions. This program particularly involves :

- the backup or permanent sources for the electricity supply to safety-important equipment,
- the physical separation of the two transformers and of the two distribution stations,

- the routing through different premises for the two electricity lines to each piece of safety-important equipment (especially for cell ventilation and handling equipment).

2.4.2 Earthquake behaviour

The supporting structure of the buildings is made of a reinforced concrete "column and beam" framework, with brickwork filling. The concrete cells are made of thick, but only slightly reinforced, solid concrete elements. The design of the main building is characterized by irregularities in plane and in elevation, a bad distribution of its mass and differences of rigidity throughout the building. This leads to a low earthquake-resistance capacity. Furthermore, interactions between the building and the cells modify the general behaviour, inferring an "impact effect" which can worsen the behaviour of fragile structural elements. In addition, an interaction exists between the main building, which contains concrete cells, and the smaller one, which contains lead cells. This newer building cannot be stabilized with respect to earthquake. In conclusion, the construction elements of the plant form a complex unit with a heterogeneous design, whose earthquake behaviour is difficult to determine.

As explained above (see §2.3), the CEA cannot demonstrate that the plant's reinforcement to the level of "designing safety earthquake"² (in French: SMS) of the site could be feasible (reference safety levels defined for the new plants). Given this impossibility, the CEA has proposed carrying out such reinforcement to the level of the "historically likely maximal earthquakes" (in French: SMHV, corresponding to the historical known earthquakes leading to the heaviest intensity on site). This proposal is associated with a limitation of the renovated plant's life time (less than ten years), while awaiting the contaminating activity transfer to the laboratory newer part or to an extension or a future plant. According to its seismic diagnosis conclusions, the CEA proposed some basic reinforcement measures in order to improve the building behaviour at a seismic intensity of VIII MSK (SMHV) and to ensure the stability of the concrete cells at intensity IX MSK (SMS). The reinforcement measures include:

- addition of reinforced connections between the three blocks of the building,
- strengthening of the peripheral non-reinforced concrete walls located at the basement level,
- widening of joints between cells and building,
- concrete cell foundation reinforcement.

Regarding the different fields of renovation, the improvements involve upgrading of aged and out-of-date equipment, as the operator targets an overall renovation of the plant. The CEA identified the required improvements, on the basis, particularly, of previous older plant renovations, which were then assessed by the IRSN on the Nuclear Safety and Radioprotection Authority's request. This assessment confirmed the necessity for the CEA's identified improvements, in particularly those concerning plant earthquake behaviour.

After this first step, the CEA has defined arrangements to be implemented in order to realise these improvements, and has defined the associated schedules. In addition, the CEA has taken steps to reduce the total quantity of alpha emitting radioelements present in the plant, and to limit the surface contamination inside the reinforced cells (cell cleaning at regular intervals, better contaminating element recovery at source during in-cell activities, and removal of unnecessary elements).

2.5 Plant destruction consequences

Potential nuclear sources located in the renovated plant

Nuclear materials likely to be involved in an earthquake related release are enclosed inside cells. They can be process fuel dust and sludge, stored in boxes, or labile contamination spread over cell walls and workbenches.

² The "historically likely maximal earthquakes" (in French: SMHV) and the "designing safety earthquake" (in French: SMS) of a nuclear site are defined in the application of the basic safety rule I.2.c (revised 2001). The intensity, on the MSK scale, of the SMS is calculated from the SMHV using the formula: $I_{SMS} = I_{SMHV} + 1$, corresponding to a magnitude increase of 0.5. For the CEA Cadarache site, the SMHV level is VIII MSK, giving to an SMS level of IX MSK.

The release of activity into the environment is estimated mainly using the following coefficients:

- dispersion coefficient of 10^{-1} for sludge and of 1 for contamination,
- suspension coefficient of 10^{-3} for sludge and for contamination.

2.5.1 Accident situations

The operator considers the following destruction scenarios in case of earthquake:

- first scenario : partial destruction of the buildings, with maintenance of cell geometry ("realistic" scenario),
- second scenario : total destruction of the buildings ("reference" scenario).

2.5.2 Total exposure for the public

The inhabitant reference group is located 1.5 km from the plant. The radiological consequences are estimated two days, a year and fifty years after the accidental release. The attack routes threatening the and external exposure to the radioactive trail or to the scattered releases.

Regarding the first scenario, with maintenance of cell geometry, the total exposure would be of some tens μSv .

In the second scenario, with a total destruction, the total exposure at 1.5 km wouldn't exceed some mSv .

2.6 CEA's proposition assessment by the Standing Advisory Committee

The CEA's propositions and the associated safety justifications were assessed by the IRSN, which presented its conclusions to the Standing Advisory Committee³. The latter found the following measures satisfactory:

- radioactive material containment strengthening by reinforcing the cells,
- fire-prevention sectoring,
- increasing the reliability of handling equipment,
- increasing the reliability of electricity supply.

The objectives are very similar to those that would be required for a new plant.

Concerning seismic risks, the reference to the Cadarache site SMHV, and not to its SMS, to carry out the plant reinforcement studies against earthquakes was accepted given:

- the CEA commitments to limiting the plant's life time,
- the measures proposed to reduce the amount of radioactive materials in the laboratory,
- the demonstration that the consequences for the environment, in case of SMS, would be limited.

However, a schedule of the laboratory's end of life and of its possible replacement has to be sent to the Nuclear Safety and Radioprotection Authority before 2005.

³ Standing Advisory Committee for basic nuclear plants other than reactors, except those plants intended for long term radioactive waste storage (in French: GPU). Depending of the French Safety and Radioprotection Authority, it gives advices on technical safety subjects for decision by this authority.

Earthquake studies sent by the operator have been the object of a detailed assessment by the IRSN. The main question discussed was the demonstration of the stability of the buildings housing reinforced cells in case of earthquake, as the demand to be respected is the guarantee of cell integrity for the radioactive materials enclosed. In this respect, the IRSN has considered that:

-the acceptability of the reinforcements proposed had to be demonstrated on the basis of analysis with no incursion in the ductile area, and referring to parasismic engineering methods and criteria applicable to new plants (for the SMHV associated stresses on the Cadarache site). This approach allows the avoidance of a "threshold effect" beyond SMHV. By the way, the priority is to avoid any elements falling on the concrete cells,

- some complementary reinforcements had to be realized,
- the concrete cells' general stability under SMHV and even under SMS is demonstrated, in terms of the reinforcement solutions considered. The lead cell building stability under SMHV is not guaranteed, and the operator did not examine its aggression consequences on the main building, nor did he specify its future.

The assessment has led the IRSN to recommend that the operator take measures in order to eliminate any interaction risk, in case of earthquake, between the building containing the lead cells and the neighbouring buildings. Moreover, the IRSN concluded that a final check of the plant's general behaviour, as estimated after the earthquake reinforcements, was necessary to validate the definitive measures.

The examination of the questions related to earthquakes has led to a complex and long assessment, mobilizing operator and IRSN experts during several years. The plant structure behaviour assessments have led to systematic counter-assessments by the IRSN, especially with the support of foreign experts (for instance: U.S. company EQE international). Furthermore, local ground data, used to define the seismic spectra to apply to the structures, have been the object of studies by the operator and of counter-studies by the IRSN, with the support of recognized French experts. Indeed, IRSN considers it essential that questions related to behaviour and possible reinforcement of older plants be the object of a detailed examination, especially in the French regions where seismic risks are the highest (Cadarache area for example).

2.7 Conclusion

In conclusion, the safety reassessment of the laboratory older part has led the CEA to limit the plant's life time and to propose a general renovation of the plant, notably involving safety upgrading measures. The assessment, by the IRSN, of the operator's proposals has allowed the acceptance of the reinforcements proposed, with the following restrictions:

- some complementary measures concerning earthquakes have to be carried out,**
- the plant's life time has to be limited for its present activities.**

This example shows the difficulty of safety reassessment when older plants are involved and the extent of demonstration actions to be realized by the operator.