The French approach for the regulation of research reactors

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Abstract. The French Nuclear Safety Authority (ASN) regulates civil nuclear facilities in France. In addition to the pool of 58 pressurized water reactors ASN also regulates several research reactors which are all unique installations. The regulatory approach for research reactors takes cognisance of the different level of hazard encountered in their operation and hence requires a different approach to the management of safety in comparison with nuclear power reactor operations.

For a number of years, ASN has been striving to optimise its regulation of experimental reactors. To ensure the optimum level of safety by focusing on the most important safety issues and allowing the licensee to exercise its full responsibilities through the use of internal authorisations. The internal authorisations system, which has been in operation for several years now with a number of experimental reactors, is designed to achieve this two-fold objective.

In addition to the careful use of a new range of tools for its regulatory framework in the research reactors area, ASN has other safety challenges for example the ageing of most of the existing facilities and the licensing of new reactors with a high international profile such as the Jules Horowitz reactor or the ITER fusion reactor.

1. Introduction

The French Nuclear Safety Authority (ASN) regulates civil nuclear facilities in France (164). In addition to the pool of 58 pressurized water reactors ASN also regulates research reactors which are all unique installations. Most of the research reactors are operated by the atomic energy commission (CEA). The CEA is a public organisation which carries out research and development in the civil nuclear field. At the end of 2006, the CEA operated 35 nuclear installations, including 23 nuclear research facilities (reactors, laboratories, …) and 12 support facilities (treatment of effluents and waste, waste storage, nuclear material warehouse, …). These installations are located on 5 sites in France. The most important ones are now Saclay, Cadarache and Marcoule. The activities of the other sites turn into non-nuclear activities, mainly due to their urban environnment. Nine of these installations are no longer in use and, are in various phases of clean-up and dismantling.

CEA's civil nuclear research focuses on support and optimization for the entire nuclear fuel cycle industry, research on nuclear systems for the future and nuclear wastes. It has therefore an important role to play in the French and international nuclear fields. CEA is also involved in the design and operation of nuclear power reactors.

Ten of the current reesearch reactors belong to CEA ; one, the high flux reactor in Grenoble is the property of the Laue Langevin Institute (ILL), which is an international structure dedicated to fundamental research.

In France nuclear safety and radiation protection for all civil nuclear installations is regulated by the nuclear safety authority (ASN).

2. Overview of research reactors operating in France

Most of the French research reactors were built during the 60s. The function of each reactor is very different and hence each category of reactor presents particular hazards and different challenges for the nuclear safety authority.

Table 1. Type, purposes and scope of the French operating research reactors

Application → Type ↓	**Nuclear technology**	**Light water reactors**	**Pressurized water reactors**	**Fast breeder reactors**	**Industrial or medical applications**	**Study of material structure**
Critical mock-up	Minerve (1959, 100W)	Eole (1965, 1kW)	Eole (1965, 1kW)	Masurca (1966, 5 kW)		
Material testing reactors	Osiris (1966, 70 MW)				Osiris (1966, 70 MW)	
Reactors for safety tests			Cabri (2006, 25 MW) Phebus (1977, 38 MW)	Cabri (1972 to 2002, 25 MW)		
Prototype reactor				Phenix (1973, 350 MW)		
Reactors for teaching purposes	Isis (1966, 700 kW)	Minerve (1959, 100 W)				
High Flux reactors					Orphee (1980, 14 MW) RHF (1971, 58 MW)	

2.1. Reactors for neutronic studies

The EOLE, MINERVE and MASURCA reactors built on the CEA/Cadarache nuclear site, are low power experimental reactors (criticial mock-up) dedicated to neutronic studies while MASURCA is more dedicated to lattice core fast neutron reactors. EOLE and MINERVE are used for the study of moderated lattice cores, in particular for pressurized and or boiling water reactors. By nature, these facilities provide very flexible tools and their cores are different for each experimental program. Thus the challenge for the ASN is to ensured that every core configuration won't lead to uncontrolled hazards and that the level of safety of the reactor won't be reduced during new experiments.

2.2. Neutron beam reactors

Two facilities of this type, ORPHEE in Saclay and High Flux Reactor (HFR) of the Laue-Langevin Institut, are operated in France. The HFR provides the world most intense neutron source and delivers neutron beams to 34 high technology scientific instruments. Due to its unique, highly compact fuel element and the excellent thermo-hydraulic conditions, the reactor delivers thermal neutron flow of $1,5 .10^{15}$ $n.cm^{-2}.s^{-1}$. The neutron beam provided by these reactors are used by researchers in particular for the study of material structure. Many of the researchers do not have a great deal of experience of work in nuclear facilities and are not necessarily aware of the risks of irradiation. Radiation protection is thus an important issue for the operation of this reactor.

2.3. Technological irradiation reactors

These reactors are designed to meet the requirements of the nuclear industry and its research needs. By testing materials or fuels under technological irradiation, they improve the knowledge and understanding of existing materials and new ones being developed for use in future nuclear plants.

OSIRIS, in the Saclay nuclear site, a pool type open-core moderated by water and PHENIX, a prototype sodium fast breeder reactor (FBR) in the Marcoule nuclear site are the most important reactors of this kind in France. The thermal power of OSIRIS is 70 MW whereas the power of PHENIX is 350 MW. It's the only fast neutron irradiation reactor in Europe.

In the OSIRIS reactor, experimental devices can be introduced from the top of the reactor into spaces, either directly into the core or around it. Moreover some experimental devices or loops can be moved back or closer to the reactor core in order to simulate a variation of neutronic flux. These experiments have a significant impact on the core reactivity.

For these facilities, the impact of the experimental devices must be controlled and monitored. ASN has to ensure that all the potential risks have been taken into account, from the design of an experimental device to its intended usage.

2.4. Reactors for safety research tests

CABRI and PHEBUS are two research reactors located in the Cadarache centre. They have an essential contribution to improving safety through experiments leading to a clearer understanding of what actually happens during a number of serious accidents in electricity generating reactors.

CABRI was initially intended for safety studies for the FBR reactors cooled with liquid sodium (Phénix, Super Phénix, EFR). Today, Cabri is being adapted to meet the needs of the research programs in support of the development of pressurised water reactors (EDF plants for example). That's why the former sodium test loop is replaced by a pressurized water loop. After an important refurbishment, CABRI should re-start at the end of 2009 for the first test of the new Cabri International Program.

PHEBUS is a unique facility for serious accident studies. It is possible to reproduce at a small scale a meltdown of a fusion core and to study the degradation mechanisms of nuclear fuel and the quantity, type and behaviour of the radioactive elements released and transmitted through the experimental circuits.

The last test ended in 2004 and the devices used at that time are being dismantled at present. No program is planned but an international group of experts is working on possible future tests in PHEBUS. Although the conclusions of this work are not yet available, some themes are currently being explored about lost of coolant accidents (LOCA) tests or tests in support of the 4th generation reactors development.

For ASN, one of the main issues, is to ensure that all the devices to be used in the reactor are designed in accordance with the defence in-depth principle to avoid an accident due to the test. As a matter of fact, it would be very difficult to control the reactor if an unexpected event were to occur during a test. Specific parameters are then monitored to trigger automatic protections systems.

2.5. Teaching reactors

Today, the Azur Pile in Cadarache (this facility is regulated by the Delegate for Nuclear Safety and Radiation Protection for National Defence Installations and Activities (DSND)) and ISIS, the critical mock-up of OSIRIS located in Saclay, are the main installations dedicated for teaching purposes. As it was nor their first purpose neither the only one, they have been submitted to specific adaptations to allow effective teaching activities without hampering their safety.

3. The French regulatory framework for research reactors

3.1. Overall nuclear facilities regulatory framework

The French regulatory framework is applicable to all civil nuclear facilities, including research reactors. The safety analysis and methods for the regulation of research reactors safety have tended to become more and more similar in France to those for civil power reactors. For instance, even if a graded approach has always been used, the safety analysis approach applied to operating conditions on research reactors is the same as that used for power reactors. Moreover, design codes used are often the same.

Furthermore the French Standing Group for Nuclear Reactors (40 experts named on the ASN proposal by the governement) assesses both power reactor and research reactor safety cases. Indeed, ASN considers it is beneficial to have safety issues examined by the same advisory body, provided any research reactor is considered as a unique case, and a graded approach is adopted according to the importance of the risks incurred.

3.2. Research reactors safety reference systems

The French regulatory framework is applicable to all civil nuclear facilities, including research reactors.

The main elements of the safety reference system for each nuclear installation are :

- an inter-ministerial authorization decree, which describes the main requirements to consider in order to delimit a level of risks. These requirements are given in terms of objectives but not in terms of means. Legally, this type of document is placed under a law.
- Technical Prescriptions (TP), drafted by the ASN, signed by the ministers. This document details the terms of the authorization decree and gives the technical requirements, safety limits and conditions adapted to the installation.
- a Safety Analysis Report (SAR), drafted by the operator and submitted to the ASN for examination,
- General Operating Rules (GOR), drafted by the operator and submitted to the ASN for examination,
- an on-site emergency plan which describes the provisions to trigger in case of a serious accident,
- a discharge authorization which sets the release limits of liquid and gaseous effluents and the limit of water consumption.

3.3. Commissionning procedures

The commissionning of a new installation requires many authorization steps. The procedure is the same as the one for NPP. The Advisory Committee for Nuclear Reactors is involved at most of the steps. First, the main safety options file is examined in order to consider as early as possible the requirements of the safety authority in the conception studies. Then the assesment of the Preliminary safety analysis report (by the same Advisory Committee) leads to the production of an inter-ministerial draft decree submitted to the concerned ministers. The Preliminary Safety Report must be detailed enough to allow reactor construction to be authorised. Finally, when the reactor building is to be constructed the Provisory Safety Report which details more precisely the operation and the equipments is assessed in order to give the authorization for start-up. However the final authorization is given after a series of tests have been undertaken (commission tests).

As an example of a staged authorisation approach, the safety options of the RJH were transmitted to ASN in January 2002 and assessed in 2003. The ASN informed the CEA in August 2003 that there was no objection to carry on the RJH project, based on the safety options presented and provided that additional requests were taken into account. The preliminary safety report was transmitted in support of the authorization decree application, at the end of March 2006. The Advisory Committee has already met 3 days and will meet 3 or 4 days in 2007 and 2008. The authorization decree should be delivered during 2008 or 2009. The commissioning is scheduled in 2014.

3.4. The law on transparency and security in the nuclear field

Until 2006, the legislative basis for supervising the safety of the major nuclear installations, consisting of several articles dated from the 60s and based on a decree of 1963.

The law of 13 June 2006 on transparency and security in the nuclear field [1], known as the "TSN law", constitutes an in-depth overhaul of the legislative framework applicable to nuclear activities and their supervision. It creates the Nuclear Safety Authority, an independent administrative authority which, within the State, is in charge of supervising nuclear safety and radiation protection. It is also responsible for informing the public on these subjects. This law contains also significant advances in terms of transparency.

The right of access to information about nuclear safety and radiation protection in the possession of the public authorities already exists by virtue of the Environment Code. The law takes this requirement further by creating a right of access by the public to information.

Among the main principles applicable to nuclear activities, thus to research reactors, the law confirms that the four main environmental protection principles apply to nuclear activities: principles of prevention, precaution, polluter-pays and participation. In this respect it applies the Environment Charter, which is today an integral part of the Constitution. It also reaffirms the three leading principles of radiation protection, which are justification, optimisation and limitation.

It lays down the fundamental principle of the prime responsibility of the licensee for the day to day safety of its installation, as enshrined in international law, and essential to ensuring that each party, both licensee and supervisory authority, is fully aware of its responsibilities.

The law also gives ASN powers to impose individual requirements on the licensees. It is responsible for inspections and may pronounce sanctions, up to and including suspension of operation of an installation. It creates a nuclear safety inspectorate and upgrades the range of available administrative and penal sanctions against any defaulting licensees.

It gives a legal basis for management of urban development around nuclear sites and for the periodic safety reviews. Except if its own authorisation decree plan an other periodicity, each nuclear installation must be subjected to a safety reviews every ten years. It is now a legal provision.

The last decrees which define more details about the provisions of the law of 13 June 2006 are about to be published before the end of 2007.

4. The internal authorization system

4.1. Main objectives

According to the regulations, the safety reference system must be kept up to date and ASN must be informed of any changes. As research reactors are by nature undergoing frequent changes, explicit agreements by ASN before any change resulted in saturation of the expert assessment capabilities available to ASN and in very long response times. Furthermore, ASN could no longer devote enough time to the most important and long-term safety problems.

To allow the needed flexibility, it was decided to allow CEA (and some others operators of other kinds of nuclear installations) to authorize internally small modifications, of minor significance, that stay within the safety demonstration of the facility. ASN has provided a clear list of conditions that the operators must respect to prove that intended operations stay within the overall safety demonstration [2]. In particular, the authorizations that can be delivered in-house within CEA concern only the changes that do not conflict with the authorizations given by the public authorities (decrees and technical requirements).

This system targets several objectives :

- to set up the operator, which legally has primary responsibility for the safety of its installations, back at the centre of its responsibility,
- to make homogeneous, as far as possible, the procedures between the operators,
- to be kept sufficiently informed of changes that the operators plan for its installations and to maintain the safety reference systems sufficiently up to date to be used as operational basis,
- to define more clearly the requirements of the ASN in terms of information and dialog in order to focus more on the most important safety problems.

From the safety authority point of view, the internal authorization system implemented by the licensee has to be auditable, and allow sufficient transparency so as to know at any time which operations are being currently carried out.

4.2. Procedures and principles

To achieve this goal, the licensee is asked to implement within its own organization a safety expert committee that shall be open as possible outside its own organization, e.g. by integrating experts from other national or international licensees, or technical experts from universities or non-nuclear organizations. A particular care shall be taken that members of the committee charged with the examination of a file be different from the writers. For each file that is examined by the expert committee, a critical report shall be established and presented to the committee by independent assessors from the file writers. The critical report, committee discussions and conclusions shall be appropriately documented so as to allow inspection of the overall system by the regulatory authority. Guided by this opinion, the final decision is taken by the licensee representative, legally responsible for safety.

To allow sufficient transparency with regard to the regulatory authority, a program of the operations and modifications foreseen in the next year has to be established by the licensee and updated as required (generally every six months). At least two weeks before the change work starts, the licensee send to ASN a copy of the authorization delivered and a concise information document describing the operation that will be carried out. Finally, for operations that have a significant interest in terms of operating feedback, the director of each centre must transmit a final assessment document to ASN to increase its knowledge of the possible problems encountered and make them share with other licensees if appropriate. This feedback document is also to include information such as dosimetry, waste production and management routes, etc.

This information process has several objectives:

- to verify in principle that the conditions for not compromising the installation safety demonstration are met,
- to verify the overall operation for the in-house authorization process,
- to have an installation safety reference system that represents the actual physical state of the installation at any time,

- to enable effective supervision (inspections) by knowing what operations are in progress at what time in the installations
- to enable ASN to play its role with regard to operating feedback if the operation carried out generates useful experience.

For the specific case of experimental devices and experiments, ASN established a specific guide [3] for their supervision, especially for the irradiation of the new devices. As a matter of fact, the main conditions for internal authorizations of an experimental irradiation are in the whole the same as for other minor operations : it mustn't compromise the installation safety demonstration. But it is not enough to define the safety requirements for a new experimental device design. That's why ASN asked the CEA (the only one operator concerned) to established a technical guide on the safety requirements to be applied to the design of a new device. According to the safety analysis, the guide defines the number of containment barriers for the part of the device under neutron flux, the number of devices against flyoff or define which construction code and which level of safety requirements are to be used to built it.

To self authorize the insertion a new experiment in the reactor (in an existing or in a new device), the operator has then to prove that :

- the device complies with the technical design guide,
- this experiment won't lead to a risk for the security, public health and salubrity or protection of nature and the environment which wouldn't have been studied and does not compromise the installation safety demonstration : the experiment mustn't be the origin of a new operation condition.

4.3. Feedback after 4 years

Since its introduction in 2002 the internal authorization process has generated a significant amount of plant operations information which has been subject to review and feedback by both the licensee and ASN. It's important to note that ASN has not granted the use of the internal authorization system to all the research reactors of CEA. This decision depends on several factors as the safety culture, risks management or the independence of the expert committees but also on the safety reference documentation that must be up to date and the actual description of the facility state. ASN requires that the installation had undergone at least a conformity check or even a safety reassessment before granting the use of the internal authorization system.

At that time only CEA and EDF /CIDEN (unit in charge of the dismantling of the first generation of reactors) are allowed to use the internal authorisation system for the whole operating range.

ASN implements inspections of the whole internal authorization system to check whether, independence of assessment and serious critical review have been actually implemented by the licensee. Some other inspections aim to check if the assessments and the requirements of the internal expert committees have been correctly established and fulfilled.

The first feedback of internal authorization system is very encouraging. The internal expert committees are very responsible in their function, and aware of the responsibilities involved. The system seems to be also appreciated by the operators which can organize and plan more easily their operation programs.

ASN thinks out to extend its application to core management or long stop periods management, especially for refurbishment.

Table 2. Breakdown between internal or ASN authorizations since 2003 for the concerned research reactors

Year	2003	2004	2005	2006	2007*
Internal authorizations	3	9	11	14	24
ASN assessments	22	18	32	29	NS

* Includes foreseen authorizations

5. Periodic safety review and operation feedback

5.1. Ageing management

As it has been said, most of the research reactors in France were built during the 60s. The last was commissioned in the 80s. The average age of the research reactors is then relatively important. By consequence, it is essential to examine carefully the ageing of these facilities.

The French practice does not foreseen a time limit to the final shutdown of research reactors. As a matter of fact, most of the components may be changed as necessary, even the reactor vessel (it has been done for the HFR) that is not the case for a PWR. But on the other hand, it is also fundamental to regularly check the capability of the reactor to be operated with a high level of safety towards the coming years (generally a decade but this extension can be different).

Hence, periodic safety review is a key issue in the life of a Basic Nuclear Installation. It is both the means to take a decision for the continuation of the reactor towards the next decade and also to improve the safety level of the installation. It is also an important component of the internal authorization system : it checks, at appropriate intervals, that the accumulation of small changes incorporated into the installation over the preceding years does not compromise the overall consistency of the installation design with regard to the demonstration of its safety.

Now, since the law of 2006 June 13th, periodic safety reviews are a legal requirement and their periodicity has been set to ten years.

5.2. Contents of a periodic safety review

The ASN has described its requirements in a guide regarding periodic safety reviews [4]. Three mains objectives are targeted :

- to check the conformity of the installation with the description given in the safety reference system,
- to reassess the design of the installation taking into account current knowledge, codes and standards. On that subject, ASN considers as very important to take into account the lessons learned from operational experience of the installation but also of other similar installations in France and, as far as possible abroad.
- To examine the necessity to proceed to ameliorations intended to take into account both the changes in the regulations and the outlooks of new experimentations towards the next years.

Table 3. Past (over the ten last years) and planned periodic reviews of the French research reactors

Year	Reactors	Main topics
1999	Osiris/Isis	Ageing, accidental situations (≠ operating situations approach)*
2001	Phenix	Major reactor renovation work, checks of the vessel and sodium circuit, Sodium fire hazards
2002	RHF	Seismic reinforcement
2003	RJH	Safety options
2004	Cabri	Replacement of the sodium loop by a water loop, seismic reinforcement, work needed to comply with the current requirements for continuing reactor operations for twenty years (Preliminary safety analysis report of the refurbished installation)
2006	Masurca	Seismic reinforcement, power supply, command
2008	RJH Cabri	Preliminary safety analysis report Intermediate safety analysis report
2009	Eole + Minerve Orphee Masurca	Seism, Fire hazards, human and organisationnal factors, safety analysis (operating situations approach), containment, criticality, external hazards General safety analysis Safety analysis after refurbishment

* The operating situations approach is used for the periodic safety reviews since approximately 2004

5.3. Lessons learned from the operational experience and events reported

There has been a significant increase in reported events between 1999 and 2006. Last year (2006) 29 events were reported on research reactors in France (vs 5 in 1999). Most of them were rated at level 0 and are minor events.

In fact, it does not seem very evident that a correlation of the number of incidents from the date the installation started operation could be established, maybe thanks to the process of periodic safety reviews.

The rise can be explained partially by the proactive actions of ASN for the last years about the events reports. Moreover, ASN takes account, since summer 2000, of incidents in the area of radiation protection. It is a result of the actions and the requirements of ASN about transparency, to actively contributes to give confidence among the public in the safety of nuclear research facilities.

Such a rise of events rated at level 0 doesn't appear necessarily as a degradation of the level of safety of the facilities. But their reports are a mean to seek improvements through consideration of the experience feedback they can give. ASN tries to foster the information exchange between operators by publishing letters dealing with generic interesting events or by meeting the Advisory Committee for Nuclear Reactor to analyze the ten last years feedback. The Radioprotection and Nuclear Safety Institute (IRSN) is also much involved in these subjects.

In order to make it transparent and to informe the public on the level of safety of the facilities the, letters send to the operators following their plant inspections are published on ASN's website (www.asn.fr).

5.4. The importance of the human factor

For many years, ASN has noted that human and or organizational factors are a significant contributor to events. This is more particularly true when the installation is in its last months of operation (as it is the case for PHENIX for example). So ASN pays more attention to these periods , by setting up more inspections or inspections centered on this subject.

Moreover, research activities are often concerned by human intervention. For example, the information between experimenters and operating suppliers is a key issue of a safe operation. Another challenge for the organization of the research reactors is to support the maintenance of competences especially when operating is intermittent. That's why ASN is very attentive to the management systems implemented on each installation. Several inspections a year are implemented in order to evaluate it considering that it must be handled as rigorously as other technical subjects.

Furthermore, the Advisory Committee is now very often involved in assessing the way operators of nuclear installations take into account the risks related to human activities, from the design of the facilities to their dismantling.

6. Conclusion

Research reactors are a necessary tool for technologic and scientific research. For each particular reactor it is necessary for ASN to adapt the required regulation as well as developing a more generic approach for the safety analysis of these installations. So, in the last few years, the methodologies applied to NPP has been applied successfully to research reactors especially during the periodic reassessments. This approach remains graded but gives raise to major progress in the safety of these installations.

As a conclusion, due to their trailblazing role, ASN wants experimental reactors to set an example in the field of safety by achieving the highest level of safety. However as these facilities are generally old, ASN must remain all the more vigilant as the experimental reactors, often dating back to the 1960's. Inspections, incident analysis, safety reviews and assessments of the extent to which human and organizational factors are taken into account are among the wide range of tools rigorously implemented by ASN in its regulatory work.

This ageing pool of research reactors will be enriched in the next few years by two new research reactors : the Jules Horowitz Reactor, (RJH) a 100MW pool-type reactor for irradiation on the CEA centre of Cadarache, and ITER (International thermonuclear experimental reactor), a prototype of a fusion reactor. For ASN, the challenge is to deliver those authorizations necessary to allow operations to commence and by checking at the same time that the operators take into account most recent regulatory requirements and best practices. In the coming months, ASN will issue its views on the application for authorization to create the RJH reactor. For ITER, the challenge will be to regulate this installation as exhaustively as the other BNIs taking into account the international status of the licensee.

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